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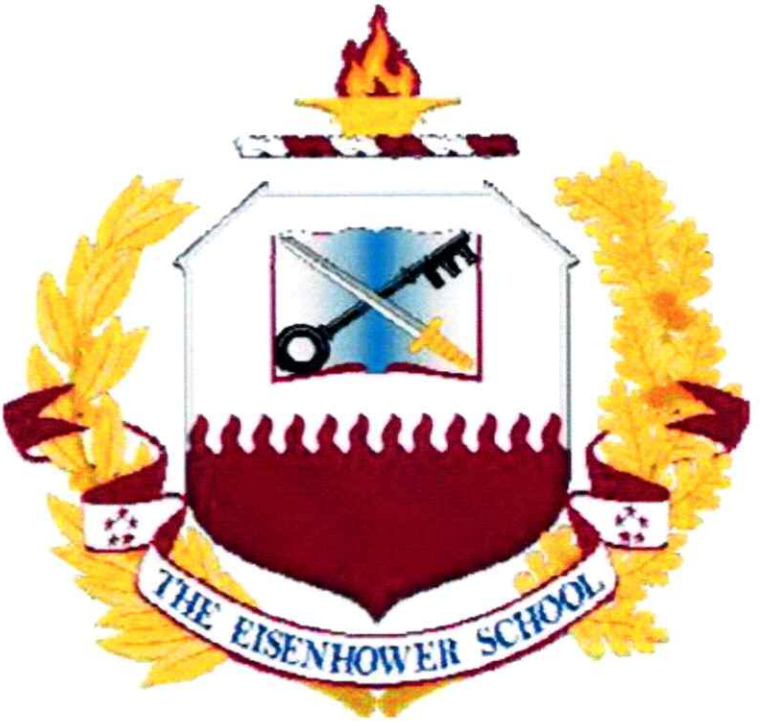
Shipbuilding Industry Study

Industry Report

Plotting a Course Through Dangerous Waters:

An Analysis of the Shipbuilding Industrial Base, Policies, Risks, and Opportunities



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SHIPBUILDING INDUSTRY 2018

ABSTRACT: Warships and commercial sealift are both critical to achieving our national security strategy, as evidenced in World War Two. The warship and commercial vessel industrial bases have been largely neglected, inconsistently funded, and the attention paid to it by policy makers has waxed and waned for over 70 years. This paper identifies the major dimensions of shipbuilding (human capital, ship yard construction and repair facilities, and financial capital and economics) and analyzes and assess them in terms of the industrial base's ability to respond to a surge based on a national emergency. The paper also includes recommendations to enable the sector to be more responsive and the government to more sensibly and consistently resource this surge.

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Table of Contents

Introduction

As the United States settles into the 21st century, the 2014 Russian invasion of Ukraine and China's *one road, one belt* effort mark the public reemergence of great power competition and refocus America's strategic priorities. The ability of the US to project power, maintain freedom of navigation in the commons and deter aggression has never been more critical. "The revisionist powers of China and Russia, the rogue states of Iran and North Korea, and transnational threat organizations, particularly jihadist terrorist groups—are actively competing against the United States and our allies and partners."[1] As America's strategic rivals actively attempt to undermine her instruments of power, a strong industrial base acts as a countervailing force to their efforts. The ability to field, man and maintain an effective seagoing force is fundamental to protecting the homeland, promoting American prosperity here and abroad, preserving peace through strength, and advancing American influence.[2]

After years of sequestration and military drawdowns, the US has committed to rebuilding its military might, including its defense industrial base, in order to deter future armed conflict. A reorientation away from counter-insurgency, and primarily land-air operations, with a refocus on full-spectrum, near-peer conflict has also driven this renewed prioritization. However, the US must also plan support for any possible conflict, and not rely exclusively on deterrence. Naval forces will likely play a major role in all phases of a future conflict, especially in the Western Pacific, and may hold the key to preventing a war in the first place. Planning and prior investment in the shipbuilding industrial base are keys to fielding adequate capabilities to command the sea in the event of a near peer or multi-front conventional conflict. Should a conflict arise, significant wartime government spending would buoy the shipbuilding and repair industry as the US attempts to meet the logistical demands of a high-end fight at sea.

The US Navy and the defense maritime industry aim to enable the US to "conduct prompt and sustained combat incident to operations at sea," including the supply chain and industrial production that enable it to execute a full-scale, multi-front operation.[3] Further, it empowers the US to "protect America from attack and preserve America's strategic influence" as well as "deter aggression and enable peaceful resolution of crises on terms acceptable to the United States and its allies and partners." Should deterrence fail, the US Navy must have the ways necessary to "defeat any enemy."

Given that, is the current shipbuilding industrial base capable of surging towards a 355-ship Navy, a corresponding increase in merchant and lift ships, and repairing and/or replacing combat losses? The answer, in our estimation, is that it can do so, but not rapidly or efficiently. That is more a function of political will and government investment than the industry's ability to innovate, produce, and deliver. The "market" (shipbuilders) would not invest in something the "customer" (United States Navy) does not want.

The current shipbuilding industrial base is sound and poised for modest growth, having maintained some stability over the previous five years as lengthy production timelines for US Navy and Coast Guard ships kept yards occupied.[4] Future expansion

will be spurred by increases in defense spending, a growing economy and recovering oil prices, and analysts predict 4.6% annual revenue growth over the next five years.[5] Should the Congress elect to aggressively pursue the Navy's wartime inventory objective of a 355-ship fleet, the industrial base and maritime workforce are able to expand significantly over the course of several years. Recruiting, training, and retaining skilled workers would set the pace for any expansion of the industrial base.

