NPS-AM-25-242

ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

Case Study on Industrial Base Planning for Future Attack Class Submarines

June 2024

Justin B. Ort, CIV

Thesis Advisors: Dr. Robert F. Mortlock, Professor
Jeffrey R. Dunlap, Lecturer

Department of Defense Management

Naval Postgraduate School

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ABSTRACT

This report analyzes the Virginia class from the DOTmLPF-P and SWOT analysis formats to assess the program for lessons learned to future program managers, with an emphasis on submarine and ship acquisition.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAF	Adaptive Acquisition Framework
ACAT	Acquisition Category
AFS	And Follow-on Ships
AoA	Analysis of Alternatives
APA	Additional performance Attributes
APB	Acquisition Program Baseline
APUC	Average Procurement Unit Cost
AUKUS	Australia, United Kingdom, United States
AUR	All-Up-Round
CAD	Computer Aided Design
CAE	Component Acquisition Executive
CBA	Capabilities Based Assessment
CDD	Capability Development Document
CJCS	Joint Chiefs of Staff
CJCSI	CJCS Instruction
CONOPS	Continuity of Operations
COTS	Commercial Off-the-Shelf
CRS	Congressional Research Service
DAU	Defense Acquisition University
DCR	DOTmLPF-P Change Recommendation
DFA	Design for Affordability
DOD	Department of Defense
DoDD	DOD Directive
DoDI	DOD Instruction
DOTmLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
DSP	Defense Standardization Program

EPA	Economic Price Adjustment
FAR	Federal Acquisition Regulation
FRP	Full Rate Production
FY	Fiscal Year
GAO	Government Accountability Office
GOTS	Government Off-the-Shelf
GPT	Generative Pre-trained Transformer
GSA	General Services Administration
IBR	Integrated Baseline Review
ICD	Initial Capabilities Document
IMF	Intermediate Maintenance Facility
ISEA	In-Service Engineering Agent
ISSR	Inherent, Structural, Systemic, Realized
JCIDS	Joint Capabilities Integration and Development System
JFFM	Joint Fleet Maintenance Manual
JROC	Joint Requirements Oversight Council
KPP	Key Performance Parameter
KSA	Key System Attribute
LRIP	Low Rate Initial Production
MBTF	Mean Time Between Failure
MDD	Materiel Development Decision
MOP	Measures of Performance
MOSA	Modular Open Systems Approach
MSA	Materiel Solution Analysis
NAVSEA	Naval Sea Systems Command
NDI	Non-developmental Item
NPES	Naval Power and Energy Systems
NSS	National Security Strategy
NUWC	Naval Undersea Warfare Center

OSD	Office of the Secretary of Defense
PAUC	Program Acquisition Unit Cost
P&D	Production and Deployment
PEO	Program Executive Office
PM	Program Manager
POR	Program of Record
PPBE	Planning Programming Budgeting and Execution
RCM	Reliability Centered Maintenance
RFP	Request for Proposal
RMC	Regional Maintenance Center
SAR	Selected Acquisition Report
SBIR	Small Business Innovative Research
SDS	System Design Specification
SECNAV	Secretary of the Navy
SECNAVINST	SECNAV Instruction
STTR	Small-Business Technology Transfer Programs
SWOT	Strengths, Weaknesses, Opportunities, Threats
TMRR	Technology Maturation and Risk Reduction
VLS	Vertical Launch System
VPM	Virginia Payload Module
VPT	Virginia Payload Tube

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I. INTRODUCTION

A. PROBLEM STATEMENT

The United States has invested significantly in its submarine force, and in doing so has developed into one of the strongest strategic naval forces in the world. That development did not happen overnight; rather, it is the product of decades of research and development alongside an ever-changing acquisition workforce. The Virginia Class (774 Class) is classified as an "attack" class submarine, and it provides the Navy with speed and air-independent propulsion to combat undersea adversaries. The Navy is in the beginning phases of the major acquisition process to procure the next attack class submarine, the SSN(X) class.

The Virginia class was developed based on a shift in acquisition strategy to a focus on affordability. The requirements for the SSN(X) procurement are centered on increases in speed, capability, and acoustic targeting compared to the Virginia class specifications (O'Rourke, 2024b, p. 2). The SSN(X) class is in the process of transition from a project to an official Program Executive Office (PEO) designation as a program of record through the materiel solution analysis phase of the adaptive acquisition framework major capability pathway. Future program managers for the SSN(X) program should look at the previous generations of submarines' benefits and shortcomings to help inform the critical decisions made during requirements generation and life-cycle sustainment plans.

Program managers must consider the strategy utilized by the Virginia class program as a reference to inform the acquisition strategy for the SSN(X) program.

B. RESEARCH OBJECTIVES

This study aims to answer the following questions, and provide an analysis of potential risks for the SSN(X) program, with applicability to other future ship programs:

- What was the major acquisition strategy employed for the Virginia Class at the outset of the program?

- What major issues did the Virginia class face that led the program manager to deviate from the original acquisition strategy?
- What issues does the Virginia Class currently face in-service and in new-construction?
- What lessons can be learned from the in-service and new-construction issues that could have been prevented or addressed in an earlier acquisition phase?

C. RESEARCH METHODOLOGY

The analysis and recommendations laid out within this case study will be formatted in the doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTmLPF-P) analysis format. The purpose of this analysis format is to ensure that there are clear and concise topics to frame the research. DOTmLPF-P analyses support the major capability acquisition pathways for the DOD. The processes and guidance for completing a DOTmLPF-P analysis will be outlined in Chapter II. In addition, there will be sections discussing the strengths, weaknesses, opportunities, and threats (SWOT) of the Virginia program to support the recommendations and resolutions to the research questions.

D. LIMITATIONS AND SCOPE

There is limited data from the 23 commissioned submarines to date, SSNs 774 through SSN795. The Virginia class submarines are broken into deliverable blocks based on capability and configuration, see Table 1. The first Block III Virginia Class submarine is going into its first major depot availability as of this writing. A large focus of this analysis will be driven by anecdotal evidence from the perspective of an In-Service Engineering Agent (ISEA) for Block I and II Virginia Class submarine combat systems and leveraging the Selected Acquisition Reports (SARs) from Congress.

Table 1. Virginia class delivery blocks by hull number.

Virginia Class Delivery Blocks	
Block I	SSN 774 through SSN 777
Block II	SSN 778 through SSN 783
Block III	SSN 784 through SSN 791
Block IV	SSN 792 through SSN 801
Block V	SSN 802 and follow-on ships (AFS)

1. Selected Acquisition Reports (SARs)

SARs are the reporting program used by the Office of the Secretary of Defense to provide a concise total ownership cost across the procurement cycle of a program. Department of Defense Directive (DoDD) 5000.01, *The Defense Acquisition System*, summarizes it as follows:

> The SAR provides the status of total program cost, schedule, and performance, as well as program unit cost and unit cost breach information; … Each SAR shall also include a full life-cycle cost analysis for the reporting program and its antecedent program. … Annual SARs are mandatory for all programs to meet the reporting criteria. (DoDD 5000.01, 2022, section 6.2.4.1)

E. THESIS OUTLINE

Chapter II will outline background on the Virginia class and SSN(X) programs, the environment and time in which it was procured as well as provide context for the various acquisition policies and practices that will be referenced during the DOTmLPF-P analysis. Chapter III will outline the program objectives of the Virginia class program and the documentation associated with the procurement in the early years of its life cycle. The chapter will then transition to a DOTmLPF-P analysis of the Virginia class program. Chapter IV will provide recommendations for the SSN(X) program contextualized by the weaknesses identified during the DOTmLPF-P analysis and strengths, weaknesses, opportunities, and threats (SWOT) analysis. Chapter V will be a summarization of major ideas, address answers to the research questions, and consolidate the recommendations into major risks and courses of action to address them.

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II. BACKGROUND

A. THE ACQUISITION SYSTEM

The “Big A” acquisition system is built upon three pillars of the DOD: The defense acquisition system (DAS), joint capabilities integration and development system (JCIDS) and the planning programming budgeting and execution (PPBE) functional areas, highlighted in Figure 1 by Winters. The overlap of these three pillars highlights the complexity of the acquisition process with major stakeholders vying for various aspects of ownership over the requirements, funding, and management of acquisition programs. The program’s responsibility is to manage the individual drivers of the pillars and ensure there is alignment between the various requirements.

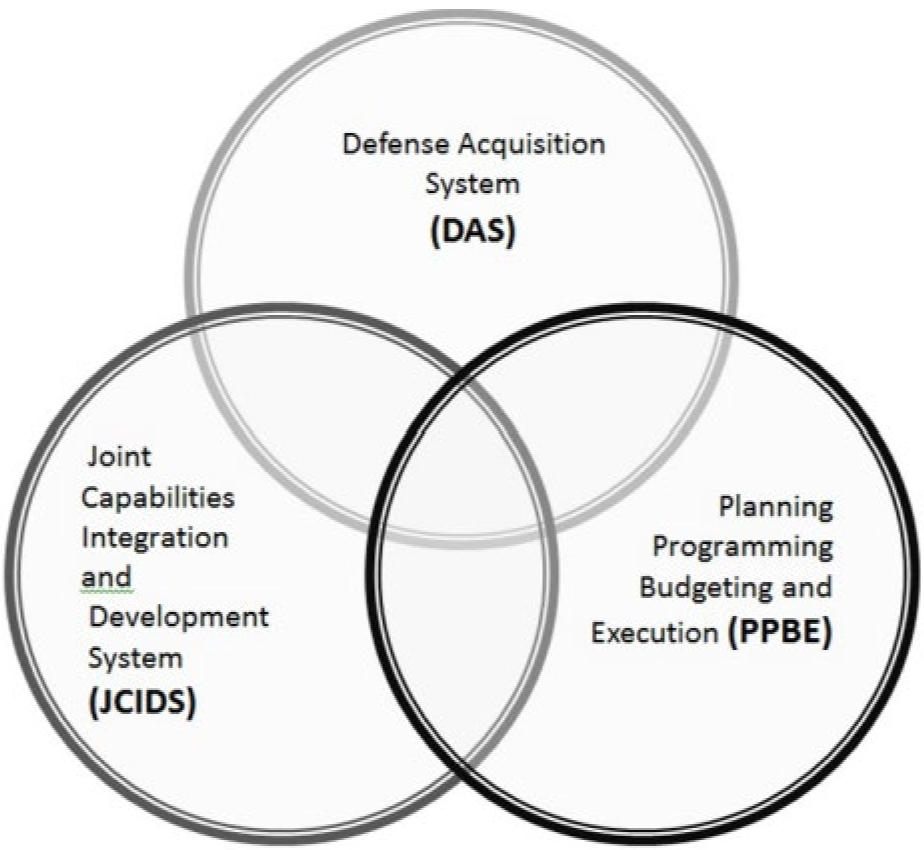

Figure 1. DOD acquisition environment functional areas. Source: Knox et al. (2014, p. 7).

The Defense Acquisition System is defined by DOD Directive 5000.01 and the workforce of the DAS. The acquisition team consists of a combination of program managers, logisticians, contractors and technical support teams, all major contributors for the planning, research, and production of the programs as required by FAR Subpart 1.102 (FAR 1.102, 2024). The JCIDS processes, regulated by CJCSI 5123.01I, generates the requirements for major programs of record and provides avenues for the Joint Chiefs of Staff (CJCS) and the Joint Requirements Oversight Council (JROC) to implement the National Security Strategy (NSS) (CJCSI 5123.01I, 2021, p. 4). In parallel, the DODD 5000.01 requires a capabilities-based assessment to generate system requirements via the initial capabilities document. Lastly, the PPBE accounts for the allocation of resources to execute the acquisition programs ensuring the correct funding is appropriated to the various stages of the life cycles (Defense Acquisition University, n.d.-s, para. 3). The PPBE process is calendar driven based on congressional budget timelines (Defense Acquisition University, n.d.-s, para. 2)

For the Virginia class program, in the overlap of the three functional areas in Figure 1, is the major capabilities acquisition life cycle, shown in Figure 2. The various blocks within the life cycle charts signify requirements and documentation to meet the program milestones, shown as triangles at the top of the chart. At the time of writing this capstone, the Virginia program is post-Milestone C in the production and deployment (P&D) phase and the SSN(X) program is in the materiel solution analysis (MSA) phase.

