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Clarity, Compromise, and Competition: Leveraging the Unmanned Arsenal of Democracy to Execute Distributed Maritime Operations and Strengthen the U.S. Shipbuilding Industry

ES 6766: Industry Studies – Maritime Domain

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- Bollinger Marine Fabricators, Lockport, LA
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- General Atomics Electromagnetic Systems Group (GA-EMS), San Diego, CA
- General Dynamics-NASSCO, San Diego, CA
- Huntington-Ingalls Industries, Newport News Shipbuilding, Newport News, VA
- Leidos, Marine Systems Division, Long Beach, MS
- MV Cape Kennedy, New Orleans, LA
- National Surface Warfare Center (NSWC) Carderock, Bethesda, MD
- Ocean Aero, Gulfport, MS
- Port of Sand Diego, San Diego, CA
- U.S. Navy, Commander, N9 and N9 War Room, Pentagon, Arlington, VA
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Virtual Field Studies – Domestic

- Congressional Research Service (CRS), Washington, D.C.
- Hydroid Inc., Pocasset, MA
- National Institute for Undersea Vehicle Technology (NIUVT), Groton, CT
- Oak Ridge National Laboratory (ORNL), Oak Ridge, TN
- ThayerMahan, Inc., Groton, CT
- U.S. Coast Guard, Offshore Patrol Cutter (OPC) Program Manager, Washington, D.C.
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- U.S. Navy, Warfare Development Command (NWDC), Washington, D.C.
- Woods Hole Oceanographic Institution (WHOI), Woods Hole, MA

Virtual Field Studies – International

- Kongsberg Maritime, Kongsberg, Norway
- Thyssen-Krupp Marine Systems/ATLAS Elektronik, Bremen, Germany

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EXECUTIVE SUMMARY

Sixteen students spent 24 academic sessions, one week of travel, and one month of independent and group research on an issue of strategic importance that thousands of experts on the Navy staff think about every day. What value can this report provide? In a word, this report attempts to provide perspective. The players within the military-industrial-congressional complex can never entirely escape the realities of Miles' Law and the inherent biases that come from the positions they fill. As students, we offer perspectives generally unconstrained by service loyalties or chains of command, informed by a year of academic study, and enlightened by engagements with business, congressional, and Naval leaders. Synthesizing these viewpoints with our own, we provide the following point of view.

Our Industry Study focused on the maritime industry and its positioning to support Distributed Maritime Operations (DMO) by introducing manned and unmanned vessels into the Navy fleet. Our research focused upon the Navy's manned and unmanned modernization efforts framed by today's Great Power Competition (GPC). Unmanned vessels' transformative technologies require a healthy ecosystem of support that includes an innovative, capable industrial base, engaged academics and researchers, and trusting congressional allies. Our Industry Study assessed the health and viability of these segments through academic sessions on national and Naval policy, the global shipbuilding industry, individual research on topics related to DMO and unmanned technologies, and both virtual and in-person visits with entities throughout the maritime ecosystem. Our findings underscore that a robust domestic shipbuilding industry is vital to realizing *National Security Strategy* (NSS) and *National Defense Strategy* (NDS) objectives and the DMO concept.

Our Industry Study assesses there is potential for explosive growth in the U.S. shipbuilding industry to support future Navy operating concepts. Unmanned systems provide an opportunity to enhance the shipbuilding industrial base through greater platform diversification, however, the current hesitancy in Congress and industry to embrace the Navy's vision highlights three underlying issues. First, industry, especially small businesses, lack a clear understanding of the Navy's commitment to DMO, complicating capital investments for mobilization. Second, the government's reliance on large, prime shipbuilders underutilizes smaller entities as maritime Defense Industrial Base (DIB) components. Finally, recent Naval acquisition challenges perpetuates congressional distrust and uncertainty on the Navy's future course. To overcome these obstacles, we recommend the Navy provide clear, consistent communication concerning DMO concepts, requirements, and force design and commit to incremental program milestones to integrate unmanned platforms.

Providing clear, consistent strategic documents and communications will enable healthy competition and future profitability throughout industry and a spirit of progressive compromise with Congress. Congress requires information to build trust and legislative support for Naval funding. Similarly, industry depends upon consistent and reliable information to create business plans and investments in research, development, and modernized infrastructure. President Roosevelt built the Arsenal of Democracy in the 1940s through communication with both Congress and industry. Just as the U.S. industrial base successfully delivered Naval mobilization in the 1940s, an effective Navy dialogue with key stakeholders will leverage the U.S. maritime ecosystem to address strategic threats and strengthen the shipbuilding industry.

INTRODUCTION

> "*The influence of the government will be felt in its most legitimate manner in maintaining an armed navy, of a size commensurate with the growth of its shipping and the importance of the interests connected with it."*[1] *- Alfred Thayer Mahan*

The *National Security Strategy of the United States* notes that "free access to the seas remains a central principle of national security and economic prosperity."[2] With the return to a sustained Great Power Competition (GPC) with Russia and China, U.S. naval capabilities are vital to maritime operability and U.S. national security. As the post-WWII international order transforms, continued U.S. naval power depends upon a modernized mindset and fleet.

Chief of Naval Operations (CNO), Admiral Michael Gilday, established his vision for the Navy's future in his 2021 Navigation Plan. The Navigation Plan states, "We are engaged in a long-term competition that threatens our security and way of life. As part of the Joint Force, we will meet this challenge by deploying forward—alongside our allies and partners—to deter aggression and preserve freedom of the seas."[3] Admiral Gilday further stated that "The Navy requires greater numbers of submarines, smaller and more numerous surface combatants, more lethal offensive capabilities, a host of integrated unmanned platforms – under, on, and above the sea …"[4] GPC threats and the current security environment call for a reassessment of the correlation between the Navy's force design and current and future challenges.

Evaluating the Navy's fleet design is urgent because adversary capabilities, particularly China, are positioned to deny maritime access critical to U.S. security and economic interests. The Navigation Plan highlights China and Russia's sophisticated sensor networks and long-range missiles, which neutralize many advantages of large, multi-mission platforms.[5] China's development of the DF-21, DF-26, and DF-100 missiles creates a denied area for U.S. surface vessels that extends for hundreds of miles.[6] As a Congressional Research Service (CRS) report notes, "U.S. Navy has not previously faced a threat from highly accurate ballistic missiles capable of hitting moving ships at sea."[7] The now-suspended Intermediate-Range Nuclear Forces Treaty between the United States and Russia, which limited U.S. and Russian development of missiles in the 500-5,000-kilometer range, never applied to China.[8] China's satellite and anti-satellite capabilities simultaneously improve China's ability to track adversary ships and disable U.S. communication networks.[9]

The change in the security environment warrants a significant shift in Navy fleet design, driven by the Navy's operational DMO concept.[10] Admiral Phil Sawyer, the Deputy Chief of Naval Operations for Operations, Plans, and Strategy, defines DMO as "geographically distributed naval forces integrated to synchronize operations across all domains," with DMO being a combination of "distributed forces, integration of effects, and maneuver."[11] Ultimately, DMO seeks to diversify and disburse the fleet, reduce targetable signatures, and retain U.S. maritime advantage and maneuverability. As will be evident in this analysis, we assess that integrating unmanned vessels into the Navy fleet will support the efficacy and sustainability of the DMO concept. Unmanned technologies are poised to increase the size and diversity of the Navy fleet and address the growing capabilities of GPC adversaries. Depending on the degree of industry participation, unmanned capabilities are also likely to be more innovative, affordable, and disposable than traditional Navy platforms, challenging many aspects of traditional acquisitions.

The Eisenhower School AY21 Maritime Domain Industry Study focused on (1) understanding the integration of unmanned vessels into the Naval fleet and (2) discerning how unmanned technologies and industry can support DMO. Our program studied U.S. shipbuilding and its impacts on the economy and U.S. naval capabilities. Building on that foundation, we evaluated the latest 30-Year Shipbuilding Plan against current and future threats and assessed the U.S. resourcing capability to support DMO. Our Industry Study analyzed the domestic shipbuilding industrial base and maritime ecosystem, with emphasis on unmanned technologies. We examined complex problems associated with shipbuilding and unmanned industries using analytical models designed to identify policy entrepreneurship and adaptive leadership opportunities. Finally, our group met with domestic and international industry leaders in unmanned capabilities, public and private naval research institutions, congressional personnel, and various Navy leaders and stakeholders. This paper provides findings from our research and recommendations to advance unmanned capabilities supporting the DMO concept.

A robust and capable domestic shipbuilding industry is vital to realizing NSS/NDS directives and the concept of DMO. Based on our analysis of the challenges in the shipbuilding industry, we assess that unmanned vessels provide a unique opportunity to enhance the competitiveness and profitability of the U.S. shipbuilding industry. Congress and industry, however, appear hesitant to shift away from legacy platforms and embrace the DMO concept and unmanned capabilities. Congressional and industrial reluctance to embrace unmanned capabilities highlights the need for increased clarity and consistency in Navy messaging that links DMO to (1) the GPC maritime threat; (2) necessary naval fleet restructuring; and (3) manned and unmanned force requirements. Further, this paper advocates compromise to address stakeholder concerns related to unmanned technologies through the Navy's commitment to a phased, gradual milestone approach to unmanned mission sets. Finally, obtaining whole-of-ecosystem buy-in on unmanned capabilities requires industry incentives to strengthen U.S. shipbuilding competitiveness and profitability.

BACKGROUND AND CONTEXT

STRATEGIC ENVIRONMENT

As Russia covets a return to its Soviet prominence, and China seeks to supplant U.S. power, the United States is engaged in a competition to obtain geopolitical, geo-economic, and military advantage. The maritime domain is central to this struggle. According to the Tri-Service Maritime Strategy, *Advantage at Sea:*

> Today, the People's Republic of China (PRC) and the Russian Federation (RF) employ all instruments of their national power to undermine and remake the international system…to corrode international maritime governance, deny access to traditional logistical hubs, inhibit freedom of the seas, control use of key chokepoints, deter our engagement in regional disputes, and displace the United States as the preferred partner in countries around the world.[12]

The erosion of U.S. strength at sea risks diminishing United States' national security, prosperity, and the post-World War II international order.

China increasingly employs its naval capabilities to assert a presence in the Indo-Pacific, particularly in the South China Sea. In a 2015 speech at the National University of Singapore, President Xi Jinping pronounced, "The South China Sea islands have been China's territory since ancient times… It is the bounded duty of the Chinese government to uphold China's territorial sovereignty and legitimate maritime right and interests."[13] According to Jane's Defense, China controls the world's largest navy based on the total number of vessels.[14] China cultivated a multi-layered fleet to include the People's Liberation Army Navy (PLAN), the PLAN Marine Corps, the China Coast Guard, and the People's Armed Forces Maritime Militia, which employ civilian vessels for naval use.[15] According to a CRS report, China does not publicly disclose its full Navy capabilities; in addition, comparing U.S. and Chinese ship numbers is like comparing "apples vs. oranges."[16] A significant percentage of the increases in China's Navy for the past 15 years are from smaller, fast patrol craft; Navy projections for future Chinese growth include substantial increases in both large and small surface combatants.[17] Available information on China's exploration of unmanned undersea vessels is limited[18] but represents a potentially concerning capability under development. According to Jane's Defense analysis, China's USV and UUV programs could advance China's ASW and sensor capabilities undersea, eroding U.S. dominance in the undersea domain.[19] Ultimately, China's forces now threaten international freedom of navigation and U.S. operability in the Indo-Pacific.

Russia also seeks to expand its naval fleet. The Russian Navy operates some 210 surface and 70 subsurface combatants. Russia deploys a fraction of its fleet to conduct piracy patrols, naval exercises, and power projection, particularly in the Mediterranean and Black Seas.[20] In 2014, Russian President Vladimir Putin claimed that Russian "interests are concentrated in the Arctic ... we should pay more attention to issues of development of the Arctic and the strengthening of our position."[21] President Putin also proclaimed the Russian Arctic submarine force a national priority, as it races to exploit contested Arctic resources.[22] While some naval experts assess that Russia lags the United States in several naval capabilities, including ASW,[23] Russia remains a significant threat due to its long-range missile systems, cyber capabilities, and modernized submarines.

STRATEGIC IMPORTANCE

The 2017 NSS emphasizes growing GPC threats while outlining overarching objectives to maintain U.S. dominance. The Navy's DMO concept addresses the shift in the strategic environment to retain U.S. advantage. As discussed above, the Chinese military can neutralize many Navy surface platforms through improved missile, sensor, and satellite capabilities at ranges thousands of miles from the Chinese coast, limiting the United States' ability to project power in the region. The intent of achieving the DMO concept is clear: as Admiral Gilday stated in December 2020, "for me, the 'why' is China. China is a strategic threat."[24]

DMO provides an opportunity to disrupt adversary operational plans by altering the naval environment to favor maneuverability. DMO calls for leveraging a diversified fleet to reduce targetable signatures, mitigate losses from adversary strikes, and reduce the effectiveness of adversary precision fire capabilities. Vice Admiral Phil Sawyer, Deputy CNO for Operations, Plans, and Strategy, states, "DMO will enhance battlespace awareness and influence; it will generate opportunities for naval forces to achieve surprise, to neutralize threats and to overwhelm the adversary; and it will impose operational dilemmas on the adversary."[25] The DMO concept, with its higher employment of small surface and undersea vessels, could hamper an adversary's targeting ability by overwhelming the adversary's ability to detect and process multiple vehicles.

DMO is more than an effort to address adversary capabilities and maintain tactical advantage. Executing DMO provides an opportunity to modernize the Navy Fleet with more maneuverable and technologically advanced platforms necessary to maintain U.S. maritime advantage in the future. Unmanned capabilities provide additional benefits at sea. Augmenting DMO with unmanned vessels expands U.S. sensor networks and domain awareness and can be deployed in areas posing an unacceptable risk to manned platforms.