World War II tested the US industrial base's capacity to respond. Ships were cobbled together with an emphasis on speed of production. Japan's fleet of warships and battle-tested mariners were able to hold command of the sea and put the US Navy on the verge of decimation at both Pearl Harbor and Guadalcanal. Grit, blood, abundant natural resources and overwhelming numerical superiority enabled the US to persevere. The aim of the current national security strategy (NSS) is to prevent the World War II scenario from recurring by maintaining "peace through strength." Germane to that strategy are a vibrant shipbuilding industry and national security innovation base.[iv]

On the security – prosperity spectrum, with *laissez-faire* at one end of the economic continuum and *central planning* at the other, the shipbuilding industry that is essential to US national security resides closer to *central planning*. Significant government intervention, planning, and partnership are required for it to function. Though financial rewards consistent with the rest of the defense industry exist, the industry is more public good than source of wealth, and prosperity is of secondary importance to security. In the last 30 years, the heavy emphasis on security and the lack of government support for the civilian shipbuilding sector drove many commercial shipyards in the US to consolidate, move overseas, or go out of business.

At present, three major economic drivers, or means, play an outsized role in the health of the shipbuilding industry and its ability to respond to a conflict: manufacturing and repair facilities, human capital, and financial capital. By *manufacturing and repair facilities*, we mean the established industrial base that can ramp up to meet the demand for new vessels, maintain the current fleet, and repair battle damage. This includes shipyards, suppliers of critical components, repair facilities, dry docks, and graving docks. *Human capital* refers to the skilled and unskilled labor required to manufacture and repair warships and support vessels, including merchant mariners, operators, and dockhands. *Financial capital* comprises the public and private capital that feed the industrial base. This treatment provides a detailed examination of these means.

Given the threats facing the United States and the economic and political pressures that inhibit bold action, the question this work will attempt to address is, in the event of a multi-theater conflict, can the United States surge elements of economic, manufacturing, political, and human capital to rapidly reconstitute combat losses and accelerate shipbuilding in order to support a sustained conflict, while also increasing the size of the Navy and Maritime Sealift Command (MSC) fleets? This work will identify the challenges confronting the shipbuilding enterprise in the United States and propose recommendations across government, industry, and defense to sustain the US's ability to command the seas.

Finance and Economics in the American Shipbuilding Industry

This section explains the financial and economic issues, opportunities, and policies that are integral to shipbuilding in the United States. These include the availability of manufacturing and repair facilities, the supply of critical raw materials and components, the size and attributes of the workforce, and the exchange of private and public capital within the industry.

Availability of Manufacturing and Repair Facilities

Currently, US shipbuilding facilities would be able to respond to a surge in production, but repairing significant US Navy battle damage would challenge existing repair infrastructure. The US shipbuilding industry is a highly concentrated oligopoly, with the four largest players accounting for 58.2% of industry activity and industrial facilities. Huntington Ingalls Industries, Incorporated, and General Dynamics Corporation alone accounted for 50.5% of industry revenue in 2017.[6] Key economic drivers for the industry are federal funding for defense, private investment in industrial equipment and machinery, US oil and gas production, and consumer spending. Federal funding for defense constitutes the majority of the demand for industry products as well as the health of the industrial base, and the market behaves as a monopsony, with the US government purchasing 79.5% of the products and services.[7]

Most facilities that manufacture Navy and Coast Guard vessels run at less than full capacity, and have the ability to ramp up or expand production if there is a demand signal.[8] The ability to surge production would be a multi-year undertaking, as ships require long lead-time items and have lengthy development and production timelines; additional skilled labor would need to be recruited. By way of example, a Littoral Combat Ship (LCS), one the Navy's smallest and least complex vessels, takes about three years to produce using one-plus shifts of labor, where one shift works in production and the other smaller shift works in support of the first shift. Like all oligopolies, there are high barriers to entry, especially in the defense sector, where highly specialized equipment, high security requirements, and facilities are required to meet the dictates of government contracts.

Defense contracts account for 79.5% of the total industrial output--65.6% in shipbuilding and 13.9% in repair. Jones Act vessels and energy production and transport make up the remainder of the industrial activity and were negatively impacted by the fall of crude oil prices in 2014. Industry revenue was $27.3 billion in 2017. Annual growth from 2012 to 2017 was 0.3% and, as previously stated, is projected to grow by 4.6% annually in the next five years. This anticipated growth is predicated on increased defense spending and recovering oil prices,[9] but may be negatively impacted by sequestration, political turmoil, or a tepid recovery in crude oil prices.

Five tier one shipyards, owned by two companies, have the capability and capacity to build large and complex military ships and submarines: General Dynamics' Electric Boat, Bath Iron Works, and National Steel and Shipbuilding Company (NASSCO); and Huntington Ingalls Industries' Newport News Shipbuilding and Ingalls. Several second-tier shipbuilders build smaller military ships: Austal, USA, Bollinger Shipbuilding, Eastern Shipbuilding, Marinette Marine, VT Halter, and Aker Philadelphia shipyard. While the Navy anticipates an increase in funding to support its target of a 300-plus-ship fleet by the mid-2020s, it will need to ensure that the shipbuilding industry is capable and appropriately incentivized.[10]

Repair and maintenance facilities for large naval vessels are a vulnerability in the industrial base, and repairing battle damage incident to combat at sea may necessitate a reliance on partner nations or prioritizing military over civilian vessels in repair yards. The dry dock and repair industry in the US is mature and driven by similar economic factors as the shipbuilding industry: military spending, crude oil production, and commercial trade. Dry docks are geographically dispersed in the US, with the highest concentration residing in Florida (23.9%), Louisiana (16.2%) and Texas (10.4%).[11] The dry dock and repair industry benefits from many of the same assistance programs that buoy the shipbuilding industry.

