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SSBN Columbia Class Submarine Case Study

Dr. Robert F. Mortlock, COL, USA (Ret.)—is a professor of the practice and Associate Chair for Acquisition Sciences for the Department of Defense Management at the Naval Postgraduate School in Monterey, CA. He holds a PhD in chemical engineering from the University of California, Berkeley, an MBA from Webster University, an MS in national resource strategy from ICAF, and a BS in chemical engineering from Lehigh University. [rfmortlo@nps.edu]

Benjamin Field, LCDR, USN— is the Engineer Officer on USS Wyoming (SSBN 742) (Blue). He holds an MS in Program Management from the Naval Postgraduate School and a BA in Business and Economics from the Virginia Military Institute. [fieldbr@wyoming-blue.navy.mil]

Abstract

This case study is written to produce an active learning environment to increase the capability of acquisition/program management professionals and senior leaders regarding program planning, decision-making, and affordability. Ballistic missile submarines (SSBNs) are a stealthy, survivable launch platform that contributes to strategic deterrence. Ohio-class SSBNs, which have filled the role of sea-based deterrence for the last 40 years, are nearing the end of their planned service life. To prevent a gap in nuclear deterrent capability, the successor to the Ohio-class, the Columbia-class, must be built to meet the Navy initial operating date requirements. However, the Columbia-class submarine is experiencing setbacks due to multiple issues with requirements, software development, funding, industrial base capacity and capability, and quality assurance with shipyards and manufacturers. This case study analyzes the Columbia-class submarine acquisition program and the path forward for the Navy.

Keywords: ship building, affordability, decision-making, critical thinking, project management

Introduction

Admiral (ADM) Michael Gilday, Chief of Naval Operations (CNO), sat at his desk facing a difficult problem in the first quarter of 2022. As the CNO, Admiral (ADM) Gilday is responsible to the Secretary of the Navy (SECNAV) for the "command, utilization of resources, and operating efficiency of the operating forces of the Navy" (United States Navy, n.d.). In carrying out his charge, the CNO is consistently facing numerous difficult challenges for the Navy. However, one challenge stood out this morning: ensuring the timely delivery of the Columbia-class submarine. He had just gotten off a phone call with Rear Admiral (RADM) Pappano, Program Executive Officer (PEO) Strategic Submarines, who was responsible for the Columbia-class submarine program. RADM Pappano called to inform the CNO of the release of the Congressional Research Service (CRS) report on the Columbia-class submarine and to provide his viewpoint on the most pressing obstacles to delivering the future USS Columbia on time. The CNO knew the success of the program was a matter of national security. Failing to deliver the Columbia-class submarine on time would result in a nuclear strategic deterrence gap for the United States. However, with little schedule margin remaining and additional pressures to minimize program cost growth, the path moving forward was unclear. Were adjustments necessary for the cost, schedule, and performance requirements of the approved acquisition program baseline (APB)?

Background

Deep under the ocean's waves and across the globe, U.S. Navy nuclear ballistic missile submarines (SSBN) are on silent patrol performing the nation's "highest priority mission"—strategic deterrence (Lopez, 2021). This mission is conducted by Ohio-class submarines. Each Ohio-class SSBN, one of which is depicted in Figure 1, carries up to 24 Trident II submarine-launched ballistic missiles (SLBMs) and serves to dissuade U.S. adversaries from conducting a nuclear attack for fear of retaliation from an un-locatable source (Submarine Industrial Base Council, 2017). After decades of service, the Ohio-class SSBNs are beginning to reach the end of their already extended 42-year service life (Eckstein, 2020b, para. 1). To continue the legacy of strategic deterrence, the Department of Defense (DOD) is developing a replacement for the Ohio-class Submarine: the Colombia-class submarines.

Figure 1. USS Wyoming (SSBN 742). (Rebarich, 2008)

The Columbia-class SSBNs, the named successor to the Ohio-class SSBNs and depicted in Figure 2, are under construction. The first SSBN in the Columbia class, the USS Columbia, is set to be completed by 2030 and ready to execute its first strategic deterrence patrol in 2031 (Government Accountability Office [GAO], 2021, p. 1). According to ADM Gilday, "[the] Columbia-class is our number one acquisition priority" and "these submarines need to be delivered on time, on budget, and ready for the fight—we have no margin to fall behind" (U.S. Navy Office of Information, 2022). However, program delays for the USS Columbia threaten its on-time scheduled delivery. If USS Columbia is not delivered on time and conducting its first patrol by 2031, the United States faces the unpalatable outcome of having an insufficient amount of SSBNs to fully perform the strategic deterrence mission at sea.

Figure 2. Artist's rendering of the future Columbia-class ballistic missile submarine. (U.S. Department of Defense, n.d.)

Strategic Deterrence

SSBNs play an integral role in strategic deterrence. Fourteen SSBNs currently patrol the world's oceans and provide an undetectable launch platform, discouraging the worldwide use of nuclear weapons by U.S. adversaries. As of 2022, nine countries had access to nuclear weapons (Federation of American Scientists, n.d., para. 1). In addition to the United States, the United Kingdom (U.K.), France, Israel, Pakistan, India, China, Russia, and North Korea contain nuclear weapon stockpiles that, in total, amount to approximately 9,400 warheads that are ready for military use (Federation of American Scientists, n.d., para. 5). The detonation of a nuclear warhead has a destructive power that can unleash a fatal level of radiation, a catastrophic pressure wave that can topple buildings, a superheated fireball and accompanying thermal flash capable of creating a sweeping firestorm, and a large amount of damaging, long-lasting nuclear fallout that will remain in the days, weeks, and years following the explosion (Wolfson & Dalnoki-Veress, 2022). However, despite such a large number of nuclear weapons available for use, no strategic nuclear weapons have been used against another country in or outside of warfare since the bombing of Hiroshima and Nagasaki at the end of World War II (United Nations Office for Disarmament Affairs, 2021, para. 1). The most likely reason for this enduring nuclear peace is strategic deterrence.

