NPS-AM-26-055

# ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

## Future of the Ford-Class Aircraft Carrier Program

March 2025

**LT Brendan Haber, USN**

Thesis Advisors: Dr. Robert F. Mortlock, Professor
Howard Pace, Professor

Department of Defense Management

**Naval Postgraduate School**

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# ABSTRACT

Difficulties managing cost growth, schedule overruns, and performance issues in the Ford-class aircraft carrier program are a critical oversight topic and a key problem area in planning for the Navy's future. While the Navy is conducting research and focusing efforts on managing cost growth in production, further research is needed into the program management structure and utilization of current acquisition policy and guidance to assess possible courses of action. A case study analysis of the Ford-class program—contextualized by a review of current literature to include acquisition policy—identified the various constraints, priorities, and impacts of acquisition strategy decisions to provide insight into future courses of action and objectives required for program success. The program has seen poor outcomes, primarily due to external pressure and an inability to mitigate constraints despite conducting detailed planning for tailored acquisition strategies. Changes are recommended to the current utilization of the Major Capability Acquisition pathway and organization of program offices and support staff to provide a clearly structured framework that mitigates constraints on the design and build process of Ford-class aircraft carriers.

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAF | adaptive acquisition framework |
| AAG | advanced arresting gear |
| ACIBC | Aircraft Carrier Industrial Base Coalition |
| AOA | Analysis of Alternatives |
| APB | acquisition program baseline |
| BUR | Bottom-Up Review |
| CEC | Cooperative Engagement Capability |
| CNO | Chief of Naval Operations |
| DAS | Defense Acquisition System |
| DAU | Defense Acquisition University |
| DBR | dual band radar |
| DD&C | Detail Design and Construction |
| DES | Digital Engineering Strategy |
| DoD | Department of Defense |
| DON | Department of the Navy |
| DOT&E | Office of the Director, Operational Test and Evaluation |
| DSP | Defense Standardization Program |
| EASR | Enterprise Air Surveillance Radar |
| EMALS | Electro-Magnetic Aircraft Launching System |
| EOA | Early Operational Assessment |
| ESSM | Evolved Sea Sparrow Missile |
| FY | fiscal year |
| GAO | Government Accountability Office |
| HII | Huntington Ingalls Industries |
| iDS | Integrated Digital Shipbuilding |
| IOC | initial operational capability |
| LRIP | low-rate initial production |
| MCA | Major Capability Acquisition |
| MDA | Milestone Decision Authority |
| MDAP | Major Defense Acquisition Program |

| | |
|---|---|
| MNS | Mission Need Statement |
| MOSA | Modular Open Systems Approach |
| MTA | Middle Tier of Acquisition |
| NAVSEA | Naval Sea Systems Command |
| NNS | Newport News Shipbuilding |
| NRAC | Naval Research Advisory Committee |
| OSD | Office of the Secretary of Defense |
| OUSD(A&S) | Office of the Under Secretary of Defense for Acquisition and Sustainment |
| OUSD(A&T) | Office of the Under Secretary of Defense for Acquisition and Technology |
| OUSD(AT&L) | Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics |
| OUSD(R&D) | Office of the Under Secretary of Defense for Research and Development |
| P3I | Pre-Planned Product Improvement |
| PM | program manager |
| PSA | post-shakedown availability |
| R&D | research and development |
| RAM | Rolling Airframe Missile |
| RCOH | refueling and complex overhaul |
| SECNAV | Office of the Secretary of the Navy |
| SSDS | Ship Self-Defense System |
| SUPSHIP | Supervisor of Shipbuilding, Conversion and Repair |
| TEMP | Test and Evaluation Master Plan |
| TRL | technology readiness levels |
| UCA | Urgent Capability Acquisition |

# I. INTRODUCTION

The Congressional Budget Office (CBO) analysis of the Navy's fiscal year (FY) 2024 shipbuilding plan describes aircraft carriers as "the heart of the battle force" (Labs, 2023, p. 37). As the Nimitz class reaches the end of its planned life cycle, the Ford class is intended to be a direct replacement by using a Nimitz hull and incorporating new design features and improvements (O'Rourke, 2024), as shown in Figure 1. Due to the critical importance of aircraft carriers to the Navy, the cost growth, schedule overruns, and performance issues surrounding USS *Gerald R. Ford* (CVN 78) and the follow-on ships in the class have become a key oversight topic.

Figure 1. USS *Harry S. Truman* (CVN 75) of the Nimitz class (top) and *Gerald R. Ford* of the Ford class (bottom). Source: Esposito (2020).

## A. PROBLEM STATEMENT

A Congressional Research Service (CRS) report written by Ronald O'Rourke, updated March 2024, lists the issues that Congress should assess prior to decisions on the procurement of future carriers as the carrier force level, program cost growth, deployment delays, and test and evaluation concerns from the Office of the Director, Operational Test and Evaluation (DOT&E). The Navy is conducting various studies to address these concerns and determine how the Navy can best achieve necessary operational concepts like distributed maritime operations in the future (Office of the Chief of Naval Operations [OPNAV], 2023). The FY23 National Defense Authorization Act (NDAA) additionally established a Commission on the Future of the Navy that will independently study the Navy's ship and aviation force structure for Congress (O'Rourke, 2024).

The Navy's ability to manage costs in the Ford-class program and deliver the desired capabilities will have a direct impact on decision-making related to aircraft carrier force levels and the Navy's overall composition. The O'Rourke oversight reporting (2024) identifies that the implementation of various changes to the build and buy strategies for future carrier procurement is planned by the Navy to allow for more accurate cost estimates, solve identified cost drivers, and improve efficiencies in the construction process. However, further research must also examine the program management framework utilized for the Ford class and the acquisition strategy decisions that affect the management of cost growth and other program issues in execution. Research into the program management framework will allow additional assessment into courses of action for the program and provide insights into the Department of Defense's (DoD) current policies related to the acquisition of complex weapons systems.

## B. RESEARCH OBJECTIVES

The primary objective of this research is to determine how the Ford class can best utilize the adaptive acquisition framework (AAF) moving forward to maintain the acquisition program baseline (APB).

### 1. Primary Research Question

- How can the Ford-class CVN program tailor its acquisition strategies moving forward to achieve the program's required cost, schedule, and performance baselines over the full life cycle?

The secondary research objectives are to study the impacts of acquisition strategy decisions over the course of the program so far to assess various courses of action for the program moving forward to enable success in both this program and similar acquisitions in the future.

### 2. Secondary Research Questions

- What constraints impacted program decisions and how did the program prioritize cost, schedule, and performance?
- How has the program used the principles of incremental development, evolutionary acquisition, and modular open systems approach?
- How have acquisition strategy decisions affected integration of critical technology and how do the technologies relate to the Key Performance Parameters?
- How have constraints on the program changed and what acquisition strategy updates have been made over the life of the program?

## C. METHODOLOGY

The primary focus of this research is an examination of the Ford program case history as it relates to program decision-making and acquisition strategy changes to contextualize the management of the Ford program so far. The case study approach is intended to be both a research strategy and a methodology for data collection to be descriptive, explanatory, and exploratory in the assessment of the management framework being utilized (Priya, 2021).

Using a case study approach also enables an assessment of the processes, practices, and interactions of the program to enable a root cause analysis of decisions and provide an interpretation of the connection between decisions and outcomes (Njie & Asimiran, 2014). Finally, an assessment of root causes will enable a discussion of recommendations to provide a way forward for program management in the production of future carriers of the Ford class.

## D. SCOPE AND LIMITATIONS

The scope of this research is intended to be a high-level assessment of the acquisition strategies and management framework utilized by the Ford class to make decisions and provide oversight during program execution. Analysis is limited by the availability of information reported in program documents and in assessments conducted by other oversight agencies, and the underlying factors behind decisions made throughout the course of the program may be hidden due to a lack of in-depth reporting. Program recommendations are based on what is allowed within existing policy and guidance.

## E. ORGANIZATION

This study is organized into five chapters, which provide background and contextualize information before presenting an analysis and concluding recommendations.

- Chapter I provides an introduction of the problems driving this research, the research objectives and associated questions, the methodology utilized to achieve the end objectives, and the scope and limitations.
- Chapter II describes the background of the Ford-class program and the rationale that forms the specific objectives of this research, as differentiated from other studies currently being conducted by the Navy.
- Chapter III provides a review of literature related to acquisition strategies and the program management framework to provide context for further analysis into the Ford's case history and an assessment of the way forward.
- Chapter IV provides analysis of the Ford program structure and acquisition strategy decision making related to program constraints and cost, schedule, and performance priorities.
- Chapter V provides conclusions based on the current literature, the Ford program structure, and the outcomes of the program so far to determine recommendations for the Ford program to mitigate constraints and maintain baselines over the full life cycle of the class.

# II. BACKGROUND

The Ford class serves as the successor to the current Nimitz supercarrier, maintaining the Navy's force-level requirements as the older class of ships decommissions (O'Rourke, 2024). The program began in 1996 with a Milestone 0, the old decision point used by the Navy to begin planning and identifying requirements, before the approval in 1998 of a large-capacity carrier based on a Nimitz-class hull and using an evolutionary acquisition strategy for technology integration (Department of the Navy [DON], 2023). However, following the 2000 Milestone I approval as the CVNX Future Aircraft Carrier, what would now be considered Milestone A approval, a 2002 Program Decision Memorandum (PDM) updated it to the new designation of CVN 21 (DON, 2023). Additionally, the evolutionary acquisition strategy changed in favor of taking technologies planned for the second ship and integrating them directly into the lead ship, with follow-on vessels as a repeated design (DON, 2023).

## A. LEAD SHIP (CVN 78)

In 2004, the Milestone B decision approved the APB and a low-rate initial production (LRIP) quantity of three ships (DON, 2023). The lead ship, CVN 78, received authorization for production in 2008, with the Detail Design and Construction (DD&C) contract awarded that year, and launched in 2013 before eventual acceptance by the Navy in 2017 (DON, 2023). This delivery was three years behind the original baseline of 2014, and the estimated procurement cost of CVN 78 had grown by 27% over the original FY08 budget request (O'Rourke, 2024). Additionally, CVN 78 did not achieve initial operational capability (IOC) until December 2021, four years after the baseline, with the first deployment delayed due to technical problems with various systems, to include the advanced weapons elevators (O'Rourke, 2024). In fact, despite getting underway for its first full-length deployment in May 2023, the ship is not yet at full operational capability, and the Government Accountability Office (GAO) 2023 weapons system assessment indicated concerns that the Ford's key systems are "about a decade away from demonstrating their reliability" (p. 142). While the lead ship, CVN 78, has been working through testing and evaluation for IOC and the first deployments, the program has been proceeding with the procurement of the remaining ships of the LRIP.

## B. FOLLOW-ON SHIPS

The second ship of the Ford class, CVN 79 (Figure 2), was launched in December 2019, two months ahead of the updated baseline, but has transitioned to a single-phase delivery from the planned two-phase delivery, with the delivery date adjusted to July 2025 to support an updated build and delivery strategy (DON, 2023).

Figure 2. USS *John F. Kennedy* (CVN 79) launches into the James River. Source: Cowan (2019).

According to DOT&E, current planning for the Ford class includes numerous changes to CVN 79, including a radar replacement, a baseline upgrade of the Ship Self-Defense System (SSDS), a block upgrade of the Cooperative Engagement Capability (CEC) system, and variant and block upgrades of the Rolling Airframe Missile (RAM) and

Evolved Sea Sparrow Missile (ESSM) systems (Office of the Director, Operational Test and Evaluation [DOT&E], 2022). These changes will establish CVN 79 as the enduring self-defense configuration for the follow-on ships of the class and require an eventual upgrade to CVN 78 to match the new configuration baseline (DOT&E, 2022). O'Rourke (2024) also estimated cost growth for CVN 79 at 38.2% due to the new program efforts and planned changes.

Additionally, the Navy intends to reduce costs through a two-ship buy strategy for CVN 80 and CVN 81, increasing the number of LRIP ships to four from the previously approved three (DON, 2023). The two-ship buy strategy is also being paired with contractor efforts to implement Integrated Digital Shipbuilding (iDS) to meet cost targets, with the system advertised as "a new set of tools that will improve the efficiency of the construction planning and execution process" (DON, 2023, p. 7). Updated budget submissions for procurement of the two ships now estimate a reduction of $3–4 billion (O'Rourke, 2024).

## C. RESEARCH RATIONALE

The primary focus of corrective efforts for the Ford program has been on cost estimating and solving the cost drivers during the construction process. Program reporting of costs has indicated that the cost growth has primarily occurred during the construction process, requiring two cost cap increases during the CVN 78 construction window from 2008–2014, as shown in Figure 3, with the Navy attributing growth "to construction cost overruns and economic inflation" (GAO, 2017b, p. 15). This attribution has been the impetus behind the Navy's efforts to work with the contractor on the build strategy and develop a two-ship buy strategy to improve efficiency in the construction process.

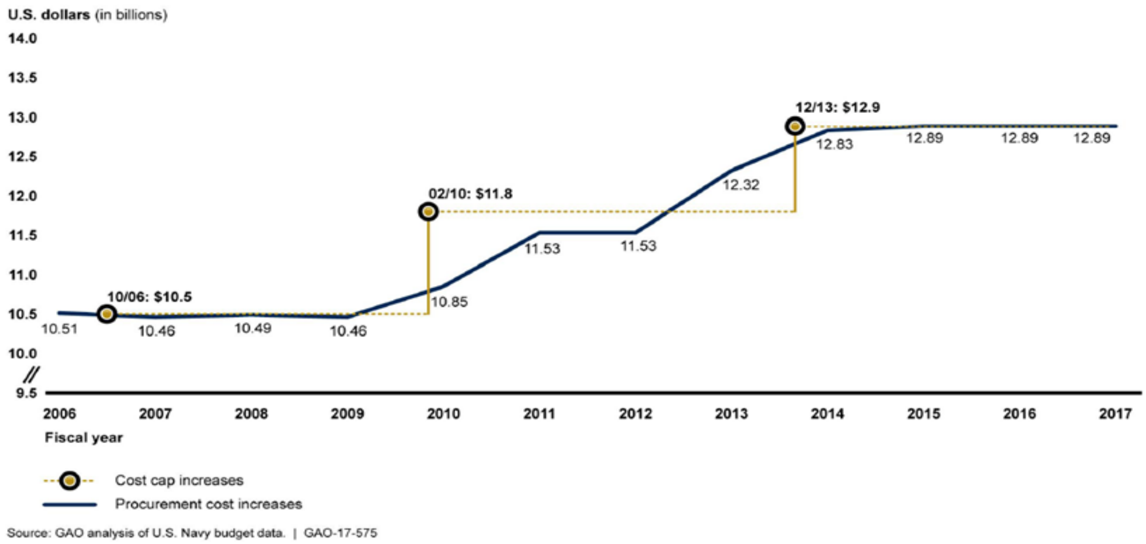


Figure 3. *Gerald R. Ford* Procurement Costs and Congressional Cap Increases. Source: GAO (2017b).

While the GAO (2017b) has conducted extensive research into cost estimate accuracy and cost drivers, concerns were also expressed regarding the program management structure and when costs were being estimated in relation to milestone decisions and funding. The GAO (2017b) also reported that between the Milestone B decision in 2004 and the planned Milestone C decision in 2015, no independent cost estimates were developed due to the lack of requirement for an estimate.

Additionally, since the Ford program is currently being managed as a single MDAP, as shown in Figure 4, there would also be no future milestone events after Milestone C and, therefore, no further requirement for independent cost estimates of individual ships (GAO, 2017b). Although the GAO (2017b) brought up the concept of each carrier being designated as its own MDAP, with the corresponding individual milestones aligned with funding decisions, no additional research has been conducted to make recommendations regarding the program framework.

A CRS report in 2016 (Peters & O'Connor) related to Nunn-McCurdy reporting made a similar recommendation to "consider designating individual carrier procurement efforts as major subprograms for purposes of Nunn-McCurdy reporting requirements" (p. 20). Despite excessive cost growth in CVN 78 and CVN 79 there was no breach as "each ship is part of a larger multi-ship acquisition program, the full program has not breached the Nunn-McCurdy thresholds" (Peters & O'Connor, 2016, p. 20).

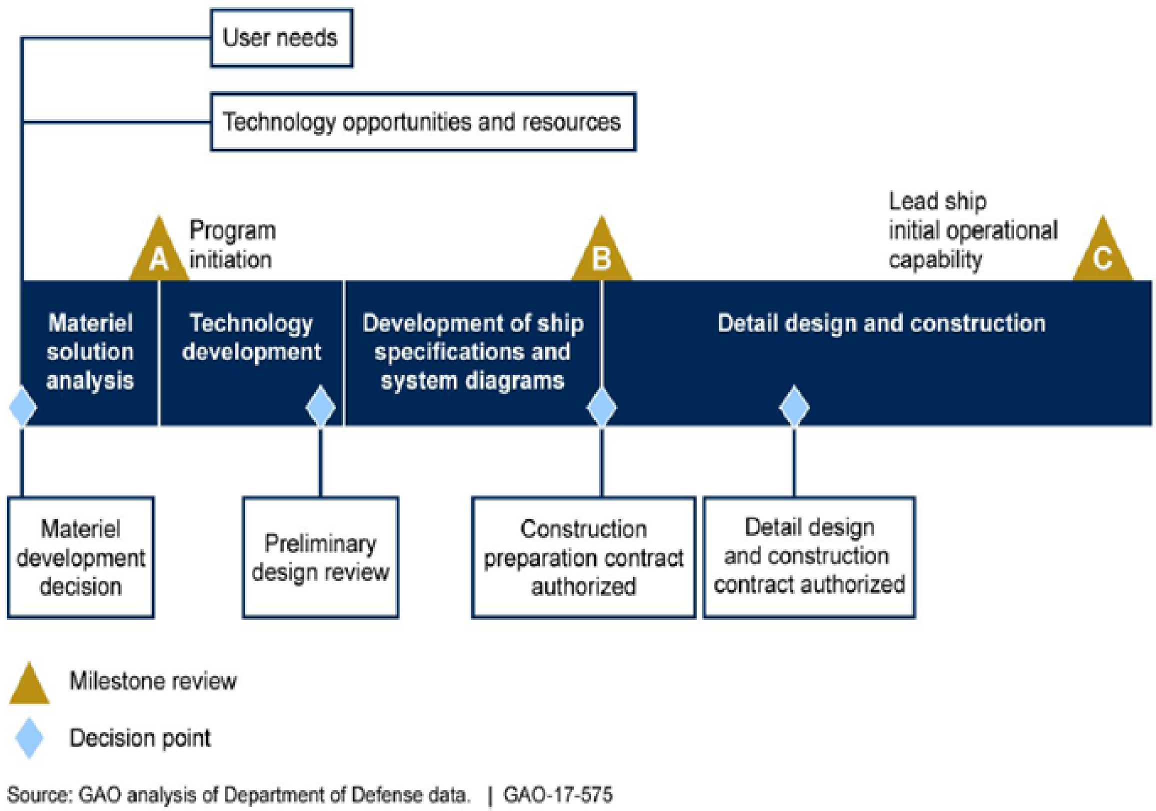


Figure 4. Acquisition Framework for Ford-Class Carrier Program. Source: GAO (2017b).

