DEFENSE STANDARDIZATION PROGRAM

CASE STUDY

The *Virginia* Class Submarine Program

This case study describes how the Navy is achieving tremendous savings in the *Virginia* class submarine program (PMS 450) by turning to standardization initiatives to help reduce total life-cycle costs, including design, construction, operation, and disposal. Standardization also has minimized the program's overall logistics footprint and reduced the class parts library.

The *Virginia* Class Submarine Program

Background

The *Virginia* class submarine program is an acquisition category 1D program to design, develop, and acquire 30 submarines at an estimated total cost of $94 billion. The integrated logistics support efforts associated with this procurement include providing both organic and nonorganic support for each ship of the class, and the class itself, including spare parts, corrective and preventive maintenance planning and execution, human systems integration (manning, manpower, training development and conduct, trainers), logistics technical data, configuration management, stowage planning, facilities support, test and handling equipment procurement, and life-cycle planning, programming, and budgeting.

The *Virginia* class of attack submarines is the first class of U.S. submarines designed for a broad spectrum of open-ocean and littoral missions around the world. They have improved stealth, sophisticated surveillance capabilities, and special warfare enhancements to meet the Navy's multimission requirements. Designed as a cheaper alternative to the Cold War-era *Seawolf* class attack submarines, the *Virginia* class submarines are slated to replace aging *Los Angeles* class attack submarines, some of which have already been decommissioned. Three submarines—USS *Virginia* (SSN-774), USS *Texa*s (SSN-775), and USS *Hawaii* (SSN-776)—have been commissioned and are in service. An additional five submarines have been ordered to date.

Problem

In the mid-1990s, U.S. shipbuilding was in a downturn, which required all stakeholders in the marine community (government, industry, and academia) to examine various improvements to reduce time and related costs in all phases of ship design, construction, and life-cycle support. The community identified two key areas that should be improved:

- Parts standardization
- Process standardization.

Traditionally, shipbuilding design and construction has focused on custom design to suit the limited number of ships or classes of ships being built. As a result of this practice, the number of specifications—and the number of functionally similar or nearly identical items—proliferated. Because standardization received little or no consideration, the costs associated with parts definition, configuration management, test maintenance, spares, vendor selection, and warehousing increased significantly. The lack of standardized processes—for example, a process to ensure that integrated logistics support considerations are built into the design early—also has contributed substantially to ship life-cycle costs.

The *Virginia* program office recognized the need to apply standard practices to the sparing, training, and technical data management processes to reduce the overall logistics footprint, lower life-cycle costs, and take advantage of commonalities to provide the same or better level of support products at a lower cost. By implementing standardization initiatives, the program office can reap substantial cost savings benefits without a reduction in capability. At the same time, the standardization techniques are crucial to fulfilling the program's mission: "provide world-class leadership and management to acquire a cost and operationally effective integrated submarine weapon system, which is sustainable throughout its life cycle and responsive to emerging requirements."

Approach

The *Virginia* program is the Navy's first major program to fully implement acquisition reform initiatives. The affordability of *Virginia* class submarines is due largely to integrated product and process development (IPPD), modular construction, parts reduction, and aggressive insertion of advanced commercial off-the-shelf (COTS) technologies. The IPPD concept teamed the Navy' s designers, shipbuilders, and vendors to ensure the most efficient and effective design early in the design process.

Driven by significant budget pressures, program office and design yard principals were challenged to effectively integrate the efforts of some 50 Navy and commercial organizations to produce more than 8,200 shipbuilder deliverables, 1,100 government-furnished equipment deliverables, and 1,900 end items (trainers and simulators, support and test equipment items, insurance spares) to deliver a cost-effective, yet robust, support solution to the fleet.

Parts Standardization

Prior class design and construction suffered from parts proliferation. The *Trident* class required 28,000 procured parts, the *Los Angeles* class called for 29,000 procured parts, and the *Seawolf* class lead ship construction required 45,000 procured parts.

In contrast, the initial issue of drawings for the *Virginia* class called for 17,963 procured parts. How was this accomplished?

- ***Empowered design teams***. Early and focused efforts using the IPPD teams brought the combined experience of the shipbuilders, vendors, designers, engineers, and ship operators to bear

on the ship design. The early involvement of production personnel on these teams ensured an excellent match between the design and the shipbuilder's construction processes and facilities, allowed a smoother transition from design to production, and reduced the number of engineering change orders typically required during lead ship construction.

