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Changing Course to a 21st Century Acquisition Strategy: Navy-Industry Collaborative Design

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Changing Course to a 21st Century Acquisition Strategy: Navy-Industry Collaborative Design

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Abstract

The U.S. Navy (USN) and U.S. naval shipbuilding industry are facing an historic inflection point to realize the growth in the number of warships in the fleet over the next 2 to 3 decades. And a demanding shipbuilding program demands a new 21st-Century Acquisition Strategy: Navy–Industry Collaborative Design. This new strategy will enable and promote open, substantive collaboration between the U.S. Navy and naval shipbuilding Industry and will ensure the design, construction, and sustainment of a more affordable, adaptable, and durable fleet. The team of four authors of this paper with collectively more than 200 total years in naval ship acquisition, design, and construction management believes strongly the time is long overdue for such a bold strategy. No longer will the recent failed acquisition approaches enable the USN and U.S. shipbuilding industry meet and/or surpass the existential and growing challenges of its naval adversaries. Based on the team's significant experience and insight into naval ship design and shipbuilding as well as a decade of American Society of Naval Engineers (ASNE) Global Shipbuilding Executives Summits (GSES), the authors have compiled in this paper a set of recommendations for a bold new acquisition strategy for the USN.

Executive Summary

The U.S. Navy and U.S. naval shipbuilding industry are facing an historic inflection point to realize the growth in the number of warships in the fleet over the next 2 to 3 decades. And a demanding shipbuilding program demands a new 21st-Century Acquisition Strategy: Navy–Industry Collaborative Design. This new strategy will enable and promote open, substantive collaboration between the U.S. Navy and naval shipbuilding Industry and will ensure the design, construction, and sustainment of a more affordable, adaptable, and durable fleet. The team of four authors of this paper with collectively more than 200 total years in naval ship acquisition, design, and construction management believes strongly the time is long overdue for such a bold strategy. No longer will the recent failed acquisition approaches enable the USN and U.S. shipbuilding industry meet and/or surpass the existential and growing challenges of its naval adversaries. Based on the team's significant experience and insight into naval ship design and shipbuilding as well as a decade of American Society of Naval Engineers (ASNE) Global Shipbuilding Executives Summits (GSES), the authors have compiled in this paper a set of recommendations for a bold new acquisition strategy for the USN that is well-grounded on successful acquisitions for the Cold War fleet, proven recently in allied navies' acquisitions and, moreover, will help avoid the mistakes of the past 2 decades.

Additionally, best practices and lessons learned on naval ship design, engineering, construction, and sustainment are reviewed based on the innovations and breakthroughs global naval-shipbuilding leaders have implemented over the past 2 to 3 decades. For example, lean process re-engineering, digital shipyard process simulation and optimization, and enterprise-wide digital transformational have produced double-digital improvements in construction productivity, cycle reduction, and capacity throughput. Increase in shipbuilding capacity could be crucial in the U.S. shipbuilding industry to satisfying the dramatic increase in naval shipbuilding rates that are projected over the next 2 decades.

The team finally lists a set of acquisition-related recommendations to build a long-term commitment to naval shipbuilding continuous improvement and to create a pipeline of seasoned naval shipbuilding professionals to guide the future of the U.S. Navy through-out the 21st century and beyond.

USN SITREP

Figure 1 is our assessment of the current situation. What has been called the post-Cold War era is over. China is now a peer Navy, and Russia is a near-peer Navy. Both are growing in size and capability. U.S. sea control is being challenged for the first time in many years.

SITREP

- Post-Cold War era is over.
- Peer navies growing in size and strength.
- COCOMs' requirements overstress ships and personnel
  - Number of battle force ships stuck at 300 for over a decade
  - Many ships offline for maintenance/modernization for long periods
  - New ships "deliver" years before deployable and over budget
- Future force **level** uncertain: 350 or 400 or 500
- Future force **mix** also uncertain: DDG(X), CVLs, Light Amphibious Warship, and broad array of Unmanned Systems

Figure 1. USN at Historic Inflection Point

Our ships and personnel are overstressed, and even so, not all of the combatant commanders' requirements can be met. USS *Nimitz's* most recent deployment stretched to 340 days, yet gaps in aircraft carrier coverage—once unheard of—now occur. The number of battle force ships dropped below 300 15 years ago and has hovered near 300 since then. The high tempo of ops creates a backlog of maintenance. Many ships are offline for maintenance and modernization, and most complete late—often quite late. Some new ships are delivered and commissioned but are years away from being deployable.

