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Foundational Improvements for Better U.S. Navy Shipbuilding

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KEY TAKEAWAYS

The Navy, shipbuilders, Congress, and the public need to be on the same page when it comes to building the Navy needed in an era of great-power competition.

Addressing constraints involved in building the Navy the nation needs will require becoming a smarter shipbuilding customer and learning from the recent past.

A better understanding of shipbuilding fundamentals can help to bridge divides and ensure that our maritime industry delivers warships on budget and on time.

On November 30, 2020, the Chief of Naval Operations (CNO) decided to forego replacement or repair of the severely damaged USS *Bonhomme Richard* following a days-long fire during the previous summer. The obvious rationale was easy to digest: $3 billion for a new ship was too much compared to $30 million over a year's time to decommission the ship.[1] However, easily missed in the Navy's press statements was the compounding rationale of limited shipyard capacity even to consider repair or replacement. This is a troubling admission given that the Navy must grow to meet the rapidly rising combined challenge of China's and Russia's navies.

America's post–Cold War shipbuilding record is not reassuring. A culture of organizational efficiency and cost savings has encouraged an institutional predilection for reducing fleet size, atrophy of supporting infrastructure, and near elimination of in-house naval engineering design. Despite a presidential policy requiring a 355-ship fleet by 2034[2]—a policy codified in law since 2017[3]—shipbuilding has been limited and budget requests have been reduced. The Navy's December 9, 2020, "Annual Long-Range Plan for Construction of Naval Vessels" intends to bend this curve and sustain increased shipbuilding rates over the next five years, funding 82 new ships at a cost of slightly more than $147 billion.[4]

Addressing these constraints effectively and building the Navy the nation needs is not impossible, but it will require becoming a smarter shipbuilding customer and heeding important lessons of the recent past.

The U.S. Navy's December 2020 "Annual Long-Range Plan for Construction of Naval Vessels," focusing on great-power competition and covering fiscal year (FY) 2022 to FY 2051, is a useful statement but inadequate by itself. As was true during President Ronald Reagan's naval buildup, the greater budgets required to enlarge the Navy as envisioned by the most recent shipbuilding plan must be accompanied by commitments to greater diligence and effectiveness in the use of these funds.

Specifically, naval shipbuilding must improve on its 2008–2018 track record of $8 billion more than planned in cost overruns for 11 lead ships produced and half of those more than two years overdue.[5] While things have improved, the ultimate metric for judging commitment to this promise is, first and foremost, delivering warships on time and in the numbers needed to keep pace with China's and Russia's maritime threats. At the same time, partnership with Congress will be vital to ensuring predictability in shipbuilding plans with long-term budgeting, stability in design, and adequate interval in series production to take advantage of economies of scale and fabrication experience.

Construction of Navy Ships

Navy shipbuilding is guided by instructions promulgated by the Secretary of the Navy,[6] by federal law,[7] (i.e. Title 10 U.S. Code section 254), and by customary precedent. Although little discussed, how these elements come together to guide or constrain decision-making in and resourcing of the Navy's shipbuilding program is important. The overarching "Two-Pass Seven-Gate Process" incudes one pass for senior leadership to decide on design requirements, a second to ascertain acquisition planning, and seven decision gates along the way. The key decision-makers in design progression from conceptualization to construction are the Chief of Naval Operations and the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN RD&A).[8]

Weighing heavily on these decision-makers and a key element throughout the design and construction of the Navy's warships is the setting of engineering requirements. The successful development of long-lived classes of warship depends on setting the right requirements to address specific tactical and operational challenges, both current and projected, but the Navy does not identify or develop capabilities to address these challenges in a vacuum. It must first validate and define future capabilities through the Joint Capability Integration and Development System (JCIDS). This is intended in part to ensure that the joint military forces are addressing capability gaps in a comprehensive and effective manner. As appropriate, this considers how new operational concepts (CONOPs) using existing and future systems can mitigate capability gaps before new platforms are developed.

The Need for Resourcing Predictability

In recent times, the Navy has tended to underestimate the costs of bringing new classes of warships to the fleet. This has been due in part to the changing nature of the naval threat from China and Russia and wartime lessons that inform military specifications meant to ensure survivability. It has also been due to a resourcing environment that encourages the underestimation of costs.