- ***Parts Standardization Board***. The program established a Parts Standardization Board—more than 2 years before completion of the ship specifications—to identify, implement, and maintain a parts standardization program. The board, the gatekeeper of allowable parts, functions under the direction of program management and has members from the engineering, design, materials, planning, quality, and operations departments. A team leader reports directly to the program manager to ensure that standardization goals are maintained. In addition, the shipbuilder's president signed and supports the standardization policy and procedures. Finally, the shipbuilding specification directs the use of standard parts. The use of standard parts is tracked as a technical performance measure throughout design and construction.
- ***Digital environment***. The program makes extensive use of computer-aided design, facilitating digital sharing of design data and controlling part selection. (In fact, the *Virginia* class is the first submarine program to use electronic data as its primary data format.) For example, the design/build team's ability to search and utilize only standard parts, with the requirement to submit requests for new parts to the board, prevented proliferation of nonstandard parts. Using a tool called the Single Parts Manager, parts data are captured once, validated, audited, and made available. Further, it facilitated implementing a *Virginia* class contractor-furnished equipment provisioning process as a standardized method of processing provisioning technical data to generate the spare parts inventory for each ship. By the time the contract for construction was awarded, *Virginia* class standard parts numbered 14,889. The Single Parts Manager also captures parts materials, substances, and environmentally preferred notations, facilitating end-of-life disposal and minimizing disposal costs. Moreover, these data also facilitate obsolescence planning, which becomes more critical with fewer unique parts potentially affecting more systems.
- ***COTS components***. Integrated electronics systems with COTS components not only contributed to parts standardization, but also will facilitate the introduction of state-of-the-art technology throughout the life of the class, avoiding obsolescence. The command, control, communications, and intelligence electronics packages, as well as the combat systems package, promote maximum flexibility for growth and upgrade. The modular isolated deck structure provides acoustic and shock isolation (versus individually mounted parts, each requiring acoustic and shock protection) and allows for expanded use of commercial items.

Process Standardization

Standardization of processes, notably the following, also is a key feature in the success of the *Virginia* class program:

- ***Sparing***. The team developed a reliability-based sparing method for critical systems. This is a standardized method of computing critical onboard repair parts based on single-point-of-failure criteria and desired system reliability. The focus is on preventive—rather than corrective—maintenance, which is important in the submarine environment. The process is used on both government- and contractor-furnished equipment. This capability reduces the overall number of spares carried and maximizes stowage capacity, while maintaining organic repair capability. (Parts standardization in design also contributes to a reduced number of required onboard spares.) The USS *Virginia* had 98.4 percent of required onboard spare parts when delivered—a number significantly exceeding the 97 percent requirement and far superior to the provisioning of any other lead ship.
- ***Training***. In concert with the Naval Submarine School, Submarine Learning Center, and Naval Sea Systems Command (NAVSEA) Human Systems Integration Division, the program ensures that *Virginia* class interactive multimedia instructional materials are standardized to the latest requirements driven by Shareable Content Object Reference Model specifications and the Learning Management System selected for use throughout the Navy, and are integrated into all *Virginia* class products early in the development cycle. Standardized instructional material reduces or eliminates shore-based training.
- ***Technical data support***. The management of technical data also is being standardized. For example, the user interface for more than 600 interactive electronic technical manuals is standardized, easily allowing sailors to work across multiple systems and ships within the class—a first for submarines. Also, standardized technical documentation, including all of the ship's drawings, is integrated with the supply-ordering process and with onboard training products. This effort culminated in the publication of the *Web-Based Interactive Electronic Technical Manual (IETM) Common User Interface Style Guide*, Version 2.0, July 2003, which is available for use by all DoD departments and agencies.
- ***Maintenance processes***. Reliability-centered maintenance efforts with NAVSEA drove the producers of preventive maintenance products (the prime contractor and the government) to a standard method of deriving submarine maintenance requirements that melded with NAVSEA's efforts to reduce maintenance actions to the lowest practicable level by use of a condition-based maintenance philosophy. This practice has reduced the overall amount of maintenance required for ship equipment and systems without sacrificing operational availability.[1] Moreover, ship specifications are crafted to stan-

dardize special tools and test equipment, and they specify standardized COTS test equipment to improve operator understanding and reduce support requirements. These initiatives have decreased the organizational-level maintenance actions as compared with legacy classes. They have also reduced the number of meters and test gear required onboard, in turn reducing the logistics footprint and the cost of procuring test equipment. (The complement of test gear onboard *Virginia* class submarines is 101 items at a total procurement cost of $550,000 per ship. This is a 32 percent reduction in the number of test items—148—procured for *Seawolf* class submarines at a cost of $600,000 in FY05 dollars.)