The aim of strategic deterrence, the “highest priority mission of the Department of Defense,” is to dissuade another country from launching nuclear weapons at the United States out of fear of a retaliatory strike (Lopez, 2021). The United States uses a “nuclear triad” to provide a credible and capable source of strategic deterrence. The nuclear triad is composed of three components: air, land, and sea-based deterrence. Air-based deterrence is accomplished by the U.S. Air Force by outfitting airframes with nuclear weapons. More specifically, the Air Force B-52 Stratofortress bombers and B-2 Spirit bombers carry gravity-based nuclear bombs, and the F-15E Strike Eagle fighters carry nuclear cruise missiles (OSD Nuclear and Missile Defense Policy, 2020, p. 7). The Air Force is also responsible for land-based strategic deterrence. Minuteman III intercontinental ballistic missiles (ICBMs) are “spread out over 400 hardened, underground silos” (OSD Nuclear and Missile Defense Policy, 2020, p. 3), ready to strike. Sea-based deterrence is the responsibility of the SSBNs of the U.S. Navy.

Each portion of the nuclear triad offers its own unique advantages, and together they establish a formidable source of strategic deterrence. The land-based strategic deterrence afforded by U.S. ICBMs represents the most “responsive” leg of the nuclear triad. The president of the United States can, at any time, give the order to launch ICBMs through methods of “assured connectivity” (OSD Nuclear and Missile Defense Policy, 2020, p. 3). ICBMs are manned by Air Force personnel and can respond immediately to a launch order (OSD Nuclear and Missile Defense Policy, 2020, p. 3). Meanwhile, air-based deterrence provides the most “flexible” (OSD Nuclear and Missile Defense Policy, 2020, p. 7) leg of the nuclear triad. Air Force nuclear weapon–capable airframes are a mobile, visual strategic deterrent that patrol forward-deployed air space, serving as a reminder of the “U.S. commitments to its security and the security of its allies and partners” (OSD Nuclear and Missile Defense Policy, 2020, p. 7). If required to launch a nuclear payload, air-launched cruise missiles (ALCMs) offer a large degree of flexibility through their advanced targeting capabilities. According to the article “Importance of Modernizing the Nuclear Triad,” B-52s can “carry up to 20 ALCMs, allowing one bomber to threaten 20 geographically separated targets” simultaneously (OSD Nuclear and Missile Defense Policy, 2020, p. 7). The U.S. Navy’s SSBN fleet, which conducts the sea-based strategic deterrence mission, is the only platform that represents a clandestine, survivable threat to U.S. adversaries. According to the Center for Arms Control and Non-Proliferation, the “sea-leg of the triad is often considered most essential, since submarines are difficult to track and destroy” (Schumann, 2021, para. 8). Given this noteworthy distinction, SSBNs have and will continue to receive a significant amount of attention and funding. To appreciate the state-of-the-art capabilities that will allow the Columbia-class submarine to execute the sea-based leg of the nuclear triad, it is important to understand the state-of-the-practice class Ohio-class SSBNs.

Ohio-Class Ballistic Missile Submarine

The first ship of the Ohio class, USS Ohio (SSBN 726), was commissioned on November 11, 1981 (General Dynamics Electric Boat, n.d.). The Ohio-class submarine was the successor to the “41 for Freedom” fleet ballistic missile (FBM) submarines, which were comprised of five different classes: the George Washington, Ethan Allen, Lafayette, James Madison, and Benjamin Franklin (Naval History and Heritage Command, 2021). Each of the earlier variants of FBM submarines could carry 16 Polaris missiles, and in later variants, Poseidon C-3 or Trident I C-4 missiles (Strategic Systems Platforms, n.d.). The FBM submarines provided successful strategic deterrence patrols for years. However, advances in submarine technology and the desire to equip vessels with substantial numbers of Trident ICBMs led to the development of the Ohio-class submarines.

Eighteen Ohio-class SSBNs were commissioned between 1981 and 1997 (General Dynamics Electric Boat, n.d.). The first four Ohio-class SSBNs, which completed numerous strategic deterrence patrols, were converted into guided nuclear missile submarines (SSGNs) from 2000 to 2010. SSGNs are SSBNs that are outfitted with Tomahawk land attack missiles (TLAMS) instead of ICBMs. The remaining 14 SSBNs provide the sea-based leg of strategic deterrence today.

Ohio-class submarines, an example of which is depicted in Figure 3, are 560-foot-long nuclear-powered warships that can carry up to 24 Trident I C-4 or Trident II D-5 missiles. They are homeported in either Kings Bay, GA, or Bangor, WA. Each SSBN has two crews (known as the blue and gold crews), which operate the submarine on its nominal deployment cycles. One crew takes the submarine to sea for a strategic deterrence patrol that lasts approximately 75 to 90 days. Once the strategic deterrence patrol is complete, the submarine returns to port, and a crew turnover occurs. Once the new crew has taken responsibility for the submarine, a 30-day maintenance period begins. When the maintenance period is complete, the submarine goes back to sea. The crew that has returned from sea and is in port operates submarine simulators, conducts training, and plans for the upcoming maintenance period following crew turnover.

Figure 3. Ohio-Class Submarine, USS Henry M. Jackson (SSBN 730). (U.S. Navy, 2015)

Columbia-Class Ballistic Missile Submarine

The decision to replace the Ohio-class submarine with another “sea-based strategic deterrent” originated out of an agreement between President George W. Bush and U.K. Prime Minister Tony Blair in 2006 to have their “next generation SSBNs carry the Trident II D-5 Submarine Launches Ballistic Missiles (SLBMs)” (O’Rourke, 2022, p. 37). After the Joint Requirements Oversight Committee approved an initial capabilities document (ICD), the Ohio Replacement Program (ORP) office was established in 2008 (O’Rourke, 2022, p. 37). Milestone A for the ORP was approved on January 10, 2011 (O’Rourke, 2022, p. 38). Following the approval of Milestone A, in 2016 the ORP was renamed the "Columbia Class Program" (O'Rourke, 2022, p. 4). Milestone B was approved on January 4, 2017 (O'Rourke, 2022, p. 38), and the Navy officially started construction of the first Columbia-class submarine in November 2020 (Eckstein, 2020a, para. 1). A list of the major developments for the Columbia-class submarine can be seen in Table 1.