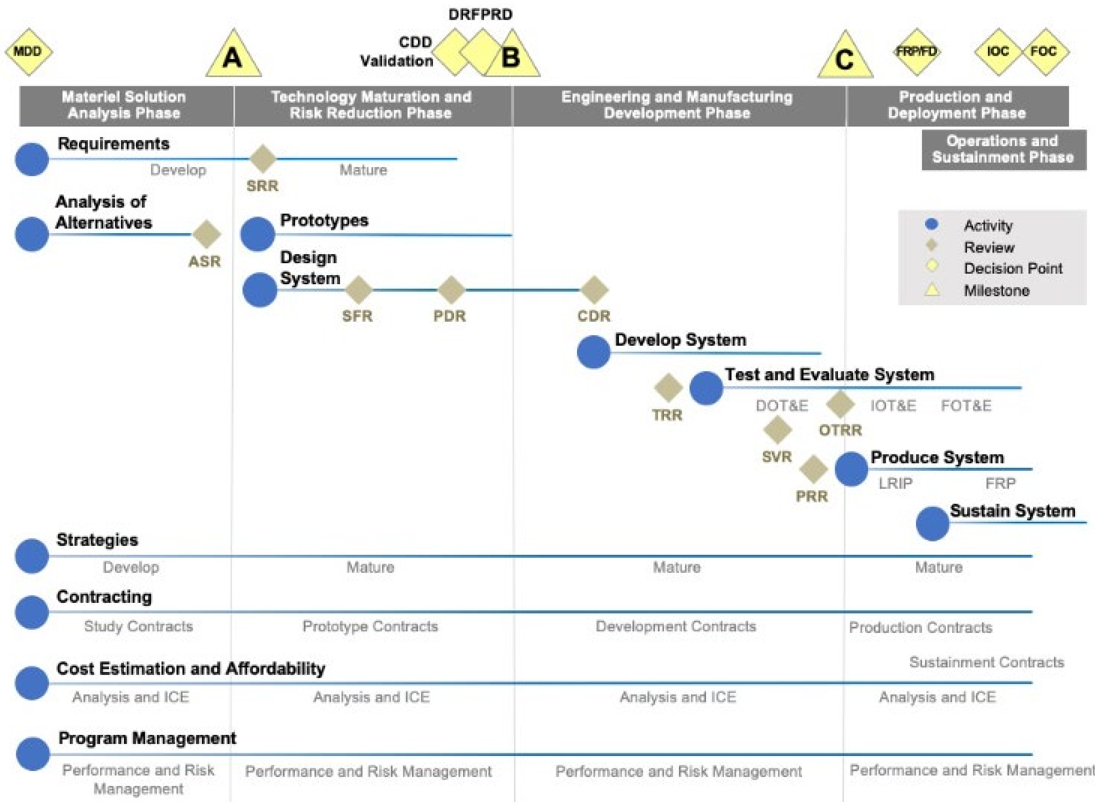

Figure 2. Life cycle view of major capability acquisition. Source: Defense Acquisition University (n.d.-m, p. 1).

1. Joint Capabilities Integration and Development System (JCIDS) Processes

Programs acquired by the Department of Defense are designated an ACAT category based on cost, complexity, and level of interest. Generally, ACAT I acquisitions are those with RDT&E funding requirements greater than \$525 million or total procurement costs greater than \$3.065 billion (Defense Acquisition University, n.d.-a, para. 3). ACAT II programs have RDT&E funds greater than \$200 million or total procurement costs greater than \$920 million. ACAT III programs are those that do not meet the requirements of ACAT I or ACAT II programs and have less restrictive requirements placed upon the acquisition process. The Virginia class program is classified as an ACAT I program.

The JROC sponsors programs based on the results of analyses performed on program requirements documentation. The approval and sponsorship of a major program of record by JCIDS aims to ensure the program receives bureaucratic support as required. The first analysis is the capabilities-based assessment (CBA). The JROC chooses to accept the risk levels in the capability gap or continue to develop the initial capabilities documents. However, if there is an alternate pathway as opposed to the ICD to reduce the capability gap, for non-materiel solutions, a DOTmLPF-P analysis is performed (Defense Acquisition University, 2024, n.d.-a, para. 1). Both avenues for reducing the capability gap converge at the capability development document (CDD)/DOTmLPF-P change recommendation (DCR) review. The JCIDS process is outlined in Figure 3.

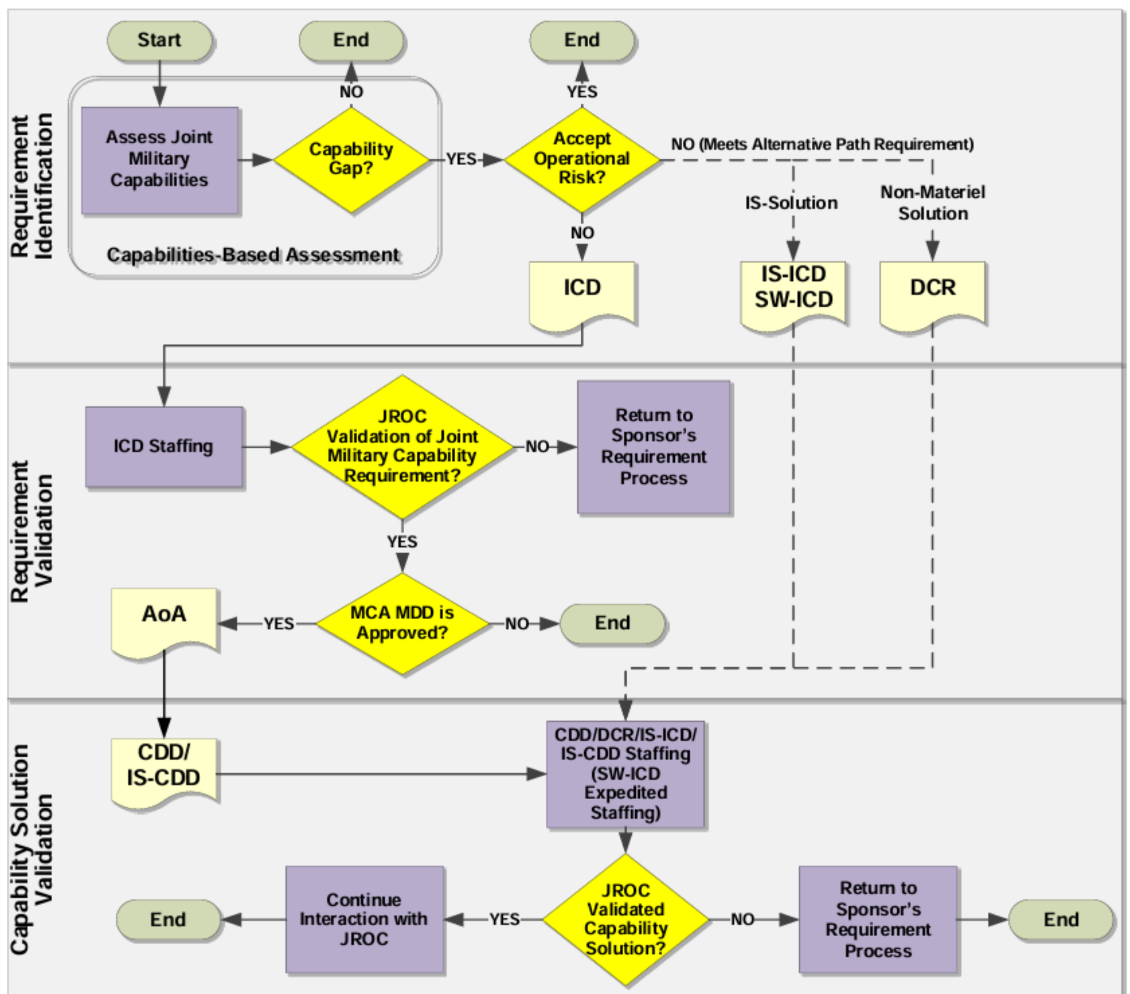

Figure 3. Overview of the JCIDS process. Source: CJCS (2021, p. A-A-3.).

2. Adaptive Acquisition Framework (AAF)

The adaptive acquisition framework outlines pathways to deliver value and capability to the warfighter, seen in Figure 4. The AAF is built upon six tenets: simplify acquisition policy, tailor acquisition approaches, empower program managers, data driven analytics, active risk management, and emphasize sustainment (Defense Acquisition University, 2024-b, p. 1). The pathways withing the AAF provide opportunities to develop an acquisition plan that match the characteristics of the capability being acquired (DODI 5000.02, 2022, p. 4).

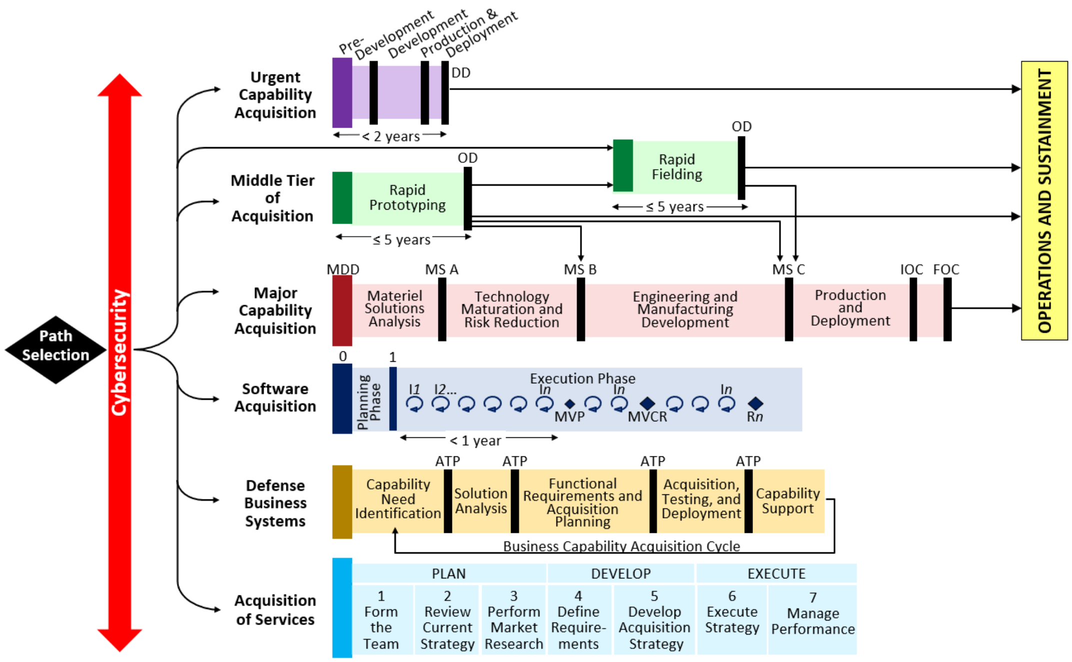

Figure 4. The AAF pathways. Source: DAU (n.d.-c, p. 1).

The Navy provides further guidance for the acquisition process, prescribed in the SECNAV Instruction 5000.2G "Department of the Navy implementation of the defense acquisition system and the adaptive acquisition framework" (SECNAVINT 5000.2G, 2022, p. 2). The Navy's guidance on implementation of the AAF is shown in Figure 5, the two-pass seven-gate framework is documented in enclosure 9 of SECNAVINT 5000.2G. The two-pass seven-gate framework "ensures alignment between service-generated capability requirements and system acquisition…throughout a program’s entire development cycle” (SECNAVINST 5000.2G, 2022. p. 5). The two passes represent the requirements generation and the acquisition of the program, while the seven gate reviews representing the major program documentation consisting of, the ICD, AoA, CDD, SDS, RFP, Post IBR/CDD Update/Pre FRP DR, sufficiency, and sustainment.

1. Gate 1: Endorses the initial capabilities document (ICD) and the proposed analysis of alternatives (AoA) study guidance. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 6)

2. Gate 2: Endorse, or approve, the AoA report and preferred alternative(s); approve the CDD and CONOPS guidance and assumptions. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 7)

3. Gate 3: Endorse the capability development document (CDD) and continuity of operations (CONOPS). (SECNAVINST 5000.2G, 2022. Encl. 16, p. 8)

4. Gate 4: Approve the system design specification (SDS). (SECNAVINST 5000.2G, 2022. Encl. 16, p. 9)

5. Gate 5: Endorse, or approve, the development request for proposal (RFP) release. Milestone B. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 9)

6. Gate 6 (Post IBR): Sufficiency review of the Integrated Baseline Review (IBR) results and the contractor’s performance measurement baseline. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 10)
   Gate 6 (CDD Update): Endorse the revised CDD. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 11)
   Gate 6 (Milestone C): Approve, or endorse, the program’s entry into Milestone C. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 12)
   Gate 6 (FRP): Approve, or endorse, the program’s entry into full rate production (FRP). (SECNAVINST 5000.2G, 2022. Encl. 16, p. 13)
   Gate 6 (Sufficiency): Sufficiency review of the system’s mission

readiness, affordability, and sustainability. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 14)

7. Gate 7: Conduct sustainment reviews. (SECNAVINST 5000.2G, 2022. Encl. 16, p. 15)

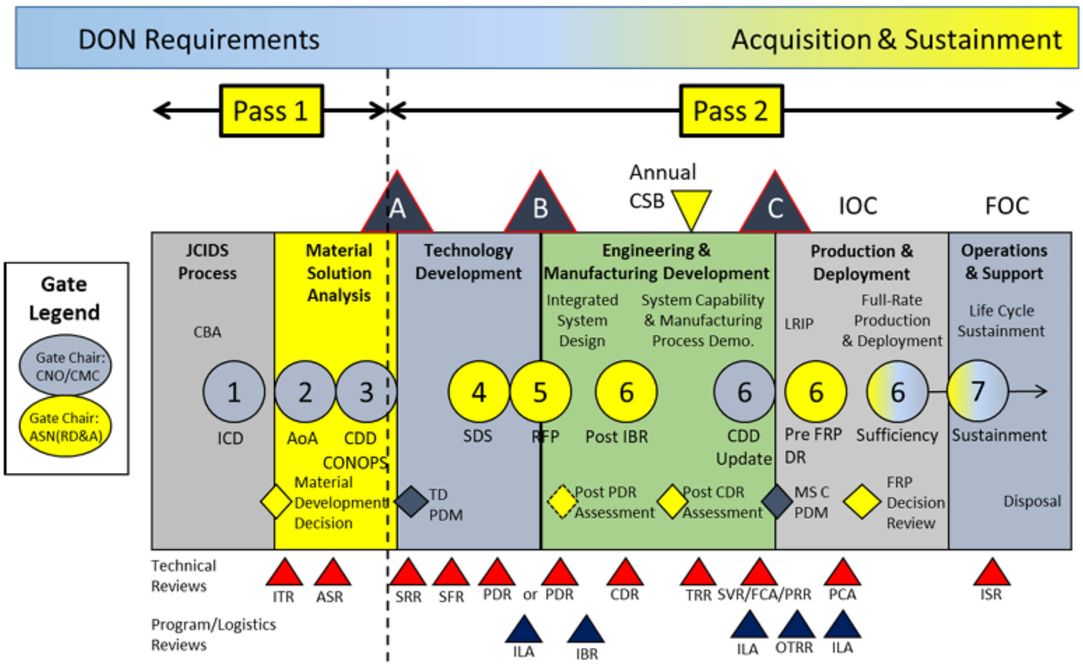

Figure 5. Requirements/acquisition two-pass seven-gate process with development of a system design specification. Source: SECNAVINST 5000.2G, 2022, p. 4.