- ***Self audits***. Continuous audits ensure ongoing compliance with program requirements. These audits are conducted monthly and identify non-standard material use, facilitate standardization evaluations, and provide a vehicle for continual standardization training.

Benefits

Standardization awareness and empowerment were present in all aspects of the design and planning for ship and class support. The results are impressive:

- In FY05, the USS *Virginia* was delivered on time, a significant achievement for a lead ship.
- The USS *Virginia* class parts library at delivery was 80 percent less than that of the USS *Seawolf*, the lead ship of the prior class of submarines built.
- USS *Virginia* had 98.4 percent (of more than 8,600 computed parts) of all her required onboard spare parts when she was delivered, a number that significantly exceeded the required 97 percent and is far superior to the provisioning of any other lead ship. The follow-on ships did even better—USS *Texas* and USS *Hawaii* had 99.8 percent and 99.9 percent, respectively, of their required onboard spare parts at delivery.
- The initial issue of drawings for *Virginia* class ship construction called for 17,963 procured parts, a 60 percent reduction from the *Seawolf* class lead ship construction.
- The USS *Virginia* is the first submarine to use all-electronic procedures and technical manuals. As a direct result of IETM standardization, crew knowledge has improved over previous ship classes.
- Use of standardized COTS electronic test equipment has resulted in a 32 percent reduction over the amount of test equipment procured for *Seawolf* class submarines.
- Implementation of standardized preventive maintenance actions by means of reliability-based maintenance has resulted in a decrease in the number of organizational-level maintenance actions over legacy class submarines.
- Standardized reliability-based sparing computations allow *Virginia* class submarines to have the mission-critical, single-point-of-failure parts they need while identifying parts that have redundancy and can be eliminated from the onboard inventory—which reduces the cost of spares

procurement and the onboard stowage footprint.

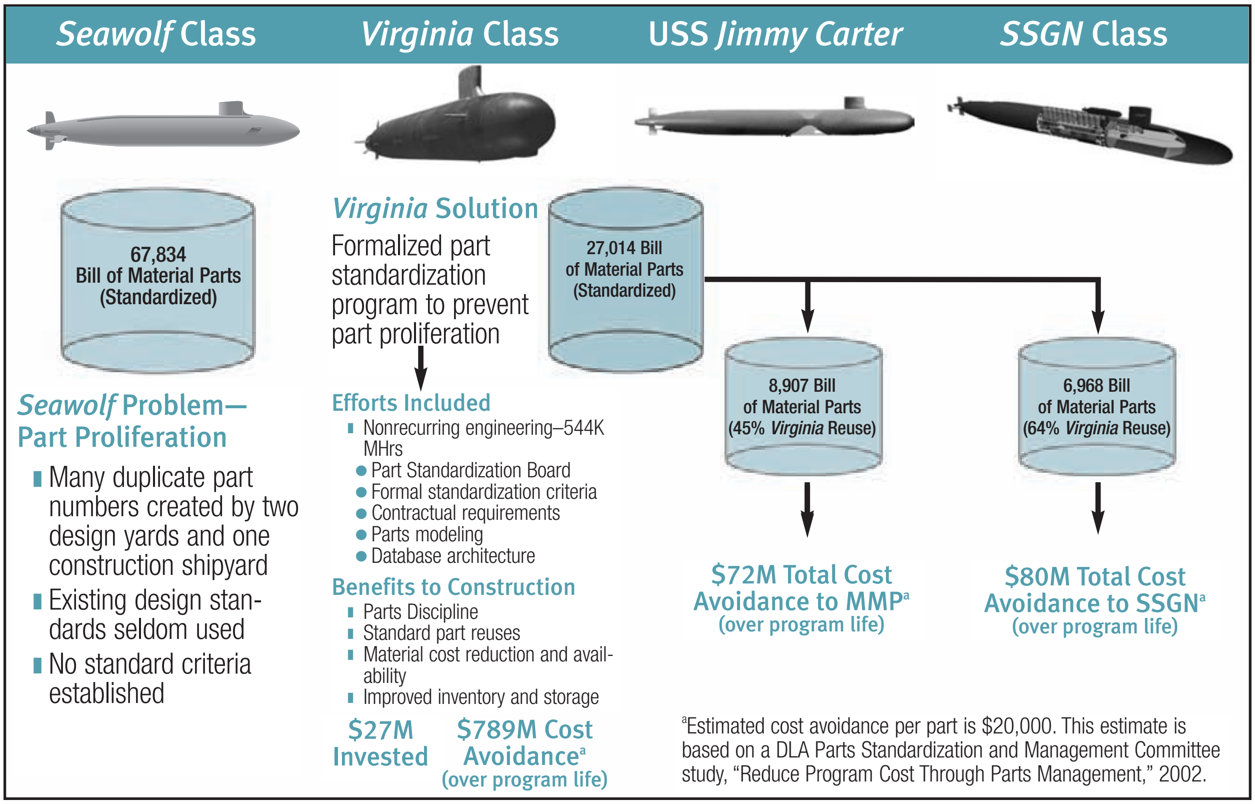
The bottom line? Over the life of the *Virginia* class program, the $27 million investment in parts standardization is projected to lead to $789 million in cost avoidance. Moreover, the USS *Virginia* already has shown a marked improvement in crew readiness, utilizes cost-effective onboard parts support, and benefits from a reduced logistics footprint.