The Navy is therefore at an historic point in time, but when it comes to the future fleet, there is uncertainty about both force level and force fix. Is the goal still 355, or is it much higher as the last administration proposed? As for the mix of ships, there are knowns like DDG(X), and unknowns like CVLs, light amphibious ships, and a host of unmanned vehicles.

Over 30 years, DDG51 capability has substantially increased in a series of flights, but further growth is no longer feasible. Future weapons will require substantially more electric power and the ship space to accommodate larger missiles. This requires a new hull that incorporates the time-tested service life allowances, which enabled DDG51 Flight I to evolve into Flight III. DDG(X) will provide this future growth capability.

CVNs are costly, and less expensive solutions are periodically examined and, up until recently, rejected. The F-35B, far more capable than the venerable AV-8B, operating off big deck amphibs, is seen by some as a game changer.

The Marine Corp's recent shift in emphasis from inland wars in the Middle East to Indo-Pacific littorals, has translated into the need for light amphibious warships.

Finally, the broad array of unmanned vehicles presents both challenges for design and acquisition and opportunities for new concepts of operations.

Build on Success

There are lessons to be learned from successful acquisition programs for the Cold War fleet, including recent acquisitions of our allies (see Figure 2).

BUILD ON SUCCESS

- US submarine community
  - Design-build strategy
  - Shipbuilders' collaboration early in Navy - led design
- Asian Aegis Shipbuilders
  - Proven design-build strategies
  - No arbitrary displacement/size constraints thus less dense ships
- NATO Shipbuilders
  - Long-term commitment (>30 years) to more adaptable surface combatants
  - Shipbuilders' early collaboration (including other nations)
  - Modular combat systems
- 1980s build up to 600-ship Navy
  - Tailored approaches with Navy-led designs: FFG 7, CG 47/52, DDG 51 FLTs I/II/IIA, CVN 76, LPD17
  - SEA 05 controlled ship design resources/capabilities

Figure 2. Leverage Best Practices and Proven Principles of Good Design

In the *Virginia* class, the U.S. submarine community built on lessons learned from the *Seawolf* (SSN 21) program. In SSN21, there had been a winner-take-all approach and as was also common in surface ship acquisitions, production started well before detail design was complete. A "design-build" strategy was adopted in *Virginia* to control costs, and both building yards acted as collaborators vice competitors. The *Virginia* class is built through an industrial arrangement designed to maintain both GD Electric Boat and HII Newport News, the only two U.S. shipyards capable of building nuclear-powered submarines. Under the present arrangement, the Newport News facility builds the stern, habitability, machinery spaces, torpedo room, sail, and bow, while Electric Boat builds the engine room and control room. The facilities alternate work on the reactor plant as well as the final assembly, test, outfit, and delivery.

In comparing U.S. and foreign shipbuilders, different ship types built to different requirements and facing different threats may present difficulties. A major exception appears to be the Asian shipbuilders, Japan and South Korea, which have built their own versions of DDG51 Flights I and IIA. The Aegis Combat System is common to all three navies, but the ships are quite different. Both displacement and size constraints had been imposed on DDG51 in a (vain) attempt to control cost. This was due in part to undue emphasis placed on weight (vice work content) when estimating cost. *Kongo*, the Japanese version of Flight I, is substantially larger than *Arleigh Burke* but being less dense was much easier to build.

Our NATO allies will be covered later in the paper, and there is much to learn from them. They have pioneered in developing adaptable ships. In part to meet the needs of their own services, but also to appeal to a variety of foreign customers. Shipbuilders frequently collaborate, and this can include multinational programs.