Concerns regarding the management structure and decision-making rationale for the Ford class were also brought up by Paul Francis, managing director for the GAO's Acquisition and Sourcing Management team, in his testimony to the Senate in 2015. He stated that the cost, schedule, and performance issues seen with the Ford were a result of "unexecutable business cases in which ship construction begins prior to demonstrating key knowledge, resulting in costly, time-consuming, and out-of-sequence work during construction and undesired capability tradeoffs" (Francis, 2015, p. 12). Additionally, these results are despite reforms to the acquisition framework because the Ford class "illustrate(s) the limits of focusing on policy-and-practice related aspects of weapon system development without understanding incentives," as "strong incentives encourage deviations from sound acquisition practices" (Francis, 2015, p. 13).

These assessments indicate that there is additional research that should be conducted into the acquisition strategies used to manage the Ford-class program. A review of current AAF guidance from the DoD and DON and how that guidance supports engineering approaches and acquisition strategies related to Navy shipbuilding will help contextualize the strategies and decisions made by the Ford program in an analysis of the program's case history.

# III. LITERATURE REVIEW

This literature examines the DoD policy documents that govern acquisition management and various reforms to the governance process that have occurred over the course of the Ford-class program. The review is intended to look at the top-level guidance that provides context to decisions made for the acquisition strategy of the Ford class, as well as the underlying principles used by the DoD to achieve acquisition objectives. Research into those underlying principles is analyzed to determine what literature exists that can inform the intent behind the DoD's reforms and where gaps exist in the research regarding what the DoD policy currently states compared to what prior research recommends.

## A. ADAPTIVE ACQUISITION FRAMEWORK

DoD Directive (DoDD) 5000.01, *The Defense Acquisition System* (DAS), is the current DoD publication from the Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD[A&S]; 2022a) that governs DoD acquisitions. It is in this publication that the guidance is given to utilize an "adaptive acquisition framework [AAF]" to support the desired principles of the DAS (OUSD[A&S], 2022a, p. 4). DoD Instruction (DoDI) 5000.02, *Operation of the Adaptive Acquisition Framework*, is now the publication that provides detailed guidance on how the AAF should be utilized by the DoD to achieve acquisition objectives while still giving "Milestone Decision Authorities (MDAs), other Decision Authorities (DAs), and Program Managers (PMs) … broad authority to plan and manage their programs consistent with sound business practice" (OUSD[A&S], 2022b, p. 4).

Prior to the most recent reforms that added the AAF, DoDI 5000.02 was a more robust single document intended to provide "overarching management principles and mandatory policies that govern the Defense Acquisition System" (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 2013, p. 2). For example, in the 150-page 2013 Interim DoDI 5000.02, *Operation of the Defense Acquisition System*, the guidance included a "Generic Acquisition Phases and Decision

Points" chart as well as baseline models and hybrid models of acquisition approaches that are "tailored to the dominant characteristics of the product being acquired" (OUSD[AT&L], 2013, p. 9). Mortlock's 2020 research, "Studying Acquisition Strategy Formulation of Incremental Development Approaches," which was presented in the *Defense Acquisition Research Journal*, identified that the older DoDD 5000.01 and DoDI 5000.02 publications provided clear emphasis on utilizing evolutionary acquisition strategies with incremental development. Mortlock (2020) examined the challenges in previous DoD guidance related to how PMs should implement an incremental development/evolutionary acquisition strategy based on the specific program requirements.

The guidance in the 2022 DoDI 5000.02 still directs MDAs to "tailor program strategies and oversight, phase content, the timing and scope of decision reviews, and decision levels based on the characteristics of the capability being acquired" (OUSD[A&S], 2022b, p. 9). Additionally, the procedural guidance now states that "PMs will develop an acquisition strategy for MDA approval that matches the acquisition pathway … processes, reviews, documents, and metrics to the character and risk of the capability being acquired" with six pathways provided for selection, as shown in Figure 5 (OUSD[A&S], 2022b, p. 10). The Navy also has its own supplementary instruction, Secretary of the Navy Instruction (SECNAVINST) 5000.02G, *Department of the Navy Implementation of the Defense Acquisition System and the Adaptive Acquisition Framework*, which is designed to nest under the DoD instructions for Department of the Navy (DON) acquisition programs utilizing the AAF pathways (Office of the Secretary of the Navy, 2022). SECNAVINST 5000.02G focuses initially on how the Navy's Urgent Needs Process (UNP) and Urgent Operational Need (UON) submissions should align with the Urgent Capability Acquisition (UCA) pathway included in the AAF; the document then transitions to providing amplification on the roles and responsibilities, entry requirements, approval authorities, and more for the Navy's implementation of the AAF in compliance with the DoD instructions (Office of the Secretary of the Navy [SECNAV], 2022).

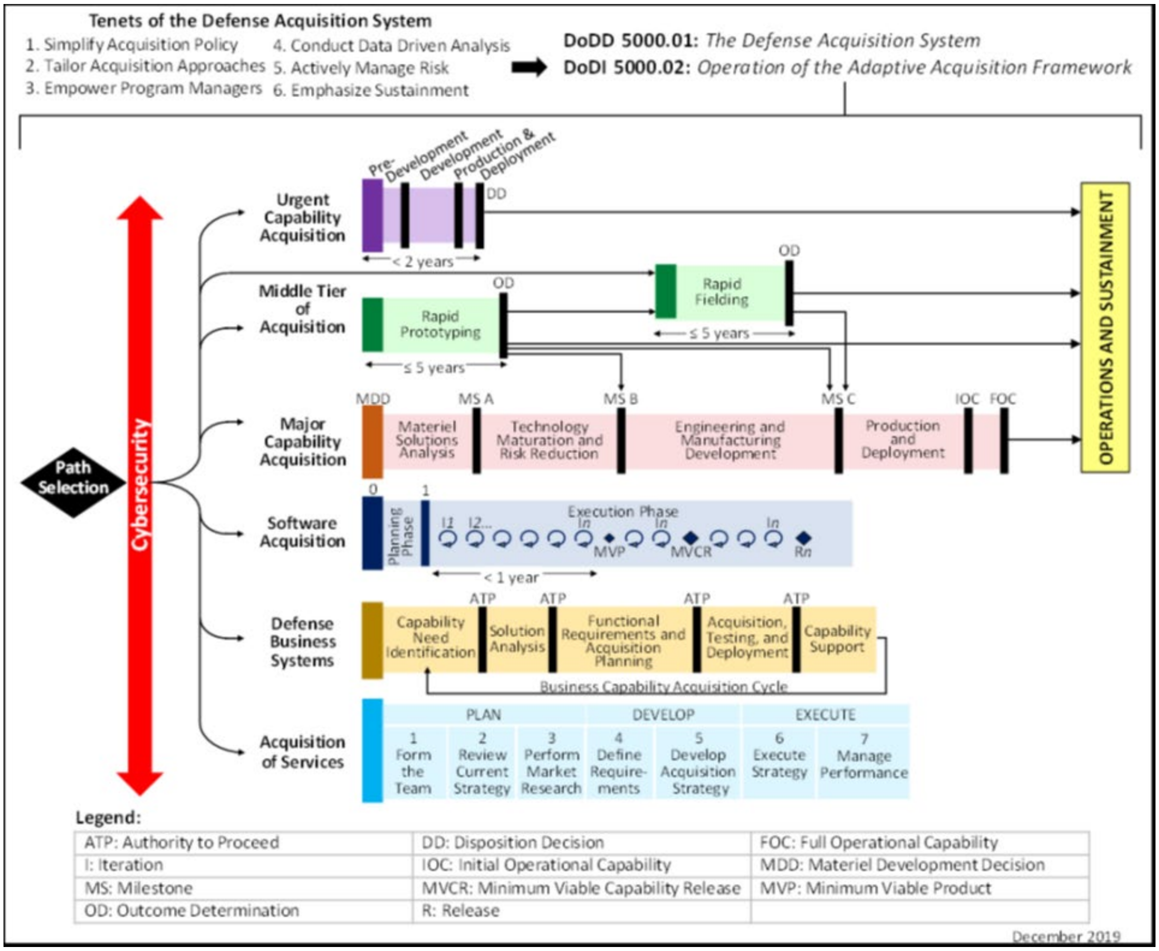


Figure 5. Adaptive Acquisition Framework. Source: OUSD(A&S) (2022b).

While guidance in how to utilize the AAF does state that PMs "may leverage a combination of acquisition pathways to provide value not otherwise available through use of a single pathway," no additional models or hybrid examples are provided (OUSD[A&S], 2022b, p. 10). Additionally, DoDI 5000.01 now has a single reference on how to "enable incremental acquisition strategies and continuous capability improvement," with no other references to tailoring strategies for incremental development/evolutionary acquisition (OUSD[A&S], 2022a, p. 5). DoDI 5000.02 has no references to incremental development/evolutionary acquisition strategy, instead focusing on tailoring individual pathways or combining pathways to achieve acquisition objectives (OUSD[A&S], 2022b). The individual publication for the pathway utilized by the Ford-class program, DoDI

5000.85, *Major Capability Acquisition* (MCA), similarly only provides a model for the standard MCA pathway (see Figure 6; OUSD[A&S], 2021).

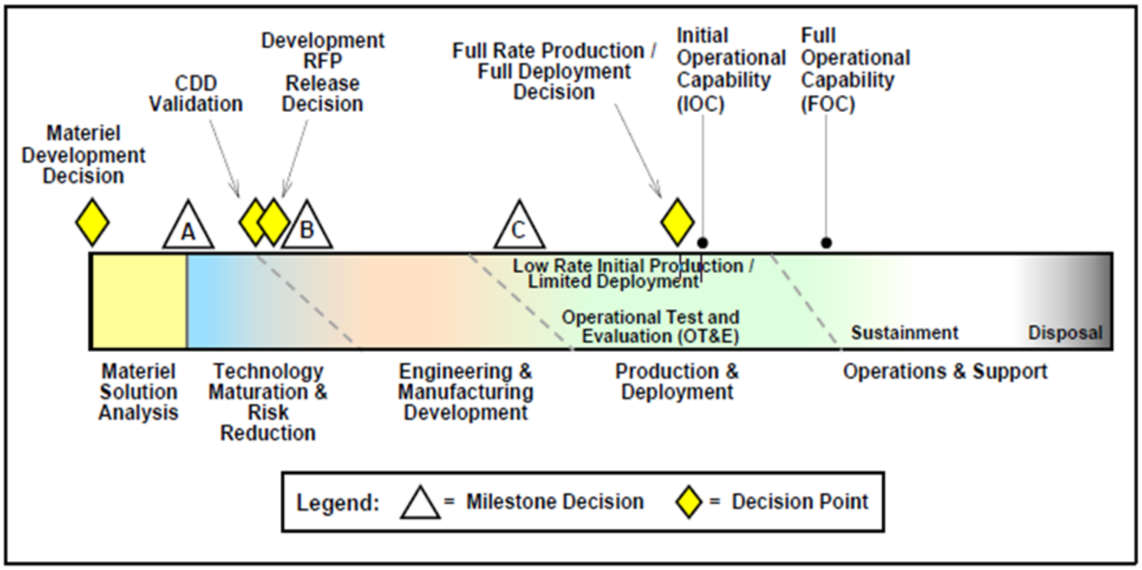


Figure 6. Major Capability Acquisition Model. Source: OUSD(A&S) (2021).

The Navy uses a Two-Pass Seven-Gate governance process to "provide an integrated, collaborative, and disciplined framework for DON senior leaders … to make sound investment decisions" in alignment with the milestones and decision point guidance required for the MCA pathway (SECNAV, 2022, p. 156). Figure 7 is included in SECNAVINST 5000.02G to display the DON decision gates and other reviews required over the program life cycle across the phases of the MCA.

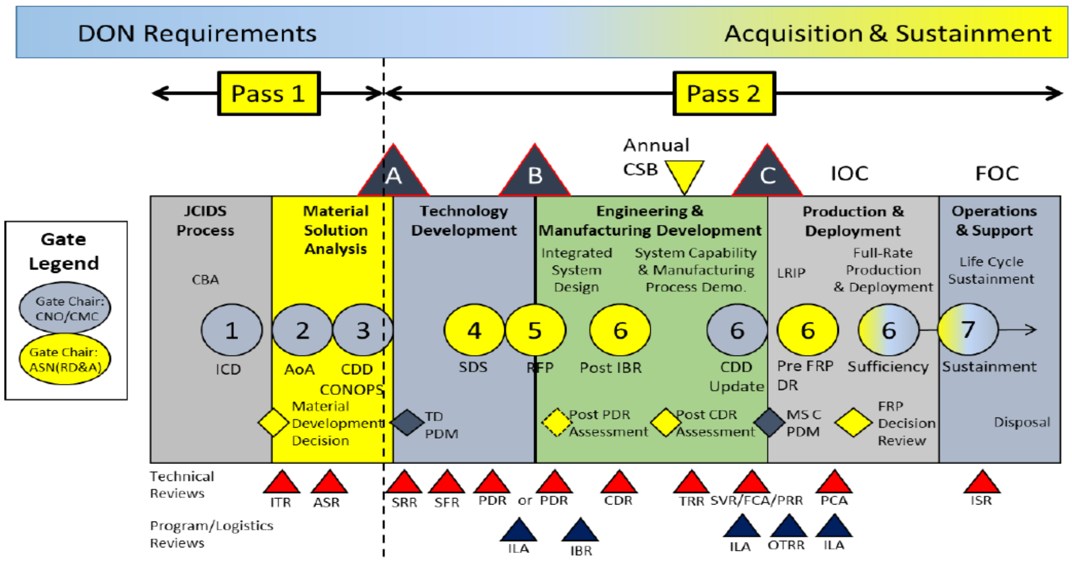


Figure 7. Navy Two-Pass Seven-Gate Process. Source: SECNAV (2022).

While the Navy's guidance includes language on how PMs are allowed to tailor requirements, no other models are presented on how the tailoring could be applied over the life cycle of a program using the MCA pathway. The instruction instead states that for shipbuilding considerations, "tailoring will ensure all statutory reporting, decisions, and sustainment requirements are satisfied by utilizing Gate reviews, in-progress reviews, or other program events" and that while "reviews and decisions might not occur in the same sequence as other MDAPs … tailoring shall describe the timing of these program reviews and decision points" (SECNAV, 2022, p. 35). A presentation created by the OUSD(A&S; 2023) on the overview of the AAF, *Adaptive Acquisition Framework (AAF) 101 Brief*, provides an example model of MCA with an increment 2, as shown in Figure 8; however, the model presented is primarily focused on combining pathways from the guidance in DoDI 5000.02 to demonstrate technologies before an on-ramp to the MCA pathway.

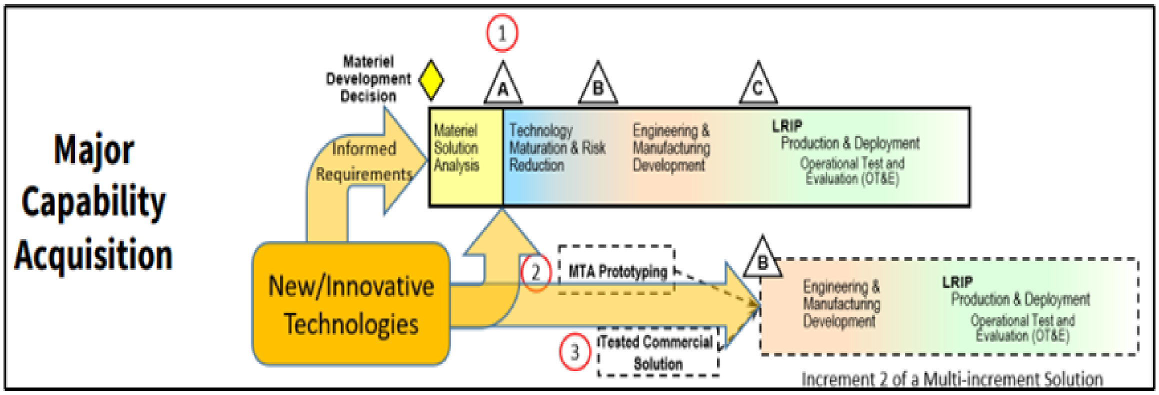


Figure 8. AAF 101 MCA Model Example. Source: OUSD(A&S) (2023).

A GAO report on acquisition reform in December 2024 found that programs actually use the Defense Acquisition University (DAU) for a lot of "AAF-related training and other reference materials, such as documentation requirements for different pathways and guidance on selecting, using, and tailoring the pathways" (2024a, p. 14). However, no models for how to tailor the MCA pathway, outside of the standard MCA models from current guidance, are available from the DAU. The DAU (n.d.) does still maintain a full life-cycle overview of MCA, which was previously contained in an older version of DoDI 5000.02, to provide a more in-depth view of all program activities, reviews, decision points, and milestones across the phases (see Figure 9).

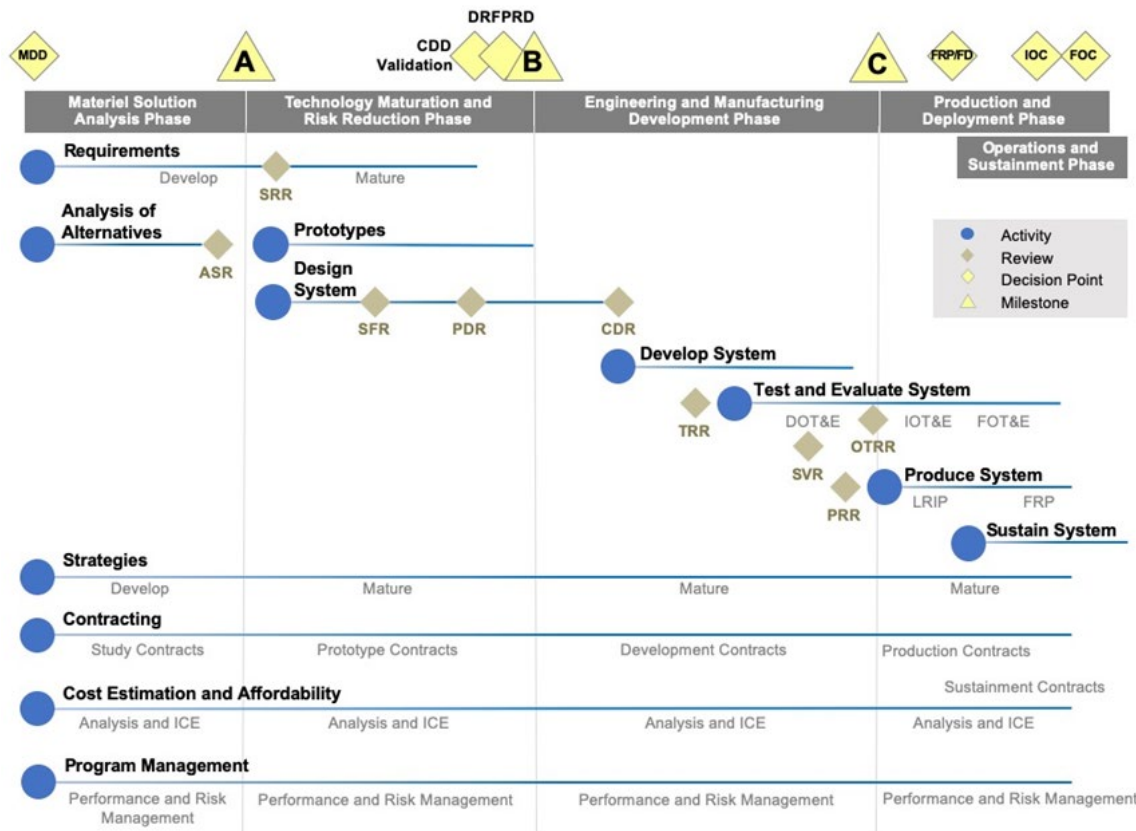


Figure 9. Life-Cycle View of Major Capability Acquisition. Source: Defense Acquisition University (DAU) (n.d.).