3. DOTmLPF-P Analysis

DOTmLPF-P analysis can be done to "identify non-materiel solutions as a result of a Capabilities-Based Assessment (CBA) or other study to satisfy a gap in capability requirements "for programs of record (Defense Acquisition University, n.d.-p. para. 6). This analysis refines the capability gaps from previous analysis and ties them to the eight major components show in Figure 6.

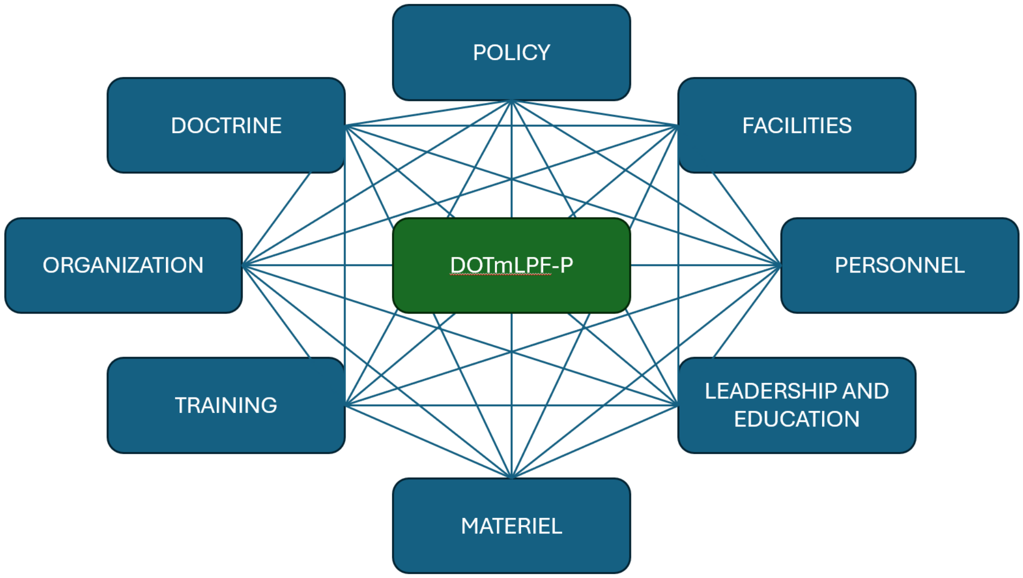

Figure 6. The eight components of DOTmLPF-P Analysis

The DAU acquipedia identifies and defines the eight parts of the DOTmLPF-P analysis as follows:

- Doctrine: the way we fight
- Organization: how we organize to fight
- Training: how we prepare to fight tactically
- Materiel: all the "stuff" necessary to equip our forces that DOES NOT require a new development effort
- Leadership and education: how we prepare our leaders to lead the fight
- Personnel: availability of qualified people for peacetime, wartime and various contingency operations
- Facilities: real property, installation, and industrial facilities
- Policy: DOD, interagency, or international policy that impacts the other seven non-materiel elements (Defense Acquisition University, n.d.-p, p. 1).

If there are non-materiel capability solutions that could meet the requirements or serve to complement the capability, a DOTmLPF-P change recommendation (DCR) can be initiated. The DCR would then advocate for increased quantities or alternate applications of existing materiel to include commercial off the shelf (COTS), government off the shelf (GOTS) or non-developmental items (NDIs) (Defense Acquisition University, n.d.-p).

4. Initial Capabilities Document (ICD)

The ICD identifies the requirements to prevent unacceptable operational risks if left unmanaged (Defense Acquisition University, n.d.-h, para. 1). The broad requirements will associate materiel or non-materiel solutions with the respective capability gaps identified in the CBA and DOTmLPF-P analysis. The ICD is then used as an entrance criterion to pass the materiel development decision (MDD).

5. Capabilities Based Assessment (CBA)

The CBA identifies capability requirements and associated capability gaps as outlined in the JCIDS manual (CJCS, 2021, p.C-B-B-3). The output of the CBAs are initial capabilities documents (ICDs) which define the capabilities that are unacceptable if not addressed (Defense Acquisition University, n.d.-e, para. 2). This assessment draws the connections between strategic guidance, operational missions, and capability solutions necessary to facilitate accurate requirements generations. Upon completion of the CBA analysis, if a capability gap is identified, a DOTmLPF-P analysis can be leveraged.

6. Analysis of Alternatives (AoA)

The analysis of alternatives (AoA) study enables the program to review potential materiel solutions against parameters effective to the program. Per the DODI 5000.85, the AoA will typically "focus on identification and analysis of alternatives, measures of effectiveness, key trades between cost and capability, life-cycle cost, schedule, concepts of operations, and overall risk (DODI 5000.84, Section 4). The AoA helps define the program within the trade space and ensure down-select to a more effective initial solution.

7. Capability Development Document (CDD)

The CDD, required by JCIDS, breaks down the requirements outlined in the ICD into the following: Key Performance Parameters (KPPs), Key System Attributes (KSAs), and Additional Performance Attributes (APAs) (Defense Acquisition University, n.d.-f, para. 2). KPPs are critical and essential attributes that are measurable and testable that reflect the measures of performance (MOPs) outlined by previous requirements, typically in the format of a threshold or objective (Defense Acquisition University, n.d.-f, para. 1). KSAs on the other hand are less critical requirements translated to attributes that are also measurable and testable (Defense Acquisition University, n.d.-f, para. 1). The KPPs, KSAs and APAs will be leveraged heavily during test and evaluation in the engineering and manufacturing development (EMD) phase.

8. Milestone A

DoDI 5000.85 states that Milestone A is the entry requirement to transition from the MSA phase into the technology maturation and risk reduction (TMRR) phase (DoDI 5000.85, 2021, p. 38). Milestone A approval ensures that acquisition strategy is sound and releases the final request for proposals to industry for the TMRR activities.

9. Program of Record

During a program's MSA phase, it is the responsibility of the Component Acquisition Executive (CAE) to select a program manager (PM) to lead the planning of the programs execution (Defense Acquisition University, n.d.-t, para. 2). With the appointment of a PM for major acquisition programs, it is the PMs job to form the program office that will be responsible for the acquisition. It is also the responsibility for the PM to tailor the acquisition strategy, meet with stakeholders and prepare program documentation. The PMs are typically assigned early on throughout the acquisition process as the most important requirements documents are formed during the first two major phases, MSA and TMRR. Normally, programs utilizing the major capability acquisition pathway will become a program of record at the completion of Milestone B, but for ships the program of record is established at Milestone A (DODI 5000.2G, Encl. 5, p. 3)

10. System Design Specification (SDS)

The system design specification, as outlined in the Navy's SDS Guidebook, performs three major functions:

- Derives the platform specific mission performance requirements and attributes from higher level capability documents.
- Identifies naval and industry design criteria and standards that are used during system development.
- Details the expected producibility, operability, maintainability, and supportability of the system. (Department of Navy, 2008, p. 2).

11. Request for Proposal (RFP)

The RFP is the document used to communicate requirements to prospective contractors in solicitation of proposals from industry (Defense Acquisition University, 2024-u, para. 1). FAR 15.204-1 requires RFPs to be prepared in the uniform contract format (UCF) unless exempted by the FAR (FAR 15.204-1, 2024). In high dollar value, or complex acquisitions, a source selection authority (SSA) will be designated to evaluate the RFPs and select a contractor to award the contract to in accordance with FAR Subpart 15.3 (FAR 15.3, 2024). For DOD acquisition greater than $100 million, the SSA will be someone other than the procuring contracting officer (Defense Acquisition University, n.d.-v, para. 4).

12. Integrated Baseline Review (IBR)

The IBR process reviews the risks inherent to the performance measurement baseline (PMB) and ensures the contractor addresses them satisfactorily (Defense Acquisition University, n.d.-i, para. 1). During the IBR, the work breakdown structure (WBS) and the integrated master schedule (IMS) of the system are developed, including the risks for the program. Earned value management systems (EVMS) is the tool for the IBR reviewing the performance measurement baseline (PMB) for cost and schedule impacts (Defense Acquisition University, n.d.-i, para. 1).

13. Milestone C, and Entry into Production and Deployment (P&D) Phase

Milestone C approval approves the program for entry into Production and Deployment (P&D) phase based on review of the developmental testing and evaluation, maturity of design, manufacturing risks, and funding levels (DODI 5000.85, 2021, Section 3.12). This enables the program to award production contracts in accordance with FAR subpart 16.001, types of contracts (FAR 16.001, 2024), and FAR subpart 34.005, major system acquisition general requirements (FAR 34.005, 2024.). The contract types outlined in FAR part 16 are split into two broad categories of fixed-price contracts and cost-reimbursement contracts. The various contract types balance responsibility for performance and the resulting profits and losses between the contractor and the government (FAR 16.101, 2024).

14. Low Rate Initial Production (LRIP) and Full Rate Production (FRP) Decision

Upon successful completion of initial operational testing and evaluation (OT&E) and receiving Milestone C approval, low rate initial production (LRIP) is initiated and the MDA will determine if the manufacturing process is adequate to successfully produce the system that meets the requirements in performance and reliability (Defense Acquisition University, n.d.-g, para. 3). Results of the MDA review of LRIP informs the FRP decision and considerations, described in detail in DODI 5000.85, section 3.14.

15. Sufficiency and Sustainment

The developmental test and evaluation sufficiency and sustainment requirements are required in accordance with Sections 2366b(c)(1) and 2366(a)(4) of Title 10, U.S.C. for MDAPs (DODI 5000.89, 2020, p. 12). These sufficiency tests evaluate the test plans for the program and ensure risks of meeting goals within the program are addressed.

B. VIRGINIA CLASS PROGRAM

1. The Environment

The Virginia class program was the first program to be independently developed by a non-government entity, Electric Boat through cost-plus fixed fee and cost-plus award fee contracts. The Virginia class program succeeded the cold-war era Seawolf class. The Seawolf program faced termination during the 1990s when cost and schedule slip for the lead ship resulted in a 125% increase in delivery cost over the initial contract cost estimates and an overall reduction in national security threats from the Soviet Union (D'Esopom & Fisher, 1994, p. 2). Rather than termination, the class was reduced from the planned 29 subs, to three. At the time of initial planning for the Virginia program, there were three other classes of nuclear-powered submarines: Ohio class, Los Angeles class, and Seawolf-class. The Ohio class of submarine fits into a different role, that of strategic deterrence through the ballistic missile submarines (SSBN) and the guided cruise missile submarines (SSGN). The Los Angeles class, developed in the 1970s and the Seawolf class, developed in late 1980s, were fast-attack, hunter-killer submarines (SSN) (O'Rourke, 2024b, p. 4).

A significant influence on the Virginia class during its development and initial planning was the Seawolf class. At the height of the Cold War, the Seawolf class was designed to provide unprecedented performance capabilities to deter the Soviet Union. This led to a significantly more expensive submarine compared to previous generations at an average cost of $3 billion (Office of the Inspector General, 1998, p. 1).

2. Block Designations

The Virginia Class submarines are broken into deliverable blocks. The first two blocks are designed to carry twelve Tomahawk all-up-round (AUR) cruise missiles, each in their own missile tube in the Vertical Launch System (VLS), see Figure 7. The follow-on blocks had a configuration change to carry twelve Tomahawks within two banks of large diameter tubes, each holding six Tomahawks in the Virginia Payload Tube (VPT) system, see Figure 8. The latest blocks, block five onward are scheduled to include an additional Virginia Payload Module (VPM) amidship, adding the capability of an additional 28 Tomahawks or other payloads depending on configuration of middleware, see Figure 9 (NAVSEA 00D, 2024, p. 1). Table 2 summarizes the capabilities for AUR per block.