Although the Navy has already begun to diversify its fleet, fully executing DMO will likely require further innovation and technology integration. The NSS underscores the importance of U.S. leadership in advanced unmanned technology, including autonomy and AI,[26] which will be critical to improving the unmanned capabilities needed to execute DMO. Additionally, the 2018 NDS lists "advanced autonomous systems" as one of the eight specified capabilities prioritized for modernization to develop competitive military advantages.[27] Admiral Gilday reaffirms the significance of unmanned technology in the *Unmanned Campaign Framework*: "Unmanned Systems (UxS[28]) have and will continue to play a key part in future DMO, and there is a clear need to field affordable, lethal, scalable, and connected capabilities."[29] Developing and integrating unmanned capabilities is critical to DMO success and current and future maritime advantage.

DISTRIBUTED MARITIME OPERATIONS AND FORCE DESIGN

The DMO concept seeks to deliver the fleet deemed necessary by Admiral Gilday and USMC Commandant General Berger, characterized by the Congressional Research Service as a "once-in-a-generation change in fleet architecture."[30] According to Naval Warfare Development Command (NWDC), the ultimate purpose of the DMO concept is "fleet-centric fighting power, enabled by integration, distribution, and maneuver that allows simultaneous employment of synchronized kinetic/non-kinetic mission execution across multiple domains to fight, and win in complex contested environments."[31] The current employment of Naval assets seeks to grow the DMO concept, broadening integration of platforms through expanded networking of fleet architecture; the Navy's recent Unmanned Integrated Battle Problem 21 demonstrated how unmanned systems are an essential capability for the force.[32] The Navy initiated efforts to diversify its fleet in its December 2020 shipbuilding plan,[33] but fully transforming the fleet envisioned by the DMO concept will take years to execute. While unmanned concepts are being tested and proven on a small scale, the fleet-centric DMO capabilities as defined by NWDC do not yet exist.[34]

The Navy is pursuing an 18% force-level increase to 355 ships (to include 66 nuclear-powered submarines) and simultaneously redefining ship sizes, capabilities, and uses. The 2045 fleet is structured to align with DMO, comprised of (1) a decreased number of large ships, including aircraft carriers and destroyers; (2) an increased number of small, maneuverable ships such as corvettes, frigates, and light amphibious warships; and (3) a new layer of UxS including optionally manned or unmanned platforms.[35]

Based on existing shipyard capacity, supply chains, and authorized budget, the Navy will not achieve the 355-ship goal until at least 2035.[36] While previous shipbuilding plans did not include unmanned systems, the 2020 proposal for a fleet of 405 manned ships envisioned augmentation by unmanned surface and undersea systems, ranging from 120 to 160 unmanned platforms.[37] This configuration brings the overall fleet to over 500 ships. This augmentation presents an enormous undertaking for shipbuilders, as the current naval force totals just under 300. Building an additional 200 ships, large or small, is also an enormous authorization and appropriations request to Congress.

Unmanned capabilities could accelerate required changes in fleet design provided these systems are lower-cost and built at greater speeds than traditional platforms. Integrating unmanned capabilities into the fleet, however, also poses challenges. One risk of integrating unmanned capabilities is that the platforms rely on technology that is still under development. See Appendix C for a thorough discussion on the technical challenges of autonomy.

Technology-driven acquisitions also risk Congressional scrutiny due to concerns about timelines and cost. Finally, unmanned capabilities raise significant regulatory and ethical questions. See Appendix A for a discussion of the ethical challenges of autonomy.

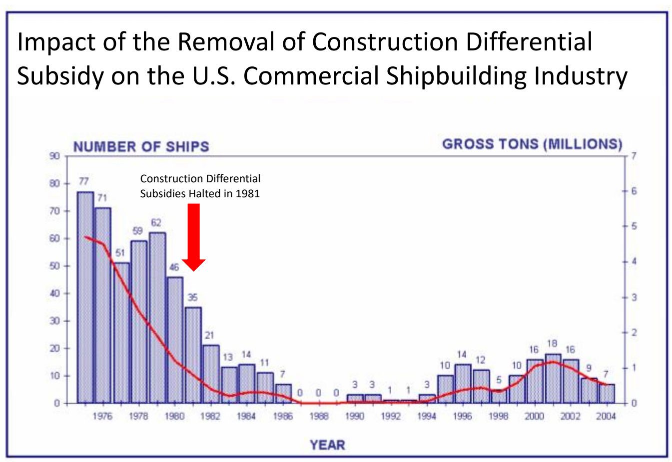
Despite these challenges, however, we assess that unmanned technologies should be prioritized and pursued. As the DMO concept evolves into doctrine, communicating DMO objectives to stakeholders may require more dialogue than typically required by traditional acquisition programs. A clear DMO vision allows researchers, industry, and civilian officials to realign resources and capital investments to generate diverse, innovative capabilities aligned with DMO objectives. Integrating unmanned technologies will depend upon Congressional support, Navy leadership, and a healthy, innovative, and competitive shipbuilding industrial base.

RELEVANT SHIPBUILDING HISTORY

The United States reached its apex as the global leader in commercial and military shipbuilding following World War II. Since that time, the profitability and competitiveness of U.S. shipbuilding drastically declined. One aspect of U.S. shipbuilding and resourcing for the Navy is the 100-year-old Merchant Marine Act of 1920, commonly known as the Jones Act. The Jones Act seeks to ensure the existence of a robust Merchant Marine fleet for national security and economic needs.[38] Since the law requires all commodities shipped between U.S. destinations to travel on U.S. flagged vessels and requires U.S. merchant mariners to operate those ships, the law contributes to high U.S. shipbuilding costs. These requirements contributed to a long-term lack of competition in the U.S. shipbuilding industry. The implications of the Jones Act have, and continue to define, U.S. domestic shipbuilding. Refer to Appendix D for a detailed discussion on the Jones Act debate.

A second significant government action impacting the competitiveness of the U.S. shipbuilding industry is the 1981 repeal of the Construction-Differential Subsidy (CDS). CDS had helped ensure the relative position of U.S. firms by compensating shipyards for the difference in the price of a commercial vessel compared to those that were foreign made. The CDS revocation marked the start of a significant decline in the U.S. shipbuilding industry and increased competition for government contracts. A comparison of U.S. shipbuilding before the CDS' termination and the present-day illustrates the policy decision's significant impacts (see Figure 1).

Figure 1

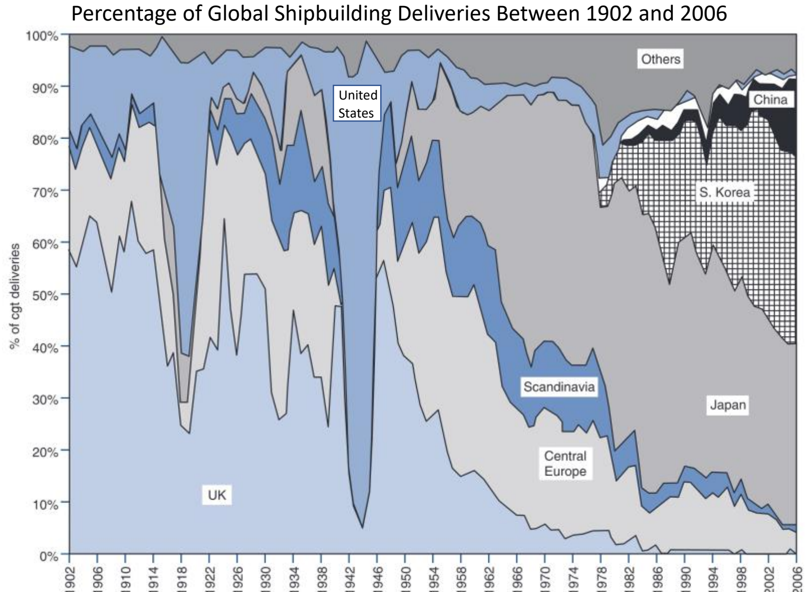


Source: U.S. Department of Transportation Maritime Administration Office of Shipbuilding and Marine Technology, "Report on Survey of U.S. Shipbuilding and Repair Facilities," December 2004, https://www.maritime.dot.gov/sites/marad.dot.gov/files/docs/ports/national-maritime-resource-and-education-center/9491/2004-reportonsurveyofusshipbuildingandrepairfacilities.pdf.

Before the CDS cancellation (1955-1985), U.S. domestic shipyards delivered an average of 20 commercial ships per year. The commercial workload supplemented domestic shipyards and focused primarily on Department of Defense (DoD) contracts while diversifying the national industrial base and developing a skilled multi-generational labor force. The U.S. military fleet peaked at 491 vessels in 1981; U.S. commercial shipbuilders, buoyed by construction subsidies through 1981, had orders for 89 commercial vessels in 1975.[39]

Following the revocation of CDS, roughly one-third of the shipbuilding workforce became unemployed, and 40% of shipyards closed within five years.[40] Higher labor costs and Jones Act-mandated use of expensive American steel pushed U.S. shipyards into a steady decline, as domestic shipyards struggled to compete against foreign shipyards, many of which received subsidies from their governments.[41] Foreign competitors continue to outcompete U.S. industry on cost, capturing the majority of the international shipbuilding market, [42] as illustrated in Figure 2.

Figure 2 Percentage of Global Shipbuilding Deliveries Between 1902 and 2006



Source: Lloyd's Register of Shipping, Clarkson Research, illustrated in Martin Stopford, *Maritime Economics* 3rd edition (London: Routledge, 2009): 616, http://search.ebscohost.com.nduezproxy.idm.oclc.org/login.aspx?direct=true&AuthType=ip,url,uid&db=nlebk&AN=262632&site=eds-live&scope=site.

Ultimately, the Jones Act requirements and removal of CDS increased the shipbuilding industry's reliance on U.S. government and military contracts and reduced U.S. competitiveness globally, funneling commercial shipbuilding into servicing niche markets protected under the Jones Act, particularly the oil industry.[43]

As a result of such government policies, foreign shipbuilders currently dominate international shipbuilding markets, offering ships at reduced cost and on faster schedules than U.S. shipyards. This report provides a detailed comparison between the competitiveness of the shipbuilding industries of the United States, China, and South Korea further below.

STATUS OF U.S. SHIPBUILDING INDUSTRY

As suggested in Figure 1, the current U.S. shipyard footprint regressed from the early 1980s, when more than 20 shipbuilders met the country's large-ship construction needs and employed over 140,000 workers.[44] A Census Bureau report further concluded there is an overall ~40% employment decrease in the industry.[45] Internationally, U.S.-based companies comprise almost 27% of the global market for shipbuilding and submarines, primarily supporting United States' large defense requirements.[46]

Today, the U.S. shipbuilding industry consists of two significant players, Huntington Ingalls (HII) and General Dynamics. Each builder has several subordinate companies (Bath Iron Works, Electric Boat, NASSCO, Newport News, Ingalls) that help them meet the needs of the Navy (and to a small extent, civilian new construction orders). The ascending smaller builders Fincantieri and Austal are increasing market share by focusing on the small surface combatant class of vessels. These four companies and their subsidiaries make up 100% of U.S. warship production servicing the U.S. government with seven major shipyards throughout the country, employing approximately 75,000 people. Appendix F contains a more detailed foray on the details of the current U.S. shipbuilding industry.

Overall, current U.S. government policies neither contribute to U.S. competitiveness nor innovation in the shipbuilding industry. In the mid-19th century, U.S. shipyards outcompeted then-superpower Great Britain by building ships at reduced labor and material costs, with higher rates of productivity, and designed to satisfy global demand for fast ships; Great Britain ultimately regained shipbuilding supremacy by the late 1800s embracing new technologies such as steam power and by repealing protectionist measures.[47] As history suggests, leveraging new technologies like unmanned capabilities has the potential to transform and strengthen the overall shipbuilding industry.

DEFINING THE UNMANNED INDUSTRY

The unmanned market is a relatively new niche within the shipbuilding industry. The evolution of the unmanned industry began with aerial vehicles and expanded into sea and ground applications. The UxS industry for surface and subsurface is much younger than the Unmanned Aerial Vehicle (UAV) industry. It is also much smaller than the UAV industry, generating $885 million annually through 14 businesses, with approximately 10% profit margins.[48]

The unmanned systems industry has three related but distinct segments: sea, air, and ground. Technological advancements or business successes in one segment may influence the others, but the unique technological and market conditions for each one limit direct effects across the group. Within the unmanned sea industry, two sub-industries exist, focusing on either surface vessels or sub-surface vehicles.

U.S. firms generally dominate the unmanned industry. General Atomics, Northrup Grumman, Textron, AeroVironment, and Boeing, control nearly 75% of the industry, but barriers to entry in this industry are declining due to lower start-up costs and widely proliferated technology. Similarly, IBISWorld reports approximately 75% of the industry supports government requirements while only 25% address civilian demand.[49] The top three companies globally--General Dynamics, Boeing, and Kongsberg Maritime--comprise only 17.6% of the market share, suggesting that the market is not highly concentrated.[50] In 2020, the global unmanned industry accounted for over $2 billion in revenue, with sales projected to nearly double over the next decade.[51] These facts combine to foreshadow a ripe future market, thriving not only in private industry but translating to realized benefits for the future of Navy strategy and operations.

ANALYSIS OF THE GREAT POWER COMPETITORS

As we analyze the U.S. shipbuilding industry's capacity to support DMO, it is helpful to compare its strengths, weaknesses, opportunities, and threats (SWOT) against those of the global shipbuilding industry. It is also beneficial to utilize the Porter's Diamond economic model to assess its competitive position relative to the global shipbuilding market. There are four main

Porter's Diamond attributes: (1) Firm Strategy, Structure, and Rivalry; (2) Factor Conditions; (3) Related and Supporting Industries; and (4) Demand Conditions;[52] however, determinations are dynamic, in that Porter's Diamond evaluations are also influenced by shifting government policies (e.g., the end of construction differential subsidies) and market chance. The Chinese, South Korean, and U.S. shipbuilding industries are analyzed accordingly below. Though Russia is equipped with commercial and military shipbuilding capabilities, a Porter's Diamond assessment does not identify it as globally competitive, and Russia is thus omitted here. Appendix H contains a more detailed SWOT analysis comparison between the United States, China, South Korea, and Russia.