Table 1. History of significant developments for the Columbia-class submarine. (U.S. Department of Defense, 2019)

History of Significant Developments Since Program Initiation

History of Significant Developments Since Program Initiation	
Date	**Significant Development Description**
July 2008	USD AT&L issues ADM directing entry into the Concept Refinement Phase and conduct of an Analysis of Alternatives.
October 2008	Secretary of Defense sends letter to United Kingdom (UK) Secretary of State for Defense to affirm the U.S.-UK Mutual Defense Agreement and cost sharing for the Common Missile Compartment.
September 2010	SCP approved with new design SSBN based on 12 ships with 16 - 87" missile tubes.
January 2011	Milestone A ADM issued which authorized entry into Technology Maturation and Risk Reduction (TMRR) phase to complete a new design SSBN based on 12 ships with 16 - 87" missile tubes.
February 2012	PB 2013 shifts lead ship construction from FY 2019 to FY 2021; the two year recapitalization delay removed all margin during the OHIO-OHIO Replacement (OR) transition period (FY 2027- FY2042), any delay in OR delivery or unexpected aging impact to OHIO will have significant impacts on SSBN Ao.
December 2012	RDT&E Design Contract issued to General Dynamics – Electric Boat.
December 2014	National Sea-Based Deterrence Fund established by Public Law 113-291.
November 2015	Incremental funding authority and authority to enter in contracts for Advance Construction and economic order quantity provided by Public Law 114-92.
January 2017	Milestone B APB approved (Program Initiation).
September 2017	Award of the Integrated Product and Process Development (IPPD) contract. The Navy has transitioned all design efforts from the OHIO Replacement Research & Development (R&D) Design contract to the IPPD contract.
September 2018	Award of the Two Year Advance Procurement Funding modification to the IPPD contract.
February 2019	APB updated to reflect actual award of IPPD contract (September 2017) and align affordability targets with approved CDD.

The Columbia-class submarine will be the world's state-of-the-art SSBN. Some of these innovative technologies can be seen in Figures 4 and 5. The Columbia class will feature a nuclear reactor that, unlike that of the Ohio class, requires no refueling for the lifetime of the submarine (Larson, 2021). The new submarine class also features the first electric-drive propulsion system and an X-shaped stern configuration, which will increase the ability of the submarine to remain undetected (Osborn, 2018). The Columbia-class submarine will carry up to 16 Trident D-5 missiles. This is eight fewer missiles than the Ohio-class submarine, which carries up to 24 Trident D-5 missiles. However, Columbia-class submarines will maintain the same number of overall missiles at sea because the Columbia-class submarines will not need to conduct mid-life refueling of the nuclear reactor. Fewer lengthy refueling periods result in fewer Columbia-class submarines in port and an increased number of SSBNs at sea (O'Rourke, 2022, p. 5).

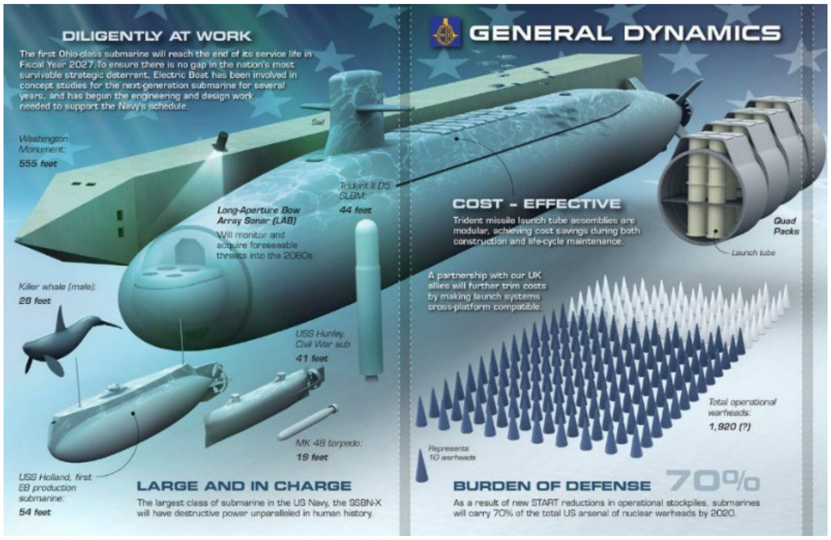

Figure 4. Columbia-class submarine size and deterrent capability. (General Dynamics, n.d.)

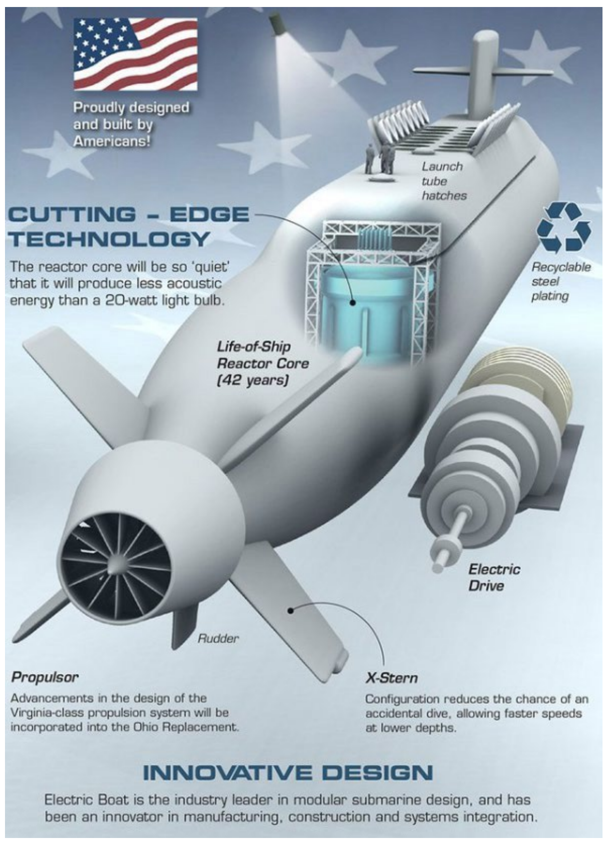

Figure 5. Cutting-edge technology on the Columbia-class submarine. (General Dynamics, n.d.)