Table 2. Vertical Tomahawk AUR capability per class

Class	Tomahawk Stowage	Quantity (maximum)
Virginia Block I/II	12 individual bow tubes, 1 AUR each	12
Virginia Block III/IV	2 bow tubes containing 6 AURs each	12
Virginia Block V AFS	2 bow tubes containing 6 AURs each and 4 amidship tubes containing 7 each	40

Figure 7. Vertical launch system submarine (Los-Angeles class). Source: Seaforces online (n.d., p. 1)

Figure 8. Virginia payload tube on Virginia class submarine. Source: General Atomics (2023, p. 1).

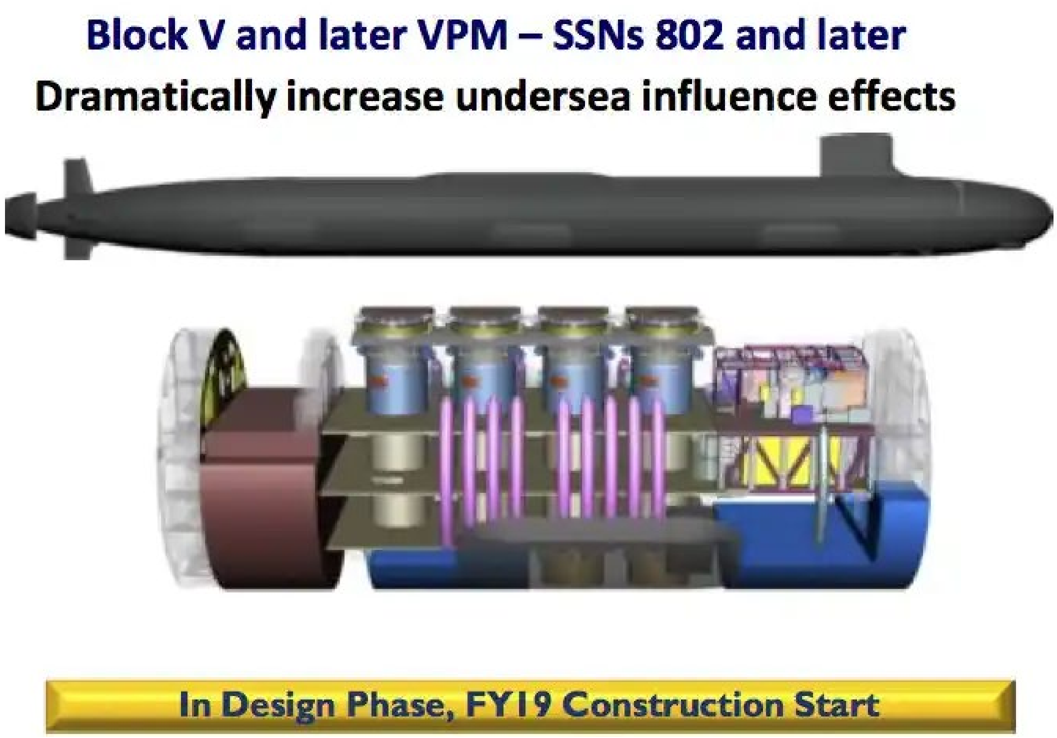

Figure 9. Virginia payload module section of Virginia class submarine. Source: Eckstein (2014, p. 1).

3. A Need for Cost Savings

The Defense Standardization Program Office outlined a key problem for the U.S. shipbuilders as costs began to rise at the end of the production of the Seawolf class, the predecessor to the Virginia class (Executive Agent for the Defense Standardization Program, 2024, p. 8). There was a push to reduce time and related costs throughout "all phases of ship design, construction, and life-cycle support" (Executive Agent for the Defense Standardization Program, 2024, p. 8). The key ideological change going into the Virginia Class program was an increased focus on standardization of parts and processes. The Seawolf class's design, a result of cold-war era development, nearly doubled the required combat systems parts. The defense standardization program's cost saving initiative focused on parts and process standardization, reduction in drawings through parts standardization boards, and updated database architecture (Defense Standardization Program, 2024, p. 4). The parts standardization process included the integration of commercial off-the-shelf (COTS) technology. Specifically, the defense standardization program's (DSP) implementation of COTS components in the command, control, communications, and intelligence electronics suites resulted in a 32% reduction in electronic test equipment required when compared to the Seawolf program (Executive Agent for the Defense Standardization Program, 2024, p. 5). The Seawolf class was designed by two yards in tandem and created duplicate drawings and part numbers for many commonly used parts. The Virginia class, being designed by a single yard, reduced the duplication of work for common part drawings and test plans for additional cost savings. The combination of implementing COTS components, parts and process standardization, and a push for equipment designed to last "the life of the ship" resulted in the Virginia program meeting its program goals for cost saving (Defense Standardization Program, 2024, p. 5).

4. Delivery of the Lead Ship

The benefits of the acquisition strategy at the delivery of the first boats seemed to pay off as the DSP reported the USS Virginia had 98.4% of her required spare parts at delivery, followed by the USS Texas and the USS Hawaii at 99.8% and 99.9%, respectively

(Executive Agent for the Defense Standardization Program, 2024). Spare parts for many components will become an issue as the Virginia class progresses. Amongst other initiatives, a push for digital manuals and maintenance documents, reduction in overall required test equipment, and reduction in the parts library, the Virginia Class program projected $789 million dollars of cost-avoidance (Executive Agent for the Defense Standardization Program, 2024, p. 10). Figure 10 shows the various cost avoidance of the classes because of parts and process standardization and reuse. One realized benefit of the parts standardization was an 80% reduction in total class parts compared to Seawolf, and the total issued drawings for the Virginia class was 60% of that for the Seawolf class.

The Navy's projected procurement for the Virginia class was initially one boat per year on average until fiscal years 11 onward where it ramped up to two projected procurements per year, seen in Figure 11 from the CRS report on the Virginia class submarine program.

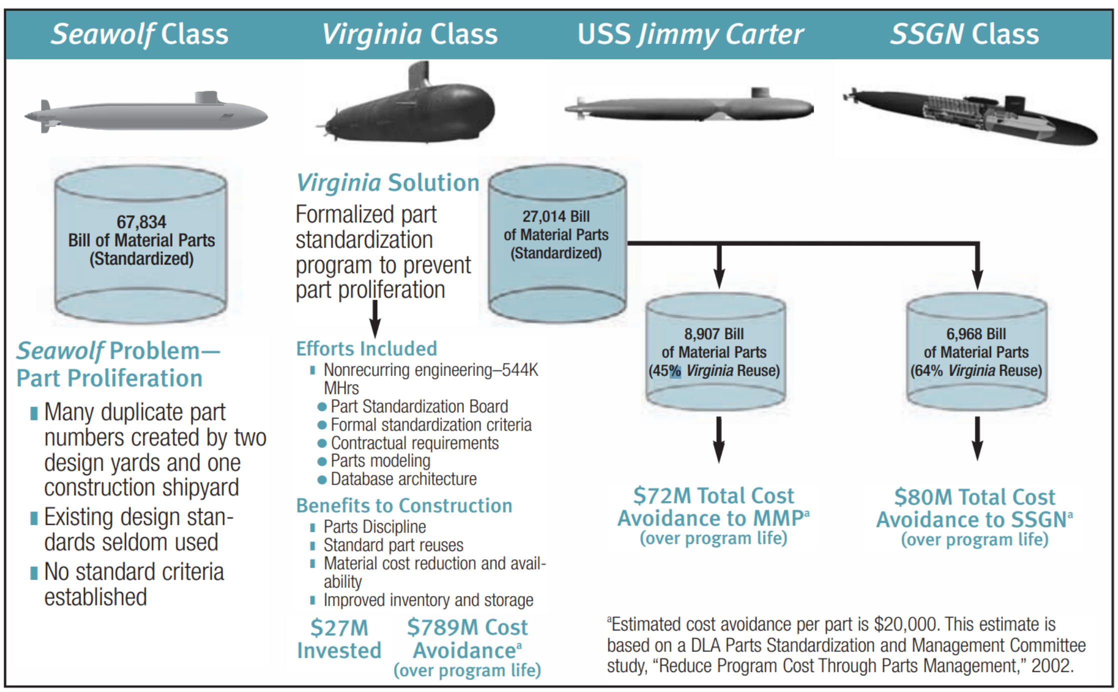

Figure 10. Four of the current submarine classes with total cost avoidance. Source: Executive Agent for the Defense Standardization Program (2024).

Projected quantities for FY2024-FY2028 as shown in Navy's FY2024 budget submission

FY98	1	FY06	1	FY14	2	FY22	2
FY99	1	FY07	1	FY15	2	FY23	2
FY00	0	FY08	1	FY16	2	FY24	2
FY01	1	FY09	1	FY17	2	FY25	2
FY02	1	FY10	1	FY18	2	FY26	2
FY03	1	FY11	2	FY19	2	FY27	2
FY04	1	FY12	2	FY20	2	FY28	2
FY05	1	FY13	2	FY21	2		

Source: Table prepared by CRS based on U.S. Navy data.

Figure 11. Actual and projected Virginia class procurement quantities. Source: CRS (2024, p. 9).

5. Multi-year Contracting

The shift in delivery schedule from one boat per year to two boats per year was enabled by the Navy's use of multi-year contracting. All but the lead ship for the Virginia class was procured on multi-year contracting options (O'Rourke, 2024b, p. 9). The intent of procuring the boats under this contracting option is to "maximize efficiency and supplier firm stability in those years" (O'Rourke, 2024b, p. 10). This allows the shipbuilders to bulk purchase materials for construction and reduce base costs.

6. Increases in Program Acquisition Unit Cost (PAUC)

The effectiveness of cost savings measures for the Virginia class program waned as the program matured as reported costs did not trend in accordance with cost savings estimations originally reported. The 2021 SAR for the Virginia class program reported "an increase in the program acquisition unit cost (PAUC) and average procurement unit cost (APUC) … which exceeds the original 1995 baseline estimate by at least 30 percent" (Department of the Navy, 2021, p. 4). A program with an increase of PAUC or APUC by 15% over the current approved acquisition program baseline (APB), or an increase of 30% over the initial APB must report a cost breach to the congressional defense committees per the Nunn-McCurdy Act (10 U.S.C. §2433). The Virginia class program triggered a Nunn-McCurdy breach in 2005 when the PAUC reached 32% over the 1995 baseline (Department of the Navy, 2021, p. 12). The result of the Nunn-McCurdy breach was a rebaselining of the program as more accurate costs were realized during design and lead ship construction. The resulting cost variance measured against the 2005 updated APB showed cost savings for delivery of future ships in the class, seen in Table 3.

Table 3. Virginia class cost growth by variance. Adapted from Knox et al. (2014, p. 46).

Category	1995 Baseline	2005 Baseline
PAUC	+32.66%	-5.93%
APUC	+29.91%	-6.92%

In 2017, the APB was updated to include additional capability to keep up with adversaries, and the program reported the cost savings initiatives implemented reduced the cost increases to 1.1% for PAUC and 0.8% for APUC respectively (Department of Defense, 2021, p. 4). In 2021, congress was notified of a re-breach of the original APB established in 1995 as the program reported an increase of 30.6% PAUC and 30.5% APUC. The actions taken to control the future growth across the program's acquisition include:

- Modular design and construction of blocks I and II. Designed by Electric Boat, built by Electric Boat and Newport News Shipbuilding.
- VLS redesign to VPT system and transition from air-backed sphere to LAB Array through the Design for Affordability (DFA)
- Leveraging of multi-year procurement, block buys to gain benefit from economic order quantity. (Department of Defense, 2021, p. 10).

7. Design for Affordability (DFA)

In addition to the cost savings initiatives implemented after the Nunn-McCurdy breach, Electric Boat during the design of block III Virginia class submarines implemented the DFA plan, based a cost saving framework by a company called "Strategty&." The inherent, structural, systemic, realized (ISSR) cost reduction framework from Strategy& weighs cost drivers against the potential cost reductions and the degree of difficulty to implement. The ISSR framework also breaks down costs into the cost drivers of inherent, structural, systemic, and realized as opposed to traditional cost estimation of individual cost categories, seen in Figure 12. The ISSR framework's estimated cost reductions to the program were $3.8 billion (Dehoff & Kronenberg, 2008, p. 15). The DFA program focused on the redesign of the bow of the submarine with the transition to a large aperture bow array for sonar and the transition to the VPT system.