CHINESE SHIPBUILDING

Porter's Diamond analysis designates the Chinese shipbuilding industry as globally competitive, with great production power and well-positioned to expand. Overall, Chinese shipbuilding is characterized by (S) low product concentration and heavy government subsidization; (W) lower-quality production; (O) high-performance drivers and PLAN demands; and (T) overleveraged shipyards and South Korean competition. Domestic competition is strong, with China's two leading state-owned shipbuilders, China State Shipbuilding Corporation (CSSC) and the China Shipbuilding Industry Corporation (CSIC), accounting for 40% of Chinese production in 2019.[53] 46% of the industry was dedicated to bulk carrier production, 27% to oil tanker production, and 20% to container cargo production in 2020, creating significant production economies of scale.[54]

According to a 2020 IBISWorld global shipbuilding report, "The continued rise of China as a major shipbuilding country in recent years has led competition to take on a new dimension, with the country experiencing a significant cost advantage over its rivals due in large part to lower-cost labor and government subsidies."[55] Chinese shipbuilders have an advantage through direct domestic access to significant supporting industries, such as steel---reducing production prices and lowering supply chain barriers. Government investments in R&D support improved technology and contribute to advances in ship autonomy.

For national security reasons, China bars foreign naval imports. The expansion of the Chinese Navy--projected to reach 550 warships and submarines by 2030[56]--will continue to drive the domestic shipbuilding industry. According to IBISWorld analysis, however, overall global demand for Chinese ships is tempered by "relatively low levels of advanced technology, low marine equipment capacity manufacturing, and the appreciation of China's yuan."[57] Government direction on foreign investment and geopolitical and geoeconomics factors influence Chinese shipbuilding and, with it, relative U.S. maritime strength.

SOUTH KOREAN SHIPBUILDING AND WHAT WE CAN LEARN

Porter's Diamond analysis assesses the South Korean shipbuilding industry as globally competitive. South Korea is considered the shipbuilding leader in the world with (S) significant government subsidies and complex design capability; (W) vulnerability to corruption; (O) increased demand due to recent economic partnership (the Regional Comprehensive Economic Partnership Agreement of 2020); and (T) WTO restriction and Chinese competition. The South Korean industry focuses on large LNG carriers, crude carriers, and large-scale container ships and experiences significant international demand. South Korea's Daewoo Shipbuilding and Korea Shipbuilding accounted for 10.1% of the shipbuilding industry revenue in 2020[58] and possesses the production potential to help or hinder the United States in the maritime domain.

This analysis submits that the successes of the South Korean and Chinese shipbuilding industries hinge upon (1) significant government subsidies and investments in shipbuilding infrastructure, such as modernized dry docks; and (2) foreign investment into their shipbuilding industries. While not commercially competitive, U.S. shipbuilding does, however, boast strengths in technical capacity and innovation. The U.S. benefits from strategic clustering and capacity in medium and small yards. With high technical standards and generally high levels of international trust, the United States is also well-positioned to lead international discussions related to policy and ethical use. If combined with government investment and incentives, it could translate to an advantage in building small and mid-sized platforms and unmanned capabilities.

U.S. SHIPBUILDING

Based on a Porter's Diamond analysis, the U.S. shipbuilding industry is not globally competitive, though the United States is the largest market of the global military shipbuilding industry. The U.S. shipbuilding industry is characterized by (S) specialized design capabilities, low domestic competition, and low imports; (W) high government regulation and contract dependence; (O) high revenue and innovative performance drivers, such as USVs and UUVs; and (T) low federal funding for defense. Unlike China and Russia, the United States uses private shipbuilding companies to build military and commercial fleets. 63% of the U.S. shipbuilding industry focuses on military shipbuilding; a remaining 15.8% is involved in military ship repair, and 20.4% is engaged in nonmilitary shipbuilding and repair.[59] The scale and sophistication of naval demand led to a highly concentrated shipbuilding industry with high barriers to entry. The four prominent U.S. players-- General Dynamics, Huntington Ingalls, BAE, and Austal--account for 75.9% of industry revenue.[60]

Due to unionization, U.S. laborers earn higher industry wages compared to laborers in Asia, increasing overall industry costs. Related and supporting industries include steel, industrial equipment, supporting shipyards, and repair businesses. The commercial shipbuilding segment of industry is small due to the domestic development of naval vessels for national security secrecy and advantage. Foreign Military Sales (FMS) stimulate some international sales and serve to offset naval procurement costs. Looking at the industry overall, however, the Jones Act shields U.S. shipbuilders from foreign competition and, conversely, deters the possibilities for foreign commercial sales.

As the Navy pursues DMO objectives, a robust industrial capability is required. According to IBISWorld reports, "an expansion of the fleet size would be required to carry out missions such as control of the seas, power projection, trade lane protection, and deterrence. Attaining this goal would necessitate constant ship construction, both to increase fleet size and replace ships at the end of their life cycle."[61] Achieving this objective will also require stimulating innovation within the shipbuilding industry. Harnessing innovation, however, will require leveraging the entire maritime ecosystem to drive future naval emerging technologies, support DMO, and bolster joint lethality.[62]

U.S. INNOVATION ECOSYSTEM

The *Unmanned Campaign Framework* emphasizes the national consortium between government, industry, research organizations, and academia collaborating to drive maritime innovation growth. Common elements strengthening the ecosystem include (1) political and congressional support; (2) access to funding and skilled workforce; (3) proximity to clients and partners, including academia; (4) cost advantages through lower workforce wages; (5) tax incentives; (6) access to common networks for communication; and (7) a culture that fosters collaboration through competition and information sharing. These elements play critical roles within the maritime innovation ecosystem.

The culture within the ecosystem centers on the entire ocean marine system and requires stakeholders with a long-term interest in its success. Related industries—including offshore power, sea transport, fishing, and marine science—demonstrate commitment to innovation with substantial investments in maritime platforms and technology.[63] Innovation institutes, non-profit organizations, government research labs (e.g., Oak Ridge National Laboratory, Woods Hole Oceanographic Institution, and Defense Advanced Research Projects Agency (DARPA)), and others serve as additional participants, illustrating how varied components of the maritime innovation system are linked.[64]

The U.S. Navy also plays a vital part in the ecosystem's culture through investments into the maritime domain, including directing research and innovation into future naval high-impact capabilities.[65] The Department of the Navy's (DoN) innovation and agility cell, NavalX, seeks to guide naval stakeholders by connecting naval laboratories, industry, and academia through shared programs.[66] NavalX's digital engagement platform and Tech Bridge influence innovation through investments in small business research. These programs also provide regional, interconnected networks to aid collaboration across all maritime participants, all focused on coastal sciences, unmanned vehicle development, and operational oceanography.[67]

The three elements of the innovation ecosystem our team considers most impactful are Congress, industry, and culture. We assess the only way the DoN will maintain an innovative edge in shipbuilding is with the full buy-in from congressional policymakers. Additionally, as we leverage the necessary innovative technology from private industry, incentives may be the only way to fully fund a skilled workforce. Finally, a top-down emphasis, fostering a culture based on open collaboration and dialogue between DoD, Congress, and industry, is paramount to future unmanned success.

FUTURE TRENDS OF THE UNMANNED INDUSTRY

This paper posits that unmanned technologies provide an effective way to execute DMO and strengthen the health of the U.S. shipbuilding industry. Not only will the Navy's DMO vision benefit from incentivizing the unmanned commercial industry's efforts, but industry will reap rewards as well. The USV industry is currently worth approximately $1.62 billion, and market researcher's project will grow by a little under 12% by 2027.[68] Both commercial and military acquisition will drive market growth. We assess the USV market will experience steady growth as technologies continue to mature in both the government and commercial sectors.

In USVs, multiple commercial ventures deliver artificial intelligence (AI) and autonomy to address Navigation and Collision Avoidance performance for unmanned systems, implying that a robust commercial market exists for these systems. Similarly, the industry's developments to re-design mechanical and electrical shipboard systems for transoceanic shipping (via Rolls Royce) or offshore energy applications (via Swiftships) offer a direct compliment to Navy requirements for reliable autonomous machinery management. These efforts have dual-use potential to translate commercial market products to core Navy technologies for Positioning, Navigation and Timing, Sense and Decide, and Cyber Security. Not all commercial platforms will translate to dual-use military applications. The Navy's stated USV mission profiles require operating on networks proposed by Project Overmatch in the Joint All-Domain Command and

Control (JADC2) environment,[69] posing challenges unique to the military applications for UxSs. Based on the future steps outlined in the *Unmanned Campaign Framework*, we anticipate the Navy will address these challenges in concert with communications advances, hardened networks, and C2 infrastructure.[70]

In contrast, the market for UUVs is broader and more mature, particularly in smaller-scale products, advanced sensors, and delivery vessels. UUVs also offer a range of mission profile capabilities, including depth, range, or endurance. The UUV industry is currently worth approximately $2 billion, and market researchers project growth to reach $4.4 billion by 2025.[71] Though government acquisitions will drive growth, researchers forecast commercial applications, especially for remotely operated vehicles and sensors, will experience the highest growth rates due to their applications in offshore drilling, pipeline inspection, seabed mapping, and measuring element concentration.[72] Defense requirements and acquisitions will also drive market growth, particularly for dual-use applications. Commercial applications are less likely to drive innovation given commercial requirements for missions with extended time and distance are limited.

The mission sets, technology requirements, and trends are significantly different between USVs and UUVs and place markedly different demands on industry. The varying mission sets also pose vastly different risks, contributing to stakeholder concerns related to unmanned technologies. Appendices A and C respectively address the ethical and technical challenges of autonomy in more detail. Ultimately, the most effective path to address the future unmanned industry's technological, ethical, and political challenges is likely to be a consistent but gradual approach. Clear messaging on the intended phasing of surface and subsurface unmanned capabilities is paramount. Limiting initial capabilities to non-lethal missions focused on sensing, sustainment, command and control, and logistics provides time for both operators and stakeholders to gain confidence in unmanned systems. At the same time, industry helps build the market and allows more advanced technologies to evolve.

MAJOR CHALLENGES

Linking DMO to a strong and profitable U.S. shipbuilding industry will facilitate the Navy's successful procurement of manned and unmanned systems. Beyond adapting Navy messaging, there remain multiple challenges to integrating unmanned capabilities into the future fleet. Although the technical aspects of unmanned capabilities present ongoing challenges (mainly related to autonomy and AI, discussed in Appendices A, B, and C), obtaining whole-of-government support of unmanned platforms will require additional Navy attention to various communication, political, and policy considerations. General Berger offers the critical traits of a deliberate way ahead in the *Unmanned Campaign Framework*, a plan that "depends on an iterative discussion with the Fleet Marine Force, our Shipmates, the Joint Force, Congress, allies, and industry."[73]

The unique relationship between the U.S. federal government, private industry, and Congress (aka the Iron Triangle) is instrumental in integrating national security objectives and necessary technological advances. Also referred to as the military-industrial-congressional complex (MICC), United States' Iron Triangle dynamic is alive, well, and vital in ensuring the readiness of our armed services today. Clear and strategic communication between the federal bureaucracy, Congress, and private industry is critical to successful naval modernization. Funding for naval platforms and industrial advancement depends upon transparent and collaborative communication within the Iron Triangle, specifically through a congressional engagement plan.

This paper assesses that the Cynefin sensemaking strategy for addressing "complex" problems, where cause and effect are unpredictable and often require new management practices, offers a practical approach to considering the challenges of unmanned technologies. Using a "probe-sense-respond"[74] strategy, crafting a deliberate approach and gradual dialogue with industry and Congress is key to resolving these challenges.

COMMUNICATING DMO TO INDUSTRY

Naval proposals for a larger fleet supporting DMO and NDS objectives warrant greater articulation at the unclassified level.[75] The Tri-Service Strategy outlines distributed operations as a "mix larger platforms with standoff capabilities and smaller, more-affordable platforms, including optionally manned or unmanned assets, that increase our offensive lethality and speed of maneuver."[76] Similarly, the CNO's Navigation Plan for 2021 references distributed forces made up of greater numbers of smaller and more affordable surface vessels and subsurface vehicles, including both manned and unmanned.[77] Classification levels make it challenging to discuss strategic threats openly or specifically and, therefore, are a barrier to smaller businesses and new entrants without security clearances, potentially hindering innovation and expanding the DIB for unmanned systems.

DMO is an innovative and urgent Naval response to the challenges of a new strategic environment. Shipbuilding expert Clinton Whitehurst observed that Americans are generally "at their innovative best in time of adversity."[78] Change in the strategic environment, however, does not necessarily mean that there is a corresponding incentive for U.S. industry to change to support unmanned capabilities. U.S. industry may understand the urgency of the DMO concept from the U.S. government perspective. Still, the U.S. government has not yet created the circumstances for industry to fully commit to unmanned technology innovation nor translated DMO into tangible, specific, and profitable priorities for industry. Autonomous undersea manufacturing represents about $885 million out of the approximately $30.3 billion in revenue for the shipbuilding industry.[79] While the autonomous undersea industry is growing, it is currently only a small segment of the overall industry.