DAU's 2024 *Guide to Program Management Business Processes* separately provides guidance on tailoring, calling it a "technique used to streamline certain acquisition processes, documents, work efforts and reviews…to minimize the time it takes to deliver a materiel solution" (p. 57). The guidance also notes that "tailoring has been constrained in a risk-adverse environment coupled with bureaucratic processes for decision making" and "may require…time educating stakeholders on the benefits and risk factors" (DAU, 2024, p. 57). A 2015 RAND study on tailoring in DoD identified that "PMs do not have the time or incentive 'to fight the gauntlet' up to [the Office of the Secretary of Defense (OSD)] through the service approval process" and instead typically "take the path of least resistance, which is to 'check all the boxes' or 'follow the cookbook' to get to the next milestone" (McKernan et al., 2015, p. 31). Additionally, the study found it was commonly believed that "support contractors frequently write acquisition documentation" while government officials focus more time on “executing the program and less time fulfilling oversight requirements” (McKernan et al., 2015, p. 32). This “cottage industry” could also be a process that “hinders tailoring because it removes the link between document development and program planning” (McKernan et al., 2015, p. 32).

The DoDI 5000.85 guidance for the MCA pathway provides overarching guidance on developing a program strategy utilizing the standard model provided (see Figure 6). Flexibility is provided in the option to develop technologies separately through Rapid Prototyping or Middle Tier of Acquisition (MTA) (Ref DoDI 5000.80) before transitioning to MCA to support a strategy that can “incrementally improve a program capability in support of approved requirements or support the development and insertion of more efficient program components” (OUSD[A&S], 2021, p. 9). This flexibility is mirrored in the SECNAVINST 5000.02G guidance that allows for transitions from Rapid Prototyping into Rapid Fielding, MCA, or sustainment, as well as for “transitioning successful [Rapid Fielding] programs to operations and sustainment and, when applicable, to the MCA pathway” (SECNAV, 2022, p. 8-9). Otherwise, the MCA pathway guidance does not provide any additional incremental development/evolutionary acquisition concepts for use by PMs, instead referencing the statute requirement to utilize a Modular Open Systems Approach (MOSA) that can separately enable incremental development/evolutionary acquisition principles (OUSD[A&S], 2021).

## B. MODULAR OPEN SYSTEMS APPROACH

According to the DoD Defense Standardization Program (DSP), MOSA is the approach implemented by the DoD to utilize open systems as required by law, in order to design systems that are both more affordable and adaptable. In accordance with the law, “all major defense acquisition programs (MDAP) are to be designed and developed using a MOSA” (Defense Standardization Program [DSP], n.d., para. 1). One of the objectives that is important for acquisition programs is to utilize a MOSA strategy that “allows severable major system components at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation” (DSP, n.d., para. 7).

The guidance provided in DoDI 5000.85 is in alignment with the description of MOSA from the DSP, stating that the strategy for applicable MDAPs "must be designed and developed with MOSA to the maximum extent practicable" in order "to enable incremental development, and to enhance competition, innovation, and interoperability" (OUSD[A&S], 2021, p. 26). The guidance also states that the MDAP strategy needs to describe "the evolution of capabilities that will be added, removed, or replaced in future increments" and "the additional major system components that may be added later in the life cycle" (OUSD[A&S], 2021, p. 26). While MOSA is given as a requirement, minimal additional guidance is provided on how AAF pathways could or should be adjusted based on the utilization of MOSA in the acquisition strategy to enable evolutionary acquisition and incremental development concepts. In fact, despite DoDI 5000.85 stating that one of the main policy objectives is "continuous adaptation, and frequent modular upgrades," the framework for MCA has no milestone or decision points to enable oversight of a continuous development or upgrade process, and no additional models are provided as examples (OUSD[A&S], 2021, p. 4).

Although research on the implementation of MOSA in DoD acquisitions has identified the need for "a comprehensive decision-making framework that can provide guidance to program managers in defense acquisition," the AAF does not seem to have any specific reforms designed to provide better guidance for implementing MOSA with the provided pathways (Davendralingam et al., 2019, p. 389). According to Davendralingam et al. (2019), the DoD's MOSA strategy relies on five principles that must be driven by the PM to achieve successful implementation. These principles are establishing an enabling environment; employing a design with modules that are cohesive, encapsulated, self-contained, and highly binned for reusability; having interfaces between modules designated by the program manager; using open interface standards; and having conformance characteristics that can be externally certified through a verification and validation process (Davendralingam et al., 2019, p. 395).

Like the DoD instructions, the guidance provided in SECNAVINST 5000.02G does not have any examples of how AAF pathways could or should be tailored to support the implementation of MOSA in line with the desired principles shown in the research. The

Navy instruction does, however, include guidance connecting the implementation of MOSA to a requirement to "ensure opportunities for application of Digital Systems Engineering approaches, including Model-Based Systems Engineering" in order to "digitally represent the system of interest in a model that describes and defines major system components and interfaces, to the maximum extent practicable, to support integration, interoperability and future upgradeability" (SECNAV, 2022, p. 64). While the instruction does not provide any models depicting how the program management structure of the AAF pathways can be tailored to enable MOSA, the guidance does provide a better explanation of the use of digital engineering practices to meet the requirements of using "Modular Open Systems Approach (MOSA) design principles" with systems engineering, as well as meeting program management requirements where the PM needs to "incorporate MOSA requirements when developing contract requirements and source selection criteria" (SECNAV, 2022, p. 64).

## C. INCREMENTAL DEVELOPMENT AND EVOLUTIONARY ACQUISITION

While MOSA is a newer adoption by the DoD to enable development objectives, the underlying concepts of incremental development/evolutionary acquisition have been explored by the DoD for decades. In fact, the DoD conducted research into the implementation of Pre-Planned Product Improvement (P3I) or Modular Evolutionary Development as far back as the 1980s, attempting to identify "a strategy of system design and improvement with the potential to significantly increase system quality and at the same time decrease total life cycle cost" to compete with the Soviet Union (Sickels, 1981, Abstract). Leading up to the more recent reforms with the DAS, the General Accounting Office in 1999 assessed the DoD's ability to integrate key technologies into weapons systems, referencing the intent of the Office of the Under Secretary of Defense for Acquisition and Technology (OUSD[A&T]) to update DoD policy in line with "the practices of leading commercial firms … taking a more evolutionary approach to developing weapon systems" in order to "reduce the tendency to add technological advances that are unproven and immature into weapon acquisition programs" (p. 18).

Following some initial confusion with the adoption of the new guidance, a 2002 memo from E.C. Aldridge, Jr., the new, at that time, Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]), provided amplification on the updates that had "established a preference for the use of evolutionary acquisition strategies" (p. 1). The memo stated that P3I was the traditional method and provided the definitions for Evolutionary Acquisition, Spiral Development, and Increment or Block, indicating that the new evolutionary acquisition strategy was "focused on providing the warfighter with an initial capability which may be less than the full requirement as a trade-off for earlier delivery, agility, affordability, and risk reduction" (Aldridge, Jr., 2002, p. 1).

Research in 2004 on the use of evolutionary acquisition in Air Force programs provided recommendations that aligned with the further DAS. Some of the recommended keys to success were flexibility paired with accountability, early testing, open systems architecture, stable funding, and requirements throughout development, and, finally, an overarching culture change in terms of what success looks like for technology development and implementation (Novak et al., 2004). Research in 2006 specific to testing with evolutionary acquisition also provided a recommendation that aligns with the AAF pathway reforms, stating that DoD policy should "explicitly recognize and accommodate a framework in which the primary goal of all acquisition testing and evaluation programs is to experiment, learn about the strengths and weaknesses of system components, and to incorporate these results into system enhancement initiatives" (Nair & Cohen, 2006, p. 3). Additionally, the researchers identified that the desired "evolutionary acquisition framework ideally allows for a fielded system to undergo further improvement without initiating a new procurement program" (Nair & Cohen, 2006, p. 10).

The SECNAVINST 5000.02G guidance for the Navy's implementation of the DAS has deleted direct references to the use of incremental development or evolutionary acquisition. However, the Navy instruction does include guidance for reporting that "new, improved capability, or capability modifications for a system, regardless of whether additional quantities are procured, will not be acquired under a non-reporting program" but must "be managed as a separate program within an appropriate AAF pathway or as a part of the original program" (SECNAV, 2022, p. 38). A *capability modification* is then also defined as either "acquiring new or improved capability (e.g., upgrades, increments, engineering change proposals, pre-planned product improvements) that materially changes system performance," referencing both increments and the older concept of P3I, or "changing the system's operating environment" (SECNAV, 2022, p. 38).

## D. NAVY SHIPBUILDING

While the Navy's guidance in SECNAVINST 5000.02G is designed to align with the overarching requirements in the DoDI 5000 series, there is clear recognition that shipbuilding has "unique considerations" for tailoring, "such as combining development and initial production investment commitments and a combined Milestone B and C" (SECNAV, 2022, p. 35). Additionally, specific requirements exist for situations unique to shipbuilding, like the concept of a "first-in-class," with a "First Ship in Shipbuilding Program Report" due to Congress "at least 30 days prior to the approval of the start of construction of the first ship for any major shipbuilding program" (SECNAV, 2022, p. 34). The GAO (2018a) reported that "nearly all of the Navy's recent lead ships have experienced cost growth" (p. 8) and while lessons learned reduced growth in follow-on ships, the costs had "generally still been higher than the Navy's initial planned cost per ship for the class" (p. 8). Additionally, all eight lead ships reviewed by the GAO in the report were delivered late, and "more than half of these ships were delayed by more than 2 years" (2018a, p. 9). RAND researchers in 2011 determined in their interviews that the generally accepted differences in shipbuilding from other programs were "length of time to design and build, influence of industrial/political factors, concurrency of design and build, higher complexity, low quantity/production rate, high unit cost, type of funding, [and] test and evaluation (T&E) approaches" (Drezner et al., 2011, p. 21).

Due to these differences with shipbuilding, programs generally deviate from accepted best practices and struggle with maintaining planned costs, schedules, and performance. In fact, the GAO's report (2018a) found that "the effort necessary to secure funding for a shipbuilding program sometimes runs counter to the process of attaining sufficient knowledge" (p. 19) so that "the requirements, technologies, and cost estimates for a shipbuilding program—essential to the development of a sound business case—may not be well understood at the time the Navy makes its funding" (p. 19). This process constraint runs directly counter to the GAO's research on successful programs that work toward "attaining critical levels of knowledge at key points in the shipbuilding process before significant investments are made" (GAO, 2018a, p. 14). Additionally, the small number of shipyards available for shipbuilding projects "limit the government's ability to negotiate favorable contract terms and the Navy absorbs the preponderance of risk for cost overruns, schedule delays, and quality deficiencies" (GAO, 2018a, p. 20).

A RAND study from 2011 found that the schedule to execute the shipbuilding process "is largely defined by the level of overlap between the development, design, and construction phases" (Drezner et al., 2011, p. 55), as seen in Figure 10. In a schedule with no overlap, there is a trade-off between taking longer to deliver the capability but with a fully developed design and delivering more mature technologies. Alternatively, "as the level of overlap between phases increases, technical and production risks increase, whereas technology obsolescence, requirements change, and industry base risks decrease," so that, generally, technologies need to already be more mature to support a shorter schedule (Drezner et al., 2011, p. 55). Drezner et al. (2011) identified these trade-offs as creating "conflicting program objectives that tend to maximize technology and minimize production time" (p. 59-60). Ultimately, RAND found that there are key constraints on the acquisition process as seen in Table 10, that influence the design process, resulting in the constrained process shown in Figure 11 (Drezner et al., 2011). The GAO's report also found a trend of "significant overlap—known as concurrency—between the technology development, design, and construction phases" where "instead of recovering schedule losses, concurrency typically results in cost growth and schedule delays" (2018a, p. 16).

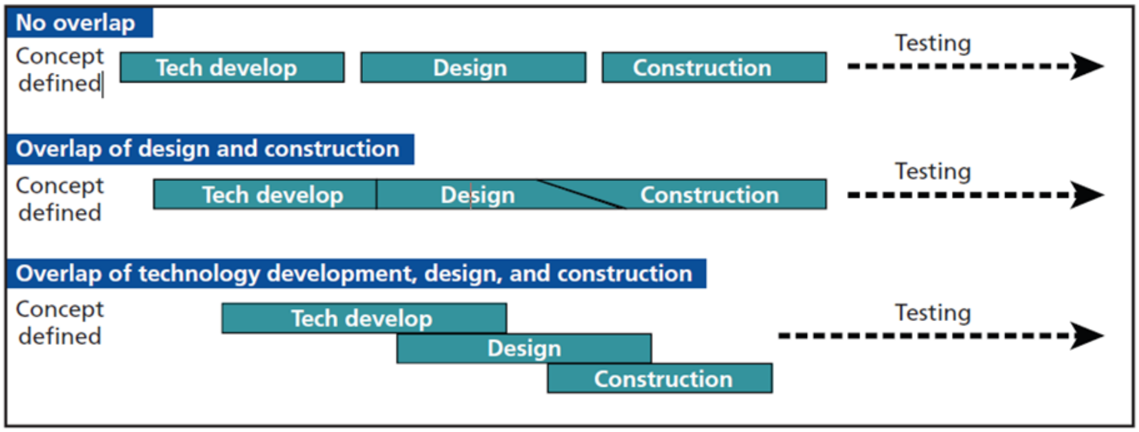


Figure 10. Ship Design/Build Process Alternatives. Source: Drezner et al. (2011).

Table 1. Key Constraints on Ship Acquisition. Adapted from Drezner et al. (2011).

| |
|---|
| Technical/Engineering |
| Regulatory and Statutory Requirements |
| Industrial Base Parameters |
| Workforce |
| Shipyard Financial Viability |
| Capital Equipment/Tooling |
| Force Structure Requirements |
| Political Factors |
| Fiscal Constraints |

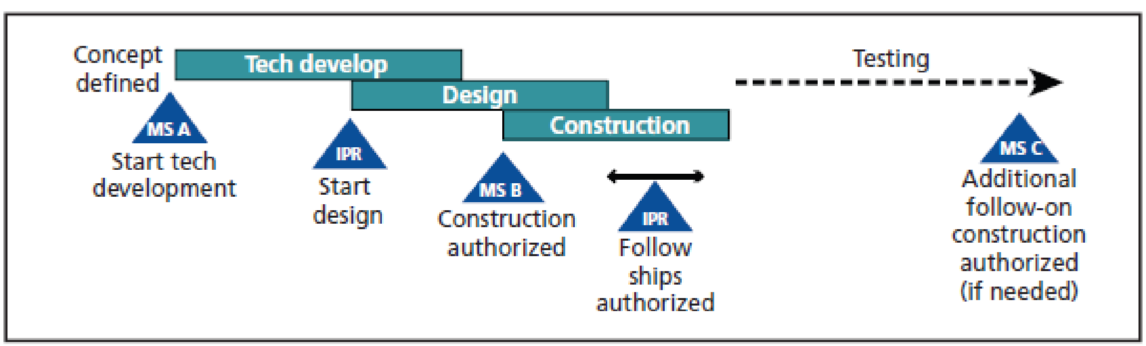


Figure 11. Constrained Ship Design/Build Process. Source: Drezner et al. (2011).

Due to cost and schedule constraints, the GAO (2022a) found that the Navy has been accepting "ships with large numbers of uncorrected deficiencies, including starred deficiencies, which are the most serious deficiencies for operational or safety reasons" (p. 10), in contravention of normal policy. This issue is something the Navy has been working to reduce, but as of 2018, there were still ships being accepted with starred deficiencies needing correction (GAO, 2018a). Ultimately, the GAO (2018a) identified that shipbuilding programs typically "over-promise the capability the Navy can deliver within the planned costs and schedule" (p. 13), and then later in the program "come under pressure to control growing costs and schedules, often by changing planned quality and performance goals" (p. 13). In fact, program officials reported that ships were known to be incomplete but were accepted anyway to avoid "cascading delays to other ships in the shipyard" (GAO, 2018a, p. 22). The GAO (2018a) also found that the Navy was accepting incomplete ships to reach the delivery milestone since these metrics are usually only measured until the ship is delivered.

The findings of these studies indicate that the current management process forces a schedule-driven mentality in shipbuilding programs, leading to results like those found by the GAO (2018a), where reports of IOC completion were "often based on meeting certain schedule milestones rather than demonstrating capabilities through successful completion of operational testing [OT]" (p. 24). From 2008–2018, only three of six ship classes passed their OT, and four of six were also found to have "had significant reliability issues" (GAO, 2018a, p. 11) Additional research in 2022 identified that the program management process used for shipbuilding has also been limiting the success of Supervisors of Shipbuilding, Conversion and Repair (SUPSHIPs), the office intended to "serve as the Navy's on-site technical, contractual, and business authority for the construction of Navy vessels at major private shipyards" (GAO, 2022a, p. 1). One of the major challenges faced by SUPSHIPs was determined to be "Navy practices prior to ship delivery that diminish the SUPSHIPs' accountability and ability to influence shipbuilding results" (GAO, 2022a, p. 35). While waivers from the Chief of Naval Operations (CNO) for incomplete work are allowed by policy, the approval process (see Figure 12) was found to potentially "dilute the SUPSHIPs' input before it can reach the CNO, thus reducing the opportunity for the CNO to make approval decisions fully informed by the SUPSHIPs' insights" (GAO, 2022a, p. 50).

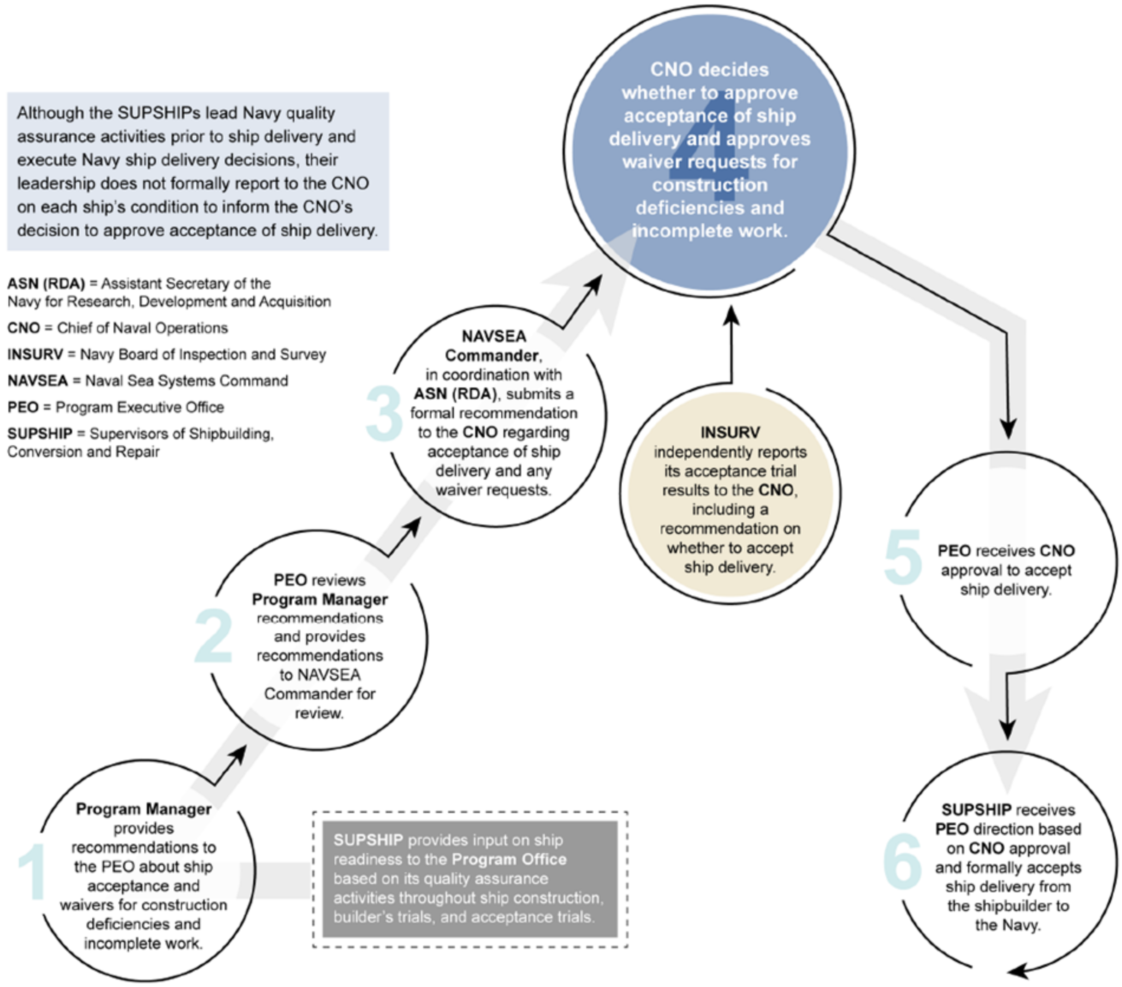


Figure 12. General Navy Process Supporting the Approval and Acceptance of Ship Delivery. Source: GAO (2022a).

