TITLE: Ensuring Successful Ship Construction Outcomes: Using More Physics-Based Design Tools in Early Concept Design

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ABSTRACT

The Naval Sea Systems Command (NAVSEA) has explored a number of initiatives to implement modular design and construction. These initiatives included the Ship Systems Standards Program, Affordability Through Commonality (ATC), Product-Oriented Design And Construction (PODAC), Total-ship Open System Architecture (TOSA), and the Navy's Mid-term Sealift Technology Development Program (MSTDP). The MARITECH and National Shipbuilding Research Program (NSRP) funded comprehensive shipbuilder studies such as Product Work Breakdown Structure (PWBS) or zonal design and construction and MASE (MARITECH Advanced Shipbuilding Enterprise) Project 21 (Develop and Implement "World Class" U.S. Material Standards and Parametric Design Rules to Support Commercial and Naval Auxiliary Ship Construction).

These initiatives were all well intended and experienced some limited success. Yet, the Navy continues to experience unique, one-of-a-kind, complex Detail Designs with the resulting cost and schedule problems. Why aren't the valuable results of these many research projects on modular or zonal design and construction being fully implemented? One reason may be that the fundamental early stage ship design process has not changed. The early stage ship design process does not deal with the ship in terms of modules or zones (PWBS) and the process itself is not structured for re-useable design modules.

Deciding the appropriate level of design process definition is a major challenge that must be addressed at the beginning of each design phase. Designing the ship design process is a process in itself. Reinertsen (1997) emphasizes the key to designing a process which must be both disciplined and flexible is structure; that is, standardize the lower levels of the process architecture. When we design a design process, we want to create standardized building blocks that are defined primarily at their interfaces, rather than by their internal procedures. By standardizing the process interfaces, we can evolve the internal structure as necessary to meet changing requirements. When the external properties are controlled, we can change internal methods without unraveling the entire design process.

Early stage design is a critically important phase because decisions that lock in the construction and ownership costs are made during this phase. Important details are addressed during Contract Design, but major decisions regarding the basic architecture of the ship and ship systems are made during Concept and Preliminary Design. The greatest return on invested time would be from defining the Concept and Preliminary Design Process in greater detail.

Current naval architecture practices, however, specify selection or design of the hull form first. Then, all necessary systems are forced to fit within the physical hull confines - "outside-in" design (Keane et al, 2007). The decomposition-based approach proposes the exactly opposite design approach. In other words, the systems are designed first, and

then the hull is designed to enclose the cumulative system volume and area as mapped through functional allocation - “inside-out” design (NSRP Project 21, 2000). This approach provides a means to conduct functional vice physical ship design. This methodology identifies functions requiring fulfillment, presents physical design parameters to meet these needs, and maps the interrelationship between the two. Decomposing into subsystems creates a logical structure with bounded subsystems that can be more easily analyzed, designed, built, and maintained.

In 2007 at the Navy’s Center for Innovation in Ship Design (CISD), a small Navy-industry-academia team with over 200 years of naval ship design and shipbuilding experience conducted a workshop on the Initial System Architecting sub-process, which begins the Preliminary Design (PD) phase of the naval ship design process. The architecture of the ship is almost invisible to most, yet it has an extraordinary impact. As the CISD team applied the framework to “leaning” the critical initial phase of the Preliminary Design process, it became evident that early attention to the ship physical architecture would pay big dividends. Architecture in this sense goes beyond basic general arrangement to include the philosophy of mission systems and auxiliary systems distribution and connectivity, survivability, the impact of build strategy on the arrangement, and other systems engineering considerations.

The Initial System Architecting sub-process was selected because this is the first allocation of major shipboard functions throughout the ship, where the total-ship system architect determines whether there are sufficient ship resources (space, weight, power, etc.). It is driven by the general arrangement task. Large blocks within the ship are allocated, defining the area and volume, location, adjacency, and separation requirements for the major systems of the ship. If done well, the development of the various systems can be accomplished during subsequent design phases with minimal rework to the total-ship functional layout--a stable design.

The team achieved the objective of the CISD workshop and a much improved Initial System Architecting future state sub-process was developed. The future state sub-process would better meet the sub-process objective of developing an initial ship configuration and size with a much higher degree of confidence, meaning one that does not grow significantly during follow design phases or does not overly constrain design solutions. In order for the design to meet schedule and cost requirements with minimal rework in later stages of design and production, a stable design for production must be established as soon as possible. And the first critical step in establishing a stable design is locking in the ship arrangements; that is, subsequent subsystem detail design would not require redesign of the ship arrangements and thus the total ship.

The author will describe the need for dramatically changing the pre-production design process to a more modular architecture. These pre-production processes need to apply standardization to material, equipment, design methodology, cost estimating methodology, interim product definition, functional arrangements, zone/modular designs and whole-ship designs. The principal objective will be to demonstrate how a significant reduction in design and engineering cycle time and man-hours can be achieved through a more effective use of design tools and a different approach to the Design-Build-Own Process.

The author will also describe a number of new design tools which will help achieve the objective of reducing design and engineering cycle time and man-hours. These tools are being developed under the Computational Research & Engineering for Acquisition Tools & Environments (CREATE)-SHIPS Project. The CREATE-SHIPS Project is sponsored by the DoD High Performance Computing Modernization Program Office. The CREATE-SHIPS Project objective is to design out defects, and to optimize the total-ship design, while meeting acquisition schedules. To accomplish this objective, time-to-solution for a given design option, within a very large set of design options, is a necessary quality of the overall process. Some of these new tools include the University of Michigan's Intelligent Ship Arrangement (ISA) design analysis software, and CREATE-developed Hull Form Generation and Transformation, and Multidisciplinary Design Optimization (MDO), and integrating these into a Rapid Ship Design Environment (RSDE).

The author will describe that the way ahead for efficiently producing a Warship can be achieved through the use of more early-stage physics-based design tools and a more collaborative approach to the design-build-own process. He will elaborate that the surface navy needs to dis-continue the practice of first starting with the hull form and based on the false economies of cost and size, arbitrarily constraining the design and driving up ship density. A lesson learned is to start the pre-Acquisition ship concept design studies early and invest more resources in those design studies, including more funding and more stakeholder involvement. This is what it takes to do more robust ship design and systems engineering. The methodology results in successful ship construction outcomes such as significantly reduced design-build cycle times and construction costs.