During the buildup to the 600-ship Cold War Navy, a number of tailored collaborative acquisition strategies were adopted. When it came to ongoing programs (and even some new starts) this included business practices such as multiyear procurements and the emphasis on fixed price contracts. Clean sheet of paper designs such as FFG7 and DDG 51 were in-house designs with co-located NAVSEA-led design teams, assisted by the Navy labs (current Warfare Centers), industry (shipbuilders), and local design agents. The time from earliest concept studies until delivery of a lead ship takes a decade or more (source selection alone may take up to a year), the combat system may still be evolving, and yet the first of class must be “fully successful.” Indeed, in the case of DDG51, seven follow ships were on order or under construction at two shipyards **before** *Arleigh Burke* delivered, and three more before IOC was achieved. This is inherently risky, but the time scale for ships prevents the use of prototypes and “fly-offs” common to other DoD acquisitions. To minimize risk the Navy became **“self-insured,”** meaning NAVSEA (and predecessor organizations) developed a comprehensive shipbuilding specification which the potential shipbuilders bid on and followed. Combat systems were developed by the Navy, tested at sea and ashore, and delivered to the shipbuilder(s) as GFM. Land-based testing of new propulsion plants was also common, and their procurement was specified. Time has shown that this approach ensured that the new ship met its operational performance requirements and minimized the risk of incorporating new technologies.

AVOID PAST MISTAKES

- Acquisition Reform
  - Gutted NAVSEA 05- Shifted early design responsibly to industry
  - Reassigned ship design funds from SEA 05 to PMs
  - Wasted scarce resources on designs never built
- DDG 1000
  - Many high-risk developmental systems
  - Took too long- basic mission became OBE
- LCS
  - Bypassed checks and balances determining requirements & costs
  - Rushed ships into production a decade before mission systems ready

Figure 3. Focus on Building a World Class Team and Reducing Risks

Avoid Past Mistakes

Over the last 75 years, the Navy has employed many different warship acquisition strategies—often directed by higher authorities. In particular, the relative roles and responsibilities of the government and the shipbuilders have differed. Total Package Procurement (TPP) shifted major design responsibilities to industry in the 1970s, then during the buildup to the 600-ship Navy in the 1980s the Navy (NAVSEA) regained design responsibility, and then in the early 2000s under the banner of Acquisition Reform, design responsibilities were again shifted to industry (TPP reborn).

As shown in Figure 3, as a result of Acquisition Reform, NAVSEA 05 was reduced from 1,200 naval engineers to 300, and lost control of ship design funding including RDT&E design funds for future ships in the Navy’s Shipbuilding Program, as well as funds to sustain the Navy’s ship design capabilities. Time-consuming industry design competitions were conducted, and as with any competition, this resulted in some designs that were never built—wasting scarce national resources. (One DDG1000 design and one LCS design were never built).

To ensure a fair competition, and to avoid protests, the Navy’s ability to influence the designs was limited. Unfortunately, the winning designs were seriously flawed. Axe (2021) states, “The U.S. Navy spent a decade in the early 2000s building warships that either don’t work, cost too much to build in large numbers, or whose designs are fundamentally flawed on a conceptual level. Or all three."

DDG 1000 must be deemed a failure. The acquisition strategy was to hold a design competition between two industry teams. The Navy requirements (speed, number of missile cells, rounds of gun ammunition, manning, etc.) were expressed as thresholds and goals. The goals could not be met without exceeding the cost constraints; the Navy did not indicate their preferences, and so each team decided which requirements to emphasize. Thus, industry assumed an inherently governmental responsibility.

In addition, the government requirement ultimately necessitated development of far too many "critical technologies." Radical new systems onboard this first-of-class warship that had to be fully integrated include: Integrated Propulsion System (IPS), Integrated Fight Through Power (IFTP), Advanced Perimeter Vertical Launch System (PVLS), Advanced Gun System (AGS), Advanced Signature Control across all spectrums, Large Composite Enclosed Deckhouse with Embedded Sensors, Total Ship Computing Environment (TSCE), Advanced Survivability and Recoverability, and Wave Piercing Tumble Home (WPTH) Hull Form.

Construction started with the majority of these systems still immature; costs grew, and schedules slipped. The rise of peer navies, discussed earlier, and shore-based anti-ship missiles, rendered the basic mission of close in land attack in a "benign" environment moot. The program was truncated, and construction of DDG51s restarted.

LCS. The problems with these two classes are well known and need not be dwelled on here. Reports from GAO and CRS are depressing to read. The LCS program has been controversial over the years due to cost growth, design and construction issues with the first LCSs, concerns over the survivability of LCSs (i.e., their ability to withstand battle damage), concerns over whether LCSs are sufficiently armed and would be able to perform their stated missions effectively, and concerns over the development and testing of the modular mission packages for LCSs.