While there has been a primary focus of correcting the reporting chain between SUPSHIP and the CNO to improve the process, the GAO (2022a) also noted that this improvement "will not on its own eradicate the long-standing problems that these programs have had with cost, schedule, and performance" (p. 50). The Navy has been working toward other reform efforts in line with easing the cost and schedule pressures that come from the overlap typical to shipbuilding, primarily working to reduce technology risk for critical technologies and increasing design stability for the design/build process (GAO, 2018a). The GAO (2018a) also previously reported on concerns with the Navy failing to provide effective guidance on "separate reporting requirements for major shipbuilding efforts, such as new flights of ships, which represent major technology or design changes within an existing class, or for individual aircraft carriers" (p.24). The most recent instruction, SECNAVINST 5000.02G, does have guidance on a First Ship in Shipbuilding Program Report but otherwise only specifies that "program tailoring will ensure all statutory reporting, decisions, and sustainment requirements are satisfied" (SECNAV, 2022, p. 35). The instruction does separately have overarching guidance on the requirement that "new, improved capability, or capability modifications for a system, regardless of whether additional quantities are procured, will not be acquired under a non-reporting program" and must "be managed as a separate program within an appropriate AAF pathway or as a part of the original program" (SECNAV, 2022, p. 39). While that guidance may cover most of the concerns regarding reporting, the Navy's guidance is not specific to the unique shipbuilding situations presented by the GAO, such as new flights or individual carriers. The guidance unique to shipbuilding in SECNAVINST 5000.02G focuses mainly on tailoring, with measures like combining phases or even milestones, acknowledging that "shipbuilding program reviews and decisions might not occur in the same sequence as other MDAPs" (SECNAV, 2022, p. 35). However, Drezner et al. (2011) previously reported that the "continuous and overlapping nature of the design/build process for modern ships makes the placing and timing of acquisition milestones somewhat problematic" (p. 60). The Navy's instructions do not provide clear guidance and models for how a successful shipbuilding program should be tailoring the AAF pathways to reduce the risk of cost and schedule pressures observed with previous ships.

## E. LITERATURE SUMMARY

The decision by the CVN 21 program to forgo evolutionary acquisition does not align with previous DoD policy indicating that it was the preferred strategy. However, the DAS reforms leading to the AAF have reduced the emphasis on evolutionary acquisition in favor of requiring MOSA to enable incremental development practices that achieve the same benefits. The Ford program's use of MCA as a singular pathway is in accordance with the policy for AAF, which states that MCA is meant for “military unique programs that provide enduring capability” and are “designed to support MDAPs, major systems, and other complex acquisitions” (OUSD[A&S], 2022b, p. 13).

Recommendations from the research into evolutionary acquisition in the 2000s align with the addition of the UCA and MTA pathways. Those pathways are intended to provide faster delivery of capabilities while managing technology integration, benefits seen by evolutionary acquisition as well. The guidance that allows for using multiple pathways would indicate that although the terminology of evolutionary acquisition is not utilized, beginning with UCA or MTA and transitioning to MCA meets the same objective. DoDI 5000.85 does state that “technologies successfully demonstrated in an operational environment via the Rapid Prototyping procedures in the Middle Tier Acquisition pathway, or other prototyping authorities, may be transitioned to major capability acquisition” (OUSD[A&S], 2021, p.9). DoDI 5000.80, *Operation of the Middle Tier of Acquisition (MTA)*, does include language that states that a component acquisition executive must provide extra emphasis on naming conventions, reporting, and scope when an “MTA program is a subprogram of a larger program or is a program spiral, increment, or block upgrade” (OUSD[A&S], 2019, p. 11).

Ultimately, DoD and DON policy and guidance lack specificity in how PMs should leverage the pathways for evolutionary acquisition and incorporate the required MOSA strategy. While the option is given to use multiple pathways and research indicates that these pathways provide the benefits of evolutionary acquisition strategy despite not emphasizing that terminology, no actual models are provided for how a program should utilize multiple pathways or tailor the MCA pathway based on scope and complexity. A program as large and complex as the Ford class would naturally be inclined to utilize the normal MCA pathway only based on the policy language.

The review of the literature identifies that research gaps do exist in how the Ford-class program could tailor the MCA pathway as a complex shipbuilding program to better manage the program to baseline requirements. An analysis of the Ford class case history to identify constraints, program priorities, and impacts on acquisition strategy decisions over the course of the program will provide insight into the objectives tailoring would need to accomplish and the changes or existing processes that would enable potential tailoring options.

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# IV. FORD-CLASS PROGRAM ANALYSIS

Since World War II, the aircraft carrier can be described as the center piece "of the Navy's forward deployed peacetime presence, crisis response, and war-fighting forces" (General Accounting Office, 1998, p. 2). At the same time, the General Accounting Office (1998) also described nuclear-powered aircraft carriers as "the most expensive weapon system in the Nation's arsenal," requiring a substantial investment into both the carriers themselves and the associated support aircraft and vessels (p. 2). The Navy was a major proponent of the adoption of nuclear-powered vessels in the 1960s, and all aircraft carriers constructed since the commissioning of the USS *Enterprise* (CVN 65) in 1962 have been nuclear-powered (General Accounting Office, 1998). That total includes all ships of the Nimitz class, following the commissioning of the lead ship USS *Nimitz* (CVN 68) in 1975 with a planned 50-year service life (Prusiecki, 2018).

After the end of the Cold War and as the Nimitz approached its required 23-year, mid-service life nuclear refueling, the DoD completed a 1993 Bottom-Up Review (BUR) "of the nation's defense strategy, force structure, modernization, infrastructure, and foundations" which included a review of the Navy's carriers (General Accounting Office, 1995, p. 1). This review determined that 12 carriers should be the standard requirement for the Navy to support strategic objectives in terms of forward presence (General Accounting Office, 1995). Based on the recommendations from the BUR, the General Accounting Office, later renamed the Government Accountability Office (GAO), published a 1995 report on *Investment Strategy Options for the Navy's Aircraft Carrier Program* to examine the affordability of different force structure investment options available to the Navy, with an emphasis on the industrial base impacts to Newport News Shipbuilding (NSS) as the sole shipyard capable of nuclear-powered carrier construction in the United States. At that time, the Navy estimated NNS's minimum sustainable employment at 10–15k and minimum production requirement of a carrier every 3–4 years with the additional support to the required mid-life nuclear refueling and complex overhauls (RCOHs) (General Accounting Office, 1995). The 1995 General Accounting Office report provided an in-depth analysis of various alternatives, their affordability, and industrial base impacts, although it was noted that the report was limited in its examination of options where the Navy switched back to conventionally powered carriers. These reports and studies can be viewed as a foundation for the Navy's initiation of a program to replace the Nimitz class.

## A. PROGRAM INITIATION

The program that would later become the Ford class began with approval of Milestone 0 in March 1996, a decision point previously used by the Navy to begin planning and identifying requirements to work towards what would now be the Materiel Development Decision (MDD) (DON, 2023).

A November 1996 Mission Need Statement (MNS) was released by the DON to provide "requirements for tactical aviation (TACAIR) sea-based platforms for the 21st century" (para 1.a). The MNS contained objectives related to force structure and industrial base support, in line with the BUR and General Accounting Office recommendations, while adding the third objective of using "new technologies and design concepts that offer opportunities to develop sea-based platforms that are as capable, but more affordable than current platforms" to emphasize the goal of reducing costs (DON, 1996, para 2.e).

### 1. Capabilities Development

Alternative designs provided in the MNS for the later Analysis of Alternatives (AOA) were new ship designs, either conventional or nuclear with various hulls; an incremental development of the existing Nimitz class via "a mod repeat program…capitalizing on advanced technology" but requiring "a significantly different architectural approach in the design; or other concepts for Mobile Offshore Basing (MOB) (DON, 1996, para 4.b). Additionally, the MNS provided initial guidance on constraints, emphasizing that the system architecture and design utilize modularity in construction and in sub-systems that "optimizes life cycle cost and performance" and "allow [s] for future upgrades"; incorporate automation to reduce manning; and maximize the ability of "major functional elements" to be able to "forward fit [ to other] ship construction programs" and "retrofit into existing carrier classes" without a tradeoff in performance (DON, 1996, para 5.a).

### 2. Concept Exploration

In a 1997 article in *Naval Aviation News*, RADM Rittenour, head of Carrier and Air Station Programs Branch of the Air Warfare Division in the Office of the Chief of Naval Operations (OPNAV N98), and Captain O'Hare, program manager of the Aircraft Carrier Program Office at Naval Sea Systems Command (NAVSEA), gave their thoughts on the initial planning for the future carrier they had begun calling the CVX. They described a "dual-track approach" between the existing Nimitz class and the new CVX to "modernize the past and transition to the future while simultaneously maintaining essential capabilities and force structure" (Rittenour & O'Hare, 1997, p. 24). As the final Nimitz class ship, USS *George H.W. Bush* (CVN 77) was still planned for procurement in 2002 and commissioning in 2008, their strategy intended to use her as "a transition ship, incorporating new technologies that result from carrier research and development (R&D) efforts currently under way" to "lay the foundation" for the design of CVX (Rittenour & O'Hare, 1997, p. 24-25). This strategy would use both programs together to "enable [the Navy] to transition from the highly successful—but 1960s-vintage–Nimitz design to one specifically designed to the operational mandates of the 21st century," by having CVX add "improved characteristics in selected areas" and "features that make it more affordable to operate" while keeping "the core capabilities resident in" the Nimitz class (Rittenour & O'Hare, 1997, p. 25).

A large emphasis was placed by RADM Rittenour and Captain O'Hare (1997) on risk management in balancing their current concerns of force-structure requirements, described as "the fundamental 'drivers' of the future carrier equation," and industrial base needs with "longer term war-fighting capability" concerns (p. 25-26). Due to a lack of R& D for carriers over the life of the Nimitz class, they understood that "the CVX design, and the technology that would make it feasible at a reasonable cost, will not be immediately available," necessitating the use of CVN 77 as both a "force-structure bridge" and "a technological bridge between the Nimitz class and CVX" (Rittenour & O'Hare, 1997, p. 26). Their strategy would prevent a gap in construction to reduce the strain on the shipyard while also using "a building-block approach, relying upon a continuing R&D program and a series of technology demonstrations" to create "more capable systems, more affordable systems, or both" (Rittenour & O'Hare, 1997, p. 26). RADM Rittenour and Captain O'Hare (1997) also emphasized that their strategy was intended to be an "evolution" in the carrier program as they believed "programs that promise 'revolutionary' improvements in capability are often accompanied by unacceptably high levels of technological and fiscal risk" (p. 26).

Ultimately, their strategy would be incremental in nature with CVN 77 remaining on schedule and receiving "some of the technologies that are planned for the first CVX" but none of the "major design changes" that could be "ruled out due to high technical, schedule and fiscal risks" (Rittenour & O'Hare, 1997, p. 26-27). CVN 77 would be an improvement over the rest of the Nimitz class, could see a reduction in "total ownership (life cycle, operational and support) costs by as much as 15 percent," and would allow for evaluation of the new technology to then be "be backfitted into existing CVNs, thus significantly reducing the remaining life cycle and support costs of those ships" (Rittenour & O'Hare, 1997, p. 26). At the same time, those "technical and operational lessons learned from CVN 77" would help inform the design of the CVX class while the CVX program could then focus more energy on investigating the new technologies needed to achieve the capability improvements desired in the new class (Table 2; Rittenour & O'Hare, 1997, p. 27).

Table 2. CVX Program Office (PMS 378) Goals for CVX. Adapted from Rittenour & O'Hare (1997).

| |
|---|
| Reducing reliance on ship-assisted launch and recovery. |
| Increasing sortie generation capabilities to match the projected fast turnaround capabilities of next-generation aircraft. |
| Improving ship survivability against future threats. |
| Improving C4I capacity. |
| Alleviating topside design congestion. |
| Achieving a higher degree of commonality with the Navy's other future ships. |
| Reducing manpower requirements. |

The program office was also investigating different design elements and technologies to achieve these goals, while "recognizing that the new carrier will have a potential life span of 40 to 50 years" and requires "a design that is easily modified to accept upgrades over the course of the ship's service life" (Rittenour & O'Hare, 1997, p. 27). An additional article by Bill Deaton, Future Carrier Program Research and Development Manager at NAVSEA, was also included in *Naval Aviation News* describing technologies being considered for initial improvements to CVN 77 (Table 3), as well as the more complex concepts being examined for CVX (Table 4). His article also included concept drawings for a CVX that would look radically different to the Nimitz class based on incorporation of these technology concepts (Figure 13 and 14).

Table 3. Technology Opportunities for CVN 77. Adapted from Deaton (1997).

| Technology | Design | Benefits |
|---|---|---|
| Integrated Information System | Supports the transfer and integration of voice, video and data information between audio, video and computer systems. | Capitalizes upon advances in commercial industry. |
| Fiber-Optic Backbone | Single, integrated, commercial and military standard compliant physical grid supporting communications between systems/ equipment. | Ruggedized commercial off-the-shelf components. |
| Zonal Electric Distribution System | Open system architecture DC electrical distribution with standard interfaces between components. | Anticipated to be easier to install, require less physical cabling and provide greater flexibility for ship upgrades than current electrical systems. |
| Multi-functional Embedded Antennas | Reconfigurable, multiple apertures electronically combined to provide an antenna tunable across wide frequency bandwidth and sensitivity parameters. | Provides potential to improve performance by avoiding antenna blockages, reducing the structure required to support antenna placement, life-cycle costs and maintenance manpower requirements. |
| Modified Island Structure | The island's configuration, function and materials will be designed to satisfy aircraft support functions while minimizing its impact on ship control and flight deck operations. | Potential benefits are reduced air disturbances caused on the flight deck by the island, more efficient flight deck arrangements and reduced radar and infrared signature characteristics. |

Table 4. Concepts Considered for CVX. Adapted from Deaton (1997).

| Concept | Design | Benefits |
|---|---|---|
| Alternative Energy Catapults (Electromagnetic) | A launch-assist mechanism which will propel the aircraft to takeoff velocity using a traveling electromagnetic wave produced by a linear motor. | Independence from the ship's propulsion plant, a 50-percent reduction in weight and 65-percent reduction in volume, an increase in energy capacity with a highly controllable acceleration and deceleration profile, an increase in reliability and availability, and a 30-percent decrease in manpower required. |
| Alternative Energy Catapults (Internal Combustion) | A launch-assist mechanism utilizing liquid propellant as the energy source instead of steam. Benefits include elimination of steam system components; and reduced weight, airframe stresses and maintenance. | Elimination of steam system components; and reduced weight, airframe stresses and maintenance. |
| Ski Jumps | An upward-sloped ramp at the forward end of the flight deck which will provide aircraft with a more optimum flyaway angle. | Reduced takeoff velocity, increased payload capacity and reduced wind-over-deck requirements. |
| Automated Weapon Selection and Movement | Integrated family of procedures, magazine design, weapons elevators, passageway layout, information management systems, decision aids and reduced manpower ordnance-handling equipment. | Increase weapons' throughput, increase sortie generation rates and minimize risks associated with ordnance handling and stowage. |
| Advanced Systems for Flight Operations Management | Family of information management and decision aids to facilitate mission planning, aircraft control, aircraft/pilot information upload and download, aircraft turnaround and aircraft launch and recovery. | improved aviation safety, significant manning reduction, increased sortie generation rate, flight deck optimization, reduced aircraft support equipment, more efficient maintenance and built-in servicing and support flexibility for follow-on generations of aircraft. |

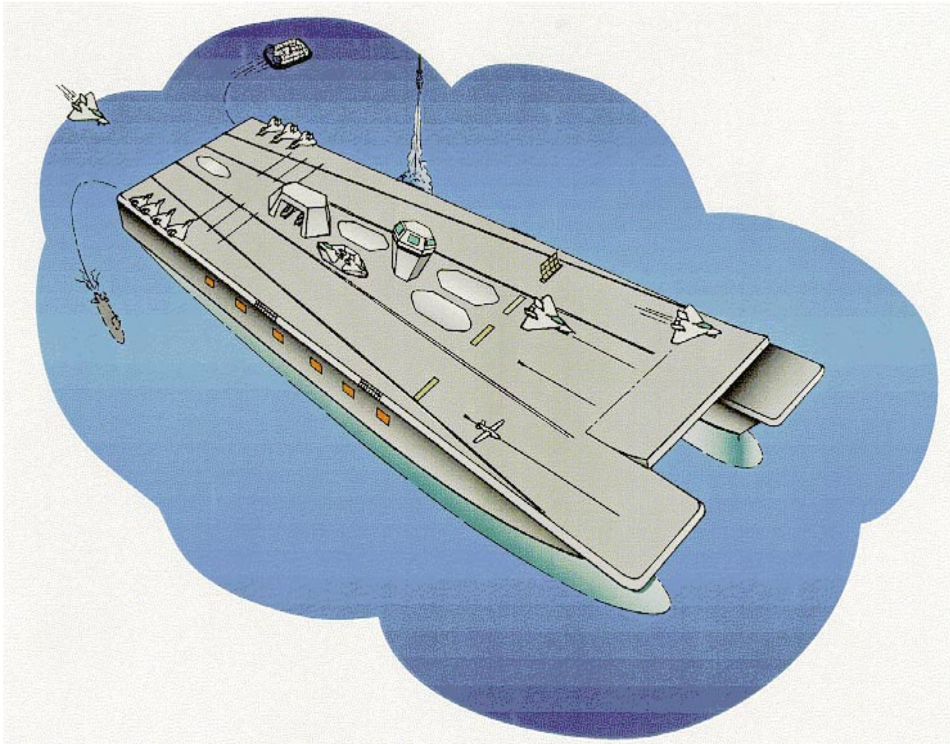


Figure 13. CVX design concept by Whitney, Bradley, and Brown, Inc. Source: Deaton (1997).