Repair, modernization, and maintenance infrastructure have simply not kept pace with the needs of the US fleet. The Navy's existing infrastructure is more than 60 years old on average and dry docks are more than 80 years old.[12] Vice Adm. Dixon Smith, head of the Navy's Installations Command, testified to Congress in 2016 that "we're not gaining ground" in Navy facilities. New dry docks for Ford-class aircraft carriers and Virginia-class submarines will likely be done just in time to service the first-of-class vessels, "possibly ten years after the first ships are commissioned."[13]

The civilian dry dock and repair sector is no better than the defense sector. Repair yards face stiff competition from overseas facilities. The largest floating dry dock in the US, *The Vigorous*, owned and operated by Vigor in Portland, Oregon, was procured from China, because the US lacks the ability to economically manufacture a similar product.[14]

Financial Capital and Economic Incentives in Shipbuilding

The Congressional Budget Office estimates that the Navy would need to spend roughly $5.4 billion per year in constant FY2017 dollars to achieve a 355-ship fleet, and an additional $11–$23 billion per year to maintain the fleet.[15] These costs exclude funds required for additional manned aircraft, unmanned systems, and weapons magazines. In the event of a national emergency, these funds would likely come from a combination of tax increases, decreased spending on entitlements, and deficit spending. The defense

capital would likely be mirrored to a lesser degree by local government and private capital investments attracted to the additional business opportunities.[16]

Shipyard work is coveted by local economies, as it tends to be high paying and relatively steady. A 2015 Rand study noted that the economic multiplier of shipbuilding capital is estimated to be between 1.7 and 1.95. State and local governments often strive to attract shipbuilding capital by making their own investments in the industry, granting tax breaks, or investing in infrastructure in and around shipyards. During a national emergency, capital would also likely come in the form of federal loan guarantees. In World War II, federally backed V-loans were used by the Maritime Commission to rapidly expand the industrial base.[17]

A political consensus would be required to fund a surge in wartime military production. The power to declare war is granted to Congress in Section 8, Article 11 of the Constitution, and the president of the United States has the ability to exercise emergency powers. This authority can be challenged by the Congress through the power of the purse, and the judiciary, through the court system. This is uniquely American, and most likely has its origins in John Locke's view that an executive must exert an increased discretion to meet special exigencies, as the legislature cannot constantly be in session.[18] The Constitution does not explicitly grant the president the power to declare an emergency, but to "provide for the common defense" and "promote the general Welfare."[19] The War Powers Resolution of 1973 bound the president and Congress by insuring "that the collective judgment of both the Congress and the president will apply to the introduction of United States Armed Forces into hostilities."[20] Several economic powers are granted exclusively to the president in the Defense Production Act (DPA) of 1950.

If a consensus is reached and the economy transitions to a wartime footing, the Congress would need to consider the long-term consequences of a surge in production. Namely, they would need to consider achieving victory without straining the fabric upon which the strategy is woven, thus assuring a lasting peace after a cessation of hostilities.[21] The economic consequences of their actions would be long lasting.

Assistance in maintaining a vibrant shipbuilding industrial base is high in the US and trending up. This assistance would pay dividends in the event of a national emergency requiring a surge in production. Several of the assistance programs are listed below:

- The Jones Act, which receives detailed treatment in the following pages.
- The National Shipbuilding and Shipyard Conversion Act of 1993 aims to support the industrial base for security objectives. Title I of the Act, the National Shipbuilding Initiative, stipulates "(1) a financial incentives program to provide loan guarantees to initiate commercial ship construction, encourage shipyard modernization, and support increased productivity; (2) a technology development

program; and (3) enhanced support for specified Department of the Navy shipbuilding programs."[22] Title II of the Act "aids in the transition of US shipyards to commercial activities or preserve shipbuilding assets essential in war or a national emergency."[23]

- The US military pays for most defense-related research and development and capital investments required to compete for military contracts. The results of these activities become part of the public good of the industrial base.[24]
- Under the Small Shipyard Grant Program, grants for capital and related improvements to qualified shipyard facilities are available through the Maritime Administration to "foster efficiency, competitive operations, and quality ship construction, repair, and reconfiguration."[25] In fiscal year 2018, $20 million is available in grant money under this program (up from $9.8 million in 2017).
- Under the American Recovery and Reinvestment Act of 2009, additional funds for capital improvements were made available to small shipyards through the Maritime Administration (MARAD).[26]

MARAD administers the Federal Ship Financing Guarantee program. The program "provides for a full faith and credit guarantee by the United States government to promote the growth and modernization of the US merchant marine and US shipyards."[27] MARAD also runs the Construction Reserve Fund (CRF), providing tax deferrals for eligible shipbuilders, allowing them "to build larger, better-equipped new vessels, to reduce mortgage debt on new vessels, or to build a greater number of vessels than would have been possible without the CRF,"[28] and the Capital Construction Fund, which assists companies in expanding shipyards and modernizing fleets through tax deferrals.[29]

No piece of legislation has directly impacted the maritime workforce as much as the Jones Act. A subset of the 1920 Merchant Marine Act, the Jones Act affects coastwise trade and requires that all goods transported by water between US ports be carried on US-flagged ships, constructed in the US, owned by US citizens, and crewed by US citizens.[29] There are other provisions that have been added or modified over the years that affect the maritime workforce such as cargo preference, which mandates a certain percentage of US aid and military supplies be transported on Jones Act ships.

According to MARAD, 181 total merchant ships are registered under the US flag as of March 2018.[30] These ships represent ocean-going, self-propelled vessels that exceed 1,000 gross tons and are actively engaged in carrying commercial cargo in either the international or domestic markets.[31] However, at least five of these ships are under long-term contracts to Military Sealift Command (MSC) and are not purely engaged in commercial operations.[32] Further, 59 of the US-flagged ships were built in foreign shipyards and are engaged in international trade, but receiving competition differential payments as part of MARAD's Maritime Security Program (MSP).[33] Though these 64 total

ships are under the US flag, if government contracts cease most would reflag to another nation or be sold for scrap by their operating companies.