The program was flawed from the start. The time-tested cost versus capability studies were compressed, and NAVSEA was basically ignored. Cost was grossly underestimated. The potential risks and large ship impact of requiring 40 knots were also ignored.

The ships (basic sea frames) were delivered on an accelerated schedule, but with many deficiencies. The government has experienced many delays in developing the three major mission modules, and the requirement to rapidly change modules had to be abandoned. Crew manning was far too low. Many years later a valid CONOPS **still** does not exist.

The latest CRS report (RL33741 dated December 17, 2019) states:

> They could argue that the LCS program validated, for defense acquisition, the guideline from the world of business management that if an effort aims at obtaining something fast, cheap, and good, it will succeed in getting no more than two of these things, or, more simply, that the LCS program validated the general saying that haste makes waste.

Bold New Acquisition Strategy

The Navy is at a crossroads. The fleet is too small to counter the increasing geopolitical threat(s). There is uncertainty about what types of ships to buy, how many of each, and how quickly. Between new construction, maintenance, and modernization the industrial base is stretched thin. Between DDG1000, both LCSs, and, yes, CVN 78, the Navy's reputation has suffered. To meet all these challenges, we urge that the Navy adopt a bold new acquisition strategy.

The key is **increased collaboration** between the Navy and the shipbuilders, capitalizing on the strengths of each. For programs like DDG(X) where there will be two shipbuilders, they must also collaborate with each other for the good of the nation. Both the Navy and the shipbuilders must agree, but there is precedent. The Navy, HII, and General Dynamics have been collaborating on the successful *Virginia* submarine program for years.

Figure 4 illustrates key aspects.

NEED BOLD NEW ACQUISITION STRATEGY

- Involve industry early
  - AOA cost/capability/risk studies which establish requirements
  - Incorporate production planning into Navy - led ship design teams
  - Ensure design decisions facilitate manufacturing and construction
    - In both shipyards when construction will be split
  - Review/comment on shipbuilding specifications/contract drawings
  - Expand contract design to include aspects of functional design
  - Assist in developing 3D product model
- Leverage digital twin/digital thread to minimize Total Ownership Costs

Figure 4. Navy–Industry Collaborate for Innovation Good for the Nation

Industry would be involved in the cost, capability, and risk studies, which establish balanced and realistic requirements. These studies are conducted before there is even a "program of record," but they lock in up to 80% of the cost and performance. The shipyards will bring a unique perspective.

The Navy's record for involving industry in the design process is mixed. With rare exceptions, FFG7 and SWATH T-AGOS19 for example, this has been too late to materially influence the design. When the acquisition strategy is one where multiple shipyards will compete against each other, they are often reluctant to share proprietary data. This reluctance must be overcome in order to develop a tailored vice a generic build strategy.

Ultimately, it is the shipbuilding specifications and contract/contract guidance drawings (now, 3-D CAD product model) which define what gets built, and the shipbuilders should be active players in their development. In addition to participating in reading sessions, this could include assigning them responsibilities for preparing selective sections and early development of the 3-D CAD product model.

The scope of the traditional contract design should be expanded to include elements of functional design—the initial step in developing the detail design.

Best practices include developing a 3D product model. There are many benefits, but past efforts have failed due to incompatibility with shipyard systems and/or requiring them to "learn" a new system after the construction contract is awarded. The 3D product model should eventually reflect the "as delivered" ship and be maintained through its service life.

Last, but far from least, greater emphasis must be placed on making decisions based on Total Ownership Costs (TOC). This sounds obvious but has proved to be difficult in practice.

The elements that comprise TOC span many budget claimants. Acquisition managers focus on delivering ships on time and under cost. Others are responsible for maintaining and modernizing them during their long service lives, yet decisions made years earlier are major factors. Finally, the fleet operators live in the real world, and words like *sustainment* and *availability* are not just buzzwords to them. The GAO (2020) found that shipbuilding programs did not consistently address sustainment risks in acquisition planning documents. For example, for six shipbuilding programs whose costs GAO could assess, the Navy had underestimated sustainment costs by $130 billion. The application of digital twin/digital thread should be leveraged here.