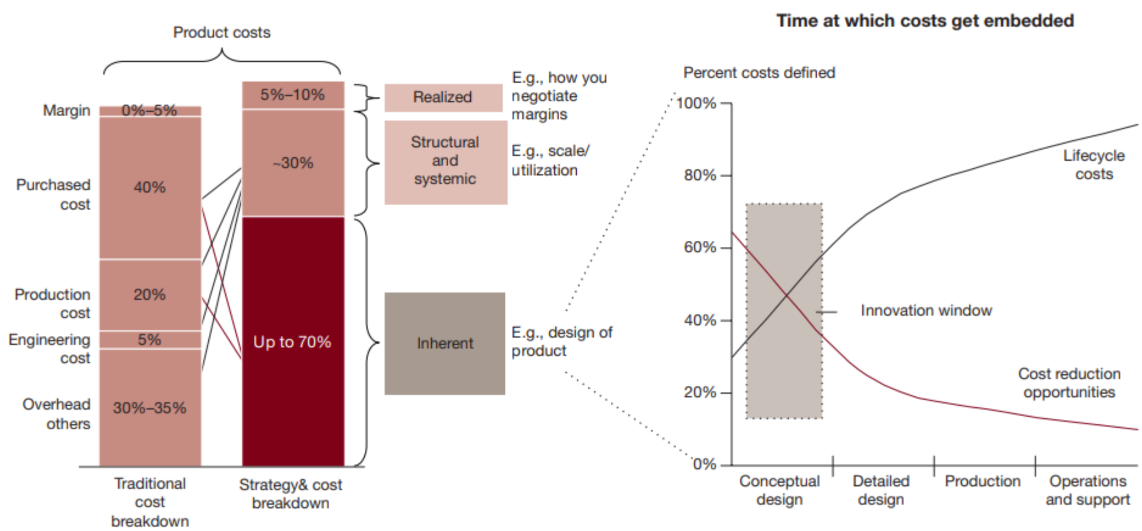

Figure 12. Inherent and structural cost drivers' potential for cost savings. Source: Dehoff and Kronenberg (2008, p. 9).

C. IN-SERVICE AND SYSTEMIC ISSUES

1. Configuration Management Issues

One of the largest takeaways from the planning of the Virginia class is that the original intent was for there to be a consistently designed fast-attack submarine that, through rigid design and engineering rigor, reduced complexity and configurations of parts while maintaining increased reliability and performance. The result (from a launcher's perspective, not including changes in other combat and non-combat systems) was three configurations: VLS, VPT, and VPM. While it is understandable that the original procurement documentation drafted in the late 1990s could not possibly have predicted the exact needs of today's missions and capability, it is imperative to consider how the complete redesign created three independent systems that required full life cycle sustainment over the course of the program.

2. Longer Lead Times for Repairs

The in-service life-cycle maintenance periods of submarines have increased as delivery of ships continues to be a struggle for the public and private shipyards. The industrial base is struggling to produce the quantity of material needed for in-service sustainment of the systems while meeting requirements for new construction as well. A contributor to the industrial base's struggles is the lack of personnel and talent resulting in less efficient production or a reduction in capability. The delays in material often translate to delays in the on-time delivery of submarines from shipyard availabilities, which reduces the number of operationally ready submarines. The number of operationally ready submarines hovered around 40±3 from FY08 through FY16, shown in Figure 13 and began to decline down to 31 operationally ready submarines reported in FY23 by O'Rourke. Much of the reduction in operational availability for these submarines can be contributed to infrastructure constraints, numbers of workers, and supply chain issues (O'Rourke, 2024b, p. 6). The shipyards and the suppliers within the industrial base are strained, leading to longer depot maintenance periods.

Average number or percentage of SSNs for each fiscal year

Fiscal year	Number in force	Number in depot maintenance	Number awaiting depot maintenance (aka idle)	Combined number in depot maintenance or idle	% of force in depot maintenance or idle	Number operationally ready
FY08	51	11	0	11	22%	40
FY09	52	10	1	11	21%	41
FY10	52	10	0	10	19%	42
FY11	52	11	0	11	21%	41
FY12	53	10	1	11	21%	42
FY13	53	12	0	12	23%	41
FY14	53	13	2	15	28%	38
FY15	53	9	1	10	19%	43
FY16	52	12	1	13	25%	39
FY17	50	12	2	14	28%	36
FY18	50	14	2	16	32%	34
FY19	50	13	3	16	32%	34
FY20	50	10	5	15	30%	35
FY21	49	14	4	18	37%	31
FY22	49	11	5	16	33%	33
FY23*	49	14	4	18	37%	31

Figure 13. Number of SSNs in maintenance or awaiting maintenance. Source: O'Rourke (2024b, p. 5).

3. Tradeoffs Between Cost, Performance, and Schedule

With the delivery of the first block III Virginia class submarine, Oldham reports the USS North Dakota (SSN 784) was commissioned on October 25th, five months later than its originally planned May commissioning date (Oldham, 2014, para. 1). The original planned construction schedule for the Virginia class consisted of an 84 month planned build per hull. That timeline was reduced to 60 months during the DFA implementation to assist in meeting the required two boats per year delivery schedule (Dehoff & Kronenberg, 2008, p. 6). A delay of five months translates to a 9% schedule slip for the USS North Dakota. The delays were attributed to components from third party vendors not meeting specifications during post-shakedown availability testing. The delivery ended up being two days prior to the contractual requirement (Oldham, 2014, para. 2). While the Virginia program manager at the time was impressed with meeting contractual delivery dates, it came with cost overruns. With the extensive redesign of the bow, which included a redesign of the sonar sphere and the VPT system integration, there were issues that required an unplanned dry-docking to correct (Oldham, 2014, para. 1). It is not uncommon for the first boats of new blocks to have problems; however, unplanned maintenance periods contribute to an overall reduction in operational availability and can impact the rest of the fleet. Fleet schedulers work to report delivery timelines and the Navy plans the usage of submarines based on agreed contractual dates.

4. Building Two Boats a Year

Longer delivery timelines and struggles to meet the two boats per year requirement continue through FY24 as the U.S. Naval Institute reports that "it will take five years for the two shipbuilders … to deliver two submarines a year" (Lagrone, 2023, para. 1). Navy officials stated in an interview with USNI that it was on pace, in 2023, to deliver 1.2 submarines a year. Lagrone discusses how the Navy attributes these schedule issues to supplier base and shortages in the workforce (Lagrone, 2023, para. 13). The Navy struggles to hold the shipbuilders accountable for the on-time delivery of subs. The contract avenue used for the upcoming block V Virginia class submarines is a fixed-price incentive fee contract for the FYs 2019 through 2023. Attempting to meet a schedule without mitigating the risks within the industrial base, not limited to the supplier base and the industrial base workforce, will result in a failure of the program to balance cost, schedule, and performance effectively.

D. THE SSN(X) PROGRAM BACKGROUND

The congressional research service (CRS) outlines the Navy's plan to procure the Next-Generation Attack Submarine, abbreviated as SSN(X). Fiscal Year (FY) 2024 budget requests indicated $554.7 million in research and development funding (O'Rourke, 2024a, p. 6). CRS states that the SSN(X) class is to be the replacement for the Virginia class, and the Navy will budget for procurement funding of the SSN(X) in the mid-2030s.

The Navy's need to procure the SSN(X) class is based on the growing threats of near peer adversaries within the undersea domain (O'Rourke, 2024a, p. 6). The designs will improve overall speed, horizontal payload capacity, acoustic superiority and non-acoustic signatures, and operational availability (O'Rourke, 2024a, p. 6). Including the listed improvements, the Navy plans for the SSN(X) class to leverage previous classes improvements in processes and requirements generation seen in the Virginia and Columbia programs. The program manager for the SSN(X) is leveraging the engineers of Naval Undersea Warfare Center (NUWC) division Newport to assist in development of the requirements for the SSN(X) class

E. WARFARE CENTERS AND THEIR ROLES

The role of the Naval Warfare centers is to:

- Make naval technical programs successful
- Provide a bridge between the technical community and the warfighter
- Determine and develop capabilities for the fleet
- Verify the quality, safety, and effectiveness of platforms and systems
- Design, develop, and field solutions for urgent operational fleet needs (NAVSEA, 2024, p. 1).

Naval Undersea Warfare Center (NUWC) Division Newport houses the submarine payloads and integration ISEAs as well as the combat control systems ISEAs. Many of the technical subject matter experts on the ISEA teams work under both the Virginia class program as well as with the SSN(X) program. Collaboration, communication, and shared knowledge are the pillars of success in acquisition. NUWC Division Newport is managed directly under NAVSEA 07, Undersea Warfare Division shown in Figure 14. The various warfare centers command leadership report directly to NAVSEA 07 leadership.

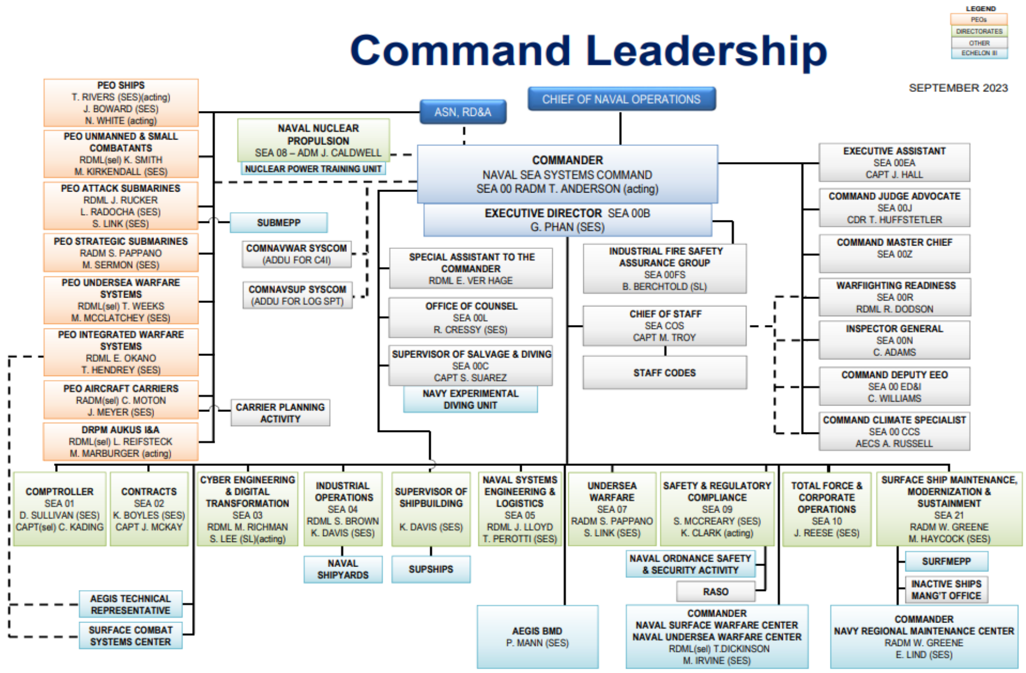

Figure 14. NAVSEA Organization Structure. Source: NAVSEA (2024, p. 1).

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III. DOTMLPF-P ANALYSIS

Chapter III will perform a DOTmLPF-P analysis to establish capability gaps today and will be used to refine program requirements and acquisition strategy for the SSN(X) program. While JCIDS outlines non-materiel solutions to a capability gap, the insights from performing the analysis can be used to inform the program decisions for the SSN(X) program.

A. DOCTRINE

Submarines fit into several unique roles in overall warfighting tactics, and the SSN(X) class fits to replace one of those existing roles: the hunter-killer submarines that are meant to search and destroy. The SSN(X)'s primary role as a replacement to the existing fast-attack submarine classes results in little to no change in doctrine for the Navy's use of the SSN(X) program. Changing the Navy's warfighting doctrine alone will not be sufficient to fill the anticipated capability gap. More effective solutions can be found in other aspects of the analysis.

B. ORGANIZATION

Supporting the life cycle of in-service submarines is a struggle for today's Navy as the ISEAs are delivered designs, often with little insight into the iterative process of getting to the mature technology. This is partly caused by the organization of technical authority and the handoffs between design agents, technical warrants, and the logistics agencies. Through involvement of the engineering support teams, the technical warrants define the requirements to meet capability needs, and those are translated into the respective system design specifications. The government then leans on the contractors to figure out how to meet those requirements. Electric Boat sits as the prime design agent and is the prime contractor for construction of the Virginia class as well as the Ohio class replacement program, the Columbia class. This is significant as the government intends on leveraging much of the design and improvements from the development of the Columbia into the plans for the SSN(X) keeping Electric Boat as the primary design agent.

While Electric Boat works well with the new construction programs of the Navy (PMS450, Virginia class program, for example), there could be more involvement from the in-service programs and their funded entities such as technical warrants or ISEAs through involvement in integrated logistic teams. While design is not finalized during these early stages of development, insight into current day procurement issues could drive decisions and design to be more reliable. Program managers can introduce the integrated logistic support teams in the early stages of program development to solicit in-service issues and common supply problems from the ISEAs and supply engineers. Intentionally opening channels between these programs can facilitate a healthier design process during TMRR phase.

C. TRAINING

There has been a shift in the role of the warfighter from system technician to system operator. The technical level of the Navy's schooling has reduced the troubleshooting and technical skill building of the warfighters and pushed them to strictly operate the systems. This divergence from giving the warfighter the tools and knowledge they need for basic system troubleshooting will increase the risk of failures during the service life of the ship. This is evident in year-on-year increases to budget for regional maintenance centers (RMCs) and intermediate maintenance facilities (IMFs) (Under Secretary of the Navy, 2024, para. 36). The joint fleet maintenance manual (JFFM) denotes responsibility for initial troubleshooting of submarines systems to the RMCs and IMFs (COMUSFLTFORCOMINST 4790.3). The ever-increasing complexity of the combat systems suite only necessitates the further need to train our warfighters to alleviate strain on the RMCs and IMFs. It is a tremendous hurdle to reorient the training programs within the Navy; Alternative paths of creating more robust and reliable designs to reduce the requirement for the warfighters to troubleshoot could be a more effective solution to reduce the capability gap.