Only 100 of these ships are Jones Act-compliant, while the other 81 vessels were built at shipyards outside the US.[34] Fifty-nine of the 100 ships built in the United States are tankers engaged in the domestic transportation of petroleum products. The remainder of the Jones Act-compliant ships are engaged in general cargo operations such as roll-on/roll-off (RO-RO) and container shipment. 156 of the 181 ships are useful to carry military cargo in a time of war.[35]

Human Capital

In 2015, the US shipbuilding and repair industry employed approximately 110,390 workers in direct labor and 399,420 workers in indirect labor, mostly clustered around the Gulf Coast, Virginia, and California.[36] The top five states with direct employment are Virginia (28,210 employees); Mississippi (12,720); Louisiana (12,230); Connecticut (9,030); and California (7,190). The market for skilled shipbuilding and ship repair labor is highly competitive. Welders, machinery operators and skilled craftsmen are sought after by manufacturing industries, construction companies and defense contractors in regions where shipyards are located. Together, the shipbuilding workforce accounted for $25.1 billion in labor income and produced $37.3 billion in gross domestic product.[37]

In 1960, the US was the world leader in ship production, with the largest maritime workforce and a Navy consisting of 812 ships.[23] Today, the US ranks 19th in the world in commercial shipbuilding, accounting for only 0.35 percent of global new construction.[24] In 1980, there were nearly 200,000 people employed in both public and private US shipyards, compared to just over 100,000 today—a decline of nearly 50% in the last 38 years.[25] Between 1982 and 1984, the US Navy procured 17, 14, and 16 ships, respectively. Between 2016 and 2018, the Navy procured nine, seven, and eight vessels.[38] The nadir of shipbuilding activity in the US was 1997, when the industry generated $8.4 billion[39] in revenue versus $27.3 billion in 2017 (both figures in constant 2017 dollars). The Navy procured only four ships in 1997.[40]

Similarly, the labor pool building existing ships in development is small and declining. According to a joint report by the Departments of Labor, Transportation, and Education, the average age of the US maritime worker is about 50 years old, and by 2020 there will be a 20% shortage of maritime workers.[11] The report's analysis also indicates that the projected annual job openings are 68 percent more than the number of people completing maritime job and educational programs. This divergence means a lack of future human capital will challenge the US government's ability to respond to a maritime crisis with the expertise needed to complete repairs in a timely manner.[12]

Even if the US government decides to make maritime education a priority, significant economic headwinds will impede efforts to grow the supply of skilled workers in the maritime industry. For example, the US is at or near full employment, and major shipyards reside in areas with strong economic activity. Unemployment is 3.7% in Virginia, 4.3% in California, 4.5% in Mississippi, 4.0% in Louisiana, and 4.6% in Connecticut.[41] Incentives would have to be sufficient to convince an ample number of workers to leave their current positions for employment in the shipbuilding industry.

An examination of the skilled workforce in the state of Alabama accurately illustrates the competitive nature of the labor market in shipbuilding regions. Alabama's Austal, USA shipyard competes for skilled labor with several other shipyards in the region: Ingalls Shipbuilding and VT Halter Marine in neighboring Mississippi, Bollinger Shipyards and Edison Chouest Offshore in Louisiana, and numerous other smaller shipyards along the Gulf Coast. Large, private manufacturing firms, such as Honda and Hyundai, and major defense contractors, such as L3, General Dynamics Land Systems, and BAE Systems, also compete for eligible workers.[42] Large energy companies and agribusiness also draw heavily on the pool of labor, and the barriers to entry from one job to another are low because of the close proximity of facilities and low cost of living.

Strategies to grow the overall shipyard workforce include incentives for current nonparticipants in the workforce, such as increased pay, expanding the availability of paid leave, affordable childcare, flexible work schedules, educational opportunities and generous benefits packages.[43] Potential candidates to re-enter the workforce include stay-at-home mothers and recent retirees; skilled workers from outside the region; and immigrant labor. Despite these incentives, the most impactful way to increase shipworkers will be to build more ships. The more complex the design, such as cruise ships, the more skilled the workforce will become to support the nation during any potential surge in the future. By way of comparison, the labor participation rate in the US is 62.8%, 63.1% in South Korea and 58% in the European Union (EU).

The US domestic fleet, which is predominantly produced under the mandates of the Jones Act, is not only an important part of the national maritime infrastructure, but also of the National Security Strategy (NSS). A large and vibrant commercial fleet helps ensure there will be an ample maritime workforce to provide sealift capacity to defend our nation in times of conflict, especially if a surge is required. Furthermore, a large commercial fleet crewed by US citizens relying on a US workforce in shipyards constructing and repairing vessels, bolsters the economy while at the same time growing the industrial base.

The maritime workforce consists of diverse jobs, many which require training and qualifications that cannot be achieved overnight. The Jones Act, thus, provides a good starting point to sustain a minimal maritime workforce, however a larger workforce is needed to ensure the US can meet the challenges and threats of the 21st century.[34] Other

countries maintain skills through a civilian reserve labor pool for times of war. For example, both Sweden and Finland require civilians to have "wartime" assignments to increase wartime production if they are already not part of the military reserve system. Civilians in Sweden are required to report for duty once per year to ensure they receive appropriate training on the specific tasks they will perform.

Although the surge in shipbuilding would likely strain the pool of available labor, policy options and incentives are available to rapidly expand the number of eligible workers. Business incentives and wage increases could have the negative effect of inducing demand-pull inflation in regions with shipyards. One counter to the inflationary cycle would be to gradually grow the workforce over a period of years. Local and state governments are generally supportive of shipyards, and a robust enterprise for training shipyard workers exists in the US, owing in large part to prior government investment. Regardless of the approach selected, direct US Government participation will be required, to which lessons learned from foreign partners can be gleaned to maximize efficiency.

Shipbuilding and Manufacturing

The Defense Production Act (DPA)

The United States has adequate access to supplies of steel to meet most foreseeable needs. Despite having available steel supplies, there are certain ship components that require specialized production not typically available within the shipyard. Many of these components are currently procured from Asian suppliers, which is a concern for US commercial shipping. Conversely, US companies such as Lehigh Heavy Forge and Scot Forge are authorized suppliers for US Navy ships and submarines.[44] In addition, there are a limited number of foundries that have the capability to produce heavy castings with organic machining. In almost any high-intensity naval engagement scenario, the demand for such supplies would almost certainly increase demand for such supplies, which means the limited number of approved foundries and forges will have to prioritize the orders received from the Department of Defense (DoD) across multiple industry needs.