While congressional appropriations committees and the Navy have utilized several financing mechanisms effectively in recent years, pressures to expand the fleet will likely strain existing methods of shipbuilding budgeting. For one thing, a larger portion of the shipbuilding plan must fund the *Columbia*-class submarine fleet while also increasing the size of the fleet to more than 355 ships by 2034 and beginning production of large numbers of unmanned vessels. To manage this, the Navy and Congress must do several things:

- **Avoid** cost overruns by better enabling good engineering decisions in design and fabrication.
- **Avoid** delays by requiring better up-front cost estimates to obviate the need for costly in-process redesign,
- **Adhere** more closely to the 30-year shipbuilding plan to reduce costs and enhance industry stability, and

- **Provide** mechanisms for capturing savings and flexible budgeting to meet planned ship delivery intervals.

Fabrication of highly complex warships takes from three to five years (and longer for lead ships in a new class) due to upwards of three years in design, giving ample opportunity for unexpected or tardy new requirements to be levied. Overall, providing greater predictability and stability in shipbuilding can provide cost savings and better ensure on-time delivery.

To this end, the Navy has used several ship purchasing methods over the years, and depending on the circumstances, each is more appropriate than a one-size-fits-all approach. Since 1950, the principal method used has been full funding of a ship in the year when it is procured. At times, however, the Navy has also used multiyear procurement, advance payments, and incremental funding. All four methods have utility. For example:

- **Multiyear procurement** is used when design changes are no longer expected and there is high certainty that several ships will be purchased, in which case the Navy contracts for a set number of ships at a set price. If the Navy or Congress reneges, the shipbuilder still gets paid, which assumes a degree of risk to the Navy budget.

- **Advance procurement** has been used to purchase materials with long lead times (e.g., ship reduction gears can take three years to produce) that otherwise would have delayed ship delivery and caused cost overruns.

- **Incremental funding** divides the total cost of procurement over several payments and allows for year-to-year budget flexibility.[9]

A final method, advance appropriations, has not yet been used for shipbuilding. In the President's budget for FY 2018, non-defense advance appropriations accounted for more than $339 billion.[10] This is a legislatively locked-in appropriation of monies in future years and would count in those future-year budgets. The Navy tried to use this in 2001 but was rebuked by congressional appropriations committees and has not attempted to use it since then.[11]

To enable purchasing flexibility, a novel method was approved several years ago and is available today. Established with the FY 2015 budget, the National Sea-Based Deterrence Fund provides the Navy with an account to hold appropriated funds for up to five years and grants several authorities within one budgetary package: the above-referenced advance procurement and incremental funding and advance construction and cross-class common component purchasing.

- **Advance construction** funds infrastructure and workforce stability needed in the fabrication of a ship.

- **Common component purchasing** is the transfer of funds between accounts for the same parts.[12]

On at least two occasions, funds have been transferred from the Navy's shipbuilding account to the National Sea-Based Deterrence Fund: $630 million was transferred in 2017,[13] and $209 million was transferred in 2020.[14] Although there could be wider utility, as currently authorized, the fund is being used only for the *Columbia* class.

The National Sea-Based Deterrence Fund is similar to a capital account. Structured similarly and using previously approved congressional authorities, it is an expanded fund for shipbuilding that offers an accounting mechanism that can enable the appropriation of multiyear monies and allow department-wide savings to be used to fund an approved 30-year shipbuilding plan.

Such a mechanism could also avoid delays of budget reprogramming, which is required when moving appropriated monies between accounts. As Heritage Foundation defense budget expert Frederico Bartels has observed, reprogramming is cumbersome, involves multiple offices with veto power, and can take four to six months to approve, which likely runs into a new budget.[15] The use of a multiyear shipbuilding capital account also mitigates the year-on-year shocks caused by unpredictable continuing resolutions or budgets frozen at the previous year's levels by program lines, widely viewed as deleterious to Navy shipbuilding.[16]

The Navy's FY 2020 budget request included a two-ship aircraft carrier procurement, saving an estimated $3.9 billion compared to buying the ships separately.[17] With a capital account, such savings, when realized, could be rolled over to mitigate unexpected engineering challenges and cost growth while delivering on the shipbuilding plan. In 2004, for example, the Navy delayed the *Ford*-class aircraft carrier and *Zumwalt*-class destroyer for a year to meet immediate fiscal constraints; with a shipbuilding capital account, things might have been different. In addition, until the establishment of the National Sea-Based Deterrence Fund in 2015, the *Columbia*-class ballistic missile submarine program was two years behind schedule; it has since remained on track but with no margin for additional delays.