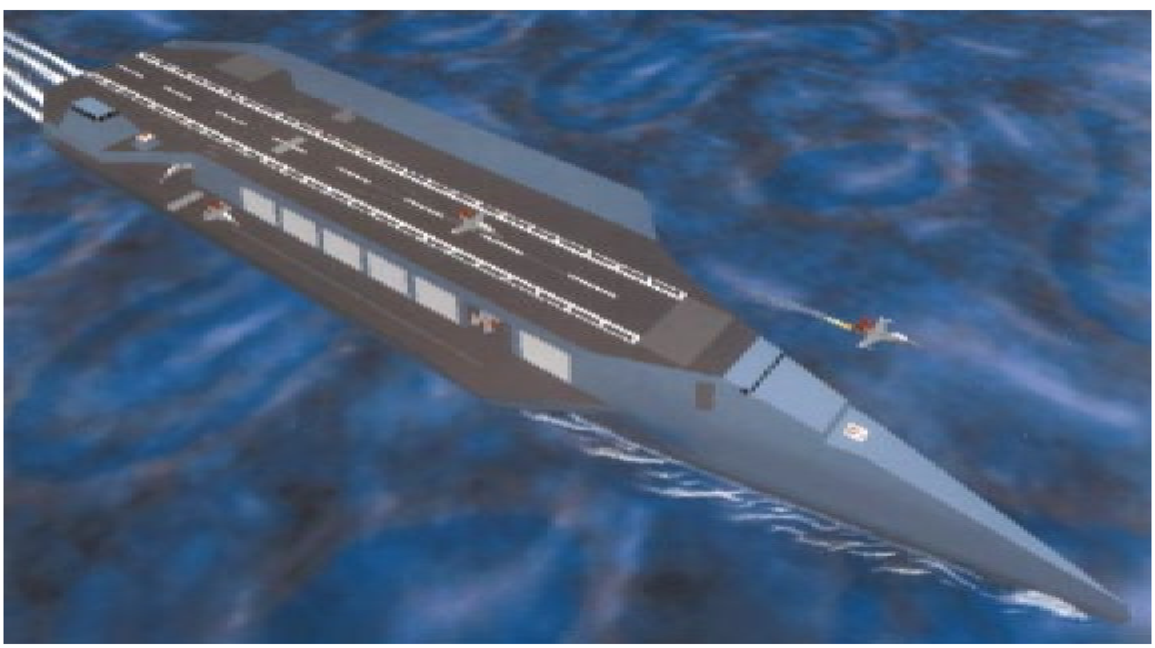


Figure 14. Artist's conception of CVX by J. David McWhite, Naval Surface Warfare Center. Source: Deaton (1997).

### 3. Initial Analysis of Alternatives

While research into technology and design concepts for CVX was being initiated, the Navy was also conducting an overall "cost and operational effectiveness analysis" (Rittenour & O'Hare, 1997, p. 27). This analysis was planned to be conducted in multiple parts and "examine various concepts of operations for employing sea-based, combat aviation in future conflict scenarios," including "the required size and composition of future air wings" (Rittenour & O'Hare, 1997, p. 27). The "part 1 of the AOA" was completed in 1997, and "focused on the carrier air wing composition and size, selecting an 80-plane air wing" (DOT&E, 2001, p. 334). In January of 1997, the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN[RD&A]), John Douglass, directed the Naval Research Advisory Committee (NRAC) to conduct a study into CVX that was titled *CVX Flexibility*.

The NRAC panel determined that "to maximize flexibility, CVX must be effective, available, reconfigurable, and affordable" with a conclusion that the design must therefore "support a large (80 aircraft) airwing and conduct flight operations in heavy sea states" for "the most demanding power projection missions" (Weldon et al., 1997, p. 5). The "four major features of CVX flexibility" found by the panel were that first "for maximum availability, the ship should have a **nuclear** propulsion plant," second "for maximum effectiveness, in all weather and for all missions, the ship must be **large**, on the order of 100,000 tons, and" a combined third and fourth "to be optimally reconfigurable, **modular architecture** and a common source of **electric** power are essential" (Weldon et al., 1997, p. 6).

Additionally, the NRAC believed that the "key to lifetime CVX affordability is an all-electric ship with modular architecture" (Weldon et al., 1997, p. 6). Although being all-electric does not require nuclear power, the panel did state that they found "arguments favoring large, nuclear powered carriers to be persuasive" based on future overseas basing and operational tempo concerns (Weldon et al., 1997, p. 7). They also recognized that continuing with nuclear-powered carriers in a budget-constrained environment would mean that "major reductions are required in ship manning, operation and maintenance (O&M) costs, as well as construction costs" (Weldon et al., 1997, p. 6).

### 4. Materiel Development Decision

Although the Navy had previously wanted CVX to move towards a "completely new-design ship" that would "reduce the size of the CVX's crew to about 50% of the Nimitz-class" in order to achieve a "total life-cycle cost…at least 20% less than that of the Nimitz-class," it was determined that a completely new-design would potentially cost "about $7 billion in research, development and design funding" (O'Rourke, 1998, p. 3). It was deemed to be more prudent to use the strategy of continuing to make incremental improvements off the Nimitz design until what could be considered an "all-new carrier design (including a new hull design different from that of the Nimitz class) might eventually emerge" with the second of the CVX ships (O'Rourke, 1998, p. 3). At the same time, despite ongoing studies into the cost effectiveness of conventional vs. nuclear power, the then-CNO, Admiral Jay Johnson, decided that CVX would be nuclear powered based on the recommendations in the NRAC study (Polmar, 1998).

Ultimately, "Part 2 of the AOA" was reported as complete in October of 1998, finding that the best solution was a "Nimitz hull for CVNX1 with evolutionary improvements in CVNX2" (DOT&E, 2001, p. 334). Based on the completion of the second phase of the AOA, a Defense Acquisition Board (DAB) chaired by USD(AT&L) was held October 1998 and approval was given for the "request for a large-capacity (75 aircraft) carrier with new nuclear propulsion plant and electric plant design, employing an evolutionary acquisition approach" (DON, 2023, p. 12).

## B. MATERIEL SOLUTION ANALYSIS

The strategy the Navy intended to use was similar to that developed in the initial planning of RADM Rittenour and Captain O'Hare, recognizing that the Nimitz class design needed to be improved on in terms of performance as the design was over 30 years old, the schedule would be under pressure based on the force structure requirement, and a reduction in costs was necessary due to the constraints being placed on the Navy's budget at that time (Nathman, 1998). The schedule would be based around CVN 77 and CVX 1 being required to maintain the force structure minimum with the planned decommissioning of the *USS*

*Kitty Hawk* (CV 63) in 2008 and *USS Enterprise* (CVN 65) in 2013, maintaining continuous carrier construction to support the industrial base (Figure 15; Nathman, 1998).

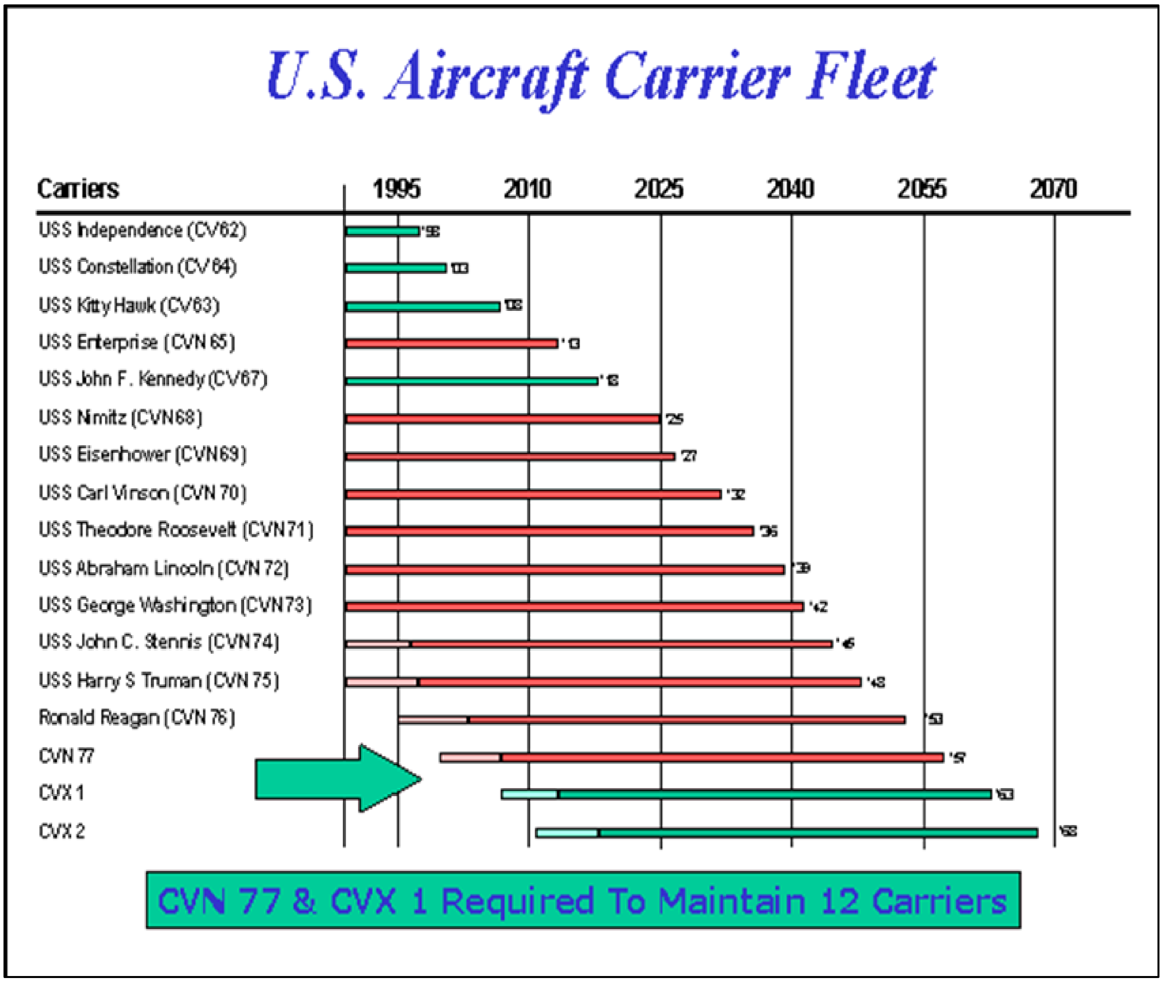



Figure 15. U.S. Aircraft Carrier Force Structure Planning. Source: Nathman (1998).

### 1. Strategy Development

While the strategy was approved as an "evolutionary approach," it was made clear that leadership did "want technology developed earlier to achieve savings sooner" with a "need to prioritize technologies for backfit to existing carriers" (Nathman, 1998, slide 11). To achieve this, the Navy would need to execute the phased approach (Figure 15) and "develop CVN 77 as a transition carrier by investing in LCC reduction technologies and warfighting enhancements that all forward fit to future CVXs, with opportunities for backfit to NIMITZ class" (Nathman, 1998, slide 5). The CVX development could then continue building incrementally towards the "revolutionary 21st Century carrier design" that was desired by the Navy with CVX 1 adding the initial larger systems determined to be "key enablers for future technology insertion" so that the CVX 2 design could "focus on internal redesign / technology insertion" (Nathman, 1998, slide 13).

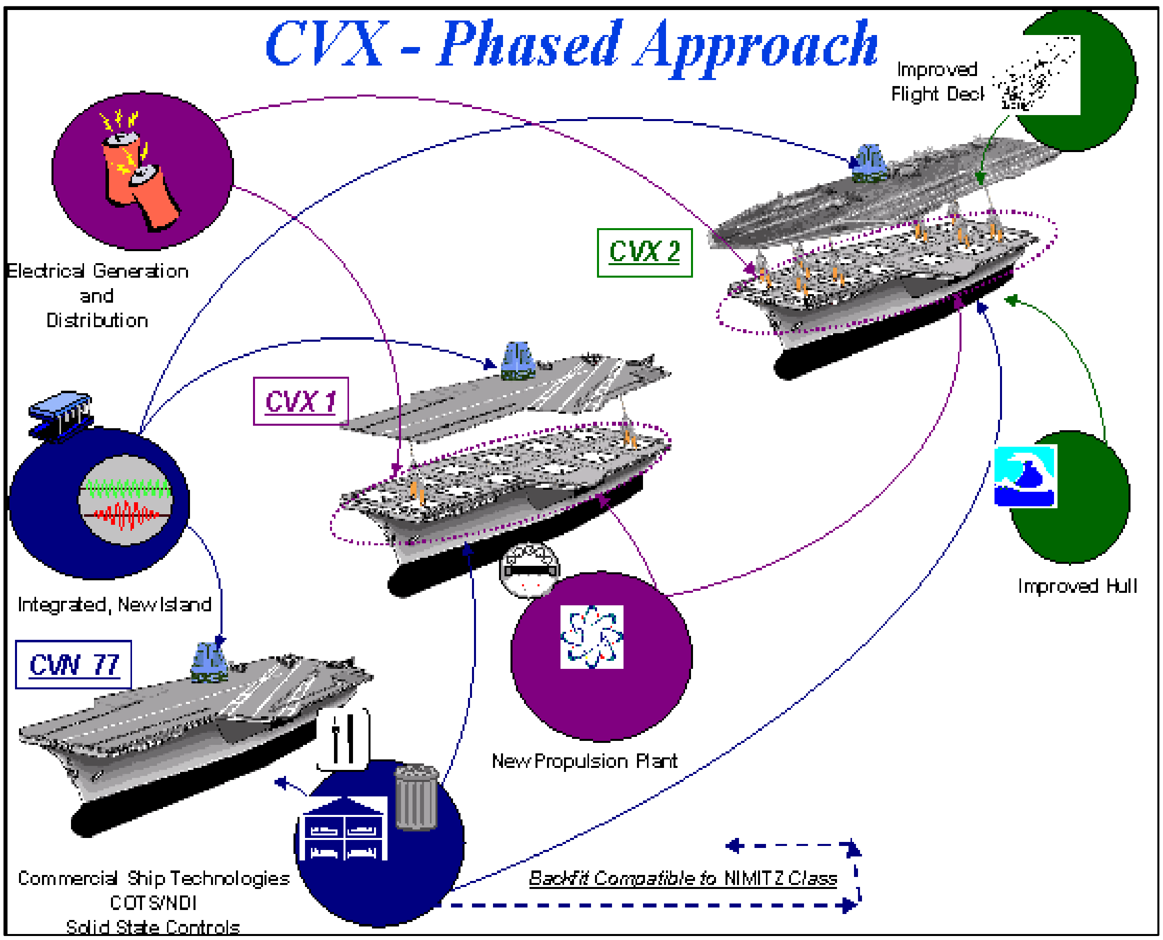



Figure 16. CVX Phased Approach. Source: Nathman (1998).

Despite the shift from an all-new design to an incremental approach, the Navy's updated strategy brief still determined that the original goal of 50% reduced manning to support a 20% reduced LCC could be achieved with CVX 2 after cumulative reductions across CVN 77 and CVX 1 (Nathman, 1998). The Navy's estimates anticipated a reduction of 3-8% LCC and 5-10% manpower for CVN 77, an additional reduction of 5–10% LCC and 8–10% manpower for CVX 1, and an eventual cumulative reduction of 20–40% LCC and 30–50% manpower with CVX 2 (Nathman, 1998). The Electro-Magnetic Aircraft Launching System (EMALS) was highlighted as a specific "break-out technology" that would be a "key enabler for reduced manning and increased maintainability" and achieve a LCC reduction of $200M/ship to offset the estimated total investment of $450M by the second or third ship (Nathman, 1998, slide 15–16).

### 2. Final Analysis of Alternatives

As the Navy proceeded with executing the strategy approved by the DAB, a final part 3 of the AOA was planned to provide additional design analysis for CVX 1 and CVX 2 with the DAB specifically encouraging further evaluation of including EMALS in CVX 1 (Nathman, 1998). That final part of the AOA was conducted in 1999 before completion in January 2000 "and considered six new designs and eight modified CVNX1 designs before settling on concept designs for CVNX2" (DOT&E, 2002, p. 175). At the same time, to better understand the efficacy of utilizing EMALS in the different designs, multiple Program Definition and Risk Reduction contracts were awarded to General Atomics and Northrop Grumman (DON, 2023).

Captain Manvel, then the program manager for Future Aircraft Carriers at NAVSEA, described the Navy's AOA as "what may have been the most exhaustive analysis in the history of Navy shipbuilding" and believed that it was time for the Milestone I review by the DAB (Manvel, 2000, para 28). He believed that the Milestone I "decision will balance the availability of near-term funding versus the warfighting and life-cycle-cost benefits of the various options" and that it was "time to make the decision and get on with the job" so the Navy could "focus clearly on a particular end product" (Manvel, 2000, para 29). On June 15, 2000, the Future Aircraft Carrier Program referred to as CVNX received Milestone I, now Milestone A, approval based on the strategies and design concepts developed by the AOA (DON, 2023).

## C. TECHNOLOGY MATURATION & RISK REDUCTION

Following Milestone I approval, contracts were awarded to Northrop Grumman Newport News for "research and design development engineering services" and the program reported that "design and integration efforts" had officially started with the award of "the Integrated Product and Process Development contract" (DON, 2023, p. 12). As the program progressed into what would now be the Technology Maturation & Risk Reduction (TMRR) phase of the MCA pathway, DOT&E (2001) was also placing an "emphasis on early program involvement" and was preparing both the Test and Evaluation Master Plan (TEMP) and Operational Requirements Document (ORD), with the TEMP also containing "an Early Operational Assessment (EOA) that will commence in 2001 to evaluate the CVNX1 preliminary design" (p. 334). Inputs were also being provided to the initial draft of the Navy's Vulnerability Assessment Report (VAR), and DOT&E expressed early concerns that the draft VAR "presented no data on Nimitz class vulnerabilities, even though CVN 76 was the baseline design for the Analysis of Alternatives," and also "failed to establish that the survivability of any of the design alternatives was better or worse than the Nimitz class ships currently in service and in production" (DOT&E, 2001, p. 335).

At that time, DOT&E (2001) believed that the EOA would be sufficient "to identify and correct any significant shortcomings in the CVNX1 design and reduce the requirement for costly changes during the construction process" as the team reviewed design documents and testing results (p. 334). It was noted that they would need to "pay special attention to DD21 Program technologies that are candidates for insertion beginning with CVN77 and to the progress of [EMALS] testing" as critical technologies, and that "as CVNX depends on technology advances pursued in DD21… [a]ny slide in the DD21 program will have repercussions on CVNX" (DOT&E, 2001, p. 334–335).

### 1. Requirements Validation

In April 2001, the planned Systems Requirement Review (SRR) for CVNX-1 was completed and reported as "a major milestone toward commencement of design activities to support the Milestone B" review that would take place in 2002 (DON, 2023, p. 12). However, at the same time, a General Accounting Office report published in August 2001, titled *MILITARY TRANSFORMATION: Navy Efforts Should Be More Integrated and Focused*, highlighted a lack of strategic integration by the Navy that foreshadowed external pressure on the CVX program. The General Accounting Office (2001) report identified that although the Navy had begun the process of transformation in line with DoD guidance, "the Navy's "evolutionary" approach to transformation promotes incremental changes" when the "fiscal and technological challenges suggest that more fundamental changes may be needed" (p. 2). Additionally, the General Accounting Office (2001) believed that DON had "not given sufficient attention to long-term technology and concept experiments, which are necessary for the Navy to analyze and implement more significant force structure and operational changes," while "innovation activities have not been sufficiently coordinated and tracked across the Navy" (p. 2).