The impact of this success has been experienced beyond the program, as the lessons learned and extended application have led to projections of $72 million and $80 million of cost avoidance for the USS *Jimmy Carter* Multi-Mission Platform and SSGN-class programs, respectively.

- USS *Jimmy Carter*: 8,907 bill of materials parts—4,005 (45 percent) reuse of *Virginia* class parts; $72 million cost avoidance
- SSGN class: 6,968 bill of materials parts—4,447 (64 percent) reuse of *Virginia* class parts; $80 million cost avoidance.

Figure 1 compares the number of items for the *Seawolf* class, with those for the *Virginia* class, USS *Jimmy Carter*, and SSGN class.

Figure 1. Comparison of Parts Requirements



Future Efforts

USS *Virginia* was delivered on October 12, 2005, 2½ months before her threshold delivery requirement determined 10 years earlier. When she was delivered, USS *Virginia* was the best logistically prepared lead ship of any class, as evidenced by the results of her board of inspection and survey inspection, which is required for the Navy to recommend taking delivery of the ship. Less than 4 percent of the 588 discrepancies were determined to be related to integrated logistics support. USS *Virginia* was so well prepared that she already has completed a successful deployment in support of the Submarine Type Commander, performing her operational mission before completing her post-shakedown availability period and more than a year before her expected initial operational capability declaration.

PMS 450 continues looking for additional ways to reduce the cost of each follow-on ship under construction by $400 million each, and standardization remains a critical way to attaining this goal.

Lessons Learned

A key to success was the *Virginia* class submarine program office's insistence that lessons learned be shared, especially among the shipbuilders, to facilitate further standardization. This required active engagement by the program office throughout design and construction. Looking back on its success, the program office cites additional lessons learned.

Digital Environments

Building on the success of digital environments—each unique to the *Virginia* class submarine and other acquisition programs—the Navy launched the Navy Product Data Initiative in fall 2006 for surface ships and submarines. The initiative has two main objectives: ensure and enable the interoperability and configuration management of integrated product data environments (IPDEs).

Currently, Navy engineers and logisticians face considerable barriers in navigating across 10 custom IPDEs, each a substantial investment. Moreover, considerable expense is required to handle inevitable IPDE changes during design, construction, and life support.

NAVSEA, in conjunction with the National Shipbuilding Research Program, is developing IPDE interoperability and configuration management specifications to be invoked in future acquisition programs.

- ***Program office and contractor management commitment***. Both corporate management and the customer organization must be committed to the standardization program's goals and control processes. Standardization must be embraced early in the design phase.
- ***Engineered standardization***. By constant and active participation in design/build teams, pro-

gram logisticians ensured that life-cycle support considerations were integrated directly into the design very early in the planning stages, overcoming the old ideas of "design first/support later" (if funding remains available). *Virginia* class design engineers designed with consideration for supportability and standardization in all of the ship's unique systems and in the overall arrangement of the ship's design.

- ***Process consistency***. Standardization must extend to processes, not only parts, to yield the highest payoff. For example, the processes for determining all aspects of logistics support—including maintenance requirements, spares provisioning, and configuration management—is critical to achieving cost, time, and stowage efficiencies across the class. Process standardization has the potential to extend efficiencies across all Navy platforms—surface and submarine.

Note

[1]Reliability-centered maintenance is the practice of maintaining equipment on the basis of the logical application of reliability data and expert knowledge of the equipment. Normal preventive maintenance is performed on the basis of time; in other words, maintenance operations are performed on a schedule to prevent poor performance or failure. Condition-based maintenance is a set of maintenance processes and capabilities derived from real-time assessment of weapon system condition obtained from embedded sensors and external test and measurement using portable equipment. The goal of condition-based maintenance is to perform maintenance only upon evidence of need.

DEFENSE STANDARDIZATION PROGRAM ★ MAKING SYSTEMS WORK TOGETHER ★

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