Assuming the foundries are not able to maintain adequate production, sourcing parts from European allies will become necessary. Most of these parts will likely come from Germany as US engine maker Fairbanks-Morse, and Finnish engine maker Wartsila, both utilize subcontractors in Germany for their heavy castings based on visits to their respective factory floors. This supply chain is in contrast to that found in Sweden, where the primary shipbuilder is Saab-Kockums. As discovered during the Eisenhower School international field study, their preferred method is to first source from Sweden, then from the rest of Europe. In total, about 90% of Saab-Kockum's raw materials, components, and systems come from Sweden or the rest of Europe with the majority of supplies sourced from local companies within Sweden.

Even if the United States is able to obtain limited supplies, the next problem will be having enough shipyard space to conduct repairs while continuing to build the fleet. There will also be a need for additional skilled welders and pipefitters to increase current throughput. The US has a handful of active private naval shipyards for shipbuilding and repairs. Bath Iron Works and Ingalls Shipbuilding work on surface combatants, Newport News Shipbuilding focuses on nuclear-powered aircraft carriers and submarines, Electric Boat constructs submarines in Groton, Connecticut, and Quonset Point, Rhode Island, and NASSCO in San Diego concentrates on smaller vessels and ship repair. The two newest shipyards to join DoD ranks are Fincantieri Marinette Marine (FMM) in Marinette, Wisconsin, and Austal, USA based in Mobile, Alabama, both producing US Navy LCSs.[45]

There are also four public shipyards dedicated to US Navy repairs, maintenance, and modernization in Portsmouth, Virginia; Kittery, Maine; Bremerton, Washington; and Pearl Harbor, Hawaii.[46] Other US shipyards, such as Philly Shipyard, VT Halter Marine, and Eastern Shipbuilding Group are focused on constructing Jones Act-compliant vessels, though the latter is transitioning to also add the US Coast Guard Offshore Patrol Cutter to its production line beginning late 2018.[47]

Through this handful of US shipyards, there are skilled welders, pipefitters and electricians who are able to 'surge' to increase their capacity to build vessels by adding more shifts to current work schedules. However, there are a few key critical components that most of these shipyards are not able to produce in-house leading to direct dependencies on a limited number of global suppliers.[48] It is these critical components that are key to increasing shipbuilding capacity in times of crisis. Specifically, these items include: bulbous bow stem- and stern frame castings, stern tubes, marine engine reduction gears, and marine air conditioning (A/C) units.

A bulbous bow is typically below the waterline of a vessel with a purpose of generating a second wave to destructively interfere with the bow wave created from forward motion of the ship in order to reduce drag and increase fuel efficiency.[49] This bow is typically attached to the vessel via a steel casting at the bow stem. Depending on the size of the vessel, the casting will likely need to be acquired from a heavy forge. Therefore, US forges will be needed to produce these castings, but as previously mentioned, Bradken Forge in Tacoma, Washington, is the only one approved for 'casting' HY-80/HY-100 with in-house machining to reduce work on the shipyard. Procurement priority should be applied for these high yield HY-80/HY-100 steel castings to meet the shortfalls that will likely occur in any conflict with China.

Stern frames and stern tubes are critical components required for ship propulsion to occur. Again, due the complexity involved with their manufacture, local shipyards are not capable of producing such parts efficiently and will buy them from outside manufacturers.[50] Stern frames can weigh in excess of 40,000 pounds, and there are few

US manufacturers who can handle such large pieces. It is possible to steel plate a stern frame after the fact, but the skill to bend plates varies among shipbuilders.[51]

Stern tubes, on the other hand, must be forged and milled to precise standards to connect the propeller with the engine crankshaft through the hull without allowing water to leak through.[52] Although forging and milling capability for stern tubes in unlikely to be an issue given the number of open die press forges that can fabricate 10,000-pound stern tubes, production may be competing with other commercial parts given that open die press forges are also used for aerospace, oil, and gas industries to name a few.

A reduction gearbox is required to ensure optimum speeds occur between the engine and the propellers for propulsion.[53] There are few manufactures of reduction gears within the United States, so most shipbuilders will be looking to foreign suppliers such as Rolls-Royce, Wartsila, or Renk.[54] One company with the capacity to potentially produce such gears would be Fairbanks-Morse in Beloit, Wisconsin, which has experience making the opposed piston engine used in submarines.[55] Since wartime damage to gears from adversary torpedoes and/or missiles is likely, reduction gears will become a necessity and will require priority procurement to ensure timely repairs.

Although A/C units may not be the first item one may think of when it comes to shipbuilding, these have become critical components. However, not only do they provide sailor comfort, they are also a necessity to keep computer systems cool that run software essential to critical ship functions such as navigation, weapons release, and propulsion.[56] Many marine A/C units are produced by York manufacturing which is a division of Johnson Controls. However, York does not focus on only marine A/C units, they provide heating, ventilation and air conditioning (HVAC) for buildings, offices, and even homes which has a much larger consumer base than ships.[57] Therefore, the DoD will need to prioritize defense shipbuilding needs over other orders to ensure ships would not be lacking for a basic, yet key component for operations. While it is possible to increase the supplier base of A/C units, it is likely this is not necessary given the large consumer base already in existence through existing companies.[58]

Now that five critical components have been identified, the question is how to ensure priority procurement? The answer is the Defense Production Act of 1950, which allows the government to require private industry to produce needed supplies at a higher priority than commercial orders.[59] There are two codes that can be applied to orders under the DPA. The first code, DO, means that those products deemed “critical to national defense” must be prioritized over any non-rated commercial orders.[60] The second code is DX, which has a higher priority over DO rated orders are for items designated as having “highest national defense urgency.”[61]