Defense budgets are discretionary spending (comprising approximately a third of the federal budget), and subject to annual congressional authorization and appropriation. This is different from Social Security, Medicaid, and other entitlement programs that employ mandatory funding.[18] Since defense spending requires annual appropriation, budgets are rarely passed on time, and continuing resolutions are often used as stop-gap funding mechanisms.[19] This has led to fiscal inefficiencies, hiring delays that exacerbate manning shortages, and delays in contracting for needed work.[20]

In a unique session before the Senate Armed Service Committee in November 2013, the service chiefs detailed the impacts of budget uncertainty. For the Navy, there were immediate implications for shipbuilding and maintenance that included (among others listed) cancellation of five deployments, a six-month delay in deployment of a carrier strike group, a 30 percent reduction in facilities restoration, and a 20 percent reduction in base operations.[21]

One way to avoid the consequences of this budget uncertainty would be to establish a Navy shipbuilding capital account. This type of account would enable greater predictability and engineering practicality by moving funds across a wider number of ship construction accounts. It would be funded according to a congressionally approved 30-year shipbuilding plan with five-year authorized monies automatically appropriated annually in the absence of specific congressional action, thereby encouraging adherence to a 30-year plan that considers shipyard level loading and cost-effective production.

In addition to the budgetary tools granted the National Sea-Based Deterrence Fund, consideration should also be given to utilizing advance appropriations in line with an approved 30-year shipbuilding plan. This could be an effective way to shield shipbuilding from costly uncertainties in an annual budget cycle while ensuring congressional oversight.

Rebuilding the Naval Architect Design Factory

A 2018 Government Accountability Office (GAO) report made a key assessment: The greatest root cause of cost overruns and delays since 2008 has been concurrency. This is a term of art that refers to the overlap in technology development, design, and construction of a ship. For example, in the case of the *Ford*-class carrier, there was a prolonged period during which technology development, design, and construction all took place at the same time. This led to redesign and its concomitant effect on construction, costs that were $2 billion higher than original estimates, and a two-year delay in delivery.[22] There will likely always be some level of concurrency in naval shipbuilding; the key is reducing it to a manageable level.

In the late 1990s, seeking cost savings, the Navy reduced its in-house naval engineer staff by 75 percent. The effect was to outsource new warship design to industry, which required an average of 48 months to reach preliminary and contract design compared to 24 months with in-house design.[23] A similar effect was noted by the British Royal Navy when it downsized its Royal Corps of Naval Constructors. Having outsourced its design competencies, the Navy relied on industry to design the Littoral Combat Ship (LCS) and the *Zumwalt*-class DDG 1000 destroyer.[24] As a result:

- Neither ship completed originally planned series production: Only 32 of 52 LCS ships and only three of 32 DDG 1000 destroyers were completed.

- Both incurred significant cost overruns: 173 percent growth for the LCS and 47.9 percent growth for the DDG 1000.

- Both incurred lead ship delays: two years for the LCS and two years for the DDG 1000.[25]

In the final analysis, the lack of in-house naval architecture expertise in developing specifications that are useful for industry has made the Navy a less than fully informed customer, and this has led in turn to costly decisions.

An effective remedy for concurrency is better design and requirement development, which is more likely with greater in-house expertise in ship design. Best business practices indicate that unexpected engineering problems and fabrication issues (availability of dry dock, special machined tools, etc.) can be minimized by using Integrated Product Teams (IPTs) led by Naval Sea Systems Command (NAVSEA) with industry subject-matter experts. IPTs can devise manufacturing strategies for each class of ship to be built, to include Long-Term Supplier Agreements. These strategies should be developed both to plan delivery of critical parts and subsystems and to inform the 30-year shipbuilding plan for better budget planning.