D. MATERIEL

When discussing DOTmLPF-P analysis, the "m" is often lower case as to alleviate capability gaps through non-developmental materiel changes; the solution to the capability gap is advocating for increased quantities or alternate material through COTS, GOTS, or NDI systems. Rather than develop the technology, the deferral of ship design to the prime and subprime contractors combined with the failure to procure intellectual property rights to the design of many combat systems components led to obsolescence issues in-service when manufacturers stopped producing legacy products (Lopez, 2022, para. 13).

Fortunately, with the procurement of future classes through iterative design like the increases in capability for block III Virginia class, the Navy can take advantage of these materiel deficiency issues and obsolescence cases to drive future need. The future programs combat systems suite can leverage modular open systems approach (MOSA) reduce the risk of sole sourced proprietary technology at the system design level (Defense Acquisition University, n.d.-n, para. 3). MOSA severs major system components from each other to allow for incremental addition, removal, or replacement during the life cycle of a platform. Effectively designing systems with the MOSA requires isolating functionality to components, identifying the key interfaces between equipment to develop modules with few interdependencies to other modules, and utilizing open standards that are widely available or used throughout industry (National Defense Authorization Act, 2024, sec. 804). The Office of the Secretary of Defense (OSD) established requirements for standards on MOSA systems in the National Defense Authorization Act (National Defense Authorization Act, 2024, sec. 804).

When it comes to fixing the materiel or procuring new materiel for the life of the ship, the Virginia class faces a serious problem with sole-sourced equipment. Buying the intellectual property rights through requirements in contracts for some critical systems that tie directly to mission capability can allow for the Navy to procure independently from the sole-source and boost competition within the industrial base. This is directly contrasting to the standards within DOD acquisition for intellectual property; The DOD should only own the intellectual property of systems designed by the DOD.

E. LEADERSHIP AND EDUCATION

Leadership styles vary greatly throughout the Navy. Some agencies and divisions facilitate open communication channels going up and down. Others lean toward a top-down communication standard with direction being given strictly from above. The tolerance for failure within the leadership structure varies, but as McGrath establishes, communicating effectively and learning from failure is paramount to developing a strong workforce (McGrath, 2011, p. 1). There is value in the experience of tenured acquisition professionals and value in younger critical thinkers. Ensuring there are channels established within the program executive office for both directions of communication and ideas will promote a healthier social structure and increase retention in the program (McGrath, 2011, p3).

F. PERSONNEL

It is important to focus on ensuring that the right people are supporting the program managers for SSN(X). The increase in complexity of submarine systems, the quantity of submarines, and a declining civilian workforce creates valuable assets in the ISEAs. The ISEAs and the technical warrants are tuned into the in-service issues and should be leveraged during design and technical maturation stages of the program in a consultation role. Pulling ISEAs off existing programs costs money however, and budgeting for increased manpower requirements for the TMRR phases can ensure system engineering teams are manned properly. The community of interest on design should consist of innovative young engineers, journey-level in-service engineers and tenured procurement specialists. A diverse team of engineers will provide feedback to the program requirements and accurately evaluate technology readiness levels of systems (Office of the Executive Director for Systems Engineering and Architecture, 2023, p. 17).

G. FACILITIES

The Virginia class program was well supported with training facilities and virtual mock-ups of the boat. The various combat systems have multiple simulation trainers throughout the DOD enterprise that serve to train the warfighters on all aspects of their system. One critical facility type that supports the in-service sustainment and reduces impacts to the shipyards is designated overhaul points (DOPs). DOPs can be contracted through the original vendor, a support contractor, or a government entity. Setting up government DOPs for repairable equipment can reduce the manhour requirements on depot availabilities and provide more ready material to supply in areas where the industrial base is struggling. Recommendations for the SSN(X) program should include physical and virtual simulation where possible for hands on and remote training capability and look to establish DOPs for common failure items from the test and evaluation processes.

H. POLICY

Policy is a major driving force in large program acquisition, and it provides seemingly limitless possibilities for program managers to pull from and leverage for the programs' specific intricacies. Finding the right policy and regulation to leverage can be difficult, but hopefully the following policies can help bridge some of the logistical gaps identified by the Virginia class.

1. Federal Acquisition Regulations (FAR), Part 12

FAR Part 12 outlines the requirements and applicability to procurement of commercial products, including commercial components, and commercial services (FAR Part 12). The FAR subpart 12.2 expands upon the special requirements required for commercial parts acquisition. Identifying market research and descriptions of needs is an essential element of the acquisition of commercial products (FAR Subpart 12.202). It is within the purview of the program manager and technical design agencies of the SSN(X) to properly evaluate the markets for components prior to commercially procuring the parts. Leveraging commercial markets for more common parts can be an effective tool to mitigate the need for intellectual property rights.

Using power supplies as an example, some combat systems require 28V power supplies that fit within a certain profile and meet shock, safety, and several other military standards. The power supply selected by the planning yard could meet all specifications listed and be approved to be used within the system, but it was produced by a single vendor, with the government owning little to no technical data rights to the design. Over the course of the past four years, those power supplies have doubled in price and the Navy has no avenue, except for extensive redesign, for procuring new components to fill that need. If the program had pushed to procure the data rights for this critical component, contracts could be sent out and new commercial vendors could potentially have been found. Failing to procure data rights to critical components introduces risk in an inability to sustain in-service assets as pricing and control over system design is in the hands of the design contractor.

While FAR Subpart 12.211 outlines that the government shall acquire only the technical data and the rights in that data customarily provided to the public with a commercial product or process, the value added in procuring technical data rights for combat systems outweigh the increased initial procurement costs (FAR Subpart 12.211). The costs of initial procurement will be offset by a healthier competitive industrial base for the manufacturing of a product.

2. DOD Directive 5000.01

The focus of DOD Directive 5000.01 is to push the DOD to acquire products that "satisfy user needs with measurable and timely improvements to mission capability, materiel readiness, and operational support, at a fair and reasonable price" (DoDD 5001.01, 2022, p. 4). DOD 5001.01 frames this acquisition process around 26 objectives; the most relevant will be discussed here.

Section 1.2.e. emphasizes the importance of promoting a competitive environment for acquisition. That is tied directly to considerations of alternative systems, data rights, and modular designs (DoDD 5001.01, 2022, sect. 1.2.e). Echoing the discussion during commercial item designation, the DoDD 5001.01 doubles down on the importance of data rights. The leverage the government gains by owning the design and parameters of components or systems allows them to go to the larger industrial base rather than a sole source. Promotion of competition lowers prices and increases availability, even for long lead-time components.

Section 1.2.m. highlights the importance of life cycle management and integrating that into the program life cycle. The Navy employs a Reliability Centered Maintenance (RCM) program for development of life cycle maintenance on submarines. The RCM process breaks down a system to its functions, and then extrapolates that to failures and then evaluates what maintenance can be accomplished to reduce the mean time between failure (MTBF) and keep system uptime high. Many components are sold with the disclaimer that they are "life of ship" components. The number of components that truly last an entire life cycle of a submarine, which can be anywhere from 30 to 45 years, is low. Program managers should evaluate all components in the RCM program and plan for life cycle maintenance costs.

Lastly, Section 1.2.z. states that the program manager will verify that their items are producible by conducting assessments to ensure there is sufficient industrial base capability and capacity (DoDD 5001.01, 2022, sect. 1.2.z). There has been significant consolidation of companies under larger umbrella corporations over the past few decades. In a DOD Report, Todd Lopez states "that since the 1990s, the defense sector has consolidated substantially, transitioning from 51 to 5 aerospace and defense prime contractors" (Lopez, 2022, p. 5). While the capability of these prime contractors has increased, it also fosters an anti-competitive environment. Competition drives technological improvements at decreased costs. The DOD is at a greater risk of being unable to surge production should we leave this peace time.

3. SECNAVINT 5000.2G

The Navy's transition into the AAF through SECNAVINT 5000.2G broke out many of the enclosures into new instructions. The most significant sections of SECNAVINT 5000.2G for the Virginia program outline requirements for systems engineering (DoDI 5000.88, Engineering of Defense Systems), life-cycle sustainment (DoDI 5000.91, Product Support Management for the Adaptive Acquisition Framework) and analysis of alternatives (DoDI 5105.84, Director of Cost Assessment and Program Evaluation and the Analysis of Cost Estimating Handbook). There is extensive documentation and policy outlining each step of a major acquisition program.

a. Analysis of Alternatives (AoA)

Prior to MSA, the program must develop the AoA, and, according to the DAU, compare the "operational effectiveness, suitability, and life-cycle cost of alternatives that satisfy established capability needs" (Defense Acquisition University, n.d.-d, para. 1). As system requirements and initial capabilities are drawn, it is imperative the PM understand the significance of how the AoA guides the MSA phase to completion. The AAF also initiates updates to the AoA during the TMRR phase and is re-reviewed at Milestone B.

Iterating and revising program documentation requirements throughout development can help mitigate risk and ensure more effective and cheaper solutions in the long term. In addition, the defense acquisition guidebook chapter 4–3.1.2, Analysis of Alternatives, outlines that the life cycle logisticians should participate in the AoA to provide subject matter expertise to identify impacts to the cost, maintainability, and reliability (Defense Acquisition University, n.d.-d, p. 1).

4. Economic Price Adjustment Clauses

A 2022 Acquisition Alert from the GSA identifies the impacts of and the need for Economic Price Adjustment (EPA) clauses in contracts (Koses, 2022, para. 7). To combat inflation, these EPA clauses allow for adjustment of contracts in times of inflation or strong economic uncertainty. Covid-19, record winter storms hitting Texas, and other natural disasters have caused numerous supply shortages and general inflation in materiel pricing. These EPA clauses can be leveraged to re-evaluate at designated time periods and provide more accurate representations of costs for materiel and labor.

I. ALTERNATIVE PATHS

Through the DOTmLPF-P analysis, it was found that a capability gap can be lessened through proper utilization of the flexibility allowed within the DOD 5000 processes. The major gaps identified are in Table 4.

Table 4. Capability gaps and areas of opportunity from DOTmLPF-P analysis

DOTmLPF-P Findings	
Section	Findings
Doctrine	Major changes not required or effective to warfighting doctrine for addressing capability gap.
Organization	Integration of logistic and in-service engineering teams into technology maturation discussion could drive more reliable and maintainable design.
Training	The effort to transition from "operator" warfighters to "technicians" is a costly and unlikely solution to capability gap.
Materiel	Designing in modern system design approaches like MOSA could promote a more competitive industrial base and combat obsolescence in-service.
Leadership and Education	Ensure communication channels are open for top-down and bottom-up communication. Top-down communication of requirements will stifle innovation.
Personnel	Ensure diverse teams of journey level to new engineers are involved in the acquisition process to promote diverse ideas and creative solutions.
Facilities	Establishment of virtual and physical simulation can help troubleshoot in-service issues and train maintenance personnel. Additionally, setting up government DOPs where possible can reduce life cycle maintenance costs.
Policy	Tailoring the DOD 5000 series instructions for major capability acquisition is required to alleviate a capability gap in future attack class submarines. Many supplementary clauses have been added in FAR and 5000 series instructions to accommodate for unique issues like Covid-19 pandemic.

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IV. REVIEW AND RECOMMENDATIONS

A. STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS (SWOT) ASSESSMENT OF THE VIRGINIA CLASS

When analyzing a program as large as the Virginia class program, it is important to utilize existing framework like the strengths, weakness, opportunities, and threats (SWOT) analysis to match the programs goals to the environment it operates within. Gomer and Hille (2015) emphasize that, "SWOT analysis is about making better decisions, both large and small" (p. 1). SWOT can be used in conjunction with the DOTmLPF-P analysis to highlight the major opportunity areas and align them with the DOD acquisition processes.

1. Strengths

- Parts and process consolidation provided cost savings across the class and increased spare parts availability on initial delivery of ships.
- Leveraged multi-year procurement to reduce costs by bulk purchasing of materiel for new construction.
- Utilized computer aided design (CAD) software to leverage technology and increase speed of iterative design during the TMRR phase.

Without the attempted parts and process consolidation and a push for cost saving in the Virginia class, it is likely that the disparity in delivery cost of the class would have been greater than it was. The Navy was ultimately successful in providing those avenues for cost saving with multiyear procurement contracts. The transition from hand-drawn system drawings to CAD software was an effective use of emerging technology for the Virginia class program. A 2021 GAO report identified that delays in shipbuilding for the Columbia class are a direct result of struggles with a new CAD program aimed at reducing average hours needed to complete design disclosures. The program was supposed to reduce average hours by half, but it failed to do so (Oakley, 2021, p. 13). The original timelines were developed with the reduction of manpower for this design process in mind and, as a result, there were delays in the construction. Evaluation of new technology and an implementation plan for utilizing new software is critical to producing accurate labor quotes.