The subsequent cancellation of the DD21 program and shift to DD(X) in November 2001 already represented pressure placed on the Navy's shipbuilding due to these concerns (Polmar, 2001). The reasoning at the time was that DD21 had "scored poorly in DoD evaluations of the warship's role in transformation to future systems and platforms" and "ranked low among new systems to be funded, especially under the Bush administration's drive for "transformation" projects" (Polmar, 2001, para 7). Additionally, despite DOT& E previously warning that DD21 delays could impact CVX due the planned earlier development of technology, it was reported that the Navy's aviation community was not a proponent of DD21, viewing "the development costs of the new ship as a potential drain on its plans to construct…another supercarrier…in fiscal year 2006" (Polmar, 2001, para 9). While the new DD(X) program would still work towards "evolving…a series of system upgrades for aircraft carriers as well as surface combatants" that would benefit CVX, the DD21 cancellation represented both a delay that would impact the maturation of technology needed for the CVX program, as well as a warning example of external pressure that could impact the program's planning (Polmar, 2001, para 2).

### 2. Schedule Pressure

At the beginning of 2002, it also became necessary to shift the overall program schedule a year to the right, moving the purchase of the lead ship from FY06 to FY07 and delivery from FY13 to FY14 (Bohmfalk, 2002). The shift was described as a "budget move…made as Navy leaders tried to balance the requirements to buy many new ships and other platforms while improving current and future readiness," while also being pitched as helping to "enable the Navy to make sure many of the new technologies and systems going into the ship are fully ready when they are installed permanently" (Bohmfalk, 2002, p. 4). It was recognized by RADM Roland Knapp, then PEO Carriers, that this delay would mean added pressure to "to be on-track" and the program "can't suffer delays," as they would have "taken the flexibility out to be able to absorb any kind of contingency one way or the other" in terms of the active carrier requirement (Bohmfalk, 2002, p. 4). At the same time, he stated that what was most important was "the ability to keep deployment rotations on schedule" and he believed the delay was a "manageable risk" as the goal was really to have the new ship "ready to take the deployment cycle prior to when the Enterprise would have had to make its next deployment" (Bohmfalk, 2002, p. 4-5).

As the overall program shifted a year, the MS B only shifted from the original April 2002 to September 2002 to remain on an accelerated decision timeline, as the separate development of individual systems were continuing "on the same time frame as…before the CVNX budgetary move" with the Navy needing "the milestone B system development and demonstration decision in order to keep some of those efforts moving" (Bohmfalk, 2002, p. 4). However, DOT&E (2002) stated in their FY2001 Annual Report that the PM's decision to "accelerate the MS B decision several years to Summer/Fall 2002 to support advanced funding for the nuclear power plant" had "raised concerns at all levels regarding the maturity of the program to adequately support" the decision (p. 176).

The EOA was still reported as on track for completion in March 2002, with final approval of the TEMP planned for February 2003, while the Live Fire Test & Evaluation (LFT&E) Management Plan needed for MS B was not yet approved (DOT&E, 2002). But the report also stated that "OT&E planning is off to a slower than expected start and there is concern that a meaningful EOA may not be completed before the Summer/Fall 2002 MS B decision" (DOT&E, 2002, p. 176). The acceleration of a MS B forced the creation of "two parallel test tracks," a "low risk track [that] involves the propulsion plant" and a "high risk track [that] involves the successful integration of at least seven highly complex warfare systems at various levels of technical maturity," and now required a "test plan that adequately supports both high and low risk test tracks" (DOT&E, 2002, p. 176). The program eventually reported an additional delay in the MS B decision from September 2002 to February 2003 due to the Operational Requirements Document (ORD) being delayed for further development.

### 3. Acquisition Strategy Update

Despite there already being concerns in delays and risks associated with integration of new technologies using the existing acquisition strategy, a Defense Science Board (DSB) report published in October 2002 increased pressure on the program. Although the DSB recommendation was still to build CVNX-1, the report made this recommendation while stating that it was because a replacement to the Nimitz is needed and "options for new carriers are limited to the CVNX-1" as the Navy had "not sufficiently developed additional concepts and their use to the point where there are viable alternatives" (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 2002, p. 75). While CVNX-1 should still be constructed to "serve as a prototype for many new shipboard technologies" and on a "schedule [which] would keep the U.S. carrier building competence intact," they believed that "CVNX-2 and future carriers should not be a foregone conclusion" (OUSD[AT&L], 2002, p. 75-76).

Instead, they recommended that further "appraisal of available technologies should be completed before each new sea-based platform design is approved," with a new "continuous design and technology development program…to push the design of carriers to the limits of what is technologically effective" through identification of "technology packages and 'on-ramps' associated with future and current ships" (OUSD[AT&L], 2002, p. 11). This new process could also include a "board, chaired by the Under Secretary of Defense for Acquisition, Logistics and Technology (USD[AT&L]), to review how the system of systems is developing and how the Navy is addressing and accomplishing technology insertion" (OUSD[AT&L], 2002, p. 12).

Following the release of the DSB report, the SECDEF, Donald Rumsfeld, was questioned "if the DoD was still considering delaying or canceling CVNX-1" (Ma, 2002,

p. 8). At that time, the SECDEF answered that no decision had yet been made regarding the program as it was a component of the budget still being decided on by President Bush. Due to the increased scrutiny placed on the program's acquisition strategy and design, it was also reported that Secretary Rumsfeld had already made a request to RADM Dennis Dwyer, then the program executive officer for aircraft carriers (PEO Carriers), earlier in 2002 to "to review a series of possibilities about the CVNX program's direction – including accelerating production" (Castelli et al., 2002, p. 5). Although it had been the Navy's previously approved strategy to use the sequence of CVN-77, CVNX-1, and CVNX-2 as "transitional step [s] in an evolutionary acquisition strategy" leading to "more significant changes" in CVNX-2, the added pressure meant discussions were being held in the Office of the Secretary of Defense (OSD) about "whether to skip CVNX-1 and leap directly to CVNX-2" (Castelli et al., 2002, p. 5). Secretary Rumsfeld stated at the time that he understood the need for the "exact balance between moving things forward and not going so far that you inject risk" with a consideration for "the maximum amount of new technology and transformational capabilities and not one thing more that would be sufficiently far into the future and advanced that it would…not be able to be achieved" (Castelli et al., 2002, p. 5).

RADM Dwyer's report to Secretary Rumsfeld expressed the opinion "that accelerating CVNX-2 to replace the CVNX-1 was unnecessary because the first ship had plenty of capabilities" and instead "concluded the primary drawback in waiting for CVNX-2 is its impact on the industrial base" (Castelli et al., 2002, p. 5-6). The schedule at that time was for CVNX-1 to begin construction in 2007 with CVNX-2 in 2011, although it was already being discussed to potentially accelerate CVNX-2 to 2009 if CVNX-1 was skipped. Although the delay was potentially only two years, the concerns were great enough that "as many as 185 members of Congress…signed a letter to be sent to Rumsfeld that discusse [d], among other issues, how skipping CVNX-1 could trigger industrial base challenges" (Castelli et al., 2002, p. 5). While a congressional source stated their doubt that it would be "a big enough concern to persuade Pentagon officials to stick to a 2007 start date," the Navy had separately begun using new "terms like CVNX-1 plus, CVNX-2 minus and CVNX-1.5" in their discussions on making a compromise for the design and acquisition strategy "in an attempt to ensure a start date of 2007 instead of 2009" (Castelli et al., 2002, p. 5).

### 4. Technology Off-Ramps

Ultimately, the decision was made to maintain the CVNX-1 schedule while pulling forward the future technology. A Program Decision Memorandum (PDM) in December 2002 officially "redesignated CVNX as CVN 21, pulling forward technologies originally planned for CVNX-2" and making the next ship a "modified repeat" (DON, 2023). The update to the design strategy also coincided with concerns from OSD about the program budget, resulting in an additional change boosting funding but "forcing the Navy to use traditional shipbuilding accounts to develop and buy the ship…rather than research and development accounts" (Castelli, 2002, p. 2).

It was well understood at the time that technology acceleration would create risk that could be managed by having "alternatives, in the event that a certain technology cannot be accelerated in time," and that these "off ramps could be legacy systems or upgrades to them" (Ma, 2003, p. 2). However, certain technologies were already viewed as essential to the improved capability of the new carrier. Matthew Mulherin, Northrop Grumman's VP in charge of the program at the Newport News shipyard, stated that EMALs was one of those technologies he viewed as "fundamental to the ship," where an off-ramp back to older steam catapults would be too "disruptive to the design" (Ma, 2003, p. 11). RADM Dwyer, PEO Carriers, stated that only technology mature enough to be delivered on the requested schedule was being pulled forward, and that the propulsion plant and EMALs were also systems he believed were essential to the new carrier (Ma, 2003). He believed that the key to managing risk was "starting early" so systems like the propulsion plant, already having detail design work in progress, and EMALs, in development separately with testing already in progress that year, were not high risk (Ma, 2003, p. 12).

In fact, Navy and industry experts were able to convince senior leaders that the acceleration of technology was possible on the desired schedule, after what Mr. Mulherin said was "a solid week going through what the requirements were, what the technologies were" until "everybody felt pretty comfortable that there's a little bit [of] risk – we're reaching on this stuff – but we think we'll be able to make it" (Ma, 2003, p. 12). Following the decision, Irwin Edenzon, Northrop Grumman VP of business and technology development at the shipyard, reiterated that the "planning and management work at the beginning of the program" to identify both the off-ramp technologies and when to use them gave them the confidence to pull the technology forward without "an undue amount of risk on the program that you're going to delay the ship or increase the cost" (Ma, 2003, p. 12).

As the program approached the Milestone B decision on proceeding with system development and construction, it was reported to the GAO that the program was expecting to proceed move forward "with very few of its critical technologies fully mature" due to the accelerated development (GAO, 2004, p. 43). The report stated that all necessary risk mitigation measures were in place, either because there was additional development time for that technology until it would need to be ready for installation later in the ship's construction timeline, or because of the off-ramp to mature technology (GAO, 2004, p. 44).

The program continued to emphasize that "each new technology has a development timeline with identified decision points…linked to key events in the platform design schedule and the technology development schedule" so that "if sufficient maturity has not been demonstrated…an "off-ramp" can be selected to a fallback technology…that can be incorporated into the design within ship delivery schedule constraints" (GAO, 2004, p. 44). Although the changes in strategy caused a delay to the Early Operational Assessment and therefore an additional delay to the Milestone B decision, already delayed previously from September 2002 to February 2003, the program eventually proceeded to a Milestone B decision in April 2004 using the new acquisition strategy (DON, 2024).

## D. ENGINEERING & MANUFACTURING DEVELOPMENT

The DAB Decision Review in April 2004 approved the timeline as planned for a 2007 construction start and 2014 delivery, as well as the program's APB for an LRIP of three ships, and the Construction Preparation contract was subsequently awarded (DON, 2024). The schedule remained compressed following the delays for a 2007–2014 build window to align with a 2014 delivery to replace the USS Enterprise after her scheduled decommission that year (GAO, 2004). In accordance with the approved timeline, the program office awarded various preparatory contracts in May 2004 for long lead time materials and other components that would need to be procured or constructed in advance to support start of construction in 2007 (DON, 2024). However, the eventual FY06 budget released in 2005 moved funding to 2008, requiring a shift in delivery of one year to the right (DON, 2024). Ultimately, contract authority for the construction of CVN 78 was received on the FY07 NDAA, and the DD&C contract was awarded in September 2008 following production authorization from a DAB the month prior (DON, 2024).

### 1. Critical Technologies

The primary concern using the compressed schedule from the acquisition strategy changes continued to be the maturity of technology included in the lead ship's design. The reporting of critical technology maturity and analysis conducted by the GAO used technology readiness levels (TRLs) to assess if a technology is mature, near maturity, or immature. Based on the DoD definition of TRL levels (Table 5; Office of the Undersecretary of Defense for Research and Development [OUSD (R&D)], 2023), the GAO considers a technology with a TRL of 7 or greater to be mature, a TRL of 6 to be nearing maturity, and a TRL of 5 or below to be immature (GAO, 2013b). The best practice found by the GAO is to have all critical technologies matured at a TRL 7 or greater prior to awarding a detail design contract to minimize risk (GAO, 2013b).

Table 5. DoD Hardware TRL Definitions. Adapted from OUSD (R&D) (2023).

| Maturity | TRL # | Definition |
|---|---|---|
| Mature | 9 | Actual system proven through successful mission operations |
| | 8 | Actual system completed and qualified through test and demonstration. |
| | 7 | System prototype demonstration in an operational environment. |
| Nearing Maturity | 6 | System/subsystem model or prototype demonstration in a relevant environment. |
| Immature | 5 | Component and/or breadboard validation in a relevant environment. |
| | 4 | Component and/or breadboard validation in a laboratory environment. |
| | 3 | Analytical and experimental critical function and/or characteristic proof of concept. |
| | 2 | Technology concept and/or application formulated. |
| | 1 | Basic principles observed and reported. |

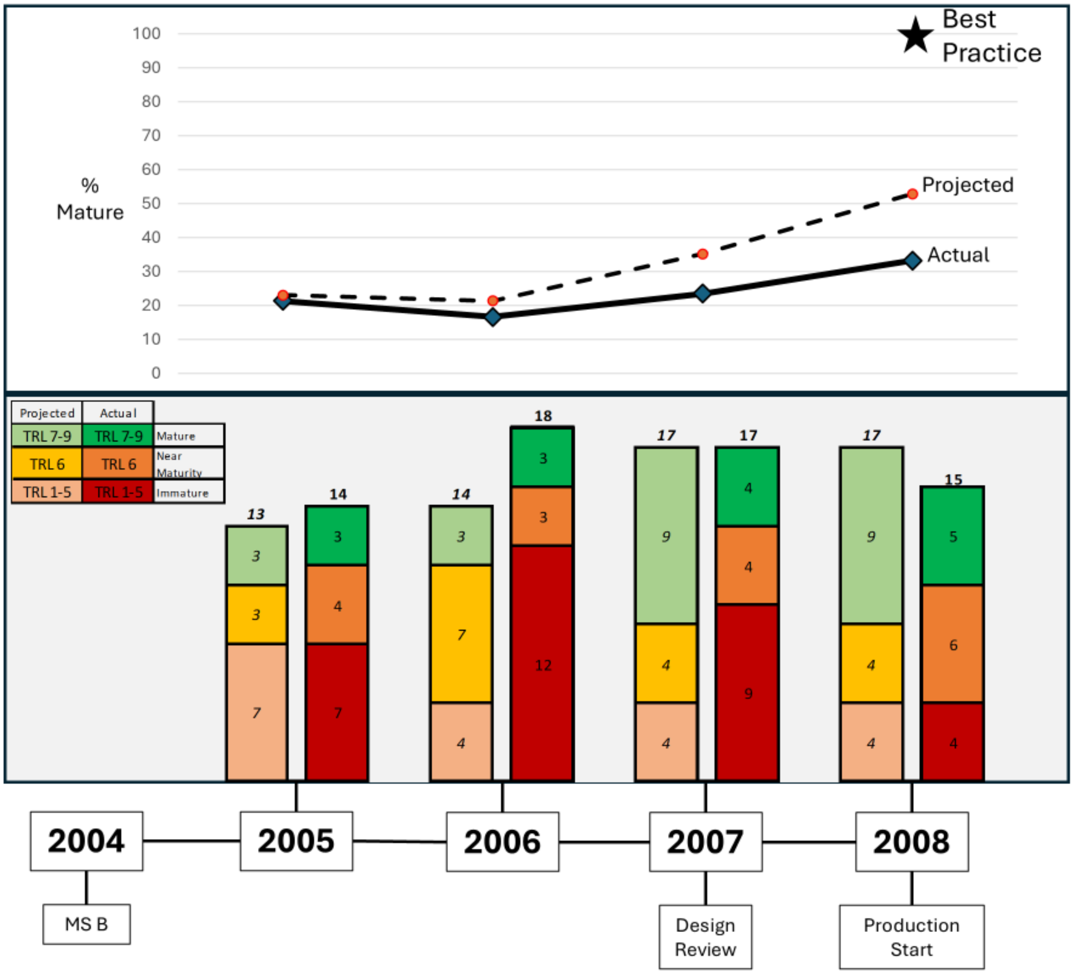
Prior to approval of system development, the program office estimated three of fourteen critical technologies would be mature at the decision point with another three approaching maturity (GAO, 2004). All six of those more mature technologies were from the original strategy, with the other seven technologies being pulled forward "at much lower levels of readiness…due to a mix of factors, including decisions by acquisition officials, standard practices in Navy shipbuilding, and feasibility of sea-based testing" (GAO, 2004, p. 44). Additionally, multiple immature technologies (Table 6; GAO, 2005) were in development through other programs so that the maturity timelines were dependent on external progress out of the direct control of the program (GAO, 2005).

Table 6. Critical Technologies Developed Via Other Programs. Adapted from GAO (2005).

| |
|---|
| Dual Band Radar (Multi-Function Radar and Volume Search Radar) |
| Advanced Arresting Gear |
| Evolved Sea Sparrow Missile |
| Joint Precision Approach and Landing System |

Leading up to production, the program office continued to reiterate that risk was being managed as the shipbuilding process allowed for "evolving technologies to be brought to the ship later in the construction cycle" and systems "not mature in time for ship construction…will be replaced by a fall back technology that…will at least be equal to current capability" (GAO, 2005, p. 46). At that time, the projection for the design review planned in 2006 was that maturity would significantly improve to ten of fourteen mature or near mature (GAO, 2005). However, in 2006 additional reporting stated that there had been an increase to eighteen critical technologies with twelve immature in addition to the same three mature and three near maturity (GAO, 2006). In fact, it was later reported there were up to twenty-two critical technologies being monitored at one point in 2006 (GAO, 2007a). If a technology was considered "new or novel" and inclusion in the design was necessary "to meet development, production, employment, and operations" it would be added to the critical technologies list for greater focus, but could later be removed from the list if it was taken out of the design or if it became mature enough that it did not need to be considered a developmental system (GAO, 2007b, p. 7). It is unclear from reporting which technologies were added and removed and if any technologies were replaced with the mature fallback systems that the program stated were available to manage risk.

Updated reporting in January 2008 had the program monitoring fifteen critical technologies prior to the award of the construction contract later that summer with five mature, six near maturity, and four immature (GAO, 2008). Between the Milestone B decision in 2004 and the start of construction in 2008, the progress in achieving mature technologies was consistently below projections, as shown in Figure 17.




Data from annual GAO Assessments of Selected Weapon Programs reporting (2005–2008).

Figure 17. Critical Technology Maturity.

While best practice determined by the GAO is to have all critical technologies mature at construction start, the program began construction with only 1/3 of the critical technologies matured to the recommended level. The decision was again justified by the belief "that a lengthy construction period provides additional time to mature technologies" and that the critical technologies were being effectively "managed through proven design processes, risk assessments, site visits, and contracting methods to ensure adequate maturity" (GAO, 2007a, p. 58). The management effort also included "quarterly integrated product team meetings with the various program offices and developers responsible for systems that will be installed on the ship" (GAO, 2007b, p. 8).