In addition, a life-of-project (design through lead ship delivery) flag-level officer or Senior Executive Service civilian should be assigned to oversee a review board made up of members from the Navy and industry who can use good engineering sense to address changes in the operating and policy environment. This way, leaders can execute a sustainable long-range build plan while making judicious decisions when weighing the risks involved in the incorporation of new technologies.

Several key lessons can be derived from the history of Navy shipbuilding:

- **Do not change too much in a new class of ship; evolutionary change is cost-effective.** A success story was the use of a common hull design from the *Spruance* class in the *Ticonderoga* class and common systems from the *Ticonderoga* class in the *Arleigh Burke* class. Adequate built-in excess capacity is important for future enhancements (e.g., modifications for *Ticonderoga* to employ the Aegis radar and for flight IIA *Arleigh Burke* to include space for two helicopter hangars).[26]

Spurred by Secretary of Defense Donald Rumsfeld's push in the early 2000s to include revolutionary capabilities, the *Ford*-class aircraft carrier attempted to incorporate too many novel technologies—the Electromagnetic Aircraft Launch System (EMALS); a new aircraft arresting system, the Advanced Arresting Gear (AAG); the ship's primary radar, the Dual Band Radar (DBR); and the advanced weapons elevators (AWE) to facilitate rapid arming of aircraft—and this led to significant delays in delivery. Delays in the *Ford* class and the Navy's emphasis on unmanned systems spurred Senators Jim Inhofe (R–OK) and Jack Reed (D–RI) to argue that critical subsystems must be successfully prototyped before being integrated into a ship's design, as was done with the SPY-1 advanced radar system before its initial integration into the *Ticonderoga* class.[27]

In ship design, three components generally make the ship: the hull, propulsion, and installed systems. Changing any one or two is manageable, but changing all three in a new design comes with elevated risk of cost overruns and production delays as was seen with the *Ford* class in the early 2000s. A good sign that the Navy appreciates this lesson is that the next-generation radar (SPY-6) being installed on *Arleigh Burke*-class destroyers will also be included on the next-generation destroyer or DDG(X).[28]

That the enemy also has a vote is shown by the fact that rapid Soviet undersea acoustic advances caused the Navy to design a technological leap-ahead with the *Seawolf*-class attack submarine. As the Cold War came to an end, the Navy could not validate the increased costs associated with improved acoustic stealth, a complex weapons handling system, and new hull materials and design.[29] Eventually, what was envisioned as the successor to the *Los Angeles*-class nuclear attack submarines resulted in only three boats built.

- **Build ships with room to grow.** Allowances for excess tonnage for future growth actually has resulted in designs that are cheaper to build, easier to operate, and easier to maintain. For their *Kongo*-class destroyer, for example, which resembles a U.S. *Arleigh Burke*, the Japanese allowed tonnage requirements to grow by 1,000 tons, providing the space needed for future upgrades, simplified maintenance, and eased fabrication.[30] The added space allowed by increased tonnage enabled cost-effective fabrication and eased lifetime maintenance. The South Korean navy also incorporated this lesson into its *Sejong*-class (KDX) destroyers. A good rule of thumb in shipyards regarding the ratio of time to manufacture a ship is a factor of one when built in an enclosed shop in modules, three times longer when fabricating unprotected from the environments, and five times longer when conducting fabrication in a hull that is completed. Bottom line: a little extra space in a surface ship can provide long-term cost savings.

  As new classes of ships field high-energy weapons, rail guns, electric drive propulsion, and a battery of new power-hungry sensors and radars, adequate power generation is critical. For the same reasons already given for excess tonnage, excess power generation capacity facilitates future upgrades and modifications of power-intense defenses and sensors. The *Ford* class is a power-hungry ship, and its design had to triple electrical power generation over the preceding *Nimitz* class to drive its radar, EMALS, and potential future high-energy defenses.[31] Whether the *Ford* and other future classes of warship become obsolete prematurely will be in part a function of designed excess power generation.