12 Columbia-class SSBNs are set to replace the 14 active Ohio-class SSBNs over the next 20 years, with the lead submarine to be delivered to the Navy no later than 2030 with the first strategic deterrence patrol no later than 2031. The Columbia-class SSBNs offer a large upgrade in capability over the Ohio-class SSBNs. Some of the most notable upgrades include a nuclear reactor that requires no mid-life refueling, an electric-drive propulsion system, an X-

shaped rudder and stern plane system, the most modern sonar suite, and the most advanced sound silencing capabilities. In addition to the major upgrades, the Columbia-class submarine carries the Trident II D-5 Submarine Launched Ballistic Missiles (SLBMs) as seen in Figure 6. These are the same nuclear weapons that are carried by the Ohio-class SSBNs. Utilizing this capable weapon reduces the risk of a delay of the first Columbia-class strategic deterrence patrol in 2031 by avoiding the development and acquisition of a new nuclear weapon.

Figure 6. Unarmed Trident II D-5 missile launched from a ballistic missile submarine. (U.S. Navy, n.d.)

Nuclear strategic deterrence is one of the most important missions of the DOD, making the Columbia-class submarine acquisition program critical for national security. As the Ohio-class submarines begin to reach the end of their useful service life, Columbia-class submarines must be ready to replace them. In the worst case, if the first Columbia-class submarine is not ready to conduct its first strategic deterrence patrol by 2031, there is a potential for a nuclear strategic deterrence gap, which could potentially jeopardize the national security.

Big "A" Acquisition

The CNO knew the difficulties RADM Pappano was facing. The PEO was responsible for managing the "triple constraint" of the program's acquisition program baseline: cost, schedule, and performance. Though a simple concept, the CNO knew there was more to it than met the eye. At most, a PEO or PM could optimize the triple constraint for two of its three variables and would be required to make concessions for the other. As an example, RADM Pappano could focus on delivering a quality submarine on time if he were able to increase the overall cost of the program. Conversely, RADM Pappano could also choose to drastically cut costs for the program and risk decreasing quality or performance. None of these decisions concerning the triple constraint, however, can be made in isolation. A PEO or PM finds themselves eternally in the middle of the Big "A" acquisition system. Big "A" acquisition consists of three interacting systems: the Joint Capability Integration and Development System (JCIDS), the Programming, Planning, Budgeting and Execution System (PPBE), and the Defense Acquisition System (DAS), commonly referred to as Little "a" acquisition or more recently, the Adaptive Acquisition Framework (Moran, 2008). Figure 7 provides a visual representation and summary of the Big "A" concepts.

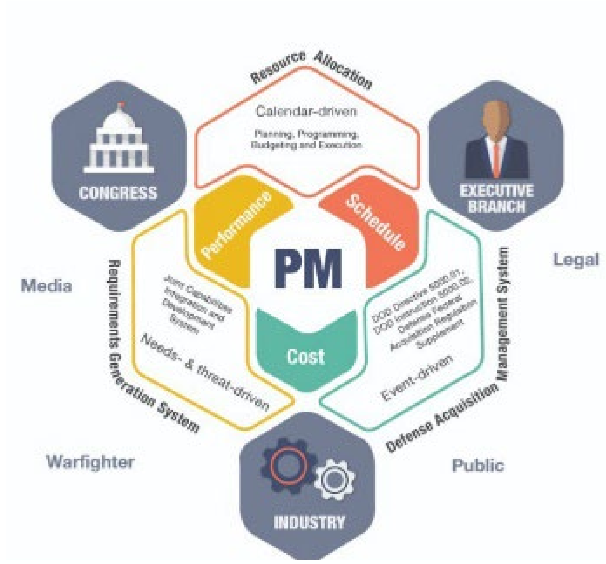

Figure 7. Big "A" acquisition. (Mortlock, 2021)

The JCIDS process is responsible for requirements generation and is a needs-driven process. The need assessed by the JCIDS process is defined in the initial capabilities document (ICD), and discrete operational requirements are derived from the ICD in the capability development document (CDD). In the case of the Columbia-class program, that need is providing a source of sea-based strategic deterrence. The PPBE process is responsible for the allocation of resources to programs. Unlike the other two parts of Big "A" acquisition, the PPBE process is a calendar-driven system. The final portion of Big "A" acquisition is the DAS or defense acquisition management system, which is an events-driven system. The PEO or PM guides their programs along one of the pathways of the Adaptive Acquisition Framework (AAF), as seen in Figure 8. The Columbia-class submarine program follows the major capability acquisition pathway that entered the engineering and manufacturing development (EMD) phase following an approved milestone B decision in 2017. RADM Pappano had his work cut out for him—operating within the Big "A" framework for one of the most important programs in the country was far from an easy task. His major challenge was to manage the APB (cost, schedule, and performance constraints) within the Big "A" environment.