More Affordable, Adaptable and Sustainable Naval Ships

Asian navies are building larger warships that are easier to construct, easier to maintain, and that have greater service life allowances for future combat system upgrade. They are also doing this at significantly lower acquisition and life-cycle costs than U.S. practice. A critical element in their ship design process is early application of production engineering and design optimization analysis that improves ship performance, life-cycle maintenance, and future combat system upgrade while reducing work content, reducing design variation, and ensuring design alignment with their warship manufacturing processes. Best early-stage warship design optimization practices include the following:

- **Superior Performance at Lower Cost.** Early production engineering and lean design optimization analysis supports development of superior and more robust warship designs with reduced work content, reduced variation, design alignment with manufacturing processes and lower total ownership costs (TOC).
- **Integrated Product Team (IPT).** Modern design practice harnesses the combined knowledge and experience of the Navy, shipbuilders, key suppliers, operators, and maintainers to consider alternative design solutions and select superior designs that can be produced at the lowest possible time and cost.
- **Production Engineering Focus.** Stressing production engineering analysis in early-stage design supports lean design (reduced work content) and design for manufacture and assembly (design alignment with manufacturing process); strategy improves design quality and reduces time and cost.
- **Robust Contract Design**. Utilizing a robust design process with functional design level definition that meets current and future requirements, minimum work content and variation, and design alignment with manufacturing processes provides a stable basis for design execution and reduces time and cost.
- **Increased Displacement, KG, and Service Life Allowances.** Modern warship designers use significantly larger displacement, KG, electric power, and cooling system service life allowances and design margins than U.S. practice. This strategy reduces design rework and program execution time and cost.
- **Reduced Outfit Density.** Modern warships have significantly lower outfit density than recent U.S. practice. This design strategy provides significantly improved access resulting in reduced construction, life-cycle maintenance, and future combat system upgrade time and cost.
- **Design Optimization.** Utilizing modern engineering analysis tools (e.g., FEA, CFD, M&S, Functional Affinity Analysis, etc.) to optimize designs for functional performance, reduced work content, and design alignment with the manufacturing process improves design quality and reduces time and cost.
- **3D Product Model.** Utilizing 3D Product Modeling Systems starting in early-stage design provides a single voice of truth for design development, configuration management, production planning and control, and resource/material requirements planning; strategy improves design quality and reduces time and cost (see Figure 5).