Unmanned technologies have the potential to revitalize U.S. shipbuilding and become a profitable commercial, industrial segment. U.S. shipbuilding has a comparative advantage in building specialized military ships that integrate advanced technologies, which in theory, could translate to leadership in the global unmanned market. Developing a broad and diversified commercial base for unmanned technology could lower procurement costs and identify additional uses. UxS pose great opportunities in exploration and commercial shipbuilding ranging from protecting critical infrastructure to exploring new resource deposits. Most importantly, unmanned capabilities represent a niche market or sector that the U.S. shipbuilding industry could leverage to begin building a competitive advantage in the global commercial sector.[80] U.S. industry, however, requires more specific Navy commitments that link DMO to changes in Navy force design and increased procurement of unmanned technologies.

MILESTONE TESTING AND FIELDING PARTNERSHIPS

Successfully integrating unmanned capabilities into the Navy Fleet will depend upon providing clarity in autonomous testing and experimentation milestones to build industry and congressional confidence. Determining when unmanned capabilities are "ready enough" or "tested enough" is a challenge and critical to identifying actions that demonstrate progress in development. See Annex C for additional background on the technical challenges of autonomy. Providing milestones and using an iterative approach based on the Cynefin strategy should enable the dialogue necessary to obtain stakeholder and allied input to determine when autonomous systems have reached maturity. Researchers at the Institute for Defense Analyses (IDA) recommend building a "body of evidence" through autonomous systems testing and the acquisition process over time.[81] The lack of tangible end objectives for unmanned systems and autonomy creates enormous risks for industry partners seeking to invest in unmanned systems and poses challenges in communicating progress to Congress. Despite flexibility in acquisition models (e.g., Middle-Tier acquisition (MTA)), increased industry teaming may be necessary for successful unmanned development.

Two critical organizations which can help maximize industry engagement with the Fleet related to unmanned technologies include the Naval Undersea Warfare Center (NUWC) and Naval Information Warfare Center – Pacific (NIWC-Pacific). NIWC-Pacific, located near SURFDEVRON in San Diego, has almost 60 active Cooperative Research and Development Agreements (CRADAs) with industry and academic research institutes.[82] NUWC, with its Keyport location located near UUVRON-1 in Washington State, similarly works with industry partners to transition technology through patent licenses, Technology Bridges, and efforts to engage small businesses on innovative new technical solutions.

The Technology Bridges are a particularly valuable resource for engagement with industry. These organizations accelerate development via a broad industrial ecosystem that includes academia, government, and industry. One innovative proposal from a small company involved analyzing speech and written text with the goal of rapidly analyzing data in multiple forms and languages.[83] Technology Bridges is part of a consortium that promotes engagement with companies and academia focused on a specific sector where the players can form a problem-solving ecosystem. There are multiple NavalX[84] Tech Bridges in the United States.

Harnessing the unique capabilities of organizations such as the National Institute for Undersea Vehicle Technology (NIUVT) are additional avenues to engage Navy operators with U.S. industry. NIUVT strives to leverage government, industry, and academia to build a strong undersea technology ecosystem, utilizing government funding, industry manufacturing, and academic human capital to further undersea innovation. NIUVT also explores multiple funding and partnership methods to accelerate technology, including diffusion of new technology through industry partnerships, the transition of developing technology to industrial manufacturing firms, and technology transfers leveraging the U.S. start-up and venture capital resources. Naval integration with industry partners into research and experimentation, for example, taking inspiration from Oak Ridge National Laboratory's (ORNL) Additive Manufacturing program to move innovation forward rapidly, could be highly advantageous.[85]

In addition, successful integration of unmanned capabilities could benefit from expanded testing and experimentation partnerships with international allies and international industry. We assess the integration of products from international firms will create additional competition developing unmanned capabilities, such as leveraging advances in commercial modular technology.[86] In addition, expanding experimentation with allies contributes to interoperability and burden-sharing for unmanned missions. It also creates a base for unmanned foreign military sales to European military markets.

Finally, the technical warrant process creates additional challenges for industry to bring innovative technologies to final approval for fielding. We observed significant trends relating to inter-organizational tension between Naval Warfare Centers. For example, bringing new components to certification often requires both Naval Surface Warfare Center (NSWC) Crane and NSWC Carderock to review if the technology overlaps subject matter. While this review ensures products retain the highest reliability and safety standards, the individual NSWCs decisions also often vary, placing additional burdens on industry. In addition, technical warrant holders can modify requirements for vessels in production, increasing the complexity or material expense of construction. Due to the unique authorities articulated in NAVSEA doctrine, warrant holders can recommend technical authority determinations without a fully justified business case, balancing the demands of cost and schedule. For instance, the TAO fleet oiler program is undergoing an extensive "affordability initiative" review to find material cost savings; the Navy identified as much as $30 - 45 million in potential savings from design and material choices imparted by technical authority determinations in the design review process.[87] The impacts on the Navy and industry of these two shortcomings in the technical warrant holder network are program cost and schedule overruns. Industry is eager to achieve success in its programs but requires clarity on achieving technical certification and a more collaborative process to balance technical requirements against cost and schedule demands. In conventional human-occupied platforms, the technical authority process provides final protection against engineering shortcuts to meet cost or schedule objectives. For unmanned systems, the technical authority paradigm needs to change, allowing for increased levels of acceptable risk, better balancing cost and schedule constraints, allowing industry and the Navy to learn faster while also increasing trust in the process from congressional stakeholders.

POLITICAL AND THE IRON TRIANGLE

Shipbuilding program challenges related to the *Zumwalt*, *Ford*, and LCS class ships underscore a gap in communication between Congress and the Navy. In a March 2021 House Armed Services Seapower and Projection Forces subcommittee hearing, several members of Congress expressed concern that the *Unmanned Campaign Framework* discussed broad goals but lacked detailed plans.[88] Representative Elaine Luria (D-VA-2) commented that she "was disappointed with the *Unmanned Campaign Framework* as it was short on details and lacking substance."[89] She also stated that the committee was skeptical of the Navy's ability to shepherd emerging technology to deployable assets and add to Navy lethality due to recent program failures (i.e., LCS, DDG 1000). Representative Sara Jacobs (D-CA-53) expressed her concerns about compliance with International Regulations for Preventing Collisions at Sea (COLREGs) with Large Unmanned Surface Vessels (LUSV) and Medium Unmanned Surface Vessels (MUSV), avoiding collisions in international waters. [90] Representative Jack Bergman (R-MI-1) questioned if the U.S. Navy should carve out a unit to shepherd unmanned systems to where it wants to be, using the example of Admiral Hyman Rickover's impact on Navy nuclear propulsion, emphasizing the importance of adding specific longevity to the subject matter expertise (SME) over the long term.[91]

Based on these concerns, Congress incorporated additional oversight into the fiscal year 2021 National Defense Authorization Act (NDAA), creating barriers to the development and fielding of unmanned systems. Congress's final language in the NDAA provided a clear signal that there was a communication breakdown. The NDAA included restrictive language on unmanned surface vessels, including specifications on contract awards, limitations on weapons integration, and detailed requirements for analysis to be submitted directly to the congressional committees.[92] Congress' addition of specific acquisition milestone language into the NDAA[93] creates delays by adding programmatic layers that a program manager must overcome before requesting the release of a Request for Proposal (RFP) to industry. This additional layer of oversight increases program office workload, schedule delays, and increases uncertainty for industry. The NDAA's restrictive language specifying testing and certification thresholds well beyond industry standards before transitioning prototype systems into a program of record considerably slowed the Navy's progress on unmanned surface vessels.[94] Congress could become even more prescriptive, removing shipbuilding authority from the DoN and placing it under a Combat Support Activity answerable to the Office of the Secretary of Defense and civilian appointees approved by the Senate.

To rebuild trust with Congress, both the appointed civilian and uniformed leadership of the Navy require a concisely communicated strategic plan and commitment to deliver promised platforms. It is critical to demonstrate how the Navy will ensure unmanned capabilities are cost-effective, rapid, provide the capability needed, and be acquired successfully. It is imperative PEO-USC, PMS-406, and OPNAV N96 continuously inform Congress on the gradual progress, risks, and estimated risk management costs of the UxS program. We assess that committing to a gradual approach, particularly one that prioritizes the testing and fielding of non-lethal capabilities and delays lethal or fire capabilities until achieving agreed-upon milestones, is likely to remove political and ethical roadblocks to executing DMO rapidly and build additional confidence with congressional policymakers.

Resolving technical challenges associated with unmanned technologies, including those related to autonomy and AI, is a critical part of a communication plan to assuage congressional concerns. Appendices A and C specifically address technical and ethical issues associated with developing unmanned systems in greater detail. Although we assess that the Navy's focus is on resolving technical issues, this paper also highlights the need to create a more established dialogue with Congress on the gradual progress, risks, and technology development costs.

Finally, there are opportunities to engage Congress on ways to incentivize commercial unmanned technology development. Establishing incentives for unmanned industry development, including tax incentives or subsidies for using unmanned technologies, could increase commercial demand. The National Research Council noted that financing incentives, including subsidies, have "been far more important than technology in determining the competitive position of shipbuilders, and this will very likely be the rule in the future."[95]

POLICY AND REGULATORY

Finally, an uncertain regulatory and policy environment hinders investment and innovation in unmanned development. Huntington Ingalls Industries and Rear Admiral, U.S. Navy (Retired) Kirk A. Foster claimed, "The regulation of commercial sector, unmanned remotely operated undersea vehicles remains in an evolutionary phase."[96] Fordham Law School Admiralty Professor Lawrence B. Brennan, a retired Navy Judge Advocate General Captain, noted, "The general maritime law and federal statutes establish minimal legal standards. The entire admiralty law regime needs to be revisited to maximize the use of UUVs before serious investments can be prudently made." In the European market, a lack of trust in autonomous technology is a significant hurdle to the adoption of USVs and UUVs for commercial activities.[97] Naval and governmental determination of regulatory standards would contribute to increased innovation, enhancing trust in unmanned systems, simplifying critical business processes, and clarify liabilities in the event of an accident at sea.

In June 2017, the International Maritime Organization's (IMO) Maritime Safety Committee agreed to a regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS). As with the vast majority of the IMO's work, the scoping exercise only considered surface ships. IMO's scoping exercise was scheduled to be completed by mid-2020 but was delayed due to COVID-19 restrictions and now is likely to stretch until 2022 or longer. Furthermore, IMO leadership stated the resulting regulations might not be in effect until the late 2030s. From the U.S. perspective, some proposed amendments may require the advice and consent of the Senate, which could significantly delay the timeline for U.S. approval. As a formal finding from the IMO will be years or even decades in the making, informal IMO guidance based on the domestic regulations of member states will likely set the standards for the use of unmanned for at least the next decade.

Nevertheless, given the rising importance of UxS for commercial purposes, pressure from member states and industry for a transparent regulatory regime is mounting. In response to that pressure, some states developed their own regulatory frameworks. In 2016, the USCG Navigation Safety Advisory Council (NAVSAC) issued a resolution on Unmanned Maritime Systems Best Practices. More recently, in 2020, the United Kingdom (U.K.) issued a Maritime Autonomous Ship Systems U.K. Industry Conduct Principles and Code of Practice, and the Norwegian Maritime Authority issued a circular on autonomous and fully or partially remotely operated marine vessels. These multiple regulatory regimes confuse international shippers and limit innovation within the market for unmanned maritime systems.

A similar regulatory issue is the challenging lack of standards for unmanned systems related to COLREGs. Different interpretations on the applicability of the COLREGs to UxS drive industry confusion and a lack of support for an international standard. As the U.S. maritime regulatory organization, the U.S. Coast Guard is beginning to look into UxS regulation. In August 2020, it published a request seeking information regarding operations of, barriers to development, and growth of maritime UxS subject to U.S. jurisdiction. Coast Guard solicitation of the public's view looks to gain relevant information on the opportunities, challenges, and impacts of autonomous commercial vessels and surrounding technologies.[98]

Many nations have begun, or will soon begin, to institute their processes if the international community does not quickly standardize autonomous technology. Regardless of whether nations adopt a global standard, however, providing clarity to U.S. industry on specific U.S. policy and regulatory standards for UxS will help reduce risk to U.S. industry to innovate further and invest in these systems.

COUNTERARGUMENTS

This paper contends that industry and Congress require more clear linkages between DMO, force design goals, and unmanned development for unmanned procurement to be successful. One potential counterargument is that DMO is well-understood by both industry and allies and that publicly disclosing DMO information risks the concepts falling into our adversaries' hands. Although a valid concern, this paper insists that the rewards of providing clear, open DMO dialogue far outweigh the risks. DMO clarity amongst the DIB and Congress would provide critical procurement support in the face of a GPC maritime threat.[99]

Members of Congress and the DIB prime contractors are equipped with security-cleared staff, able to receive classified DMO briefings. It is highly advantageous to attend this level of secured briefings to become more familiar with DMO, the full extent of today's maritime threat, and the DoN's future concept of operations. Small and medium-sized shipyards that can support

DMO are ill-equipped to compile fragmented public remarks or obtain security clearances for comprehensive briefs, decreasing external competition. Keeping DMO in the classified domain on the congressional front complicates members' efforts to explain hard decisions, such as prioritizing investments in new technology vs. maintaining antiquated legacy systems. Finally, high levels of classification limit the Navy's ability to synchronize efforts with our allies. It is difficult to imagine achieving the CNO's vision of U.S.-U.K. naval "interchangeability"[100] with our allies excluded from materials explaining the DMO approach.

This paper maintains that seeking opportunities to ensure that unmanned markets are profitable and competitive is advantageous. There is a reasonable argument, however, that it is not the Navy's responsibility to ensure industrial profitability. Governmental intervention in markets is traditionally known to create inefficiency. Skeptics question if government acquisition strategies and subsidies unfairly distort the free market, shielding defense contractors from competition and contributing to massive profit margins at the expense of the taxpayer.