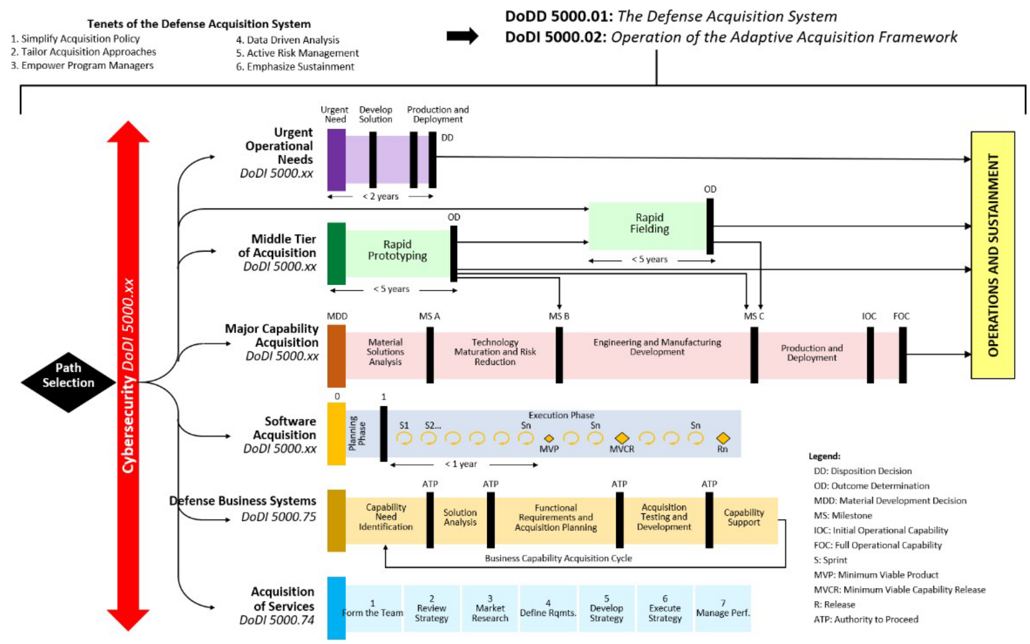

Figure 8. Adaptive acquisition framework. (Defense Acquisition University, n.d.)

Columbia-Class Acquisition Program Baseline

The current acquisition program baseline (APB) for the Columbia-class submarine was approved on February 25, 2019. An APB is developed by the Navy, is approved by the milestone decision authority (MDA), and details the threshold and objective values for cost, schedule, and performance requirements. These cost, schedule, and performance sections from the Columbia program APB are presented in Tables 2, 3, and 4 respectively.

Table 2. Cost summary. (U.S. Department of Defense, 2019)

Total Acquisition Cost							
Appropriation	BY 2017 $M			BY 2017 $M	TY $M		
	SAR Baseline Development Estimate	Current APB Development Objective/Threshold		Current Estimate	SAR Baseline Development Estimate	Current APB Development Objective	Current Estimate
RDT&E	12648.1	12648.1	13912.9	12646.7	13020.3	13020.3	13039.4
Procurement	87426.5	87426.5	96169.2	86117.0	115044.3	115044.3	113563.8
Flyaway	--	--	--	84275.3	--	--	111110.9
Recurring	--	--	--	79217.1	--	--	105415.6
Non Recurring	--	--	--	5058.2	--	--	5695.3
Support	--	--	--	1841.7	--	--	2452.9
Other Support	--	--	--	1841.7	--	--	2452.9
Initial Spares	--	--	--	0.0	--	--	0.0
MILCON	147.3	147.3	162.0	156.0	173.4	173.4	186.2
Acq O&M	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100221.9	100221.9	N/A	98919.7	128238.0	128238.0	126789.4

Current APB Cost Estimate Reference

SCP dated September 26, 2016

Cost Notes

No cost estimate for the program has been completed in the last year.

Total Quantity			
Quantity	SAR Baseline Development Estimate	Current APB Development	Current Estimate
RDT&E	0	0	0
Procurement	12	12	12
Total	12	12	12

Table 3. Schedule of events. (U.S. Department of Defense, 2019)

Events	SAR Baseline Development Estimate	Current APB Development Objective/Threshold		Current Estimate	
Milestone A	Dec 2010	Dec 2010	Dec 2010	Dec 2010	
Pre-RFP Release DAB	Dec 2015	Dec 2015	Dec 2015	Dec 2015	
Preliminary Design Review	Apr 2016	Apr 2016	Apr 2016	Apr 2016	
Milestone B	Nov 2016	Jan 2017	Jan 2017	Nov 2016	
Integrated Process and Product Development Contract Award	Jan 2017	Sep 2017	Sep 2017	Sep 2017	
Two Year Advance Procurement Funding Modification	Oct 2018	Sep 2018	Sep 2018	Sep 2018	(Ch-1)
Critical Design Review	Apr 2020	Apr 2020	Oct 2020	Apr 2020	
Lead Ship Authorization / Construction Start	Oct 2020	Oct 2020	Apr 2021	Oct 2020	
Block I Contract Award	Oct 2020	Oct 2020	Apr 2021	Oct 2020	
Lead Ship Contract Delivery	Apr 2027	Apr 2027	Oct 2027	Oct 2027	
Initial Operational Test and Evaluation Complete	Feb 2029	Feb 2029	Aug 2029	Aug 2029	
Lead Ship First Deployment Start	Apr 2030	Apr 2030	Oct 2030	Oct 2030	
Initial Operational Capability	Apr 2030	Apr 2030	Oct 2030	Oct 2030	

Table 4. Performance characteristics. (U.S. Department of Defense, 2019)

SAR Baseline Development Estimate	Current APB Development Objective/Threshold		Demonstrated Performance	Current Estimate	
Operations and Support (O&S) Cost KSA					
Average annual O&S cost per unit of $96M (CY 2010$)	Average annual O&S cost per unit of $119M (CY 2017$)	Average annual O&S cost per unit of $131M (CY 2017$)	TBD	$120.2M (CY2017$)	(Ch-1)
Net-Ready KPP					
Meet the requirements defined within the OR SSBN PIIT of the Common Submarine Information Support Plan	Meet the requirements defined within the OR SSBN PIIT of the Common Submarine Information Support Plan	(T=O) Meet the requirements defined within the OR SSBN PIIT of the Common Submarine Information Support Plan	TBD	Meet the requirements defined within the OR SSBN PIIT of the Common Submarine Information Support Plan	
Training KPP					
OR SSBN crews are capable of being certified proficient for strategic patrol operations by the Group Commander upon completion of the normal PDTP in accordance with Fleet instructions	OR SSBN crews are capable of being certified proficient for strategic patrol operations by the Group Commander upon completion of the normal PDTP in accordance with Fleet instructions	(T=O) OR SSBN crews are capable of being certified proficient for strategic patrol operations by the Group Commander upon completion of the normal PDTP in accordance with Fleet instructions	TBD	OR SSBN crews are capable of being certified proficient for strategic patrol operations by the Group Commander upon completion of the normal PDTP in accordance with Fleet instructions	
Space, Weight, Power, and Cooling (SWAP-C) KSA					
Future Growth Margin: 3% of Condition A-1 weight Cooling Capacity: 10% cooling capacity over the chill water design heat load Power – 10% electrical power future growth margin for ship's electrical loads at full power while underway at delivery	Future Growth Margin: 3% of Condition A-1 weight Cooling Capacity: 10% cooling capacity over the chill water design heat load Power – 10% electrical power future growth margin for ship's electrical loads at full power while underway at delivery	(T=O) Future Growth Margin: 3% of Condition A-1 weight Cooling Capacity: 10% cooling capacity over the chill water design heat load Power – 10% electrical power future growth margin for ship's electrical loads at full power while underway at delivery	TBD	Future Growth Margin: 3% of Condition A-1 weight Cooling Capacity: 10% cooling capacity over the chill water design heat load Power – 10% electrical power future growth margin for ship's electrical loads at full power while underway at delivery	
Procurement Cost KCP					
Lead Ship End Cost Less Plans of $6.3B (2010$) using Navy	APUC of $7.3B (CY 2017$)	APUC of $8.0B (CY 2017$)	TBD	$7.18B (CY2017$)	(Ch-2)
Inflation / Deflation Indices Average Follow Ship Hulls 2-12 End Cost of $4.9B (2010$) using Navy Inflation / Deflation Indices					
Lead Ship First Deployment Key Schedule Parameter					
Third quarter of FY2030	Third quarter of FY 2030	First quarter of FY 2031	TBD	First quarter of FY 2031	