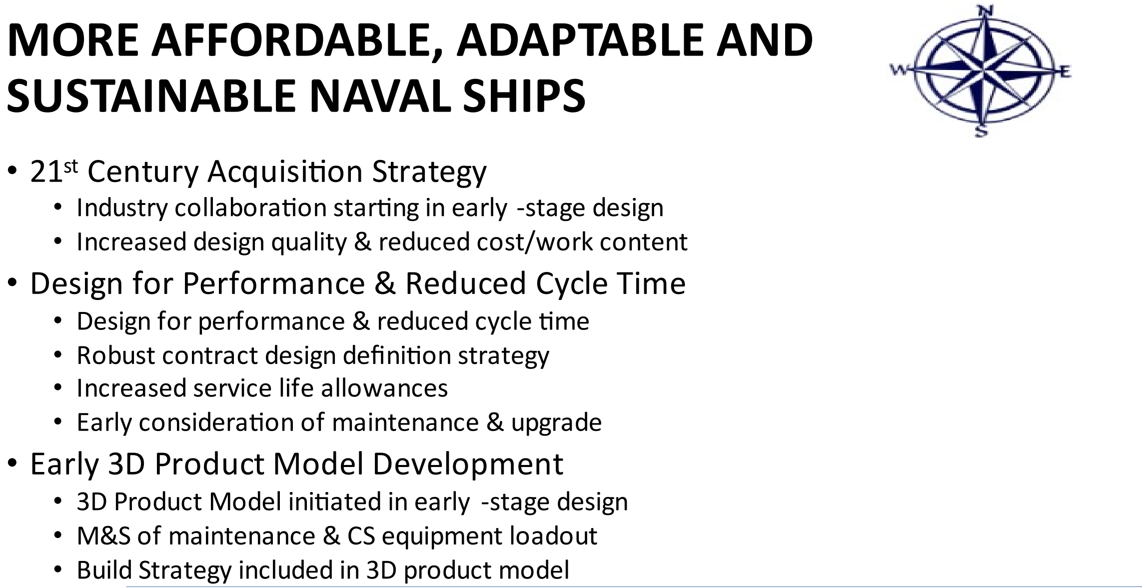

Figure 5. Design for Performance, Construction, Sustainment, and Upgrade

Use of such a collaborative design organization supports direct engineer-to-engineer communication; rapid design decision-making; and development of higher quality more producible, maintainable, and upgradeable designs than traditional methods. Implementation of these best warship design practices requires early industry involvement and a new 21st century warship acquisition strategy. Recent NEJ articles by Keane et al. (2018, 2019) describe such a strategy. Further details on best early-stage warship design practices are addressed in the recent NEJ article "Asian vs. U.S. Warship Design, Production Engineering, and Construction Practice" (Jaquith, 2019).

Optimize Design-Build Process

An excellent case study is Bath Iron Works' implementation of a comprehensive warship manufacturing plan on its FFG-7 Class program in the late 1970s (Jaquith, 2020). The plan focused on first-time quality, cost, and schedule reduction. Since the 1970s, technology developments including use of 3D product models, "interim product by stage-of-construction" based work instructions, and digital reporting of installation and test status provide further improvements in productivity. Best manufacturing practices for warship construction include:

- **Integrated Hull, Outfit, and Paint Build Strategy.** Develop integrated build strategy starting in early-stage design; target >95% metal outfit and >90% equipment, piping, ventilation, and local cable installation in pre-outfit; strategy provides the basis for requirements/material planning and reduces time and cost.[1]
- **Design and Material Support.** Ensure >98% design and material support to the manufacturing plan as measured at the work package level and >98% work packages completed without design or material change; strategy empowers production work teams and supports strategic reduction in construction time and cost.

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[1] Pre-outfitting includes the installation of outfit equipment and systems during the hull block (unit) assembly process prior to ship erection. Pre-outfitting also includes the use of shop assembled outfit modules (rafts).

- **Facilities and Tooling Support.** Ensure >98% key facilities and tooling support of the manufacturing plan (e.g., major cranes, transporters, assembly and pre-outfit halls, panel lines, burning machines, etc.); strategy empowers production work teams and supports strategic reduction in construction time and cost.
- **Repeating Workstations and Work Teams.** Utilize both real and virtual workflow to plan assembly, pre-outfit, ship erection, onboard outfit, test, and trials activities using repeating workstations and repeating work teams; strategy increases ship-to-ship learning, improves quality, and reduces construction time and cost.
- **Change Management.** Manage both internal and customer change with time fencing rules to avoid production impact; accomplish critical changes in Post Delivery Availability (PDA); strategy empowers production work teams and allows construction to proceed under planned/controlled conditions, reduces time and cost.
- **3D Product Model.** Utilizing 3D Product Modeling Systems starting in early-stage design provides a single voice of truth for design development, configuration management, production planning and control, and resource/material requirements planning; strategy improves design quality and reduces time and cost.
- **Work Instruction Design.** Utilize "interim product by stage-of-construction" based work instructions in lieu of traditional system drawings; strategy provides production work teams with clear direction reducing rework, construction time, and cost.[2]
- **Continuous Improvement, Accuracy Control, and Quality Management.** Based on Deming Quality Management System; focus on improving work sequence, increasing pre-outfit levels, reducing schedule durations, and addressing systemic quality issues; strategy improves quality and reduces time and cost.
- **Supply Chain Integration.** Supplier and sub-contractor fabrication and installation schedules fully aligned to manufacturing plan; strategy empowers production work teams, improves quality, and supports strategic reduction in construction time and cost.
- **Navy and Shipbuilder Collaboration.** Program milestones, funding for long-lead material, GFI, GFE, combat system installation and test schedules, Navy certification schedules, sea trials, and crew training fully aligned to the manufacturing plan; strategy supports strategic reduction in ship construction schedules (see Figure 6).

[2] "Interim product by stage-of-construction" work instructions include all drawings, material lists, and instructions required for efficient construction. They are prepared automatically using the 3D Product Modeling System.