At the broadest level, however, defense is a public good. Without government support, it is non-excludable, without rivalry, and undersupplied.[101] The U.S. government has a responsibility to maintain the integrity of the competitive system for critical industries like shipbuilding. As near-peer competitors like China recognize, the health of the shipbuilding industry is linked directly to national security and defense. Building the competitiveness of unmanned markets will require incentivizing additional industries, including small businesses, toward the unmanned ecosystem. These small businesses are a critical part of an innovation ecosystem that drives crucial technological advancements. In times of national emergency and limited time for open competition, the government reserves the right to enter into sole source contractual arrangements. The government aids, counsels, assists, and protects the interests of small businesses to preserve and grow free competitive enterprises, ultimately strengthening the overall economy.

Nevertheless, headlines about defense spending raise questions about whether government support is excessive. To meet potential requirements for surge and mobilization, having a standing defense industrial base with a skilled workforce and infrastructure based on a relatively predictable revenue stream is essential. That said, competition is key to managing costs and spurring innovation. We designed our recommendations to create higher levels of competition to limit government costs by expanding the industrial base using small and medium-sized shipyards. Enhancing profitability and increased commercial use of unmanned technology will help sustain these firms during periods of downturn in government demand. Policies such as the Buy American Act and regulatory certainty enhance profitability and sustainability, while an expanded industrial base promotes competition and helps control costs.[102]

Finally, skeptics question the maturity of unmanned technology. Elements of unmanned technology are already mature and in use. Scientific communities, for example, have used small and medium-sized unmanned vessels for decades[103] and large-scale deployment of unmanned vessels for ISR and as targets is achievable with available technology. While larger-scale unmanned technology requires more thorough testing,[104] progress is well underway. Dialogue with stakeholders to determine many of the operational, policy, and regulatory aspects of unmanned operations is critical as the industry refines technologies. Communicating and pursuing a gradual approach to deploying unmanned systems with clear milestones, starting with the rapid adoption of small and medium-sized unmanned systems in low-risk missions, can demonstrate the reliability of available autonomy and help build trust within Congress and industry.

RECOMMENDATIONS

Our recommendations stress the importance of clear and consistent Navy communication with Congress and industry to link DMO with unmanned deployment; leveraging compromise and commitment to gradual milestones to integrate unmanned capabilities into the Navy fleet; and building healthy industry competition and incentives to mobilize for unmanned development.

RECOMMENDATION 1: Enhance DMO communication. Link DMO messaging to specific changes in Navy force design. *Clarify* procurement requirements to achieve industrial and congressional buy-in on unmanned capabilities.

SECNAV, CNO, N9, USNI: *Concisely articulate future fleet composition requirements directly tied to current and emerging GPC threats.* As part of fleet design, make regular public commitments for increased procurement of unmanned systems with varying levels of autonomy in published documents and testimony. Encourage senior USN leadership, USNI, and Navy League to message fleet design requirements. Concise and contextualized communication enables congressional, commercial, and industrial sectors predictability of USN intentions. Engage with the Department of State to encourage discussion of policy and regulatory standards and ethical concerns with international allies and organizations to build consensus.

N9: *Clarify DoD policy and regulatory standards for unmanned capabilities*, such as COLREGs compliance.

RECOMMENDATION 2: Promote *consistency* and *compromise* with stakeholders. Build trust with industry and Congress through collaborative dialogue and gradual progress and milestones for unmanned systems.

SECNAV, CNO, VCNO, N9, Fleet Commanders: *Explicitly address congressional concerns about unmanned technology development, acquisition risk, and estimated costs to develop consistent government messaging to industry.* As part of a compromise to address Congressional concerns, commit the Navy to a gradual approach. This approach should begin with full investment in lower-risk unmanned missions, while continuing to mature technologies necessary to build confidence in lethal capabilities for gradual phasing into the unmanned fleet, all in full dialogue with Congress. Recommend that future iterations of the *Unmanned Campaign Framework* include a roadmap, inclusive of an enhanced look into the campaign's plan of action and milestones. This plan-to-oversight synchronization will equate to more manageable program oversight expectations.

SECNAV, CNO, N9, PEO-USC: *Congress and Industry both require specifics on DoD milestones for UxS mission phasing, teaming, certification, and eventual weaponization. Prioritize development of unmanned and autonomous systems for ISR, networking advanced sensors, and mitigation of kinetic attacks*. Suggest N9 and PEO-USC thoroughly define unmanned missions, identify gradual and critical milestones using an iterative process for industry, and establish a framework for differentiating UUV and USV requirements and varying levels of autonomy.

N9, PEO-USC: *Commit to Congress that a critical requirement for unmanned systems is affordability. Provide specific data demonstrating how unmanned capabilities accomplish this objective compared to traditional platforms*. This is a shift from multi-mission, survivable, and exquisite systems. Committing both DoD and industry to affordability should ensure unmanned technologies remain within manageable acquisition and sustainment cost levels.

- As a quick win, recommend initial procurement emphasis on commercial, off-the-shelf technologies.
- We recommend N-96 include a requirement in Capability Development Documents (CDD) to test affordability. Also, consider exempting unmanned systems from specific technical requirements applicable to human-occupied platforms, thus achieving faster, more affordable UxS fielding.
- We recommend PMS-406 buy the Technical Data Package across the USV portfolio, enforce interface, and integrate mature technologies to reduce life cycle risks.

SECNAV, CNO: *Identify DoD policy senior leadership and congressional sponsorship, aka champions, to increase messaging support between the Pentagon and Capitol Hill.*

RECOMMENDATION 3: Encourage industry *competition*. Institute industry incentives for unmanned development, contributing to a healthy, competitive, and profitable shipbuilding industry.

SECNAV, CNO: *Work with Congress to develop incentives for unmanned development.* Partnering with industry may not be enough to fully mobilize the U.S. shipbuilding industry given current challenges and ongoing force requirements. Due to the constrained fiscal environment and the challenges associated with executing subsidies (see Annex E for more details), this paper recommends focusing on alternative incentives, such as tax incentives, research grants, and concessional financing to encourage investment in unmanned technologies and industrial base for those platforms.

NAVSEA: *Expand industry involvement in joint wargaming and testing programs through the Naval Surface and Undersea Warfare Centers.* Closer industry involvement in experimentation and testing with DoD operators will ensure DoD prioritizes and communicates the most effective milestones and objectives for industry to build Navy confidence in deployed systems.

PEO-USC: *Expand unmanned opportunities for small businesses and new companies*. Leverage organizations like NIUVT, the Warfare Centers, and National Laboratories to incorporate more small businesses into existing and future unmanned research projects. Assist non-traditional partners in overcoming industrial barriers to entry, reducing the burdens between technology development and fielding.

PEO-USC, PM: *Leverage more flexible contracting options to facilitate unmanned development*. PEO-USC and PM-406 can develop more responsive and streamlined contracting approaches, such as PMS-406's development of a mature outreach to small businesses via NavalX engagement on Other Transaction Authority (OTA) consortiums and Small Business Innovation Research (SBIR) agreements, and Best-in-Class Indefinite Delivery Indefinite Quantity (IDIQ) contracts directed toward small business. Additional consideration could be given to using the MTA approach from the Adaptive Acquisition Framework, prescribing an iterative prototyping process to field systems and continue maturation with state of the market technologies.

TRADE-OFFS

While we designed our recommendations to be relatively low-cost, trade-offs are involved in implementing the DMO concept and the associated fleet design. One critical trade-off is time. The recommended iterative approach of deploying small and medium-sized UxS for sensing and targeting missions to assuage congressional concerns and foster trust will require additional time to develop and deploy weaponized unmanned systems, a stated objective in the *Unmanned Campaign Framework*. We assess that rushing unmanned development, however, also risks further delays, such as Congress' mandates in the FY21 NDAA. In addition, the recommendation that affordability is an explicit requirement for small and medium unmanned systems might result in a trade-off against capability as it would likely constrain the level of technology on these smaller, low-cost UxS, some of which may be single-use by design. If unmanned systems are not cost-effective, however, it is more challenging to make a convincing case why these systems should replace traditional systems.

While less expensive than direct subsidies, the recommended incentives to develop United States' small and medium-sized shipyards, including tax incentives, concessional financing, and government-supported research and development, will also require trade-offs. We assess that the inclusion of these additional yards in the DIB will result in more competition and cost savings over the medium- to long-term time horizons. It may be necessary to offset the costs of incentives to develop new entrants into the government contracting pool. Another possibility is that the Navy engages with the Department of Commerce and the Small Business Administration to direct existing support programs to shipyards working on unmanned technology.

One possible trade-off to realize cost savings would be to source a portion of DoD's required strategic sealift from allies and partners. An existing legal framework – Subchapter I, Chapter 138, Section 2341 of Title 10, U.S. Code – already supports this action through Acquisition and Cross Servicing Agreements (ACSA),[105] which enable DoD to obtain logistic support, including military airlift and sealift, from eligible countries and organizations.[106] If international sourcing proves politically unfeasible, one option is to limit capital ship investments to prioritize support for smaller UxS and procure a higher proportion of strategic sealift from commercial sources. Indeed, the Navy appears to implicitly recognize this approach, as evidenced in the DoD 30-Year Shipbuilding Plan presented to Congress in December 2020. As opposed to the previous plan, the 9 December 2020 plan reflects a 100% increase in smaller ships by 2051 and a decrease of larger ships by up to 20%.[107]

Ultimately, trade-offs between time, capability, and cost are unavoidable. Despite these obstacles, we assess that stressing affordability and building gradual capability should be the Navy's priorities in relation to unmanned development for DMO.

CONCLUSION

Maritime control of the seas is critical to maintaining the U.S.'s national security and geo-economic and geopolitical advantage. To ensure U.S. maritime security, the Navy requires modernized surface and subsurface platforms, including transformative UxS fully integrated into the DMO warfighting concept. A renewed focus to strengthen the Shipbuilding Industrial Base and support its expansion into reliable unmanned platform production significantly improves U.S. strength to realize the NSS and DNS directives and DMO objectives. Cooperation between Congress and the Navy to clarify messaging regarding the gradual introduction and employment of UxS through agreed-up milestones further encourages the maritime ecosystem to fully embrace the Navy's vision. Communicating a clear understanding of naval requirements and how they can support these concepts while maintaining profitability will incentivize industry, particularly smaller businesses, to mobilize and innovate in support of DMO. Ideally, this Industry Study provided leadership with practical recommendations, concentrated around the themes of clarity, consistency, compromise, and competitiveness, to build a 21st-century naval force comprised of fully integrated manned and unmanned platforms protecting the maritime domain worldwide.

APPENDIX A: THE ETHICS OF AUTONOMY

Incorporating unmanned systems into the Navy's surface and subsurface fleet is critical to executing DMO at an acceptable cost. As a result, the Navy and Marine Corps have invested heavily in demonstrating the need for unmanned systems in recent strategic documents. For example, in March 2020, the Marine Corps' *Force Design 2030* identified a requirement for "long-range unmanned systems with…lethal strike capabilities."[108] Underscoring this urgency, later in December 2020, the Tri-Service Strategy mentioned unmanned systems 18 times.[109] Most recently, in March 2021, the DoN released an *Unmanned Campaign Plan Framework* dedicated to establishing visions and requirements for unmanned systems.[110] Ethical considerations, however, threaten to erode domestic and international support. In the combined 91 pages of these documents, however, only one document addressed the ethical implications of the evolution of unmanned and autonomous systems.[111]

The United States has no stated policy on autonomous weapons systems but generally opposes a preemptive ban on developing this technology and prefers that these systems mature under the limitations of current international law.[112] DoD published DoD Directive 3000.09, providing broad guidance that all autonomous systems should "allow commanders and operators to exercise appropriate levels of human judgment over the use of force."[113] Each service branch has separately defined "appropriate." The Army determines appropriate as "human control over all autonomous systems…by keeping humans 'in-the-loop or on-the-loop.'"[114] The Air Force requires human involvement in decisions to employ lethal force but does not specify when or how this involvement takes place.[115] The Navy and Marine Corps, in contrast, prefer scalable autonomy where specific circumstances and the bounds of law and ethics determine human interaction.[116] This liberal interpretation of "appropriate" provides the Navy with maneuver space to pursue various technologies in both surface and undersea and opens the door to ethical challenges.

Congressional and international concerns about the trajectory of unmanned and autonomous weapon systems threaten to undermine the resourcing and employment of future capabilities. For example, in June 2020, Congressman Rob Wittman (R-VA-1), the ranking member of the House Subcommittee on Seapower and Projection Forces, stated, "There are a multitude of issues associated with the development of unmanned vessels. Concerns with their…ability to strike using the law of war all point to a developing capability, not one that is mature. I don't believe they are a product that is ready to be in the fleet."[117] The introduction of ethical concerns in hearings focused on resourcing demonstrates congressional hesitancy to invest in developing unmanned technologies. Congressional concerns parallel increased attention in the academic and international communities on the ethics of autonomous weapons. Groups like Human Rights Watch, Harvard Law School International Human Rights Clinic, The Center for a New American Security's Ethical Autonomy Project, and Campaign to Stop Killer Robots have held discussions and published numerous articles asserting that the United Nation's Convention on Certain Conventional Weapons (CCW) should include a complete ban on autonomous weapons.[118] While China and Russia remain open to continued exploration of autonomous weapons, 30 nations and over 150 non-governmental organizations support a ban on their future development and employment.[119] The Navy and Marine Corps' pursuit of unmanned and autonomous weapons, coupled with the increased scrutiny on their ethical employment, requires the Navy to be precise in its intent and language regarding the ethical use of future capabilities.

Global standards will guide the evolution of autonomous weapons systems. Today, the Geneva Convention and the Law of Armed Conflict (LOAC) provide guiding principles on weapons' ethical development and employment. Article 36 of the Geneva Convention requires nations to review any new weapon system under development. In this review, countries assess whether international law prohibits any possible use of the new weapon. First, new weapons cannot be indiscriminate in their application, affecting both combatants and non-combatants equally. Second, the intent of the new weapon cannot be to inflict excessive or needless suffering.[120] These same principles should also apply to an intended progression of autonomy. In coordination with the international community, it will be essential to determine ethical levels of independence or human control in the employment of autonomous weapon systems.