The GAO assessed the impact of all critical technologies on construction sequencing and capability in 2007 by looking at in-yard date requirements, design zone impact, and design integration requirements, as well as each technology's contribution to capability goals (GAO, 2007b). The assessment determined that "significant risks remain in the development of EMALS, the dual band radar, and the advanced arresting gear" and that these technologies had a high impact on both construction and capability (GAO, 2007b, p. 15). While the GAO agreed that the lower impact immature technologies could still be replaced by a fallback "without significantly affecting the ability of the ship to meet minimum performance requirements," it now appeared that "EMALS, the dual band radar, and the advanced arresting gear are each critical to realizing CVN 78's planned capability—and the Navy has committed to installing these technologies on the ship" (GAO, 2007b, p. 16).

The Navy agreed with the GAO's assessment that "concurrent technology development…presents the highest programmatic risk, but stated that all critical technologies are being managed through established processes to mitigate cost, schedule, and development risk" (GAO, 2008, p. 66). The competing concern from the Navy was to "ensure technologies do not become obsolete by ship delivery" (GAO, 2008, p. 66). Due to the construction schedule and delays in both the AAG and EMALS development, the Navy had decided "to consolidate [AAG] test events in order to maintain the shipyard delivery date" and was now considering authorizing the production of the EMALS generators "prior to completing initial testing in order to ensure delivery" on the required schedule (GAO, 2008, p. 66).

As construction proceeded, the program continued to make progress and achieved near maturity in all critical technologies by 2010, with eight of thirteen technologies still needing to be "demonstrated in a realistic environment" which would require shipboard testing at-sea (GAO, 2010, p. 53). By 2012, the number near maturity was still seven of thirteen, and the program office stated that "cost and labor-hour increases are largely due to the immaturity of the ship's technologies and design when the construction contract was awarded" and "the growth in construction costs may require requests for additional funding or a reduction of the ship's capabilities" (GAO, 2012, p. 66). It is unclear to what level a reduction in capability was discussed, and the following year it was reported that installation had begun for the final six near mature technologies "even though their capabilities are not yet fully proven" (GAO, 2013b, p. 12). Additionally, the program office reported that all of the critical technologies "met their system maturity goals" and the "oversight team led by the Office of the Secretary of Defense disbanded in 2012 once each of these technologies was determined to be approaching maturity or mature" (GAO, 2013a, p. 70).

The primary concern with shipboard testing was that it "may reveal a need for design changes" and "maintaining design stability depends on technologies fitting within the space, weight, cooling, and power reservations allotted them" (GAO, 2013a, p. 70). The maturity of critical technologies continued to be improved but there were still two of thirteen not fully mature in 2018, even after the ship had been delivered to the Navy in May 2017 (GAO, 2018b). Shipboard testing was still ongoing for multiple critical systems, both to finish maturing the final critical technologies but also to meet reliability goals (GAO, 2018b). The 2018 annual GAO report found that "the elevators, AAG, and DBR are struggling to meet reliability targets the Navy uses in assessing ship performance," and although the EMALS was meeting targets it was only "because the Navy lowered the EMALS reliability target" which could "also prevent the ship from meeting the program's aircraft launch and recovery requirement" (2018b, p. 85).

By 2022 all critical technologies were mature and CVN 78 was reported as achieving IOC, but shipboard testing and reliability concerns caused delays to operational testing (GAO, 2022b). The GAO (2013b) had previously done an assessment of reliability growth goals, which had a re-baselined plan to reach AAG goals in 2027 and EMALS goals in 2032. In 2022, reliability had only seen small improvements, and it was reported that the updated target was "achieving reliability goals in the 2030s" (GAO, 2022b, p. 164). Previous reports had identified the risk that "the form of these technologies and how they fit on the ship could evolve" and "introduce the need for additional design changes" (GAO, 2018b, p. 85). There are some systems where "challenges in maturing…critical technologies has led to their redesign or replacement" for the follow-on ships (GAO, 2020, p. 120). However, the AAG and EMALS systems are too critical to performance requirements, despite the current DOT&E belief that "the reliability and maintainability of CVN 78's EMALS and AAG continue to adversely affect sortie generation and flight operations, which remains the greatest risk to demonstrating operational effectiveness and suitability" (DOT&E, 2025, p. 213).

### 2. Performance and Schedule Baselines

Technology included on the FORD is intended to "improve the combat capability of the carrier fleet while simultaneously reducing acquisition and life cycle costs" (GAO, 2013b, p. 2). Additionally, the changes would also allow for "favorable design features," such as "an enlarged flight deck; a smaller, aft-positioned island with fewer rotating radars than Nimitz-class carriers; and a track-based, flexible infrastructure system that allows ship compartments to be easily reconfigured to support changing missions over time" (GAO, 2013b, p. 3). Desired improvements in capability had been identified as "increased sortie generation rates," "a near threefold increase in electrical generating capability," "increased operational availability," and "increased service life margins for weight and stability to support future configuration changes to the ship over its expected 50-year service life" (GAO, 2013b, p. 2-3).

Current Key Performance Parameters (KPPs) are in accordance with an ORD Change 2 from June 2007 that was revalidated by the Joint Requirements Oversight Council in April 2015 (DON, 2024). The original Objectives were established with the Development APB upon Milestone B approval in 2004, and current KPPs have Objectives and Thresholds that reflect the most recent APB Change 4 from 2020 (Table 6; DON, 2024). Although EMALS was designated as a major sub-program in APB Change 3 following a directive in the FY12 NDAA, no additional KPPs were established specifically for EMALS. (DON, 2012).

Table 7. 2023 CVN 78 Modernized Selected Acquisition Report (MSAR) KPPs. Adapted from DON (2024).

| Attribute | Development APB Objective | Change 4 APB Threshold | Change 4 APB Objective | Performance |
|---|---|---|---|---|
| **Sustained Sortie Rate** | 220 | 160 | 220 | 172 *Estimate* |
| **Surge Sortie Rate** | 310 | 270 | 310 | 284 *Estimate* |
| **Ship Service Electrical Generating Capacity** (times NIMITZ capacity in MW) | 3.0 | 2.5 | 3.0 | 3.25 *Demonstrated 2019* |
| **Weight Service Life Allowance** (% of full load displacement in long tons) | 7.5 | 5.0 | 7.5 | 5.82 *Demonstrated 2022* |
| **Stability Service Life Allowance** (feet) | 2.5 | 1.5 | 2.5 | 1.62 *Demonstrated 2022* |
| **Ship's Force Manpower** (billets) | 2391 | 2791 | 2391 | 2716 *Demonstrated 2024* |
| **Net-Ready** | - | Meets 100% of top level IERs designated as critical | Meets 100% of top level IERs | Meets 100% of top level IERs designated as critical *Estimate* |
| **Survivability** | - | Level II as defined by OPNAV Instruction 9070.1 with the exception of Collective Protection System | Level III as defined by OPNAV Instruction 9070.1 | Level II as defined by OPNAV Instruction 9070.1 with the exception of Collective Protection System *Demonstrated 2023* |

Although the ship was delivered to the Navy in 2017, the first KPP was not demonstrated until 2019 and the sortie generation rate and net-ready KPPs are still only estimates (DON, 2024). Earlier program SARs also included interoperability as a KPP, as well as lines to report on follow-on ships; however, SARs since 2022 no longer include interoperability as a KPP, and have a note that states the "CVN 78 performance Threshold and Objectives apply to all ships in the class" and "estimates for the follow-on ship will be updated, if different from the lead ship, when they become available" (DON, 2024). While there are no KPPs for follow-on ships, DOT&E did note in the FY24 annual report that updates to the TEMP are required to establish "the test strategy and test resources to determine operational effectiveness of new and/or upgraded capabilities on CVN 79" (DOT&E, 2025, p. 215). Despite the repeated delays to the schedule and reliability concerns related to critical technologies, the program has never reported a breach of the APB due to performance. Instead, impacts from performance have been captured by schedule deviations (Table 8).

Table 8. CVN 78 Program Schedule Deviations from Baseline.

| Milestone | Dev. APB | 2011 | 2013 | 2014 | 2015 | 2017 | 2018 | APB Ch 4 Obj. 2020 | APB Ch 4 Thr. 2020 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lead Ship (CVN 78)** | | | | | | | | | | | |
| DAB Program Review | Jan 2006 | Jul 2008 | | | | | | Complete Jul 2008 | | | |
| Start Construction | Jan 2007 | Sep 2008 | | | | | | Complete Sep 2008 | | | |
| Launch | Nov 2012 | - | Nov 2013 | | | | | Complete Nov 2013 | | | |
| Combat Systems Trial Rehearsal | Jul 2014 | - | - | - | Sep 2016 | Jan 2017 | | Complete Jan 2017 | | | |
| Delivery | Sep 2014 | - | - | - | May 2016 | May 2017 | | Complete May 2017 | | | |
| Initial Operational Capability | Sep 2015 | - | - | - | Oct 2017 | Apr 2019 | Oct 2019 | Jul 2021 | Jan 2022 | Dec 2021 | |
| **Follow-on Ship (CVN 79)** | | | | | | | | | | | |
| DAB Program Review | Jan 2010 | Apr 2013 | Oct 2014 | Apr 2015 | Apr 2015 | | | Complete Apr 2015 | | | |
| Start Construction | Jan 2011 | Jul 2013 | Dec 2014 | May 2015 | Jun 2015 | | | Complete Jun 2015 | | | |
| Delivery | Sep 2018 | Sep 2022 | - | - | - | Sep 2024 | - | Sep 2024 | Mar 2025 | Jul 2025 | - |
| **Milestone Decision** | | | | | | | | | | | |
| Milestone C | Mar 2017 | - | - | - | - | - | Jun 2022 | N/A | N/A | N/A | N/A |
| **Test and Evaluation** | | | | | | | | | | | |
| IOT&E Start | N/A | - | - | Sep 2017 | May 2018 | Jul 2020 | Mar 2021 | Aug 2022 | Feb 2023 | Sep 2022 | |
| IOT&E Complete | N/A | - | - | - | Apr 2020 | Sep 2021 | May 2022 | Nov 2023 | May 2024 | Mar 2025 | May 2025 |
| Platform-Level Integration DT Complete | N/A | - | - | Apr 2018 | Nov 2018 | Dec 2020 | Jan 2022 | May 2023 | Nov 2023 | - | May 2023 |
| **Follow-on Ship (CVN 80)** | | | | | | | | | | | |
| Delivery | N/A | N/A | N/A | N/A | N/A | N/A | N/A | Mar 2028 | Mar 2029 | - | Sep 2029 |
| **Follow-on Ship (CVN 81)** | | | | | | | | | | | |
| Delivery | N/A | N/A | N/A | N/A | N/A | N/A | N/A | Feb 2032 | Feb 2033 | - | - |

Data from CVN 78 Selected Acquisition Reports (2011–2023).

Between 2011 and 2023, the program reported schedule deviations in eight of thirteen years with six milestones having deviations reported in back-to-back years. Repeated delays to IOC, IOT&E, and Platform-Level Integration DT were a cascading impact from the original delays to delivery "associated with the shipboard testing and integration schedule" as a result of the immature technology (DON, 2015, p. 13). The delivery delays from 2014 to 2017 resulted in corresponding delays to the post-shakedown availability (PSA), leading to IOC delays from 2015 to 2019 (DON, 2015). The PSA also later required "an extension…to complete work on the Advanced Weapons Elevators (AWE), other platform systems, and the propulsion plant" which resulted in a delayed completion of the PSA and IOC in 2021 (DON, 2015, p. 13).

The delays to PSA and IOC also cascaded to the IOT&E and Platform-Level Integration schedule, causing breaches of the APB to align with the PSA and "to provide sufficient time for crew familiarization training and Platform Level DT integration testing with the new systems installed during PSA before commencing operational testing" (DON, 2015, p. 13). A three year delay to delivery grew to a five year delay in starting IOT&E, leading to an additional delay to IOT&E completion in order "to integrate the [first] CVN 78 operational deployment with the IOT&E schedule" (DON, 2023, p. 13). The ultimate outcome was that CVN 78 conducted a first operational deployment, including an extension for combat availability following the outbreak of hostilities between Israel and Hamas in October 2023, despite not having completed LFT&E and IOT&E. The most recent program updates now include a further delivery delay to CVN 79 as well, in order "to support a capability-based ship delivery/post-delivery strategy" by "shifting work from the Post-Shakedown Availability (PSA) into the construction period to incorporate CVN 78 lessons learned focused on improving the capability of the ship at delivery" (DON, 2023, p. 13).

### 3. Follow-on Ships and Strategy Updates

The Milestone B decision in 2004 approved the program's APB with an LRIP of three ships, to include CVN 79 and CVN 80 as follow-on ships after production of CVN 78 as the lead ship (DON, 2024). Authorization for the construction preparation of CVN

79 coincided with the DAB authorization of production of CVN 78 in 2008, and the Construction Preparation for CVN 79 was awarded in January 2009 not long after CVN 78 began production (DON, 2024). The three ships of the LRIP had received authorization for split funding across four years; however, in April 2009 the build cycle was updated to five years, leading to the adjustment of the schedule to reflect construction start of 2008 for CVN 78, 2013 for CVN 79, and 2018 for CVN 80 (DON, 2024). This shift meant that the next DAB Program Review planned for 2010 moved to 2013 to coincide (DON, 2024).

Implementing a five-year build cycle was viewed "as placing the program on a more fiscally sustainable path," while still meeting the force structure goal for aircraft carriers (DON, 2024, p. 11). The change brought concerns from the GAO related to overhead costs and how the production of DBR would align with ship construction (GAO, 2010). DBR development had been managed through the DDG 1000 program, formerly DD21 and DD(X), and the Navy had decided to reduce full rater production numbers, meaning that the line producing DBR would be idle and lead to higher costs to restart production (GAO, 2010). Consideration was being given to procuring radars for the follow-on ships in advance, but that strategy increased the risk of higher costs later to incorporate any design changes from the at-sea testing that still needed to be performed on CVN 78 (GAO, 2011).

At the same time, cost growth from the initial construction of CVN 78 gained attention from Congress, and a letter from Senator John McCain to the SECNAV in August 2011 led to an internal Navy review of the build plan to develop recommendations for improvement (DON, 2011). The report drove recommendations to improve execution of CVN 78 construction, as well as changes to the DD&C contract in development for CVN 79 in anticipation of award in 2013 (DON, 2011). CVN 79 was planned to be "a design roll-over from CVN 78," incorporating "changes for improved producibility, reduced cost, and limited fact-of-life obsolescence issues" (DON, 2012, p. 6). The Navy believed that improvements to the build plan coming from CVN 78 lessons learned would improve efficiency and drive down costs, and planned to negotiate a fixed price incentive contract for CVN 79, as opposed to the cost plus incentive fee used for CVN 78 (DON, 2012).

Although the design model was complete approaching CVN 79 contract award, concerns still existed for design changes required as a result of CVN 78 shipboard testing (GAO, 2013b). The program office and shipbuilder believed that the follow-on ship design would "be virtually the same as that of the lead ship" and allow for significant cost savings (GAO, 2013b, p. 44). However, in a 2013 assessment the GAO stated that the cost estimate was overly optimistic and didn't properly account for uncertainty in conducting CVN 79's construction while still resolving deficiencies seen on CVN 78, which were "likely to lead to redesign and potentially costly out of sequence work or rework for CVN 79" (GAO, 2013b, p. 44). Additionally, the sole source nature of the contract limited the government's ability to mitigate risk through contract negotiation (GAO, 2013b).

Based on the 2013 assessment, the GAO made multiple recommendations for both a cost-benefit analysis of capabilities and requirement and updates to the test and evaluation schedule prior to delivery of CVN 78, as well as deferral of the CVN 79 DD&C and an update to the cost estimate while developmental testing was completed on CVN 78 (GAO, 2013b). The Navy did in fact defer the DAB Program Review and DD&C contract award for CVN 79 until 2015, extending the construction preparation contract to prevent a pause in production while conducting "an in-depth review of CVN 79 requirements and capabilities to identify cost trades" to help "facilitate an agreement on contract terms" (GAO, 2014, p. 74).

Following the review process, the acquisition strategy for CVN 79 delivery was changed on the 2015 budget to take place in two phases (GAO, 2014). The updated strategy would allow for replacement of DBR with a new radar system and "increase competitive opportunities, reduce obsolescence at delivery and increase Government Furnished Equipment cost savings through common purchases of equipment with follow-on ship CVN 80" (DON, 2024, p. 10). The first phase of delivery would "allow the basic ship to be constructed and tested in the most efficient manner by the shipbuilder," followed by a second phase for the completion of "select ship systems and compartments" with installation "at the latest date possible" to prevent "obsolescence prior to CVN 79's first deployment" planned for 2027 (DON, 2014, p. 7).

The Navy awarded a fixed price incentive firm target contract for CVN 79 DD&C as planned in 2015, as well as a construction preparation contract modification, and the keel for CVN 79 was laid in August of that year (DON, 2024). The Navy conducted an Integrated Baseline Review in January 2016 and proceeded with the two phase delivery strategy for CVN 79. (DON, 2015). The delivery date for CVN 79 was updated from 2022 to 2024 to align with the two phase approach, although the end of the DD&C contract for phase one in 2022 would still "represent preliminary acceptance from the shipbuilder" (DON, 2024, p. 9). However, CVN 79 would not actually "be fully complete and deployable" until the end of phase two (GAO, 2016, p. 98). The GAO expressed concern that the two phase approach was simply shifting work to postdelivery, "transferring the costs of…known capability upgrades…to other accounts by deferring work to future maintenance periods" and "obscuring" the true cost (GAO, 2016, p. 98). Additionally, while the decision had been made to use a new Enterprise Air Surveillance Radar (EASR) on follow-on ships, no contract had been awarded for development yet to determine if it could "fit within the existing design" of CVN 78 or "would require design modifications" (GAO, 2016, p. 98).

In 2017, "as a result of key subsystem deficiencies" leading up to delivery of CVN 78 to the Navy, the Under Secretary of Defense for Acquisition, Technology and Logistics USD(AT&L) ordered the creation of "an independent review team to identify and mitigate potential technology risks for follow-on ships" (GAO, 2017a, p. 96). Concern was also brought up by the GAO that plans to mitigate costs for CVN 78 would not be effective, and "the costs will be shifted to follow-on ships or to other support accounts" (GAO, 2017a, p. 96). CVN 79 reached its 50% dry dock milestone in the summer of 2017 and the program reported that despite cost performance concerns "recovery targets in each of the major areas of remaining work have been identified with specific actions to achieve these improvements" (DON, 2017, p. 10).

In order to work towards lowering costs with the shipbuilder, the Navy rescheduled the DD&C contract award of the next ship, CVN 80, from 2018 to 2019, and extended advanced procurement and fabrication efforts for CVN 80 to attempt to keep it on schedule (DON, 2017). While working on the CVN 80 contract development, the Navy also began "evaluating a two-ship procurement of CVN 80 and CVN 81" in order to "take advantage of stable design through multiple builds (design once, build twice), quantity discounts for material, and level loading of industrial base capabilities (DON, 2017, p. 10). As the program was only approved for an LRIP of three ships, the addition of a fourth ship would require an update to the APB (DON, 2017). The SECDEF approved the addition of a fourth ship in December 2018 and authorized the use of a single contract for procurement of CVN 80 and 81 as a two-ship buy to achieve cost savings (DON, 2024).