- **Enforce strict mission design requirements.** For the *Oliver Hazard Perry*-class frigates of the Reagan buildup, strict displacement and manning constraints ensured that cost stayed within limits for large series production. This assumes a degree of mission design discipline that was lacking in the design of the Littoral Combat Ship and contributed to a 20-ship reduction in series construction.[32] A similar mission creep occurred with design of the *Zumwalt* class, which began as a naval gunfire support ship and then migrated to a ballistic missile defense platform, only to run into significant cost and design limitations in the employment of needed SPY radar and spiraling costs for the advanced gun system (AGS).

Moreover, lessons from the Navy's 2001 Optimum Manning experiments and the *Fitzgerald* and *McCain* collisions in 2017 indicate that there is a balance between reduced manning and workloads that must be managed. Specifically:

1. A February 2010 review found that the net effect of Optimum Manning was a lack of shipboard-experienced technicians compounded by a smaller crew. Specifically, "Limitation to our legacy manning and distribution processes are [*sic*] resulting in low attained values of Navy Enlisted Classification (NEC) fit (rank, rating and NECs) with a 2009 manning average of 61% for at-sea surface units."[33]

2. An August 2020 National Transportation Safety Board report reaffirmed a conclusion reached as a result of a December 2017 internal investigation led by then-Commander, U.S. Fleet Forces Command, Admiral Philip Davidson that an overworked and underexperienced watch team was a significant contributor to the 2017 collisions.[34]

In setting manning constraints for ship design, it appears to be imperative that crew size and experience be matched to the complexity of the systems to be carried on a future ship and to the missions the ship will be expected to execute. If costs dictate a smaller crew, then design must likewise incorporate automation, simplified maintenance, and narrowly focused missions in order to ensure that crews can operate the ship safely. A legacy of Optimum Manning is the realization that retroactively reducing manning on a ship that is designed for larger crews will have disastrous effects.

- **Early industry–Navy collaboration beginning with design can ease the challenges involved in manufacturing a new class of ship.** Given only 15 months from mid-1985, the Navy succeeded in designing and procuring the first Small Waterplane Area Twin Hull (SWATH) ocean surveillance ship, the *Victorious* class. Thanks to its Continuing Concept Formulation (CONFORM) program, which gave the Navy leadership in SWATH technologies, NAVSEA was able to convince the Secretary of the Navy that its engineers should have an active role in the design but only with significant industry involvement. Because existing ships were mission incapable in rough winter seas at a time of heightened Cold War tensions, the program was given urgent priority. Based on their extensive experience in leading high-stress design projects and specific experience with SWATH, a hand-selected ship design manager (SDM) and a design integration manager (DIM) proved critical in making design decisions on technical issues for which either only incomplete or no validated modeling was available.[35] Partnering with industry early in the design phase contributed to delivering a design that could be built on a greatly compressed timeline and with desired winter months' capability (95 percent versus the monohull predecessor's 57 percent).

Adequate Interval: Sustaining and Increasing Shipbuilding Capacity

Setting the interval during which a class of warships are built will determine whether the shipbuilding infrastructure increases, maintains, or shrinks its capacity. Shipbuilding that is too fast can outpace supply chains, overtax the workforce and infrastructure, and lead to costly delays in delivery. Too little demand, driven by overhead costs, leads shipbuilders and suppliers to reduce workforce and curtail capital investments such as modernization of precision equipment, cranes, and docks. The ideal is demand within existing shipbuilders' capacities that leads to gradual growth in capacity or at least precludes a loss of capacity. In the early 2000s, the nuclear submarine force struggled to achieve this balance during a time of reduced budgets and faced the prospect of losing the capacity to build future nuclear submarines as well as critical skilled workers such as submarine hull and nuclear power plant welders that are not easily replaced.

The problem confronting the nuclear submarine force had been anticipated in the 1990s. By 1995, it was observed that a reduced production rate of nuclear submarines following increased build rates of the later Cold War would shrink the fleet irretrievably to dangerously low levels in a so-called attack submarine valley.[36] In fact, following a submarine commissioning holiday during which no boats were delivered to the Navy from 1996 to 2004, the associated workforce and supplier base shrank precipitously, raising alarms within the Navy's submarine community.