There is no additional priority system within DO or DX rated items meaning that the only way to have the highest priority is to have a DX-rated code applied to the needed item.[62] Currently, DX ratings are only provided to weapon systems associated with nuclear operations such as the Trident, B-2 and Space-based Infrared System High.[63]

Given that DX ratings are rare, it is best to implement these codes to shipbuilding only during a time of war. Additionally, it is best to limit DX ratings to those critical items that are largely beyond the shipbuilders' control to fabricate. The following DX rating categories are proposed in a time of conflict to account for the various items described in this paper:

- Marine heavy and open-die forge castings (to account for bow stems, stern frames, stern tubes)
- Marine propulsion systems (to account for reduction gears, and other critical components such as props and shafts as required)
- Marine HVAC systems (to account primarily for A/C units required for running multiple computer systems)

While the above list is not exhaustive, it includes the highest priority items needed in conflict given their relationship to the hull, propulsion, and cooling systems. Having such critical components available to shipbuilders at a higher priority will ensure the US has the ability to expedite ship repairs while sustaining ongoing ship and submarine construction during a Pacific theater conflict.

The Classification of Naval Vessels

Ship construction is a unique process that requires shipyards to piece together steel and many components to construct a floating vessel designed to engage in commerce, drilling, or even transporting passengers. Classification societies ensure that ships are held to internationally recognized technical standards in order to maintain the structural integrity of a vessel during construction and throughout its usable life. Classification societies are commercial entities that approve construction plans, issue International Load Line Certificates which certifies the maximum draft a vessel can safely sail, and conducts routine surveys during the vessels life ensuring the owners are keeping up with maintenance requirements.

American Bureau of Shipping (ABS), Lloyd's Register, and DNV GL are some of the most recognized classification societies of ships in the world and having a full classified vessel enables vessel owners to obtain maritime insurance, transit into ports that enforce standards, and negotiate contracts with labor providers. Having a vessel within standards of the classification society is also very important if the vessel owner wants to sell or trade the ship.

While most non-combatant Navy ships are built to ABS standards, USN ships are not classified by a classification society. In the early 2000s, the Navy attempted to meld the Navy's ship construction rules with the standards from ABS under a program called Navy Vessel Rules (NVR). The Navy abandoned NVR standards and returned to constructing ships based on Navy standards. NAVSEA leadership claims that warships need special construction standards for shock qualification, damage control standards, and myriad other military-unique requirements.

However, these may not always be best practices to build ships because they cost more, are not aligned with current industry practices, and add layers to the design process ultimately driving cost and schedule up. NVR was not perfect but it did induce some best practices into the construction of USN ships. If the Navy were to abandon NVR and Navy construction rules altogether and built ships to ABS standards, there would be significant cost savings across the board from design work to ship construction costs, and an increased number of commercial yards that may now be capable of producing warships in the event of crisis. Some traditional ship designs would have to change and new practices would have to be adopted (i.e., survivability), but this risk may be worth exploring due to the potential cost savings to the yards, taxpayer, and the DoD budget.

Innovation in Shipbuilding

A recent study on innovation showed that the top five US defense contractors spent $9.43 billion on Research and Development (R&D) in 2017.[64] While US defense investment was greater than comparable spending by the top five international defense firms, US tech giant Amazon spent almost as much on R&D during the same period as the top ten global defense companies combined. In fact, the top five tech companies in the US spent a combined $65B on R&D in 2017.[65]

There are two general drivers of innovation- the desire for market share or increased profits in the civilian sector and the need for technological superiority in the military sector. Innovation can span both and often does. Wartsila, the Finnish engine manufacturer visited by the Eisenhower School Shipbuilding seminar in April 2018, is a leading innovator in reducing emissions while not sacrificing reliability or horsepower. While naval customers may not primarily be concerned with environmental impacts, they do care very much about the other two.

The US Navy has developed some of the most advanced and lethal warships in history. However, focus has increasingly shifted from the platform to investment in state of the art combat systems. Because these systems are so specialized and expensive to develop, the Navy does not build full sized prototypes. The first ship of the class is the prototype, and unforeseen flaws in design and construction of the platform/payload package quite often add costs and lengthy delays to the delivery schedule. In an effort to reduce budget constraints, the Navy has focused on smaller platforms that require fewer crew and incur cheaper operational costs that can be spread over a 30 to 50-year lifecycle.[66]

Just as the Navy has been willing to innovate with platform designs, it has also considered unique material solutions for those platforms. For example, the Independence-class LCS produced by Austal, USA, is an all-aluminum platform. However, aluminum is not without risk. Aluminum will melt and is also prone to structural cracking and repair costs significantly increased operation and maintenance

budgets in the fleet, which is one reason that drove the Navy to return to an all steel ship design in the early 1990s.[67]

Shipbuilding plans, however, must account for a number of factors to include: Defense requirements, economic constraints, strength of the industrial base and political support. Despite the "fail fast" mantra now being championed by DoD leadership, program managers still fear not meeting time driven objectives. The most risk averse and politically driven goals have one common cause—Congress. By controlling the purse strings, Congress rewards success and punishes failure.[68]

In the 2018 National Defense Strategy, Secretary Mattis outlined his vision that success no longer belongs to the country that develops a new technology first, but rather to the one that better integrates technology and adapts its way of fighting.[69] The industrial base will build any ship the Navy can envision. He correctly identifies a core problem within the Department's current acquisition process—minimize risk above all else. The United States has a long history of innovation but unfortunately that often comes after the initial shots of a conflict have been fired. The US has an opportunity to get ahead of that now rather than later, when innovation will be much messier.

Modularity in Shipbuilding

Shipbuilding is a large-scale activity involving large numbers of people and materials. Building ships requires huge investments of capital, infrastructure, material, and manpower. There is always a need to develop and implement modern construction methods to remain competitive in the shipbuilding industry. Modularity is now being adopted by all modern shipyards to reduce cost, labor and production timelines. Although many modular technologies have been available for many years, they have gained more prominence since the early 21st century.