Government Accountability Office Report

Despite the major forward progress made on the Columbia-class submarine, delays in early construction are threatening timely delivery to the fleet (GAO, 2021, p. 1). These specific problems include a “supplier base that is roughly 70% smaller than in previous shipbuilding booms,” an “inexperienced shipyard workforce,” “continuing challenges with … computer-aided software that … is [being used] to design the submarine,” and “quality problems with supplier materials” (GAO, 2021, pp. 1, 20). If the Columbia-class submarine is not ready to make its “first patrol in fiscal year 2031 … [the United States will experience] a deterrence gap … [that would have] far-reaching consequences for the nation’s defense” (GAO, 2021, p. 1).

Given the magnitude of the consequences of a delay in the construction of the Columbia-class submarine and the $128 billion that the Navy plans to invest to create the 12 ships in the class, the Government Accountability Office (GAO) was tasked with “assessing the Navy’s efforts to complete the design for the lead Columbia-class submarine and actions that the shipbuilders and the Navy have taken to prepare for construction and ensure the lead submarine is delivered according to schedule and quality expectations” (GAO, 2021, p. 2).

The GAO released report GAO-21-257, *Columbia Class Submarine: Delivery Hinges on Timely and Quality Materials from an Atrophied Supplier Base*, on January 14, 2021. This report describes the major obstacles that threaten schedule delays for the Columbia program office.

Software Issues

Electric Boat, the Columbia-class SSBN program contractor, switched to a new computer-aided software tool for the Columbia-class SSBN because the software for the previous tool was “no longer supported by the original developer” (GAO, 2021, p. 6). The purpose of the computer-aided software tool is to design arrangements, disclosures, and material orders, which are required to develop the submarine (GAO, 2021, p. 7). The arrangements, which are completed first, are 3D models of the steel structure, the electrical systems, and the piping systems (GAO, 2021, p. 7). Once the arrangements have been completed, the next step is to design the disclosures. The disclosures “complete the design work for even the lowest-level items of the submarine, including material information” (GAO, 2021, p. 7). A completed disclosure lends way to the development of work instructions, which provide shipyard workers with the procedures and parts required to build any given part of the ship, and the material orders, which allow the generation of contracts to order all required parts (GAO, 2021, p. 7).

One major advantage of the new computer-aided design tool was that it was supposed to “reduce the average hours needed to complete design disclosures by almost half of the time required for the Virginia class program” (GAO, 2021, p. 13). This would enhance the ability of the Columbia-class to stay on schedule because completed disclosures allow the program office to accurately order parts and prepare workers for submarine assembly. Unfortunately, issues with the new software have resulted in delays in disclosure and work instruction completion. The GAO cites software trouble as the major cause of delay in the construction of the Columbia-class submarine (GAO, 2021, p. 13). In the absence of work instructions, the shipyard cannot begin building portions of the submarine because they do not have procedures for their workers to follow (GAO, 2021, p. 16). Additionally, delays in disclosure completion have resulted in delayed orders of construction materials and subsequent construction because “Electric Boat cannot order materials until they are sufficiently defined in a disclosure” (GAO, 2021, p. 17).

In 2021, the GAO estimated that “Electric Boat must increase its average work instruction completion rate by 29 percent in 2020 to support the planned construction pace.” Though not listed in the GAO report, the CRS report, updated in 2022, states that “the shipbuilder [did not meet] the goal for design disclosures” (O’Rourke, 2022, p. 17).

Submarine Supplier Base

The submarine supplier base is under significant strain to produce materials required for the timely production of the Columbia-class submarine. Electric Boat and Newport News, the only two private shipbuilders who construct nuclear-powered vessels for the U.S. Navy, “plan to deliver 39 nuclear submarines during the next 2 decades, which, if achieved, would represent a doubling in output over prior years” (GAO, 2021, p. 8). The 39 submarines account for continuing to produce “two Virginia Class submarines per year through 2033 and one Columbia Class submarine per year starting in 2026” (GAO, 2021, p. 8). This pace of submarine construction has been unmatched since the height of the Cold War. Complicating the problem of increased demand for materials, the submarine supplier base has “shrunk by roughly 70–80 percent since the 1970s and 1980s” (GAO, 2021, p. 9). The GAO (2021) estimated that the number of suppliers has decreased from approximately 17,000 to approximately 5,000 (p. 9). The program executive officer for the Columbia-class program, Rear Admiral Scott Pappano, stated that “our most significant risk at the top of the list is our supplier industrial base” (O’Rourke, 2022, p. 12).