The LOAC provides the legal basis for the ethical employment of weapons in war and establishes two targeting criteria: distinction and proportionality. Distinction in the application of a weapon requires an individual to differentiate between combatants and non-combatants. Proportionality requires combatants to compare a potential military gain and potential civilian damage caused by employing a weapon.[121]

Opponents of autonomous weapons voice concerns about a machine's ability to meet the requirements of distinction and proportionality. War is a complex environment with subtle differences that are difficult to capture in code.[122] Differentiating between an engaged combatant and one who is injured or attempting to surrender will likely require some level of human judgment for some time. Similarly, assessing proportionality in an armed strike requires more than a mathematical equation. Proportionality decisions necessitate reason and judgment.[123] While experts assume AI will one day differentiate between combatants and non-combatants and meet LOAC distinction requirements, removing the requirement for human judgment will likely leave fully autonomous systems outside the bounds of the law of war.

Opponents of autonomous weapons advocate for two alternatives: (1) ban the weaponization of unmanned or autonomous platforms, or (2) codify semi-autonomous weapons systems. The first alternative would prohibit the weaponization of any autonomous or potentially unmanned platform. The overall distrust of unmanned systems in war could extend this prohibition to unmanned but not weaponized platforms utilized by military forces. The second alternative would codify semi-autonomous weapon systems as the upper limit of this technology's ethical expansion. Semi-autonomy--- with humans in the loop--- would enable desired military advantages while maintaining clear ethical boundaries.[124]

The United States Navy and Marine Corps' *Unmanned Campaign Framework* demonstrates an executive-level commitment to integrating new unmanned technologies into future naval operating concepts and operating environments. The vision, like the technology, is revolutionary in nature. To ensure the Navy overcomes the ethical and political challenges to resource its vision, the United States and its service branches must commit to rigorous standards of autonomous weapon employment. Inaction may cede the strategic initiative on both unmanned and autonomous weapons employment to others in the international community. Restricting the trajectory of this warfighting technology and keeping humans in the loop of all offensive strikes will rebuild Naval and congressional understanding.

APPENDIX B: CULTURAL RESISTANCE TO AUTONOMY

Cultural resistance to force design changes results in mixed messages to industry and Congress about the Navy's commitment to unmanned technologies. For example, technology historian Elting Morison noted that when faced with an innovative new technology that could improve the Navy's lethality at the turn of the last century, many Navy officers either ignored or minimized the new technology achievements and instead sought to protect the platforms with which they identified most.[125] Morison's comments were specifically related to the Navy's development and integration of continuous-aim firing; however, the words resonate with today's unmanned systems.

Incorporating autonomous vessels into the sea services will meet cultural resistance. Unmanned vessels and associated control systems represent disruptive technology and procedures. Potential clashes include the development of a new USVs/UUVs community and the long-established surface and undersea communities. Because autonomous vessels have unproven combat credibility., service members might perceive such disruptive platforms as a threat to specific career fields. The likelihood of cultural clashes calls for a sustained Navy effort to build communities advocating for additional small combatant and unmanned vessels.

In the case of continuous aim firing in circa 1900, fully integrating the technological change ultimately required the intervention of a civilian leader outside the Navy organization.[126] Given that this is not a reliable way to integrate new technology, Morison suggests that the most effective approach to incorporating innovation into Navy culture could be to regularly message the Navy's identity as an adaptive culture rather than championing specific platforms.[127] The reshaping of naval culture to inspire innovation and incorporation of unmanned technology can start with curriculum adjustments in officer and enlisted Professional Military Education (PME) institutions. With senior leader backing and additional professional opportunities, such adjustments could institutionalize the Navy's evolving mission sets.

Overcoming cultural barriers will require building trust with Navy operators. Integration of unmanned vessels will require a level of confidence in autonomous systems built on time-tested, safe, and demonstrated capabilities. Building this trust will require proven technical capabilities, ensuring UxSs' trustworthiness.[128] The Navy's UxS program can resource years of successful Air Force operations involving Remotely Piloted Vehicles (RPV). For decades, critical improvements in technology, enhancing situational awareness, see-and-avoid technology, and Traffic Collision Avoidance Systems (TCAS) have built trust among manned platforms operating in shared spaces. That success and confidence can be replicated by the Navy today.

As the commercial sector and DoD laboratories demonstrate technological advancements in autonomous vessels, trust in UxS operations will likely increase. These critical systems, however, must continue to work in A2/AD environments where cyber or space threats may degrade their performance. See Appendix C for additional background on technology challenges in developing autonomous technology.

Although there is significant attention devoted to the technology behind unmanned systems, there is relatively little attention to how DoD will demonstrate that humans can effectively deploy the technology.[129] As Institute for Defense Analyses researchers Brian A. Haugh, David A. Sparrow, David M. Tate note, testing and evaluation of autonomous systems "will need to be able to measure the various dimensions of trust, to support understanding of how trust affects team performance."[130] We anticipate that the development and commitment to gradual milestones for unmanned development will contribute to DoD efforts to overcome cultural hurdles associated with integration into the Fleet.

APPENDIX C: TECHNICAL CHALLENGES OF AUTONOMY

Success in the unmanned campaign requires an agile approach through incremental achievement and by readily adopting market technologies as they emerge. Expanding on some of the future trends discussed in this paper to fully realizing the *Unmanned Campaign Framework* (UCF), three critical technical areas appear paramount: (1) Artificial Intelligence (AI) in the form of Machine Learning (ML); (2) fully autonomous mechanical and electrical systems; and (3) robust data management and communications. The Navy's continued testing of USV and UUV prototypes allows for the steady progress needed to incorporate these platforms into the Navy of the future.

AI development is driving the balance between the benefits and risks of autonomy. As a result, the Navy is accelerating plans to integrate AI capabilities and seeks to have a "minimally viable capability" related to its AI modernization initiative, Project Overmatch, by 2023.[131] Despite investments and potential, however, AI programs are still under development. According to Center for a New American Security technology researchers Paul Scharre and Michael Horowitz, "AI systems can suddenly and dramatically fail if the environment or context for their use changes. They can move from super smart to super dumb in an instant."[132] The dynamics of the ocean environment preclude testing of all potential scenarios, limiting the adoption and confidence in AI systems. AI technology limitations, therefore, could have an impact on successful autonomous acquisition.

The U.S. AI industry is well-positioned to drive trustworthy AI, particularly related to control, because this factor will likely contribute the most to the increased commercialization of autonomous capabilities like autonomous vessels. Despite significant policymaker discussion of AI, however, it is unlikely that they will proactively identify how much AI testing is sufficient without a proximate event that forces the U.S. hand. Instead, providing gradual milestones, as discussed in this paper, should enable the dialogue to obtain stakeholder and allied input to determine when autonomous systems have reached maturity.

Another common challenge for both USVs and UUVs is achieving trustworthy command and control systems to achieve safe navigation and collision avoidance. While safe navigation is achievable via remote operation of existing autopilot systems, a more significant challenge is developing onboard contact recognition integrated with autonomous collision avoidance systems to generate a more robust system. The struggle is detection and identification of small, non-radar reflecting contacts.[133] Industry and ongoing government research efforts seek improved infrared and camera sensors to enhance detection and decision-making. Other items that remain a challenge are ocean debris or a person in the water due to the low surface profile and inability to perceive these targets on RADAR.[134]

The next challenge for achieving mature autonomy in command-and-control systems is ensuring adequate network access and bandwidth across multiple spectrum options. The limitations of communications in the undersea domain amplify this challenge. For example, the shift to autonomous platforms will generate increased data, requiring relay back to other network nodes as part of Project Overmatch. In addition, adding the Navy's mission data to the already existing shipboard status information will further strain limited commercial satellite communications capacity.[135]

The final highlighted technical challenge is the delivery of reliable propulsion and energy at the endurance requirements expected of unmanned vessels. Despite the continued progress achieved through the Ghost Fleet Overlord and Sea Hunter/Hawk prototype programs, congressional language in the Fiscal Year 2021 NDAA places significant constraints on the ability to evolve these prototype efforts into programs of record. The language in the NDAA places onerous restrictions on "critical mission, hull, mechanical, and electrical subsystems," requiring qualification of critical systems by Senior Technical Authority before achieving critical acquisition milestones[136] to advance either the LUSV or MUSV into a program of record.[137]

The remote operation of machinery systems is already state of the market in ship design, allowing for full-time operations without manning in engineering spaces. The classification societies have published vessel standards to achieve unattended machinery space certifications, which are already widely adopted in commercial and naval ship designs. For instance, both the American Bureau of Shipping (ABS) and Det Norske Veritas (DNV) incorporated language into their vessel design standards to account for machinery systems entirely operated from the bridge of a ship.[138] The next step for UxSs is designing shipboard systems intended for unmanned operation over the 30-day mission profile required. This will require an increase in system redundancy to deliver a reliable capability and achieve routine maintenance customarily performed by humans. The more significant challenge, however, is the response to unscheduled repairs due to machinery casualties. Both SURFDEVRON's ongoing test efforts as well as commercial industry seek to address this problem.

At the time of Sea Hawk delivery, the Leidos CEO noted, "Every mechanical and electrical system on Seahawk has unique configurations designed to run for months at a time without maintenance or a crew."[139] The Sea Hunter/Hawk program incorporated design features to achieve a machinery plant endurance of 500 hours to achieve expanded endurance. For example, Sea Hunter's main propulsion engine usually requires fuel filter renewal after 250 hours of operation but has parallel fuel filtration systems installed to expand the filtration capacity.[140] Commercially, Rolls-Royce released its vision for autonomous commercial shipping, is developing short-haul unmanned ferries and is pursuing a fully autonomous, ocean-going cargo vessel by 2035.[141] Additionally, the U.K.'s Ministry of Defence awarded Rolls-Royce the Artificial Chief Engineer project to create an "onboard, secure, decision-making control system designed to intelligently operate the machinery of lean-manned and unmanned naval vessels."[142] SwiftShips also converted an existing Fast Supply Vessel for autonomous or remote operations, with the intent of marketing to Navy or commercial customers.[143]

The technical challenges facing UxSs are solvable through the rapid adoption of state-of-the-market technologies. The continued efforts of SCO's Ghost Fleet Overlord, Sea Hawk/Hunter vessel testing through SURFDEVRON and XLUUV's Orca program remain paramount to delivering the capabilities called for in the *Unmanned Campaign Framework*. The efforts to achieve the maturity and reliability expected of larger assets are definable problems with quantifiable engineering solutions. Once the platforms mature and are proven reliable, testing the core enabling technologies of Mission AI and Cyber and Physical Security will help operational commanders gain confidence integrating these systems into the fleet under the DMO concept. The Unmanned Campaign Framework vision of an expanded unmanned fleet can be achieved through collaboration with industry, hailing of incremental successes, and demonstrated success through the developmental squadrons' efforts.

APPENDIX D: JONES ACT

The Jones Act is the cornerstone statute governing the U.S. shipbuilding industry. Perspectives and opinions on the Act's long-term effects on the industry are wide-ranging and differ based on the unique interests of maritime stakeholders. Both Jones Act proponents and opponents attest that the Act provides economic protections to the U.S. shipbuilding industry. The crux of the debate lies in whether these protections help or hinder innovation, competition, and efficiency in the industry. What are acceptable costs to the U.S. shipbuilding industry and its stakeholders?

The Jones Act supports the development and sustainment of a commercial merchant marine capability within the United States.[144] The Act's stated intent expresses the necessity of qualified mariners and quality vessels to ensure American national defense and economic prosperity. The Act specifically governs commercial shipping between domestic ports by requiring all domestic maritime trade to meet the following four criteria: 1) owned by U.S. citizens; 2) crewed by U.S. citizens or permanent residents; 3) built by U.S. shipyards; 4) operated under U.S. laws and regulations.[145]

Global shipbuilding and maritime trade have changed dramatically in the 100 years since Congress passed the Jones Act. Congress implemented these protectionist policies in an era of U.S. shipbuilding strength, where only industrialized nations produced large commercial ships. Since the 1920s, global shipbuilding production leadership shifted from the U.S. and Europe to the far east, where government support and reduced costs in material and labor created conditions for shipbuilders to thrive.[146] International maritime trade also increased, and naval technology improved, leading to larger ships with smaller crews. As international maritime competition increased, ninety nations implemented protectionist policies similar to the Jones Act to protect their domestic shipbuilding industries.[147] With these international trade and shipbuilding changes, the U.S. must determine whether the Jones Act remains the best national policy to meet U.S. national security and commercial shipping needs.

Proponents of the Jones Act cite two primary merits of the Act: economic opportunity and national security. Economically, the U.S. shipbuilding industry provides over $67.8 billion to the nation's Gross Domestic Product (GDP) each year.[148] That number increases with the inclusion of maritime transportation operations and supporting industry numbers not attributable to GDP. As a result, removing Jones Act protections would make the American shipbuilding industry unsustainable against global competition and eliminate 163,000 jobs and billions of dollars from the U.S. economy.[149] Also significant are the national security safeguards of the Jones Act. Sustaining domestic shipbuilding and operating capability within the U.S. ensures domestic ships and mariners are available to support Navy and DoD requirements in times of war, peace, and natural or man-made disaster.[150] Without this resident national capacity, the United States and its Military Sealift Command (MSC) would compete on the international market for shipping during times of crisis, running the risk of incurring high prices or non-availability due to high demand or operational risk. Maintaining this national strategic capability, on the other hand, allows the United States to quickly meet its national security needs with domestic vessels and mariners, as it did in 2003 during Operation Iraqi Freedom. On any given day, MSC controlled over 150 ships supporting the employment and sustainment of U.S. forces to the Middle East.[151] For the last century, the Jones Act sufficiently protected U.S. shipbuilding and maintained a supply of merchant mariners to meet U.S. national security demands and has contributed billions of dollars each year to the national economy.