A 2005 RAND study found that sustaining submarine design capacities at the existing two submarine shipyards (Northrup Grumman Newport News and Electric Boat) would be more cost-effective than recapitalizing and training replacements in the future. The report also found that sustaining the workforce did not equate to experience without active submarine design and construction.[37]

After years of advocating for sufficient investment to secure both submarine production and the skilled workforce required for that production, the submarine force seems to have bent the curve by sustaining a two-a-year build rate for attack submarines with a view to a goal of 66 boats by 2048. In addition, the Navy began construction of the next strategic ballistic missile submarine (SSBN), the *Columbia* class, on October 1, 2020, with about 6 percent of construction complete due to aggressive advance construction necessitated by the program's importance. The first in class must begin delivery in FY 2027 to avoid any lapse in strategic deterrence capability as the aging *Ohio*-class SSBNs retire.[38] A major current concern is the need to sustain attack submarine construction levels while avoiding shipyard delays that could be caused by construction of the *Columbia* class.

The most recent Navy long-range shipbuilding plan, released in December 2020, calls for further increases in attack submarine production. To achieve the sought-after goal of 72 attack submarines by 2045, production will increase to three a year, requiring a $1.7 billion shipyard investment from FY 2022–FY 2024.[39] After years of study and advocacy, the submarine force appears to have found what it needs to sustain and judiciously expand the nuclear submarine industrial base. (The production rates that are needed to sustain or grow the industrial base for other classes of warships are unique to each program and not generally known.)

Invariably, new classes of ships will be required, either because of operational necessity or because technologies provide new design opportunities. Perhaps the best example of successful management of this transition is the Japanese Maritime Self Defense Forces (JMSDF) submarine program. JMSDF has been building submarines at Kawasaki Heavy Industries and Mitsubishi Heavy Industries for decades, increasing their fleet from 16 to 22 boats over the past 20 years while transitioning across three designs.[40]

Our Navy must consider future class transition in its planning for shipbuilding in consultation with industry in order to avoid production disruptions and needless costs. A long-range production strategy can help to ensure that the Navy strikes the right balance on cost efficiencies and shipbuilding capacity. Failing this, costly gaps in shipbuilding will result in reduced infrastructure and workforce, as well as design inactivity that leads to the loss of highly trained naval architects who are not easily or quickly replaced.

The key to finding the optimum shipbuilding interval is having a clear target end strength so that industry can adjust to meet that demand. Each warship class is unique in this regard and places different demands on the sequencing of skilled workers across multiple shipbuilding programs while levying demands on the same workers. Additionally, industry and the labor force will diminish and disappear in the absence of adequate investment or business, and the unique skills needed in shipbuilding are not easily recapitalized. Recovering skills and industrial capacities is more expensive in the long run than sustaining them and will incur prolonged added costs until experience is regained by the workforce. Time is a luxury that would not be available in the midst of a crisis.

What the Secretary of the Navy, the CNO, and Congress Should Do

To ensure the nation's ability to meet its shipbuilding needs in an era of great-power competition, the Secretary of the Navy should:

- **Rebuild** in-house naval design capacity to Cold War levels—approximately 1,200 engineers involved in design and the development of relevant specifications—through increased recruitment from industry and universities. This would better inform design requirements at the early stages of development in order to ensure design discipline throughout program development. Given the importance of unmanned ships to the future fleet, a significant portion of this expanded engineer staff should be dedicated to specialties associated with autonomous robotic systems and artificial intelligence. Targeted signing bonuses and lucrative tuition assistance should be employed by a dedicated team of NAVSEA recruiters charged with this task.

- **Increase** advanced educational opportunities for the Navy's civilian engineers and **expand** commercial industry's participation in concept formulation teams at the Navy's Center for Innovation in Ship design (CISD) to include non-maritime industry. The Navy's Technical Warrant Holder (TWH) provides an additional method to increase experienced workforce involved in engineering planning, certification of design, and performance assessments that then can be fed back into new design.[41]

- **Designate** life-of-program System Command (SYSCOM) leads early in the material solution analysis phase to inform new design by incorporating commonality with legacy system parts and lifecycle sustainment. Associated updates to the Secretary of the Navy's instructions should stipulate specifically that SYSCOMs (NAVSEA and

Naval Air Systems Command) must consider commonality with legacy systems in new design, mitigating the risk of cost overruns throughout lifecycle management, and minimize production delays due to excessive concurrence.