The biggest challenges in shipbuilding are controlling cost, ensuring timely construction schedules, and fulfilling skilled labor requirements. Modularity can address all of them if implemented in a well-thought out way that accounts for mission, shipyard capability, and cost. "Modularity implemented in a scalable architecture enables the development of subsystems independent of the overall platform development."[70] Modules built in parallel shorten ship construction time, which in turn saves cost due to lower overhead and less impact of inflation as compared to the conventional shipbuilding methods. Furthermore, modularity reduces construction costs by providing a mechanism in which common components are produced in a factory and then transported to the shipyard for erection with other modules.

This systematic way of manufacturing different sections of the ship leverages the economies of scale that not only lowers costs but can be beneficial in surging the US' shipbuilding capacity. Any work that can be pre-fit into a module before erection in the

shipyard to other modules, saves time, costs, and potential re-work. Modularity is ideal for surging the shipbuilding industry, especially if multiple hulls of the same design are being produced, because a standardized module can be produced by a factory or sub-contracted and then transported to numerous shipyards to be erected into a common design of a particular kind of ship Whether the modules come from various geographic locations around the US or are produced by allies, gives the US shipbuilding industry the flexibility and versatility it needs to be competitive in peacetime or gives it the capacity it may need during conflict.[71]

Modularity is not without risk, however. Modular shipbuilding is an integrated approach of constructing ships. Therefore, initial designs are a key to a successful modular program. Any flaw in the modular design could be detrimental in the integration of various modules during the construction process. Modules which have an assembly line are more dependent on the correctness of design. The risk in design is greater and if not mitigated quickly would lead to grave consequences. Modularity requires better than normal engineering, better than normal quality assurance and higher level of design standards to minimize interferences and disconnects. Similarly, modular construction project planning is a key specifically for warship programs due to complex module design and future integration of mission and weapon packages, space requirements, etc. Modularity is clearly beneficial to control cost and schedule and should be emphasized as a standard method of ship construction as cost and schedule become ever more important in the future.

Comparison of Major Shipbuilding Regions and Nations

As each nation and region has its own unique culture, norms, language, and political systems, so do major shipbuilding regions have their own ways of doing business. Commonalities include government oversight, laws, regulation, policy, and funding. Each region or nation has its own shipyards, financing, workforce, design, and technical philosophies. How those elements are combined is what sets each apart. We will examine three major ‘shipbuilding cultures’ to identify ways in which the United States can do better.

A key difference between the American Way and the Asian and European Way is how the governments take a particular interest in their shipbuilding industries. A major commonality seen globally is that many developed nations provide some level of subsidization for shipbuilding, in recognition of shipbuilding’s importance to the nations’ economies and national security. In fact, the WTO’s *World Trade Report 2006* notes that a total of 11 developed countries, including 7 EU countries, provide subsidies to shipbuilding. [72]

While the biggest subsidizers are the Asian nations, European nations remain competitive for the most complex US commercial projects in terms of cruise ship construction through use of indirect subsidies to its shipbuilding industries (mostly in the

form of credits, loan guarantees and Research and Development (R&D) grants).[73] As a prime example of subsidy success, the Government of Finland invested a 30% stake in the Turku Shipyard in partnership with the German shipbuilder Meyer-Werft in September 2014 to keep the shipyard afloat. By April of 2015, Meyer acquired the Finnish government stake, and the Turku shipyard continues to produce cruise ships for customers such as Carnival Corporation.[74] Of all the lessons learned, this idea of government partnership is the one that the US Government can most benefit from in terms of how we can increase US shipbuilding capacity and production for surge purposes.

The Asian Way

Asian nations, specifically the triumvirate of China, South Korea, and Japan, heavily subsidize their shipbuilding industries. As noted, "China, South Korea and Japan have invested in productivity and capacity and taken advantage of lower labor costs and government subsidies, allowing them to produce lower-cost products."[75] These subsidies are responsible for the rise of the Asian market and their position as the top shipbuilding nations in the world. As a result, "Today, more than 90 per cent of the world's orders for new ships have been placed with Asian yards, more specifically with shipbuilders in China, Japan and South Korea."[76]

In the late twentieth century South Korea supplanted Japan as the Asian shipbuilding leader after a concerted effort by its government in the to grow its manufacturing industries and in shipbuilding in particular as part of its Heavy and Chemical Industrialization (HCI) policy. South Korea heavily subsidized its shipbuilding industry through "capital incentives, trade incentives, and tax holidays."[77] The nation helped its largest shipbuilder, Hyundai Heavy Industries, by "(i) giving access to domestic and foreign funds with preferential interest rates; (ii) helping in obtaining and providing financial guarantees for the first order; (iii) making complementary investments in facilities and complementary industries, such as steel through the Pohang Iron and Steel Company (POSCO); and (iv) providing support for acquiring new technologies."[78] These actions worked. Korea increased its share of the international shipbuilding market from 15 percent to 70 percent between 1997 and 1999.[79]

China recently moved to overtake South Korea as the world's top shipbuilder. China's 2006 "Long and Medium Term Plan" included the goal to make the Chinese shipbuilding industry the largest in the world by 2015.[80] China went after this goal through "a robust range of mercantilist subsidies to ensure an unfair advantage in world competition."[81] This includes heavily subsidizing the Chinese steel industry, 20% price subsidy for Chinese buyers, better interest rates, and preferential financing mechanisms for its state sponsored shipyards. A Princeton University study quantified the impact of the Chinese subsidies, finding that China's subsidies "artificially lowered Chinese shipyards costs by between 15 and 20 percent. In other words, subsidies reduced Chinese shipyard costs from 2006 to 2012 by roughly $5 billion." [82] These subsidies in

Asia show how subsidies, along with other favorable conditions such as low wages, can help a nation's industry grow to prominence in the international market.