Opponents of the Jones Act discredit the national security implications of the policy, focusing instead on its costs and disincentives to adapt. The United States has utilized Jones Act enabled shipping only twice in the last 30 years: (1) in Operation Desert Shield/Storm and (2) Operation Iraqi Freedom. During the 1990s deployment, only one Jones Act ship augmented the commercial fleet contracted by DoD. This limited utilization combines with an increasing number of foreign-built ships in the MARAD inventory to diminish the national security requirement and maintain domestically built ships.[152] Preventing competition within an industry creates conditions whereby businesses continue to thrive despite inefficiencies, lagging technologies and antiquated designs, and higher costs to the customer. These higher customer costs present a significant economic burden to residents and businesses in Alaska, Hawaii, and Puerto Rico. Due to the U.S. flagged shipping requirements between U.S. ports, states, and territories outside the continental U.S. that are too small to attract direct international shipping incur higher than market costs to transport goods to and from the mainland. The Government Accountability Office and other studies estimate that Jones Act requirements increased shipping costs for these three locations by over $2.8 billion.[153] Rather than artificially supporting a non-competitive industry, opponents of the Jones Act suggest allowing free-market conditions to spur innovation and allow the U.S. industry to find its competitive niche in the global shipbuilding market.

As the economic and national security requirements for U.S. shipbuilding change over time, the United States must reassess whether existing policy effectively promotes the national interest. The initial commercial and national security interests advanced by the Jones Act no longer exist. Instead, U.S. national security interests in American shipbuilding have shifted away from gross tonnage toward high-tech capabilities supporting military and commercial sectors. Our team's surface-level analysis of the Jones Act clarified that assisting and incentivizing these emerging interests may require 21st-century updates to the 100-year-old law to fully allow American ingenuity and competitiveness, rather than a continuance of the non-competitive and non-essential markets.

APPENDIX E: SUBSIDIES

Because shipbuilding is integral to most nations' economy and national defense, many countries use subsidies or other protectionist tools to shield their industry from international competition. Subsidies generally help a nation's shipbuilding industry compete internationally by lowering production costs. Because shipbuilding is labor-intensive, subsidies also allow the government to protect many jobs. In addition, the artificially lower price that results from subsidies contributes to the cyclical nature of the shipbuilding industry by drawing in consumers that may not have purchased at the higher, unsubsidized price. The global shipbuilding industry's boom and bust cycle has also created a reliance on government subsidies to avoid bankruptcy in difficult times, although subsidies also generally reduce incentives for innovation or productivity. As a result, in the long term, subsidies can harm industry and consumers.

Shipbuilding is exceptionally competitive and capital intensive. In general, competition results in productivity improvements; subsidies, however, potentially negatively impact competition. South Korea, for example, uses modular or block building and robotic welding to improve productivity and reduce costs. Modular construction builds different ship sections concurrently, in separate locations, then brings them together for final assembly. Government subsidies, however, create distorted markets and unfair competition by lowering prices in the country that provides the subsidy. Subsidies also contribute to overcapacity and reduce long-term productivity improvements because companies have less incentive to innovate. Demand is cyclical due to the ships' longevity (typically 20 -25 years) and customer's changing needs. Due to the time it takes to design and build ships (which can be up to three years), the market is unresponsive. At a macro level, subsidies sustain shipyards that should have consolidated or gone out of business. Government protection or subsidies are pervasive throughout the world and considered a norm in the shipbuilding business. As a result, shipbuilders devote resources to maintaining political support vs. improving competitive advantage.[154]

Despite its membership in the World Trade Organization (WTO), many countries suspect China subsidizes various industries. According to experts at the Center for Strategic and International Studies, Chinese subsidies between 2010-2018 included preferred financing from state banks totaling approximately $127 billion and direct subsidies of $5 billion.[155] Detecting subsidies, however, is a significant challenge as countries may choose not to disclose this information. For example, a 2017 study of the Chinese shipbuilding industry by Harvard economist Myrto Kalouptsidi found that because "international trade agreements prohibit direct and in-kind subsidies …and thus the presence and magnitude of such subsidies are often unknown."[156] Kalouptsidi stated that "using a dynamic model of shipbuilding production and firm-level production data, I found strong evidence consistent with subsidies that decreased shipyard costs by 13-20%."[157] The study estimates that China subsidized the shipbuilding industry with $4 billion from 2006-2012.[158] Subsidized vessel costs resulted in China taking a significant bulker market share from Japan. As a result, Japan's market share of bulker production has fallen from 78% to 46%, and China's increased from 15% to 49%. To avoid bankruptcy, Japan's three biggest shipbuilders merged in 2016.[159]

Although subsidies are common in critical industries such as shipbuilding, they distort supply and demand fundamentals. Subsidies have the most positive impact when they are shorter-term vs. long-term industry solutions.

APPENDIX F: SHIPBUILDING WORKFORCE AND SHIPYARD CAPACITY

Over the last 50 years, shipbuilding has suffered from diminished government subsidies, capacity, revenues, and an aging talent pool. These challenges contributed to quality control issues, rising costs, and production inefficiencies enabling our great power competitors and foreign partners to surge ahead in the industry. As the U.S. continues its pivot away from ground battles in the Middle East towards competition with sea powers such as Russia and China, many of the nation's leaders recognize the need for additional naval resources and a robust shipbuilding industry.

The preceding paper recognized many of the shipbuilding industry's challenges, and Appendices D and E respectively cover the Jones Act and Subsidies in more detail. This Appendix covers workforce and shipyard capacity challenges and outlines considerations to strengthen the U.S. shipbuilding industrial base.

<u>Workforce Challenges</u>: During economic prosperity and due to the long manufacturing time for ships, shipbuilders often enjoy steady and predictable revenue. Shipbuilding companies' revenue and long-term viability are, however, affected if the U.S. government delays or cancels contracts.[160] Contract changes or cancellations usually result in workforce layoffs and termination of agreements with suppliers and subcontractors. This drawdown in workload challenges the shipbuilders in retaining and recruiting employees. Maintaining and growing a skilled labor pool is critical to the overall health of the shipbuilding industry. As the Navy considers growth in the 30-year shipbuilding plan, consistency in workload is required for the industry to recruit and retain a skilled workforce.

The United States' focus on post-secondary degrees also impacts recruitment in the shipbuilding industry. While shipbuilders require specific skill sets, areas experiencing the most severe shortages do not require a college education. In 2016, nearly 70% of high school graduates pursued college-level courses within a year of graduation.[161] Increasingly, recent graduates are seeking college credits ahead of labor-intensive jobs that hold the stigma of employing less intelligent personnel, being dirty, and offering limited opportunities for financial growth. In addition, the dot-com emergence, the Silicon Valley boom, and an overwhelming focus on STEM participation throughout the country contribute to the rapid increase in college attendance. Currently, over 40% of the country's 25-29 age group possesses a bachelor's degree, compared to 26% in 1980.[162] Additionally, there has been a significant push nationwide by guidance counselors and teachers to inform youth of STEM opportunities and encourage pursuing technical degrees to support these fields. Unfortunately, this is often at the expense of technical skills and vocational programs. According to Education World, since 1990, the number of high schools offering vocational training has decreased by over 40%, while the emergence of STEM schools and programs has increased by 60% since 2000.[163] Fully realizing the importance of studying and seeking employment within STEM fields, one has to ask is it possible for the U.S. to support the shipbuilding industry by emphasizing STEM and vocational training simultaneously. Vocational education is one of the many areas for policy and investment changes that can help recruit, retain, and train a skilled workforce to grow the shipbuilding industry.

<u>Shipyard Capacity Challenges</u>: Lack of infrastructure to support shipyard production is an additional challenge facing the shipbuilding industry. In December 2020, the Navy released the *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels* which

Fleet	Port	Number of Certified Dry Docks	Homeported Surface Ships
Atlantic	Norfolk, VA [1]	6	34
	Mayport, FL [1]	2	15
	Charleston, SC	3	0
	Pascagoula, MS	1	0
	Great Lakes & Bath	2	0
	Atlantic Total	14	49
Pacific	San Diego, CA [1]	4	45
	Pearl Harbor, HI [1]	1	10
	Seattle (Everett), WA [1]	1	5
	Portland, OR	1	0
	Pacific Total	7	60
	Total	21	109

Note 1: Only includes non-nuclear surface ships.

Table 1. Private Shipyard Dry Dock

laid out several of the nation's shipbuilding and repair limitations. Table 1, provided from the 2020 Long-Range plan, shows the laydown of private shipyards with NAVSEA certified dry docks across the United States. The report goes on to state that "the ratio of ships to drydocks present in the Pacific presents a significant challenge that reduces margin for schedule changes and growth."[164] Looking at the entire national shipbuilding capacity, Figure 1 shows 23

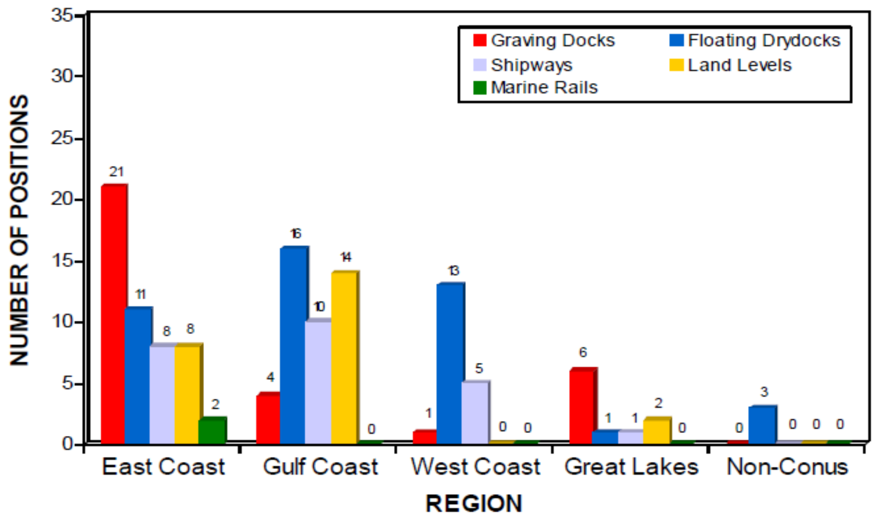


Figure 1. Number of Build and Repair Positions by Region

additional drydocks greater than 122-meters that can support the construction and repair of ships.[165] While there appears to be drydock capacity, infrastructure repairs are likely needed to receive NAVSEA certification to build and repair naval vessels. Additionally, 44 of the 126 total positions are only 122-meters in length, limiting the class of ships they could build or repair. To overcome this capacity issue, the Congressional Budget Office (CBO) estimated the private shipyards require over $4 billion in facility investments to reach the Navy's 355-ship plan by 2035.[166] Infrastructure capacity and workforce recruitment are a few of the many challenges facing the shipbuilding industry in meeting national security objectives.

APPENDIX G: INFRASTRUCTURE

The Navy desires to move quickly to field a fleet of USVs and UUVs. Accelerated acquisition programs have made this possible and meet the pacing threat, however, facilities planning and programming procedures have not kept up. Programming funds for facility projects is a deliberate, multi-year process requiring multiple levels of review before final prioritization and adjudication. Military Construction (MILCON) funds, authorized and appropriate by Congress on a project-by-project basis, follow a four-year process to program new facilities. Additionally, strategic laydown and dispersal (SLD) decisions for new platforms add a year to the process requiring CNO approval and congressional engagement. As a result, the minimum timeline for new platform projects can easily exceed seven years after including two to four years for construction. The unmanned maritime platforms face an obvious challenge in the mismatch in accelerated acquisition authorities and the deliberate facilities programming processes.

This section evaluates the various program office milestones and facility planning timelines. It uses the Orca XLUUV program as a case study since it is one of the most mature unmanned programs utilizing accelerated authorities. This analysis provides valuable insights and lessons learned for the Navy as it embarks on accelerating other USV programs.

Program Office Milestones and Acceleration Acquisition Authorities: In 2016, the Joint Requirements Oversight Council (JROC) designated the XLUUV program a JEON for FY17. This designation enables programs to follow the Urgent Capability Acquisition (UCA) process to address capability needs within a two-year timeframe.[167] In February 2019, the Navy selected Boeing to deliver four Orca XLUUVs with expected fielding by 2022, slightly longer than the two-year goal for UCAs. In total, the Navy expects to field the Orca within seven years from the initial JCIDS request. This matches the minimum timeline for the completion of new platform MILCON improvements, however, the Navy could not begin the first phase of facilities planning on the Orca until the development stage revealed detailed platform specifications and capabilities.

Strategic Laydown and Dispersal (SLD) Planning: All new platforms require a basing letter from a type commander (TYCOM) specifying the facility requirements, expected platform delivery, and preferred basing locations. For the Orca, Commander Submarine Force, U.S. Pacific Fleet (CSP) issued a series of basing letters to CNIC. In September 2019, CSP issued an initial basing letter requesting temporary facilities to support test and evaluation activities at Naval Base Ventura County (NBVC). The following May, CSP issued a subsequent letter requesting permanent basing in the Western Pacific for inclusion in the 2021 SLD plan. Based on the four-year MILCON Team Planning and Programming Process (MTP3) and one year for CNO SLD approval, construction for new facilities supporting the Orca is not likely to start until 2025. This timeline misses expected operational fielding by three to four years.