The Chief of Naval operations, given his central role in matching mission to design of future warships, should:

- **Produce** strategic development plans for specific key future at-sea capabilities. The CNO must identify new technologies, their development, and the timelines for their employment on new classes of warships as part of future 30-year shipbuilding plans. Emphasis should be given to land-based prototyping that is followed by limited installation on current warships to further refine designs and better inform total ownership costs of maintaining and operating future classes of warships. Candidates include plans for development and employment of rail guns and high-energy lasers on future warships.

The Congress should:

- **Apply** authorities granted to the National Sea-Based Deterrence Fund to the entirety of the Navy's shipbuilding budget. Additionally, any request for Department of Defense reprogramming should include a stipulation that the Secretary of Defense must ascertain that said funds would not better be reprogrammed into the Navy's shipbuilding program. This would enable Congress to ensure the adequate prioritization of resources used to build the Navy needed for great-power competition while empowering sound engineering decision-making through more flexible shipbuilding budget structures.

- **Require** the Navy to incorporate into its annual long-range shipbuilding report production strategies that include transition to follow-on classes of ships. This assumes increased collaboration between shipbuilders and the Navy. Such effort can mitigate a repeat of the DDG-51-class 2005–2010 building holiday that resulted in a 23 percent cost increase before production was resumed. Consideration should also be given to including Coast Guard long-range building plans with the intent of maximizing opportunities for system commonalities and associated cost savings.

Conclusion: The Consequences of Inaction

Given the challenges represented by a rapidly growing modern Chinese navy and an increasingly aggressive Russian navy, how the U.S. Navy plans and builds its fleet warrants focused attention and investment. This is particularly important given the time frames required to recapitalize shipbuilding infrastructure and design and build a larger modern fleet that can keep pace with these maritime threats effectively. While doing so is a national imperative, however, it does not appear that the Navy, shipbuilders, Congress, and the public are all on the same page.

Perhaps a better understanding of the foundational principles involved in shipbuilding can help to bridge these divides and also help the nation to recapture its maritime prowess and ensure that our maritime industry delivers warships on budget and on time. By focusing on best engineering design and construction principles rather than merely on numbers of ships commissioned, the Navy and shipbuilders will be better able to build the Navy the nation needs.

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Appendix: Detailed Description of the "Two-Pass Seven-Gate" Process Applied to Shipbuilding

Gate One: Initial Capability Determination

Informed by strategy, operational demands, and future force analysis such as war gaming, a new ship design begins with development of requirements that are to be stipulated in the initial capabilities document (ICD). Key players during this early step in ship design include the Naval War College (NWC), which provides war gaming and strategy insights, and the Naval Warfare Development Center (NWDC), which helps to inform the capabilities needed to implement new concepts of operations, all overseen by the Navy's Warfighting Requirements and Capabilities (N9) office at the Pentagon.

This is called the Naval Capabilities Development Process (NCDP) and can include highly classified analysis to inform the ICD; there is usually no industry input at this step. The ICD represents the culmination of analysis that considers what capabilities will be needed to address key operational problems and complement joint force capabilities such as the long-range anti-ship shore batteries being considered by the Army and the Marine Corps. After several years of concept development,[42] the Light Amphibious Warship seems to be nearing the end of this step.[43]

To progress to the next step, a favorable recommendation by the Resource and Requirements Review Board (R3B) is required in what is called a material development decision (MDD). Once the Chief of Naval Operations is satisfied that requirements meet needs, the decision to proceed is made.

Gate Two: Analysis of Alternative (AoA) Capabilities

Included in this step is a review of the shoreside support required to sustain the new ship, to include associated military construction such as new dry docks. The GAO has found that better early evaluation of sustainment costs could have saved upwards of $4.2 billion to address just 30 percent of needed repairs. In response, the Navy has begun sustainment oversight review and baseline studies, but too late in the process to be fully effective.[44]

It is during this step that it is decided what testing and evaluation are needed and that how to accomplish this is included in a capability development document (CDD). Importantly, while it is directed that this be conducted at each step, this is when affordability assessments can have a significant impact on a project's trajectory as the original ICD is assessed across an agreed set of options and underlying assumptions. A recent example of collaboration with industry that was helpful with costs is the setting of requirements for the *Constellation*-class frigate. On the other hand, significant cost increases resulted when high-speed requirements were levied on the design of the Littoral Combat Ship in the mid-2000s. To ensure that these requirements address specific operational needs, or Critical Operational Issues (COIS), an explicit connection to Key Performance Parameters (KPP) and Key System Attributes (KSA) is required.