2. Weaknesses

- Some components/systems were obsolete by delivery due to time between design and delivery.
- Schedule of delivery of boats slipping and are not meeting initial program estimates for cost and schedule.
- The Navy has not utilized quality control and inspection tools effectively during construction.

Due to the period between design and delivery of the boats, it is crucial to incorporate technical maturation periods during the stages of construction where possible. Accepting a design years before the planned delivery of the first ship could lead to out of date components, which would necessitate modernization efforts early in the ship's life cycle. Program managers must address schedule concerns early and often during the planning phases and ensure that all reports on completion percentages are accurate.

3. Opportunities

- Iterative design and acquisition pathways allow for growth of TRLs at lower risk pace.
- Artificial intelligence and large language model generative pre-trained transformers (GPT) can be leveraged to reduce manpower requirements in some applications like man hour requirements and cost estimations or even provide technical support functions.
- Concurrent shipbuilding and design of other submarine platforms provide opportunities to reuse designs across some common equipment.
- The adaptive acquisition framework is more flexible and contains faster pathways than the previous Defense Acquisition Guidebook.

With the evolution of the acquisition system from a rigid process to the adaptive acquisition framework, the SSN(X) program can tailor the major capability pathway to meet the unique requirements and struggles of building submarines that aren't faced in other major programs. Computers get more powerful daily, and there are opportunities in the acquisition workforce to leverage GPTs to help simulate and optimize acquisition strategy to reduce risks. GPTs work well to learn from large data sets and utilizing previous class data like materiel condition forms or man-hours required for various design, overhaul, and repair work, GPTs can estimate and potentially provide more accurate review of planned schedules. Another use of GPTs could be to provide technical documentation and manuals for systems to provide a basic ground level troubleshooter for systems utilizing government provided data.

4. Threats

- U.S. shipbuilders are falling behind schedule, and boats are struggling to leave the major drydocked availabilities on time, reducing operational availability.
- The U.S. faces more countries deemed near-peer threats within the undersea warfare space.
- Cost per hull has begun climbing as initial cost-saving initiatives have waned in effectiveness as actual costs continue to outrun estimations.

The United Nations trade and development database reported that China built 44.2% of the worlds ships in 2022 compared to the United States' 0.13%. One of China's efforts to increase its shipbuilding capacity that the U.S. does not do, is by providing governmental supplements and spending billions in developing its shipbuilders through nonmarket practices (Funaiole, 2024, p. 1). China blurs the lines between military shipbuilding and commercial shipbuilding weaving the capability and lessons learned from both together to undercut the market. While this data, shown in Figure 15, includes surface and submarine, commercial and military, it is anecdotal to the capacity of the workforce in the U.S. naval industrial base. There needs to be a focus on strengthening the industrial base for support of future submarine programs.

YEAR	2017	2018	2019	2020	2021	2022
ECONOMY						
China	36.04	40.07	35.01	40.26	44.20	46.59
United States of America	0.34	0.35	0.20	0.12	0.05	0.13

Figure 15. Percentage of total shipbuilding in world from 2017 to 2022. Adapted from UNCTAD (2024).

B. FLEXIBILITY IN THE 5000 INSTRUCTION PROCESS

RAND identifies that the communal perception of the 5000 series processes are intended to be flexible and moldable for major programs, but there is little guidance for outliers (Drezner et al., 2011, p. 28). The reasoning provided by RAND from the program management communities in interviews was that ships are not built in the same processes as other major programs. Concurrent design, building, and testing phases, alongside a passionate political and industrial base, make the intricacies of the milestones and processes muddy. The complexity of a submarine drives a need for further clarification and planning outside of the general 5000 series instructions. Figure 16 highlights a comparison of the Ohio class, F-16 and M-1. The major takeaways are the number of subsystems and the components within the program.

	Ohio Class SSBN	F-16	M-1
Weight (tons)	18,750	10	65
Length (ft)	560	49	26
No. of subsystems	265	32	26
No. of components	25,000	28	212
Patrol/sortie duration	3 months	1.4 hrs	1 day
Operational life	30 yrs (now 44)	8,000 hrs	20–30 yrs
Crew size	150	1	4
Unit production time (months)	72	32	7.5
No. of part numbers	350,000	175,000	14,065
No. of suppliers	4,500	850	600
No. of man-hours/unit	12 million	57.5 thousand	5.5 thousand
Annual production rate	1	200+	600

Figure 16. Comparison of technical characteristics for three programs.
Source: Drezner et al. (2011, p. 42).

To assist in the rethinking of how to implement the 5000 series processes to shipbuilding, RAND breaks down the applicability of major activities to program milestones in Figure 17. With activities like the evaluation of design maturity having applicability to all milestones, placing a single decision point at a certain milestone would provide inadequate analysis of the program. This drives RAND to recommend a design and build process that overlaps the major acquisition steps to provide more flexibility for the program managers and the Navy. By layering the tech development, design, and construction, seen in Figure 18, the Navy can balance the risks associated with technology readiness as well as the design and construction timelines. This adapted process is about balancing risk. However, there is no guarantee that the technology will meet deadlines for construction or that it will not require further iteration during the processes for LRIP and FRP. RAND believes that timing on Milestones B and C should be more flexible given the constraints that "Milestone B denotes the start of detail design and authorizes lead ship construction, and an IPR authorizes initial follow ships" (Drezner et al., 2011, p. 60).

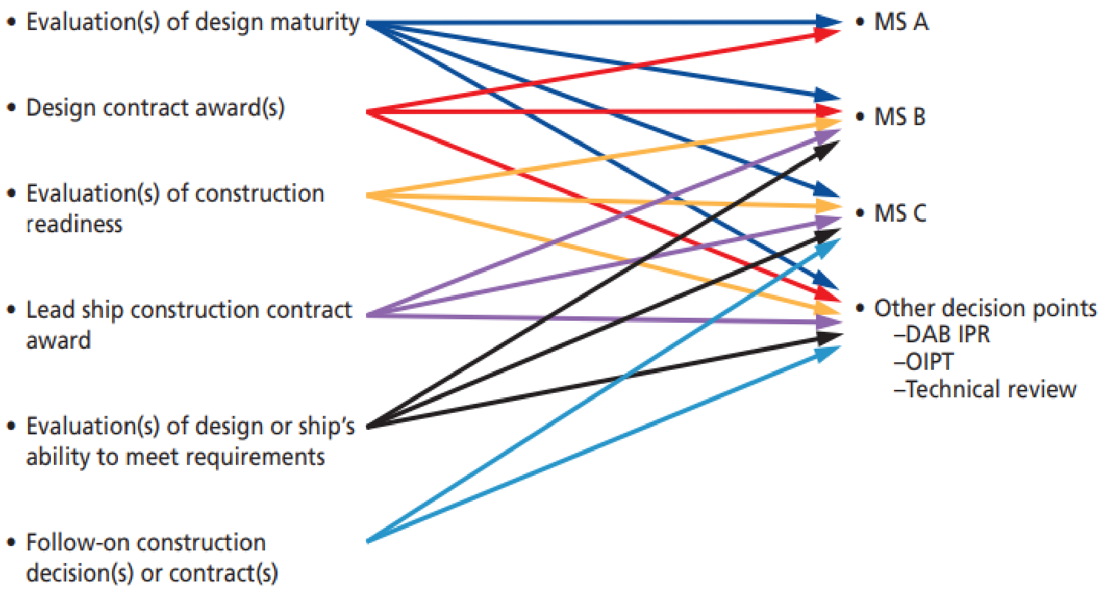

Figure 17. Potential linking of activities to milestones. Source: Drezner et al. (2011, p. 54).

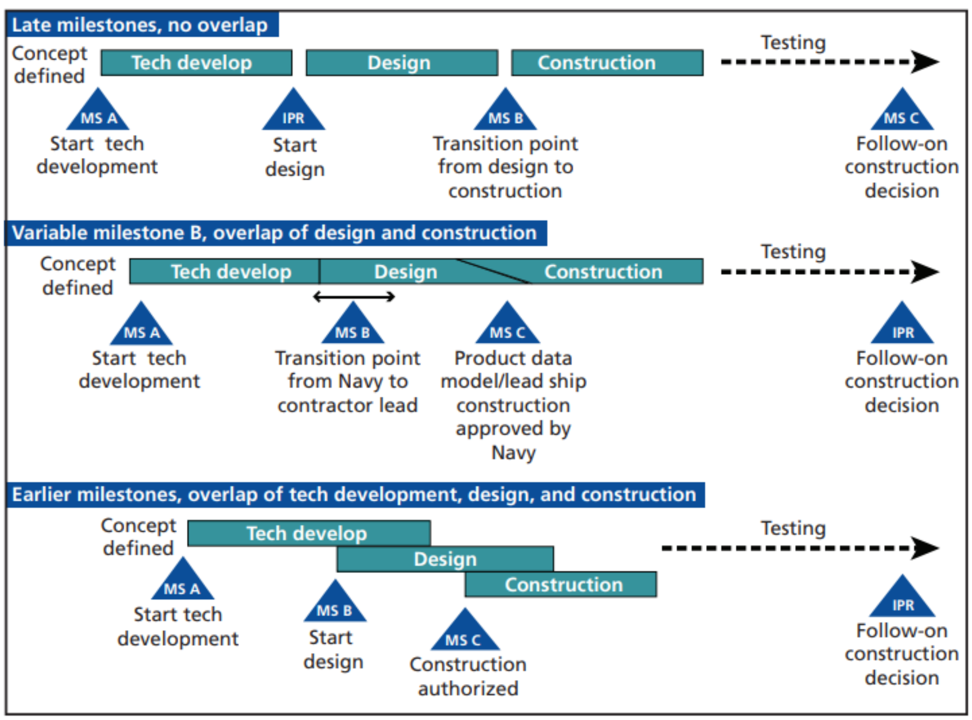

Figure 18. Three ship design/build and Office of the Secretary of Defense (OSD) oversight process alternatives (unconstrained). Source: Drezner et al. (2011, p. 57).

DODI 5000.02 allows program managers to tailor the acquisition process, and RAND's recommendation is to add clarifying verbiage specifying when LRIP and FRP are approved to begin with respect to Milestone C (Drezner et al., 2011, p. 60). Approving LRIP prior to Milestone C with an IBR approval could allow for faster delivery and a more integrated testing process. Future program managers for the SSN(X) program should leverage the ability to adapt the acquisition process to an overlapping strategy and seek clarification for ambiguous verbiage in the major acquisition capability base requirements instructions.

C. ESTABLISHING QUALITY AT EVERY LEVEL

A goal for the SSN(X) program should be to include quality control and quality assurance programs at every level of the design and manufacturing process. In a 2021 GAO report, seen in Figure 19, the responsibility of quality is outlined based on roles in the program (Oakley, 2021, p. 10). The PEO and PMs establish the high-level requirements, while the shipbuilder is required to deliver a submarine free of deficiencies, and the suppliers of the parts to the shipyards are required to provide good quality materials that have been inspected and tested. It is on the program and PM to hold the shipbuilders and designers accountable per their quality assurance programs. For the Navy and the Virginia program, SUPSHIP Groton is the on-site representative for the Navy, and SUPSHIP Groton's quality assurance department should be reviewing Electric Boat's quality assurance documentation (Oakley, 2021, p. 12). The government contract quality assurance programs are outlined in FAR Section 46.401-402. In the 2021 GAO report, it was reported that SUPSHIP elected not to perform additional government inspections on some critical missile tube welds performed by third party contractors, and that lead to significant delays and re-work (Oakley, 2021, p. 32). It is not enough to trust the contractor's quality assurance program for critical systems. Additional government inspection steps and oversight worked into program requirements will reduce the risk of delays and costly rework.