OPTIMIZE DESIGN-BUILD PROCESS

- 21st Century Acquisition Strategy
  - Navy/shipbuilder collaboration starting in early -stage design
  - Two shipyard DD&C – reduced schedule & increased learning
- Design-Build Strategy
  - Design for performance, construction, sustainment, upgrade & reduced cost
  - Early-stage production engineering & lean optimization
  - Work content identified in 3D product model
- Warship Manufacturing Strategy
  - Focus on planned & controlled production
  - Navy, shipbuilder & supply chain integration
  - Design, material and tooling support of production
  - Focus on continuous improvement & schedule reduction

Figure 6. Design-Build to Enable Durability and Longevity > 40 Years

For critical warship programs such as DDG(X), the use of two shipyards for Detail Design and Construction (DD&C) will reduce design and construction durations, increase production throughput, and increase ship-to-ship learning. Further details on best warship manufacturing practices are described in the recent NEJ article "Modern Warship Manufacturing Practice: Impact on Acquisition Cost, Schedule, and Industrial Mobilization" (Jaquith, 2020).

NATO Navy Acquisition Innovations

The international acquisition innovations that have been implemented over decades in Europe and Asia have focused in large part on the mid-range surface combatant, the backbone of most international navies. In several countries, this continuous focus on the naval frigate has spanned over 30 to 40 years. Navy officials and shipbuilders have joined forces to design and build naval ships that satisfy domestic as well as global markets. Designing a common solution to multiple markets has resulted in designs that are more versatile and adaptable. The latter being critical for a naval class to maintain its operational relevance for more than 40 years with two major upgrades. Moreover, the focus has increased shipbuilding design and construction productivity, cycle reduction, and throughput.

In Germany, the Netherlands, and Denmark, there has been an emphasis on lean processes, elimination of non-value-added tasks and the implementation of a comprehensive digital transformation to provide a single, reliable source of knowledge about a ship class and each hull number. Now this digital backbone is being extended to the supplier network and sustainment infrastructure. The latter being an essential step to improving sustaining engineering and upgrade engineering efficiency and cycle reduction.

The results of these innovations that have been dramatic improvements, for example, **design versatility,** 1,500 payload modules for one family of naval warships; **production productivity**: 50% reduction in design and construction cycle time, and **upgradability**: 75% to 90% module replacement cycle reduction and 33% to 67 % reduction in major ship systems upgrade cycle time. Additionally, leading naval shipyards in Europe have developed the processes and management versatility to enable international customers to build their designs efficiently in local shipyards. This has permitted these shipyards to expand their markets and production base to further reduce the price of their ships.

The discipline of a robust, comprehensive, and secure 3D model with all associated technical information has enabled shipbuilders in Europe to form coalitions with other shipyards that can transcend international borders to pursue new programs. For example, Luerssen in Germany and Damen in The Netherlands formed an alliance to pursue and win the Germany Navy, F126 Frigate Program [displacement 9,000 tons; four ships in the class], and Babcock Marine International won the UK RN F31 Frigate Program with an OMT Danish Stanflex hull design [displacement 5,700 tons; five ships in this class]. The total price of a UK RN F31 Frigate appears to have established a new benchmark for a naval frigate of $100,000 USD/ton. The new USN FFG62 Frigate at $135,000 USD/ton is very competitive with other current international frigates.

Successful coalitions that have been formed in Europe are examples of what can be accomplished when leading shipyards join forces and share best practices with a secure digital backbone that synchronizes processes and change management and maintains a fidelity across all operations throughout the entire design and build cycle. Moreover, a 3D Product Life Cycle Management technical definition when maintained continuously can improve sustaining engineering efficiency which in turn can boost class availability and eventually enable operational relevance for more than 40 years (see Figure 7).

NATO NAVY ACQUISTION INNOVATIONS

- **Acquisition Initiatives:**
  - Public-Private Focus on Surface Combatant Development: >30 years
  - Joint Shipbuilding Coalitions: in Germany, UK, Denmark, France, Italy, etc.
  - Versatile Designs: 1,500 payload modules for a family of warships designs
  - Durable Designs: 40+ years of operational relevance/superiority with multiple upgrades
  - Pursuit of both domestic and international naval programs with collaborative design/platform/specs.
- **Key Drivers/Motives for Initiatives:**
  - Meeting concurrently naval operational obligations and defense budgetary constraints
- **Results:**
  - Average price of first 10 FFG62 frigates = $135,000 USD/long ton(FL)
  - Average price of first 5 RN F31 frigates = $100,000 USD/long ton(FL)
  - Successful collaborative programs:
    - German Navy: F125 Frigate: tkMS and Luerssen;
    - German Navy: F126 Frigate: Luerssen and Damen
    - UK RN: F31 Frigate: BMI and OMT
    - Danish Navy: Frigate and Supply Ship common hull