In addition to having a smaller and more fragile supplier base that is working at maximum capacity to deliver critical materials for the Navy’s most important acquisition program, the number of experienced workers has declined (GAO, 2021, p. 20). This has resulted in some inexperienced workers delivering substandard quality materials to the Columbia-class lead shipbuilder, Electric Boat (GAO, 2021, p. 26). As a specific example, quality problems in the welds for the missile tubes that were discovered at the manufacturer “are likely to cause continued delays as formal construction begins” (GAO, 2021, p. 26).

Quality Assurance Issues

A strong quality assurance program not only is an industry best practice but also minimizes the probability of schedule delays and cost overruns. According to the GAO (2021), the “shipbuilder is responsible for delivering quality submarines that meet the Navy’s specifications and … is tasked with ensuring and monitoring quality based on contract requirements” (p. 10). At this point, however, the GAO assessed that “supplier quality problems have persisted, but the Navy has not comprehensively reassessed when additional government inspections at suppliers are necessary” (GAO, 2021, p. 25), which is a major driver for schedule delays.

Congressional Research Service Report

In addition to the GAO report, the Congressional Research Service (CRS) published a report that provides additional “background information and potential oversight issues for Congress on the Navy’s Columbia class program” (O’Rourke, 2022, p. 2). Specifically, the CRS report details GAO, Navy, and Congressional Budget Office (CBO) perspectives on the risk of schedule delay in designing and building the lead boat, the risk of cost growth, program affordability, and industrial-base challenges (O’Rourke, 2022, p. 3).

The CRS released its most recent revision of report R41129, *Navy Columbia (SSBN 826) Class Ballistic Missile Submarine Program: Background and Issues for Congress*, on April 27, 2022. This report expands on the GAO report and provides the most up-to-date publicly available information for key issues facing the Columbia-class program office. These problems are split into two major categories: risk of schedule delay and risk of cost growth. This report encompasses the Navy and GAO perspectives on both issues.

Risk of Schedule Delay

The Columbia-class program office had "as little as two months of [schedule] margin" remaining according to Rear Admiral (RADM) Scott Pappano in October 2021, who was then the program executive officer (PEO) for the Columbia-class submarine and is now the PEO for strategic submarines. With so little margin remaining, clear identification of problems and prevention of future schedule slips are of the utmost importance. In addition to the problems identified by the GAO report, the CRS report adds technological risk and an aggressive production schedule as threats to schedule delay.

Technological Risk

The Columbia-class submarine will contain many technological upgrades over its predecessors. With each innovative technology introduced, there is a risk of schedule delay as the program office works through design and integration issues. According to the CRS, an example of a technological challenge that could threaten schedule is the electric-drive system, which is an upgrade from the steam-based propulsion system utilized on all other American nuclear submarines (O'Rourke, 2022, p. 12). Admiral Caldwell, the director of the Naval Nuclear Propulsion Program, stated that the electric drive system "performed flawlessly" under "the most stressing conditions that we think we would encounter" (O'Rourke, 2022, p. 14). However, the GAO warns that "based on leading acquisition practices, we consider technologies to be mature after successful testing of a prototype near or at the planned operational system configuration in a realistic environment" and that "additional development and testing are required to demonstrate the maturity of several technologies critical to performance" (O'Rourke, 2022, p. 15–16).

Aggressive Production Schedule

The lead ship of the Columbia-class is slated to be built in 84 months, approximately 7 months faster than the lead ship of any other submarine class (O'Rourke, 2022, 17). This record-breaking design and construction plan also comes at a time when General Dynamics and Huntington-Ingalls are building two Virginia-class submarines per year. According to the Virginia-class program office, in 2011 when production of Virginia-class submarines increased to two per year, they experienced "cost and schedule growth at shipyards" (O'Rourke, 2022, p. 17). It is also reasonable to conclude that adding a third submarine to the construction schedule will also result in additional schedule delays.

Risk of Cost Growth

Though the primary focus of the Columbia-class program office is delivering the new SSBNs on time, another concern addressed by the CRS report is the risk of cost overrun. The Columbia-class submarine is the Navy's "top priority program" and, therefore, is a program that "will be funded" (O'Rourke, 2022, p. 18). However, costs exceeding the amount budgeted for the submarine could jeopardize other Navy construction efforts, which could affect the ability of the Navy to realize its strategic vision as currently planned.

The 2019 Congressional Budget Office (CBO) estimate showed that the cost of the first Columbia-class submarine would be "$14 billion, $700 million more than the Navy estimates" (O'Rourke, 2022, p. 20). Though there are many reasons why the Navy may be underestimating its costs according to the CBO, the GAO assesses it is due to at least two factors. The first factor is not being able to take advantage of planned cost savings in the detailed design phase due to delays in disclosure completion (O'Rourke, 2022, p. 15). Second, the GAO assessed that the Columbia-class program office had "overly optimistic assumptions about the labor hours needed to construct the submarines," which were not factored into cost estimates (O'Rourke, 2022, p. 21). As time progressed, the Navy sought to make up for these deficiencies to provide more up-to-date cost estimates. The Columbia program office incorporated the loss of cost savings in the design process and updated the estimates of labor required to complete the first Columbia-class submarine. However, even with these changes, it is important to note that accurate cost estimates are a particularly difficult challenge for any lead ship in a new class. This is primarily due to a host of unanticipated costs that are discovered during the acquisition process, which cause large changes from the initial estimates. From the FY21 budget, when the first Columbia-class submarine was first officially procured, to the most recent FY23 budget, estimated costs have been updated and are steadily increasing, as shown in Table 5.

Table 5. Change in estimated procurement costs since FY2021 budget (millions of then-year dollars, rounded to the nearest tenth). (O'Rourke, 2022)

Boat and budget	Estimated cost	Change from prior year	Cumulative change since FY2021
SSBN-826 (first boat)			
FY21 budget	14,393.4	—	—
FY22 budget	15,030.5	+637.1 (+4.4%)	+637.1 (+4.4%)
FY23 budget	15,179.1	+148.6 (+1.0%)	+785.7 (+5.5%)
SSBN-827 (second boat)			
FY21 budget	9,326.1	—	—
FY22 budget	n/a	n/a	n/a
FY23 budget	9,280.2	n/a	-45.9 (-0.5%)

Source: Table prepared by CRS based on Navy's FY2021-FY2023 budget submissions.
Note: n/a means not available.