The impact of having to meet military specifications for parts and fabrication can add exponentially to the overall costs of a new ship. Such specifications are intended to ensure reliability as well as survivability in a combat environment, and relaxing such requirements in ship designs has proven to be problematic. A 1994 effort by then-Secretary of Defense William Perry to nearly eliminate military specifications for cost savings was stymied by the fact that there were few competitive standards that were appropriate for naval shipbuilding given the unique stresses required of nuclear and conventionally powered warships.[45]

As recent deadly collisions of the USS *McCain* and USS *Fitzgerald* attest, costly military standards with regard to ship survivability have renewed merit. Central to validating these assessments across the Department of Defense is the Office of Cost Assessment and Program Evaluation (CAPE), which hosts independent analysis and simulation to inform its assessment of Navy proposals. The tendency when assessing specific requirements is to adjust the original ICD to meet cost and feasibility, necessitating narrow and explicit missions for the proposed platform so that it can meet strategic and operational needs identified by N9, NWC, and NWDC.

Gate Three: Design Review

The objective of this step is to finalize the CDD and the concept of operations (CONOPS) that informs key performance parameters of the platform or weapon system. Naval Test and Evaluation (T&E) and the Navy's N9 are responsible for reviewing these key elements of a new platform's design requirements. Once assured that the design meets CONOPS intent within allowable cost and risks, the CNO approves progression to Milestone A and the next gate.

Gate Four: Design Specification

Milestone A marks the transition into technology development for a new platform, culminating with the finalizing of system design specifications (SDS) and conclusion of this gate. These technical specifications become the engineering requirements that a proposed platform must meet. The development of meaningful and detailed engineering specifications becomes critical at this gate. In the past, this was conducted principally by in-house Navy engineers (NAVSEA 05), but it has been outsourced to industry increasingly since the early 1990s.[46]

The decision to proceed and engage industry is the first decision in this process that is not lodged with the senior uniformed leader of the Navy, the CNO. This decision is made instead by a civilian political appointee, the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN RD&A).

Gate Five: Proposals for Engineering and Manufacturing

Milestone B and the fifth gate are reached once a request for proposals (RFP) is offered to industry and the decision to proceed is made by the ASN RD&A. This marks the transition from technology development into manufacturing development. In an unusual move, Congress stipulated in the FY 2021 National Defense Authorization Act (NDAA) that this milestone cannot be approved for unmanned surface vessels until it has been certified that propulsion and electrical systems have met specific reliability goals.[47]

Gate Six: Design Sufficiency Update Before Production

There are four steps in this gate as a platform moves toward being awarded full operational capability (FOC).

1. The first step is approval by the ASN RD&A of an integrated baseline review (IBR) that assesses whether industry can produce the platform on time and on budget.

2. The second (and the CNO's only role at this gate) is to approve updates to the design (CDD update) based on IBR findings with industry.

3. Milestone C is reached once the ASN RD&A, having considered warfighter inputs regarding survivability, operation, and sustainment concerns, certifies that the platform may proceed to production.

4. Then, once any major system deficiencies and platform affordability are favorably assessed, the platform moves into full rate production (FRP).

The lessons of the Littoral Combat Ship come to mind here. The Navy never was of one mind as to its vision for this class of ship, and this led to well-known design changes, cost overruns, and operational shortcomings.[48] A key lesson from the LCS—and applicable at this gate in the design process—is mission specificity and discipline in design. The final step in this gate involves a review by both the ASN RD&A and the CNO of costs associated with platform readiness, sustainability, and sufficiency relative to threats and CONOPS.

Gate Seven: Lifecycle Sustainment

The final step in the process is approval of corrective actions to address readiness and affordability issues that emerge as the platform moves into FRP and IOC. Included is a review to determine the sustainability of the maintenance plan in light of out-year budget assumptions.

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