Figure 7. Double Digit Improvements in Productivity, Cycle Reduction, and Production Throughput

Acquisition-Related Recommendations

The progress that has been made in acquisition strategy and design, construction, and sustainment process improvements have had significant impacts on naval shipbuilding programs, but this trend needs to be adopted more widely if the USN is going to satisfy current and future challenges while remaining compliant with budget constraints. Much of the success of European allies can be attributed to a long-term commitment by government and naval shipyard officials to designing and building more capable and cost competitive naval warships for both domestic and international markets (see Figure 8).

ACQUISITION RELATED RECOMMENDATIONS

- Foster Substantive Collaboration Between USN & US Shipbuilding Industry Officials Including WSI & key Naval Suppliers
- Form Group of Industry Experts to Accelerate Digital Transformation Across the USN enterprise based on best practices from related industries, e.g., aerospace, defense, utility
- Form Flag-Level Committee to Develop a Long-Term 50-year Naval Warship Design, Construction and Sustainment Strategy
- Form Indo-Pacific Naval Special Interest Group to Maximize Return on Total Investment and Synergy Among New Naval Shipbuilding Programs in the USA, Canada, Australia, Japan, South Korea, India, etc.
- Build career development program to develop future naval Ship Design and Program Managers focused on naval shipbuilding best practices, innovations and lessons learned

Figure 8. Long-Term Commitment to the Next Generation of Naval Warships

After reviewing the progress and results over the last decade during annual naval shipbuilding summits, it was concluded, as a **First Recommendation**, that USN shipbuilding programs could benefit from forming a panel of shipbuilding experts from government, shipbuilding industry, and academia to develop a long-term shipbuilding strategic plan to improve the affordability, adaptability, sustainability, and durability of future USN warships. This panel could provide balanced and continuous advice to USN leadership to ensure that there is a focused campaign to implement the best practices and lessons learned from the leading shipbuilders in the world as well as breakthroughs from adjacent, relevant industries and academia.

As a **Second Recommendation** from the shipbuilding summits is the implementation of appropriate and proven Information Technology for USN program management offices, U.S. shipyards, and principal suppliers in early-stage design and throughout the program life to synchronize knowledge management across the extended shipbuilding enterprise. It is evident that when advanced and proven Information Technology is implemented, it can have a significant impact on design and construction productivity and quality control throughout the entire build cycle, and moreover it can boost sustaining engineering and major upgrade efficiency and cycle reduction. Since the implementation of a comprehensive IT transformation can be very complex and time consuming, it is recommended that a small team of qualified experts be formed to review best practices and lessons learned from the implementation of IT enterprise-wide solutions at naval shipyards and related industries like aerospace and automotive to ensure the success of future U.S. shipyard implementations.

The preponderance of the findings and results of the first decade of Global Shipbuilding Executives Summits (GSES) have been from shipyards in Europe and the United States. Over the next decade, **Third Recommendation**, more focus should be made on Asian naval shipyards and in particular shipyards in Japan and Korea where it appears that relatively modest increases in design dimensions may have a much greater impact on construction efficiency and reduce total construction labor. Additionally, the incorporation of automotive production and quality best practices in these shipyards may have also shortened construction cycle time and boosted throughput. Both issues are crucial to the U.S. naval shipbuilding industry as it prepares to launch a significant increase in naval shipbuilding.

The increase in U.S. naval shipbuilding for both traditional ship classes as well as some new and somewhat non-conventional designs will place enormous stress on the Navy–Industry collaborative design teams that will be tasked with managing these design and acquisition programs. It is imperative that a program, **Fourth Recommendation,** be implemented to accelerate the training and career development of the professionals who will be responsible for managing these programs over the next 30 to 40 years and avoiding costly mistakes of the recent past (Keane & Jaquith, 2021).

Finally, a dedicated team needs to be tasked to efficiently upgrade the existing, strategic USN fleet assets, like the family of DDG51 destroyers, if the USN is going to realize a **net gain** of 50 to 150 ships over the next 2 decades.

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