These rising costs are concerning due to the impact they might have on the Navy's shipbuilding program at large. Another factor that could lead to increased program costs is the contract type for the first two Columbia-class submarines.

Contract Type

The first two ships in the Columbia-class are being built under cost-plus incentive fee (CPIF) contracts (O'Rourke, 2022, p. 21). A CPIF contract is a "cost-reimbursement contract that provides for the initially negotiated fee to be adjusted later by a formula based on the relationship of total allowable costs to total target costs" (FAR 16.405-1, 2022). CPIF-type contracts transfer cost risks to the government from the contractor, and the government funds development costs within the scope of the contract above the original baseline estimates. In the case of the Columbia-class program, the likelihood of the government incurring costs more than the baseline is high because designing the lead ship in a class is a challenging endeavor, pushing the state of technology and wrought with unforeseen obstacles not initially anticipated.

Potential Impact on Other Navy Shipbuilding Programs

Columbia-class submarines have the potential to represent a substantial portion of the Navy's shipbuilding budget. Discounting the cost of the first Columbia-class submarine, which is most expensive ship in a new class of ships due to including design/nonrecurring engineering costs, producing one Columbia-class submarine will cost about $8 billion per year of the Navy's shipbuilding budget until FY35 when all 12 Columbia-class submarines are scheduled to be completed (O'Rourke, 2022, p. 23). The significance of the cost of the Columbia-class submarine on the shipbuilding efforts of the Navy depends on the actual cost of producing a Columbia-class submarine and the money budgeted in any given year for shipbuilding. The larger the percentage of the Navy's shipbuilding budget the Columbia-class submarine has, the greater the possible impact on overall shipbuilding efforts. In the FY23 budget, the Navy is requesting a shipbuilding budget of $27.9 billion (O'Rourke, 2022, p. 23). Assuming this budget is approved, the Columbia-class represents about 30% of the overall budget. Though how much impact receiving 30% of the allocated budget seriously affects the Navy's shipbuilding program at large is up for debate, it is important to recognize that this percentage could grow, given Columbia procurement cost increases or smaller budgets.

Path Forward

The CNO and the PEO summarized a host of issues standing in between the Columbia-class submarine program and a successful strategic deterrence patrol in 2031. Each issue provided a stressor to at least one side of the triple constraint.

Schedule problems are one of the significant issues facing the Columbia-class submarine program. These schedule delays were caused in part by problems with the software used to design the submarine. The prime contractor's use of a new computer-aided software tool experienced numerous issues, which resulted in delays. The next issue which has and may continue to cause schedule delays and affect performance is the significant strain on the submarine supplier base. The submarine supplier base represented a significant risk to the program. Not only is the construction of the Columbia-class submarine underway, but two Virginia-class submarines are being built per year to replace the aging fast-attack submarine fleet. This smaller supplier base is constantly competing for parts and skilled labor.

Another problem facing the schedule of the Columbia-class program office is the technological risk associated with the new SSBN. One specific risk was the maturity of the electric drive propulsion system. This system is a brand-new method of propulsion for American nuclear submarines, which had previously been powered by steam.

As if the schedule and technical pressures were not enough risk, cost risks existed. Pressure exists to improve the quality of cost estimates. Not accounting for the first submarine, which had an estimated cost of over $14 billion, each subsequent Columbia-class submarine was estimated at $8 billion apiece. The Columbia program represented a sizable portion of the Navy's overall shipbuilding budget, and in a worst-case scenario, would put pressure on other shipbuilding programs and potentially put the Navy's goal of 355 ships by the mid-2050s at risk.

The CNO carefully pondered workable solutions. His principal challenge was to determine who the major stakeholders were, figure out what their concerns were, and discuss with RADM Pappano how to manage within the triple constraints and technological risk for the Columbia-class program in a way that best addresses the most important concerns.

The schedule for the Columbia class was certainly strained. All assumptions for the timely delivery of the Columbia-class submarine were based upon the threat of a strategic deterrence gap in 2031. This need was determined by the JCIDS process and captured in the Columbia-class APB. Would the validity of the need change if the existing Ohio-class SSBNs could extend their service lives any further? The service life of Ohio-class SSBNs was previously extended to accommodate delays in the Columbia-class submarine. Also, would there be any willingness from senior leaders to tolerate a temporary strategic deterrence gap until the Columbia-class submarine is completed? Both choices would lessen schedule pressure.

In addition to seeking to alleviate the schedule strain, the CNO also considered accelerating the development of the Columbia-class submarine by strengthening the submarine shipbuilding industrial base. A more robust industrial base would alleviate material supply issues. The larger industrial base can also increase the quality of its workforce, which would minimize rework, saving time, lowering costs, and increasing overall performance. One way the industrial base could be strengthened is by employing a targeted use of Title III of the Defense Production Act (DPA). According to 50 U.S.C., Title III of the DPA “provides the president a unique and broad authority to ensure the timely availability of essential domestic industrial recourses to support national defense and homeland security requirements through the use of highly tailored economic incentives.” Should a purchase commitment be utilized to “create a guaranteed demand to reduce the risk for industry to make their own investments?” (Lehman, n.d.). Should a direct loan be made to help accommodate for the “the risk tolerance being [beyond that of] the commercial market?” (Lehman, n.d.). Are there other incentives or provisions that should be considered?

A final risk to schedule came from the innovative technologies that were being introduced on the Columbia-class. There were different opinions regarding the technology and manufacturing readiness levels of critical technologies. Is conducting thorough development and operational testing to assess technical performance compliance, operational effectiveness, and operational suitability worth the time and cost investment? If a technical flaw is discovered early, it could save large schedule delays and costs in the future. And if minimizing technology risk was a primary consideration, would there be any interest in canceling the Columbia program and building new Ohio-class submarines? The Ohio-class are considered state-of-the-practice submarines. This would come from decreasing performance requirements, but a new line of Ohio-class submarines could certainly be created by 2031 and at lower cost than Columbia-class submarines.

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Acquisition Research Program
Department of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net