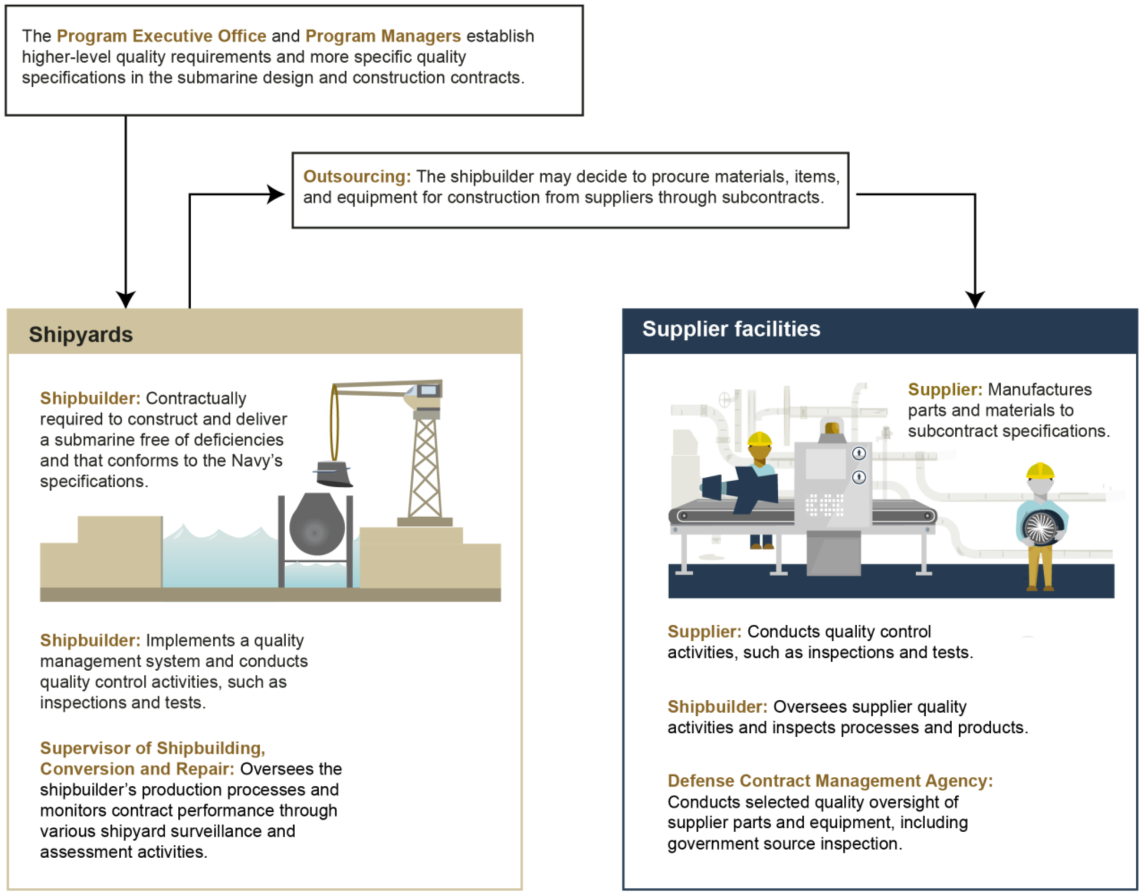

Figure 19. Department of Defense quality assurance for submarine construction. Source: Oakley (2021, p. 11).

D. THINK SLOW ACT FAST

Flyvbjerg and Gardner discuss the importance of "thinking slow and acting fast" as well as what specific factors impact the fate of big projects. This can apply directly to the multiple reviews within the major acquisition strategy. Flyvbjerg and Gardner equate the planning stages to a "safe harbor" and delivery to "venturing across the storm-tossed seas" (Flyvbjerg & Gardner, 2023, p. 17). While stakeholders and the warfighters will push to meet operational deadlines and mount increasing pressure on the program managers, it is important to take the time in the earliest stages to develop a clear and concise plan for the major acquisition phases. Once you "set sail" in project delivery, it can often be too far to make important changes to increase chances of success. Two factors they describe are the need to avoid strategic misrepresentation and the use of reference class forecasting.

1. Avoid Strategic Misrepresentation

One common pitfall in budgeting and cost analysis is the use of strategic misrepresentation. Flyvbjerg and Gardner reference a quote from Willie Brown: "start digging a hole and make it so big, there's no alternative to coming up with the money to fill it in" (Flyvbjerg & Gardner, 2023, p. 36). Intentionally misstating information or grooming data to meet higher agendas is one of the biggest pitfalls of the Virginia class program. When discussing the quantity of spare parts delivery for the first hulls, providing 98% of spare parts looks good to stakeholders but drags the industrial bases capability downward. The leveraged multi-year procurement and the ability for new construction to purchase bulk sets of spare parts for an entire block of boats drains the stock system of spares. Large contracts go to the shipbuilders and the industrial base does not support lower quantity purchases. When manpower is, the capacity for small orders decreases and results in longer lead times for delivery of material for in-service assets.

It is impossible to consider whether the Virginia class would have been approved as a program of record if the initial cost estimates were 30% higher than originally pitched to the Navy. It is on the program manager to evaluate the cost estimates and bring accurate numbers to the stakeholders. While more accurate figures may not be received well, the result is healthier for the program. Program managers should insist on empirical data and the reference models utilized when possible.

2. Reference Class Forecasting

Flyvbjerg and Gardner describe two views of project management: the "inside view" and "outside view." "Inside view" refers to examining a project in a vacuum. The "outside view" involves contextualizing the project against existing projects. There is a tendency for managers to fall into a uniqueness bias, believing that the project or program they are working on is unique, special, and one of a kind (Flyvbjerg & Gardner, 2023, p. 106). To avoid bias, it is important to utilize reference class forecasting. Reference class forecasting is focused on finding an anchor point, a set of data to start from, and adjusting accordingly. Having data to reference, an understanding of the reality of shipbuilding, and an understanding of the cost, schedule, and performance issues of previous generations of submarines can help program managers identify misrepresented data. The Virginia class and previous generations of submarines can serve as anchor points for major program milestones.

E. CONSOLIDATION IN THE INDUSTRIAL BASE

The Virginia class program's utilization of cost-plus fixed fee contacting and cost-plus award fee contracting for the initial delivery of the lead ship resulted in a consolidation of the industrial base shipbuilding into a single company (O'Rourke, 2024a, p. 54). The contract type effectively turned Electric Boat into a sole source shipbuilder for the naval industrial base, and Electric Boat contracted out the subsystems to various sub-contractors. The SSN(X) program design will be entering an already strained industrial base which is barely meeting program deadlines. Despite the cost saving strategies such as using single source of design and construction, streamlined integrated product teams, and better drafting tools, the program failed to avoid significant cost growth.

1. Competitive Contracting Value

In a study on the value of competitive contracting methods, Healy, Sok, and Ramirez (2014) identified an average of 20% cost savings on competed contracts; they attribute resistance to competitive contracting as a result of the following: lack of access to proprietary technical data, reliance on technical knowledge of incumbent contractors, and insufficient contract lead time (Healy et al., 2014, p. 49). As early in the planning phases as SSN(X) is, program managers have the opportunity to write requirements to obtain the intellectual property on design and can translate that data into developing technical subject matter experts. It is too late into the production phase of the Virginia class to address sole sourced obsolete parts for the earlier blocks, but it is not for the SSN(X) program. Future program managers should consider a system with a contractor as the subject matter expert as a risk of becoming a single point failure for the life of that system.

2. Technology Readiness Levels and System Design Maturity

The planning yards and the Navy have not been capable of keeping up with parts availability for repair and new construction. Circuit Cards and Single Board Computers designed for the first blocks of Virginia are at risk for procurement droughts due to vendors moving to the new configurations. The planning yards and the in-service support agencies are at odds with vendors trying to procure either the new generations of parts or the in-service part replacements, and that leads to long lead-times or even no-bids for contracts. If the vendors can slightly modify their production lines to produce a newer component at a higher price, there is little incentive for in-service sustainment of the legacy parts. Many parts have become sole-sourced, prohibitively expensive, or obsolete by the time that the first boats of its class are delivered. Evaluating technical maturity levels of equipment effectively increases capability through reductions in cost of redesign.

3. Growing the Industrial Base

The DOD reported on the state of the competition within the defense industrial base in 2022, identifying three factors influencing the industrial base: consolidation in the defense industry, data rights and intellectual property, and a federal wide push for use of commercial items. The report's recommendations to the acquisition workforce centered on the growth of small business vendors and reducing barriers to entry for small businesses (Office of the Undersecretary of Defense for Acquisition and Sustainment, 2022, p. 2).

Future program managers should leverage programs like the small business innovation research (SBIR) and small business technology transfer programs (STTR) to reduce the rate at which the small business industrial base is shrinking. Generating requirements for certain percentages of subcontracts from the prime contractor on development of the SSN(X) program could help drive further cost savings for the Navy. While the initial costs of the system could increase, the cost savings of the system would be throughout the in-service sustainment over the life cycle of the SSN(X) boats.

F. SUMMARY

Through evaluating the Virginia class program through a SWOT analysis and the various industry studies referenced, the recommendations provided align with the DOTmLPF-P's analysis of the capability gaps identified. Both analyses confirmed the necessity to tailor the DOD 5000 series instructions to meet the unique requirements of designing a submarine. The SWOT analysis highlights the value in the slower-methodical planning processes and emphasizes the effectiveness of proper reference class forecasting. The more accurate of models and communication of requirements for the program, the lower the risk in the design’s sustainability in service. A critical aspect for future submarine programs will be the ability to hold parties responsible for the quality of the components provided.

V. CONCLUSION

The analysis of the capability gaps in the Virginia class program, through the DOTmLPF-P analysis, identified that some capabilities can be addressed through the tailoring of policy and instruction as well as implementing modern design approaches like the MOSA. Aligning the non-materiel solutions for the capability gaps and the SWOT findings highlights the importance of designing maintainable systems. The acquisition system has greatly changed over the course of the Virginia class program's life and will continue to change as the acquisition workforce grows. Utilizing all the tools available to the SSN(X) program can provide further opportunities to reduce risk.

A. REVISITING RESEARCH QUESTIONS

- What was the major acquisition strategy employed for the Virginia Class at the outset of the program?

The major acquisition strategies employed for the Virginia class program were based on cost savings initiatives, the utilization of multiyear contraction to allow for cost savings in material purchasing, and the dual-shipyard construction utilizing Electric Boat and Newport News Shipbuilding to build critical shipbuilding skills in two major contractors. The program office oversaw the design and construction through SUPSHIP as a liaison between Electric Boat and the government.

- What major issues did the Virginia class face that led the program manager to deviate from the original acquisition strategy?

Over the course of the acquisition, costs spiraled out of control and further iteration of the acquisition strategy had to be implemented with external agencies brought in for optimizing workflows. Cost increases were driven by new-design technical challenges alongside quality of subcontracted components and manpower issues. A Nunn-McCurdy breach occurred and congressional oversight required drastic changes in future delivery of the Virginia class. Through the DFA, the Virginia class program was able to reduce cost growth for the future delivery ships. The push for drastic change in the acquisition strategy could have been implemented earlier if projected growths were identified or a lower risk threshold was set.

- What issues does the Virginia Class currently face in-service and in new-construction?

In-service support of critical spares for weapon systems is at an all-time low, with a strained industrial base struggling to deliver boats on time while designing and constructing new classes. The industrial base's struggles with manpower was concurrently plaguing the shipyards as major defense contractors absorbed small business. The consolidation of small businesses reduced capability for surge and general technical knowledge within the industrial base. A combination of the need to tailor the acquisition process more intently to the intricacies of building submarines and the lack of flexible frameworks to build the original acquisition strategy put the Virginia class program in a difficult position to support in-service assets.

- What lessons can be learned from the in-service and new-construction issues that could have been prevented or addressed in an earlier acquisition phase?

Cost misrepresentation and schedule slip throughout the acquisition process was a result of failures of the program to hold parties accountable for their work. The program office has the established offices in place to oversee and provide government required inspection where necessary to ensure quality of work remains satisfactory prior to delivery to the in-service fleet. Utilizing previous generations design costs as well as new construction growth can inform future classes through better reference class forecasting. The modern acquisition databases contain more data than previous generations had access to and they should be leveraged heavily during cost estimations. A more accurate APUC baseline can reduce risks of Nunn-McCurdy breaches or other cost growth issues.

B. RISKS AND COURSES OF ACTION

The recommendations to the SSN(X) program resulting from the DOTmLPF-P and SWOT analysis of the Virginia class are as follows:

1. Risk 1: A Need for Intellectual Property

There is a clear need for the procurement of intellectual property of combat and weapons systems to support the reliability, maintainability, and sustainability of the systems over the life cycle of the SSN(X) program. The SSN(X) program should contract full intellectual property rights into delivery of lead ship for critical weapon systems in accordance with DODD 5000.01 and SECNAVINT 5000.2G.

2. Risk 2: Addressing Obsolescence in Follow-On Ship Delivery

The SSN(X) program should begin construction of non-critical weapon systems and major ship structures while overlapping technical maturation phases for critical weapon systems. This will ensure that the readiness levels of the weapon systems are higher upon delivery of lead ship and follow on blocks require less drastic re-designs.

3. Risk 3: Utilizing SUPSHIP and Holding People Accountable

Multiple GAO reports indicate that there was a lack of initiative on the Navy and SUPSHIP to implement additional quality control on material and services from third party suppliers. The SSN(X) program should require additional government inspections on third party material and suppliers for critical weapon systems that could delay delivery or quality of systems.

4. Risk 4: Accurate Forecasting and Realistic Program Costs

The Navy's submarine industrial base is backed into a corner with near sole-sourced shipbuilding capability. The SSN(X) program must establish rigid responsibilities within the acquisition workforce and train SUPSHIP and the program office to identify accurate models for cost breakdowns to reduce variance of expected program costs and actual delivery costs.

C. FUTURE RESEARCH OPPORTUNITIES

This analysis of the Virginia class program and the comparisons made to other classes of submarines was accomplished at the organizational and programmatic documentation level. Further research could be accomplished to break down cost structures of availabilities and take a closer look at the in-service data from the Virginia class to inform the life-cycle decisions for the SSN(X) maintenance program. A comparison between program estimations could also be accomplished for other classes of boats and submarines to analyze cost growth over the course of life cycles. An in-depth analysis of the SSN(X) program's lead ship delivery could reinforce which 5000 series processes were tailored effectively to the program.

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Acquisition Research Program
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net