The European Way

The EU also "set out the framework for its Member States to provide support to their shipbuilding industries under a series of specific state aid regimes." [83] EU nations have used multiple frameworks to regulate shipbuilding industry support, with the purpose of "establishing, in a legally binding manner, a 'level playing field' in the commercial shipbuilding and repair industry through: (1) a discipline for government support, (2) a legal instrument to deal with injurious pricing actions of shipbuilding companies, and (3) binding dispute settlement before an independent international Panel."[84]

The most recent Framework on State Aid to Shipbuilding, which expired in 2014, "contained specific provisions on regional aid, innovation aid and export credits," defining what types of aid were acceptable in regards to shipbuilding.[85] Since 2014, there have been no specific EU regulations in regard to shipbuilding. In general, however, "operating aid has been gradually reduced and eventually abolished by the European Communities."[86]

In the 1990s the EU also worked with the US to try "to put an end to worldwide shipbuilding subsidies, put a moratorium on added shipbuilding capacity and provide a dispute settlement mechanism." [87] Under the Organization for Economic Cooperation and Development (OECD), the EU and the US negotiated a proposed plan "to bring shipbuilding and repair under the coverage of an injurious pricing code modeled after the General Agreements on Tariffs and Trade Antidumping Code."[88] Unfortunately, the US did not ratify the OECD Shipbuilding Framework, and other "main EU competitors do not seem motivated to discuss a substantive agreement in shipbuilding through the OECD."[89] As a result, a major shipbuilding specific agreement limiting government support looks unlikely on an international basis.

The American Way

The American Way, as evidenced by examining shipbuilders involved with Department of Defense, US Coast Guard, and commercial Jones Act-compliant vessels, can be summarized as "laissez-faire" with where the US government picks zero-sum gain winners and losers with most contracts while commercial shipbuilder futures are determined by the business cycle. The combination of these practices has resulted in the closing of more than a dozen shipyards since World War II, with the largest commercial projects (e.g., cruise ships) having production move to Asia or Europe. While the United States does have some programs that are clearly subsidies (Shipbuilding Grant Program,

Jones Act, etc.), these are paltry in comparison to those provided by Asian governments to their shipbuilding industries.

A secondary impact of the American Way is on shipbuilding labor and expertise. Take for instance, when the US government picks 'winners and losers' with defense contracts, labor must either migrate to either the new contract awardee or to a different private industry. Usually the latter makes more sense for certain trades because there is no ability, incentive, or desire to move to a new location in the United States just to work on a defense contract. For example, the LCS is built in both Marinette, Wisconsin, by FMM, and in Mobile, Alabama, by Austal, USA.[90] Should the Navy's new frigate contract go to one shipyard or the other, then economic theory would suggest a steelworker should move from Wisconsin to Alabama, or vice versa, to follow the work. However, given there are plenty of steel construction projects to work in Milwaukee or Chicago, a steelworker may not want to move from Wisconsin to Alabama to continue to work on defense-related projects should Austal win. While DoD just "won" on cost, it actually lost on long-term "investment" because new steelworkers will need to be hired in Alabama to offset the skilled labor from in Wisconsin who did not move to Mobile. This lack of retaining skilled works in shipbuilding means higher potential for fabrication errors and slower production times. Therefore, while the "laissez-faire" attitude of the American Way may be more efficient for businesses, it is less effective in terms of our ability to surge in war.

Recommendations

General

- Within the Eisenhower School, combine multiple, connected industry studies (Strategic Materials, Manufacturing, Robotics, etc.) to look at Shipbuilding more holistically to enable a more comprehensive examination of challenges and opportunities.

Manufacturing and Shipbuilding

- Develop strategy to ensure repair yards are resourced, staffed, and have sufficient capital to respond to surge demands for both warships and MSC vessels.
- Continue building MSC ships to classification society standards in order to continue reducing costs, schedules, and ensure commonality with international standards. This will also help US shipbuilders remain attractive to international customers.
- In the event of conflict, be prepared to award multiple production contracts for cargo and low-tech warships from to any vendor with minimal 'exquisite requirements, similar to the MRAP model.

Human Capital

- Identify critical shortfalls in skilled labor and create a ready-to-implement curriculum to get both skilled and unskilled workers trained in quickly at community colleges in each congressional district.

Financial Capital

- Fully fund the Navy's 30-year shipbuilding strategy to ensure a consistent shipbuilding ramp, which will both encourage industry to take prudent risk but also ensure there is sufficient resiliency in the industrial base to respond to a surge in demand.
- The US should examine and expand, if merited, shipbuilding, repair, and production subsidies and loan guarantees to ensure there is a stable, reliable industrial base ready to perform should called upon to do so in the event of a crisis.

Areas for Further Study

1. Government subsidies and incentives to regain global competiveness in the commercial shipbuilding sector. Is there a multiplier effect that would offset the subsidies?

2. Outsourcing design, modular construction, and larger or more complex components beyond what is already done. Should we use our economic power and human capital towards things we can do better and leave design and shipbuilding to others?

3. Treaties and agreements to 'borrow' capacity from allies. Is a reverse Lend-Lease more practical and cost-effective than having underutilized assets swaying at anchor 'just in case'?

Conclusion

Is the current shipbuilding industrial base capable of surging towards a 355-ship Navy and a corresponding increase in merchant and lift ships? The answer, in our observation, is that it can but only with focus, unity of effort (i.e., political will), and a lot of money. The United States Navy has yet not budgeted sufficiently to achieve that end-state and the "market" (shipbuilders) would not invest in something the "customer" (United States Navy) doesn't want.

But if the question is, can the United States mobilize its industrial might to surge on a crisis that would require acceleration of warship building, acquisition or production of cargo and lift ships, and repair or replace combat damaged vessels without damaging other elements of the national economy? Based on our analysis, it can. The US

shipbuilding industry is small, balkanized, at times inefficient, and is captured by various political and business interests, but is functional, adaptive, frequently innovative, and can surge to meet the United States' requirements given prioritization, sufficient lead times, and robust funding. The ability of the United States to meet its shipbuilding needs is not a question of "can we?" but rather "do we want to?" The means exist, but the national will to do so remains in question.

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