MILCON Team Planning and Programming Process (MTP3): The MTP3 lays out a dizzying list of requirements at various milestone decision points. Critical planning documents needed four years before the Budget Year include the Basic Facility Requirement (BFR) and an initial Military Construction Project Data Sheet (DD1391). Each document requires modest knowledge about the facility's requirements, including the category code or type of facility, number of personnel working within the facility, provisions for special areas such as sensitive compartmented information facilities (SCIFs), and an estimated project cost. Facility planners at Naval Facilities Engineering Systems Command (NAVFAC) prepare this information for review by the Shore Mission Integration Group (SMIG) to begin programming of MILCON projects at the end of the Future Years Defense Program (FYDP). Three years before the Budget Year, the MTP3 requires significantly more detailed project information, including specific equipment lists, facility engineering studies, site-specific environmental assessments, and an economic analysis assessing the life-cycle cost of construction versus repairing an existing facility. However, a program office can field a platform in less than two years from JCIDS approval in an accelerated acquisition strategy. Unfortunately, the current MTP3 requires detailed facility requirements three years before construction even starts.

Alternatives to Reduce Infrastructure Requirements: To meet the pacing threat of our adversaries, the Navy has several options to ensure our unmanned platforms have the requisite facilities to support employment. At a minimum, the Navy should consider ways to accelerate and streamline the facility planning and programming processes to align with accelerated acquisition authorities. This could include a complete revamping of the MTP3 process for all MILCON funded projects or just for those projects supporting the unmanned platforms using accelerated acquisition authorities. The Navy should also consider alternative basing and employment solutions for unmanned platforms. Some alternatives include off-shore mooring, persistent employment, or the development of service contracts for platform missions that are not inherently governmental. These alternatives look at options for the Navy to consider to limit the growth of support facilities.

Off-Shore Mooring: This alternative proposes the idea of mooring the unmanned platforms away from existing pier facilities. Locations that harbor military sealift and prepositioned ships, such as Diego Garcia, or locations with large protected harbors such as Guam are potential options under this proposal. Security of the vessels is a concern; however, the Navy can mitigate the risk by removing payloads. In locations where harbor security barriers or patrol is limited, the platforms can use existing sensors to alert the operations centers or execute evasive maneuvers autonomously. Technology exists to make this option feasible, however, the Navy will need to prove this concept through significant testing and evaluation to gain buy-in from service stakeholders and Congress.

Persistent Employment: This alternative proposes continual employment of the unmanned platforms. While the platforms will require periodic maintenance, few tasks should require the platforms to return to shore for an extended duration. Instead, operational fleets would transfer these platforms at the end of their deployments to an adjacent fleet or take tactical control when transiting or patrolling a specific area of operation.

Service Contract with Industry: An additional alternative the Navy should consider is deploying the unmanned platforms as a service. The concept is similar to existing security service contracts such as intrusion detection systems (IDSs). For example, the DoD uses cameras, motion sensors, and other detection devices in SCIFs, and along installation perimeters to prevent unwanted entry and conduct surveillance. The majority of these systems are built, installed, and maintained by security service contractors. In some cases, the DoD even contracts out the monitoring of these sensors or shares monitoring duties. When sensors fail or need replacing, the service contract stipulates mitigation and repair criteria. The Navy could extend this concept to monitor installation waterfronts, training ranges, and other critical maritime areas. Deploying these assets under a service contract could relieve the Navy from providing shore support for these assets outside of the operation centers used to monitor the sensors. When considering this alternative, the Navy should conduct a thorough legal review to ensure the service contract excludes inherently governmental functions.

APPENDIX H: STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREAT ANALYSIS OF NATIONAL SHIPBUILDING

UNITED STATES

Strengths: Build highly specialized, sophisticated military vessels. Significant backlog for military ship construction.

Weaknesses: The shipbuilding industry is dependent on Government orders. The industry is not globally competitive as a result of the Jones Act protecting the market. Regulation and labor costs are significant contributors to the high cost of building in the U.S. Highly concentrated market. Four firms dominate shipbuilding revenue (64% of industry revenue),

Opportunities: Unmanned systems provide the opportunity to diversify government contracts to a broader industry base due to the smaller size of the vessel and the extensive software requirements to support autonomous operation. Domestic oil and gas production and emerging offshore wind energy markets provide demand for vessels to support the energy sector. This dual-use capability represents an opportunity for smaller shipbuilders to diversify their portfolio to build commercial and military vessels.

Threats: The shipbuilding industry is very dependent on government funding and protection. Loss of the Jones Act would result in significant market share loss to foreign-built imports. In addition, ITAR limits U.S. military exports, which could restrict unmanned expansion.

CHINA

Strengths: PRC heavily subsidizes the shipbuilding industry for capital improvements and the shipping industry to support demand. Supporting industries for raw materials also receive subsidies. In addition, the PRC provides rebates to promote exports. PRC also has low labor rates and large labor pool.

Weaknesses: Overcapacity in the commercial market on bulker construction has created a vulnerability to a lack of demand for cargo vessels. PRC cannot compete with industry leaders South Korea and Japan for high-value, more complex type vessels such as tankers. There is a perception that product quality is less than competitor quality.

Opportunities: PLAN intentions for a 550-ship Navy[168] provides the opportunity for stable growth. The November 15, 2020, Regional Comprehensive Economic Partnership Agreement with China, Japan, South Korea, Australia, and New Zealand is likely to increase shipping in the free-trade zone representing one-third of the world economy.

Threats: Overcapacity and overleveraged shipyards will need to consolidate to survive unless they are state-owned.

RUSSIA

Strengths: Strong government demand. Russian government orders have doubled USC's revenue since 2013. Russia is the third-largest exporter of ships, accounting for 9% of global exports. In addition, the government is willing to export nuclear submarines and aircraft carriers.

Weaknesses: There is no domestic rivalry. United Shipbuilding Corporation (USC) dominates with an 80% share of naval shipbuilding. The lack of domestic competition inhibits innovation.

Opportunities: Arctic sea route development supports the niche capability in ice-breaker ships. The continued global dependence on oil and natural gas supports USC LNG and tanker production to support exports.

Threats: Sanctions, a weak economy, and depreciation of the Ruble have decreased funding for military spending.

SOUTH KOREA

Strengths: South Korea has strong subsidies for shipbuilders and carriers and an extensive network of supporting industries. South Korea is a world leader in efficient ship construction such as block construction and automated welders. South Korea is also skilled in construction of complex designs such as tankers; has a large backlog; high retention rate for its skilled workforce; robust Research and Development (R&D) investment; and is a world leader in exports, specializing LNGs.

Weaknesses: Corruption - Hyundai Heavy Industries is banned from state projects for two years due to bribery conviction.

Opportunities: The November 15, 2020, Regional Comprehensive Economic Partnership Agreement with China, Japan, South Korea, Australia, and New Zealand is likely to result in increased shipping in the free-trade zone that will represent one-third of the world economy. Demand for more fuel-efficient vessels could increase demand for new vessels. Korean shipbuilders have robust research and development and a skilled labor force with high retention, enhancing the quality of their designs to achieve improved fuel efficiency.[169]

Threats: Japan and the EU have filed a dispute resolution with the WTO regarding government intervention in shipbuilding. Price competition from China as that country improves their ability to build tankers and more complex vessels.

GLOSSARY

30-Year Shipbuilding Plan: According to 10 U.S.C. 231, DoD will submit an annual naval vessel construction plan, including combatant, support, and auxiliary vessels, that covers the period for the next 30 fiscal years.[170] According to CRS, the purpose of the plan is to provide Congress with information to assess the Navy's shipbuilding plans.[171]

Acquisition and Cross Servicing Agreements (ACSA): According to DoD's Office of the Executive Director for International Cooperation, ACSA is a mechanism to obtain or provide logistic support from specific countries, based on 10 U.S.C. 2350.[172]

Additive Manufacturing: Manufacturing items through the gradual layering of deposited materials.[173]

Anti-access/area denial (A2/AD): A strategy designed to prevent access or maneuver to a region, area, or location.[174]

Anti-Submarine Warfare (ASW): Unmanned systems have the potential to augment a nation's ASW capabilities through the deployment of additional sensors and networks.

Artificial Intelligence (AI): The use of algorithms and computers to execute actions or tasks.[175]

Autonomy: A description for the level of human involvement or interaction versus automation. Full autonomy generally does not require human involvement; human-supervised autonomy allows humans to monitor and intervene, if necessary; and semi-autonomy requires human involvement for action to take place.[176]

Construction Differential Subsidy: U.S. policy between 1936 and 1981 to provide shipbuilders with a direct cost subsidy to account for the difference in cost between foreign and U.S.-built ships.[177]

Cynefin Model: A sense-making tool to apply to challenging problems. In the model, problems may be considered as simple, complicated, complex, or chaotic; each is associated with a different decision-making approach.[178]

Defense Industrial Base (DIB): The DIB includes the industrial segments that produce and supply services for DoD.[179] The NSS identifies the DIB is "a critical element of U.S. power and the National Security Innovation Base."[180]

Distributed Maritime Operations (DMO): A Navy warfighting concept that calls for diversifying and distributing the Navy fleet to address national security challenges and retain U.S. advantage at sea.

Extra-Large Unmanned Undersea Vessel or Vehicle (XLUUV): Unmanned systems with a diameter of more than 84 inches. The XLUUV is also known as the Orca Program.[181]

Foreign Military Sales (FMS): DoD purchases of military equipment which are ultimately sold to foreign governments and militaries in support of U.S. interests.[182]

Innovation Ecosystem: The collection of government, industry, research, and academic organizations that promote a nation's innovation and technology development.[183]

Intelligence, Surveillance, and Reconnaissance (ISR): A general term that refers to a platform capable of collecting data, surveilling locations or targets, or obtaining information on an area or location. DoD deploys multiple types of military and commercial platforms to conduct ISR missions.

International Regulations for Preventing Collisions at Sea (COLREGs): An international agreement adopted in 1972 that establishes standards to avoid collisions between maritime vessels.[184]

Joint All-Domain Command and Control (JADC2): DoD's effort to build a network that connects digital command and control for all military services.[185]

Joint Emergent Operational Need (JEON): According to CJCS Instruction 5123.01H, JEONs are "urgent operational needs identified by a CCMD, CJCS, or VCJCS as inherently joint and impacting an anticipated contingency operation."[186]

Jones Act: The common name for the Merchant Marine Act of 1920. The Jones Act provides protections to the U.S. shipbuilding industry by requiring all commodities shipped between U.S. destinations to travel on U.S. flagged vessels built in the United States and by requiring U.S. merchant mariners to operate those ships.

Large Unmanned Surface Vessel (LUSV): An unmanned surface vessel with a length of over 50 meters.[187] The LUSV program within the Office of the Secretary of Defense's Ghost Fleet program is known as Overlord.[188]

Medium Unmanned Surface Vessel (MUSV): An unmanned surface vessel with a length between 13-50 meters.[189]

Middle-Tier Acquisition (MTA): As part of the adaptive acquisition framework, the MTA pathway provides a rapid prototyping or deployment pathway within a five-year timeframe.[190]

Military-Industrial-Congressional Complex (MICC): Also known as the "Iron Triangle," the MICC refers to the mutual relationships and dependencies that exist between DoD, the Defense Industrial Base, and Congress related to military programs.

National Defense Authorization Act (NDAA): The annual appropriations bill that provides funding to DoD.

Other Transaction Authority (OTA): According to Defense Acquisition University, OTA can be used as an agreement "for research and prototype projects that are principally defined in terms of what they are not."[191]

Porter's Diamond: An economic analysis model developed by economist Michael E. Porter to assess the competitiveness of a nation's industry. The model examines a market through the following factors: firm strategy, structure, and rivalry; factor conditions; related and supporting industries; demand conditions; and government policy.[192]

Project Overmatch: The Navy's effort to integrate networks, sensors, and tools with JADC2.[193]

Small Business Innovation Research (SBIR): According to SBIR, the program promotes "domestic small businesses to engage in Federal Research/Research and Development (R/R&D) with the potential for commercialization."[194]

Tech Bridge: According to the Navy, Tech Bridges "are a connected network that enhances collaboration between Naval Labs, industry, academia, and other military branches."[195] There are 15 NavalX Tech Bridges in the United States.[196]

Technical Data Package (TDP): According to DoD Instruction 5012.12-M, TDP is a "technical description of an item adequate for supporting an acquisition strategy, which defines the required design configuration and procedures to ensure adequacy of item performance. It consists of all applicable technical data such as drawings, associated lists, specifications, standards, performance requirements, QA provisions, and packaging details."[197]

Technical Warrant Holder: Technical warrant holders are responsible for verifying DoD technical programs and designs are, according to a RAND study, "safe, technically feasible, and affordable."[198] NAVSEA administers 172 technical warrants.[199]

Unmanned Surface Vessel (USV): An unmanned system that operates as a surface vessel. The sizes of USVs range from: large, with a length over 50 meters; medium, with a length between 13-50 meters; small, with a length between 8-12 meters; and very small, with a length under 8 meters.[200]

Unmanned Subsurface Vessel or Vehicle (UUV): An unmanned system that operates primarily below the surface of the water. The size of UUVs range from: the XLUUV, which has a diameter larger than 84 inches; the large UUV, which has a diameter between 22-83 inches; the medium UUV, which has a diameter between 11-21 inches; and the small UUV, which has a diameter between 3-10 inches.[201]

Unmanned System (UxS): A generic term for an unmanned platform, airplane, vessel, or vehicle.

Unmanned Vessel or Vehicle (UxV): A generic term for an unmanned maritime platform.

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- Factor Conditions: including basic factors such as geography and natural environment and advanced factors such as infrastructure, culture, human capital, and scientific knowledge base.
- Related and Supporting Industries: including supply chain resilience and flexibility, complementary industries and industry clusters.
- Demand Conditions: including the balance between commercial and government demand, ability to satisfy domestic demand, customer pressure for companies to innovate faster to achieve competitive advantage over foreign rivals, budget trends, and exportability.

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