The DD&C contract for CVN 80 and 81 was awarded in January 2019, while CVN 79 was 55% complete and still working through cost performance concerns (DON, 2018). The program continued to emphasize that "performance is expected to improve as technical risks are retired and design solutions are implemented" based on improvements being developed with the shipbuilder (DON, 2018, p. 9). Separately, the cost savings achieved in the CVN 80/81 contract was seen as "an opportunity to increase the lethality of the FORD Class and meet emerging threats" while remaining under the cost cap (DON, 2018, p. 9). A Navy Resources and Requirements Review Board met to identify "additional capabilities …that will drive future modifications" so that the "costs associated with integrating several of these modifications…into CVN 80 and CVN 81 is included in the DD&C contract" (DON, 2018, p. 10). The view of the Navy was that including the design modifications in the normal construction timeline would achieve "significant savings compared to back fitting these systems post-delivery" and enable the ships to "meet projected threats" when operational (DON, 2018, p. 10).

CVN 78 was continuing to finish shipboard testing and the maturation of critical technologies, and there remained concerns that the results of system development "could lead to their redesign or replacement on later ships" (GAO, 2019, p. 104). Additionally, the design modifications to the follow-on ships were not clear in terms of development requirements, as the EASR was not identified as a critical technology despite the fact it was "a different size and performs a different mission" compared to the Air and Missile Defense Radar used on destroyers from which it was derived (GAO, 2019, p. 104). Installation of the EASR on CVN 79 was also planned for deferral to phase two of the two-phase delivery, rather than during initial construction (GAO, 2019).

In June 2019, the House Armed Services Subcommittee on Seapower and Projection Forces brought up concerns regarding the deferral of F-35 capability as well, saying it was "unacceptable" that the new carriers could be "delivered without the capability to deploy with the service's most advanced fighters" (Werner, 2019, para. 1). Although the CVN 78 design had included F-35C accommodation, delays to the aircraft's development and testing had allowed for only "paper-based assessments to define F-35C integration requirements," while the Navy deferred "actual integration testing of F-35C and CVN 78 system hardware and software" (GAO, 2013b, p. 33). The GAO's 2013 assessment stated that this deferral potentially "introduces risk of system incompatibilities and costly retrofits to the ship after it is delivered to the Navy," and the CVN 79 two-phase delivery strategy had again deferred F-35C integration to phase two (GAO, 2013b, p. 33).

The cost cap for CVN 78 and CVN 79 had previously been established to manage procurement costs, but Congress believed it was now incentivizing the "delivery of unfinished carriers" to stay under the cost cap while "intending to pay more money later on to add critical capabilities in the future" (Werner, 2019, para. 3). F-35C integration was identified as an example of "work deferred until after delivery…during post-shakedown availability (PSA)" or "delayed until regularly scheduled maintenance availabilities even later in the ship's life" (Werner, 2019, para. 5). The belief was that this practice had already contributed to the CVN 78 PSA delays and would end up "causing the overall price…to increase dramatically" as "cost savings gleaned from production efficiencies are lost when capabilities are added in later" (Werner, 2019, para. 8).

Mark language was ultimately included in the FY20 NDAA to prohibit acceptance of CVN 79 prior to the inclusion of F-35C capability (Werner, 2019). CVN 79 was launched and christened in December 2019, two months ahead of schedule, but the Navy was forced to reexamine the acquisition strategy to return to a normal single-phase delivery with F-35C capability integrated prior to the ship's PSA (DON, 2019). The Navy released a request for proposal for the updated delivery strategy in January 2020, and awarded an updated single-phase delivery contract in November 2020 to meet the NDAA requirement that CVN 79 (Figure 18) "be delivered with its complete warfare system, including F-35

Joint Strike Fighter capabilities, before the ship is commissioned into the fleet" (Huntington Ingalls Industries [HII], 2020).

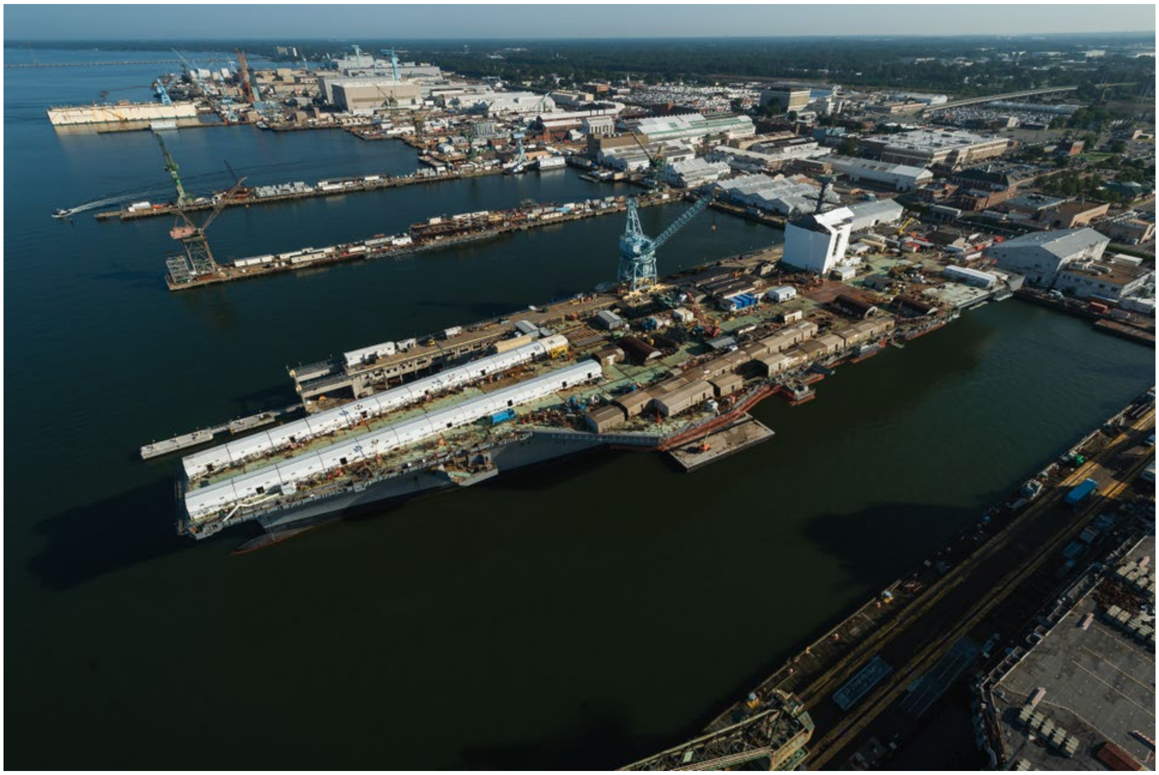


Figure 18. USS *John F. Kennedy* (CVN 79) sits at Newport News Shipbuilding on 02 November 2020, approximately 76 percent complete and progressing through final outfitting and testing. Source: Hildreth (2020).

In 2020, the Ford-class program was a major discussion topic in a study commissioned by the then-Acting SECNAV, Thomas Modly (Eckstein, 2020). Referred to as the Blue-Ribbon Future Carrier 2030 (FC-2030) Task Force, it intended "to consider the needs of the integrated naval force when making decisions on shipbuilding requirements to support new operational concepts" and would be "complementary to, and informed by, a broad review of national shipbuilding requirements being conducted by" the DoD (Eckstein, 2020, para. 2–3). Mr. Modly stated that there were "clear-eyed assessments and hard choices" required but with "time to reimagine what comes next…consider [ing] cost, survivability, and the critical national requirement to sustain an industrial base," which "can't be simply turned on and off like a faucet" (Eckstein, 2020, para. 4–5). There were some reports that the study might "reexamine how [the Navy] employed carriers, in general, potentially moving away from using them for front-line operations during major conflicts and using them instead for controlling broad areas of the ocean" which could support "shifting to a new, smaller, and cheaper class of likely non-nuclear-powered carriers" (Trevithick, 2020, para. 6–7). However, the study was not executed as planned after Mr. Modly was replaced as SECNAV, in favor of supporting a DoD study on force structure that would include the review of aircraft carriers (Trevithick, 2020).

The program proceeded with the CVN 79 single-phase delivery on schedule for 2024 followed by a CVN 80/81 two-ship buy, but still seeing cost growth "driven by first of class technical resolutions, material availability and performance in assembly trades" (DON, 2021, p. 5). Additionally, COVID-19 was impacting the "shipbuilder's labor availability as well as some material and equipment vendors" (DON, 2021, p. 5). The GAO reported that cost savings were unlikely due to the COVID-19 mitigations used by the shipbuilder, and that CVN 80/81 were likely to see cost overruns despite the Navy's use of a two-ship fixed-price contract that the Navy believed saved over $4 billion and would "limit cost liability and incentivize shipbuilder performance" (GAO, 2021, p. 168).

The Navy Aviation Vision 2030–2035 released in 2021 reiterated the importance of "large-deck, nuclear-powered aircraft carriers and their embarked carrier air wings..bring [ing] unmatched contributions of lethality, battle space awareness, and mobility to any maritime theater" (Naval Aviation Enterprise [NAE], 2021, p. 2). A key objective for Navy Aviation was to "invest in and pursue advanced technologies and operating concepts," with the FORD Class carrier both listed as an advanced technology itself and also described as being "designed to support these and other technologies well into the future" (NAE, 2021, p. 6-7). However, it was noted that advances in technology must be "done in partnership with industry" and using "open architecture, avoidance of unique and proprietary hardware and software, and development, testing and implementation that drives segmented rather than wholesale changes" in order to" accelerate the right change for the right reasons at the right time" (NAE, 2021, p. 7).

In the vision report, aircraft carriers like the Ford class "are the most survivable, agile, resilient, and lethal airfields…and will remain so for the future" because the "large size and nuclear power enable CVNs to conduct high-speed transits over great distances…without need for replenishment" (NAE, 2021, p. 9). Although it is recognized that there is "a rapidly evolving threat requiring substantial force modernization," the CVNs are viewed as assets that "remain effective, relevant, and potent year after year, and decade after decade, because they are adaptable platforms" that can "serve as the cornerstone of a lethal, agile, resilient, and readily adaptable distributed maritime force" (NAE, 2021, p. 9).

It was also reported in 2021 that the shipbuilder would begin using new Integrated Digital Shipbuilding (iDS) technology, "a new set of tools that will improve the efficiency of the construction planning and execution process," and that this was a "key to achieving the cost targets of the two-ship buy" (DON, 2021, p. 5). Newport News Shipbuilding (NNS) had begun working previously on incorporating digital engineering into their shipbuilding practices and were aligning lines of effort to parallel the five foundational elements from the DoD's Digital Engineering Strategy (DES) (Table 9; Debbink & Coleman, 2019).

Table 9. DES Foundational Elements and NNS Lines of Effort. Adapted from Debbink M. & Coleman, C. (2019).

| DES Element | NNS Effort |
|---|---|
| 1. Formalize the development, integration, and use of models to inform enterprise and program decision making | Strategy for Digital Thread and Digital Twin |
| 2. Provide an enduring, authoritative source of truth | Configuration Managed links between Navy Databases and Digital Product Model |
| 3. Incorporate technological innovation to improve the engineering practice | Implementation of AR/VR, laser scanning, IOT and other technologies incorporated into production processes |
| 4. Establish a supporting infrastructure and environment to perform activities, collaborate, and communicate across stakeholders | Integrated, Secure Cloud Environment |
| 5. Transform the culture and workforce to adopt and support digital engineering across the life cycle | integrated Digital Shipbuilding (iDS) for digital manufacturing |

While using iDS on CVN 80/81 was reported as intended to generate cost savings, it was also a component of the overall digital engineering goals of the company, transforming their own processes to better manage the complexity of projects like the Ford class with each ship having a 50-year life cycle (Debbink & Coleman, 2019). The eventual capability of effectively incorporating digital engineering practices would be the ability to maintain a real time life cycle sustainment roadmap through an Integrated Collaborative Environment as seen in Figure 19 (Debbink & Coleman, 2019).

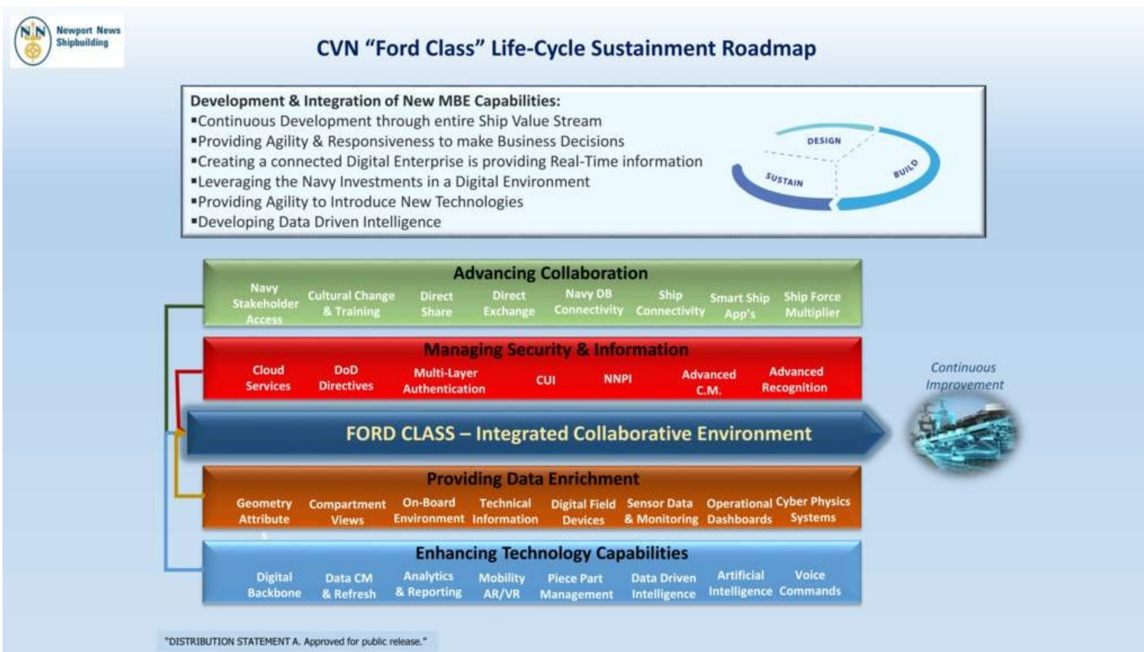



Figure 19. NNS Life Cycle Sustainment Roadmap Concept. Source: Debbink & Coleman (2019).

In order to accomplish a single-phase delivery for CVN 79, the Navy revised the delivery strategy to accomplish more work during the normal construction phase so that the "PSA will align to a traditional period of resolving discrepancies discovered during trials" (DON, 2023, p. 7). CVN 80 remained on schedule with keel laying in August 2022, and the program also initiated a Capital Expenditure (CAPEX) project in October 2022 to update the dry dock to allow for "simultaneous construction of two aircraft carriers" (DON, 2023, p. 7). The project was intended to limit "risk in the legacy heel-to-toe schedule…between the lead and follow-on ship in a two-ship buy" and enable "potential future two-ship award" (DON, 2023, p. 7). PEO Carriers had previously briefed a program update to the Aircraft Carrier Industrial Base Coalition (ACIBC) in March 2022 with a schedule, as seen in Figure 20, detailing how the program intended to deconflict dry dock utilization and build new carriers in alignment with the Refueling and Complex Overhaul (RCOH) and inactivation schedule (Downey & Davis, 2022).

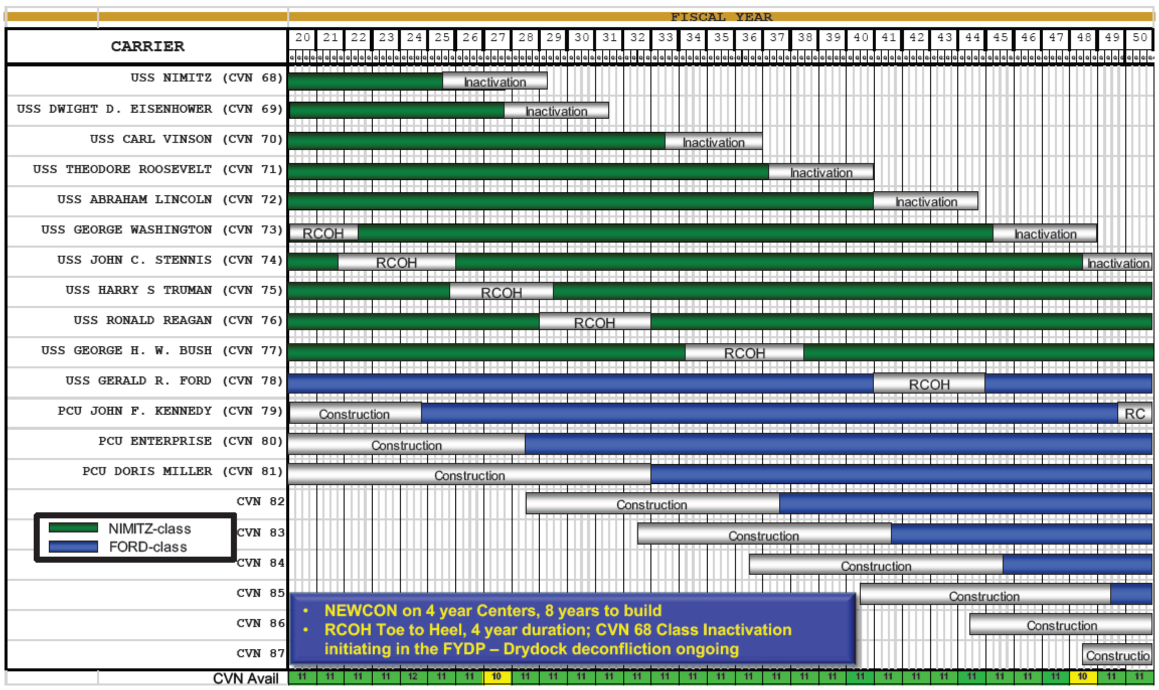



Figure 20. PEO Carrier Aircraft Carrier Delivery, RCOH, and Inactivation Plan. Source: Downey & Davis (2022).

While the Navy continued to use a 2024 delivery date for CVN 79 in the FY23 budget, testing was still ongoing for the new EASR and concerns were raised on additional delays "if EASR problems discovered during testing require rework" (GAO, 2023, p. 142). The program reported a risk being monitored was that if integration between EASR and the "Ship Self-Defense System (SSDS) isn't satisfactorily demonstrated at land-based test sites…ship milestones may be delayed due to additional shipboard integration and test" (DON, 2024, p. 15). The CVN 79 delivery was eventually delayed an additional year to

2025 to achieve the updated single-phase delivery strategy and finish F-35C and EASR integration, as well as correct discrepancies found in CVN 78 (Shelbourne, 2023). FY24 budget documents stated that "to support the added duration and incorporation of new systems, additional funding is required" (Shelbourne, 2023, para. 8). Requests also included more funding for CVN 80 "to complete the transition from using paper drawings for construction to a digital model" as the first ship incorporating iDS, and the program also indicated that there were now some doubts that cost savings could still be achieved due to "industrial base issues, including supply chain delays and inflation of material costs" (GAO, 2023, p. 142).

A *Naval News* article in November 2023 featuring commentary from RAND Senior Engineer Dr. Scott Savitz again cast doubt on the Navy's strategic development, despite previous RAND studies supporting the idea of the large-deck, nuclear-powered aircraft carrier. Dr. Savitz was asked what the Navy should pursue in the future, he stated that it is necessary "to intensively shift towards uncrewed platforms" as the Navy "has increasingly concentrated combat power in ever fewer, more capable, more expensive assets" when "ships and aircraft must be numerous if they are subjected to rates of attrition that otherwise preclude mission success" (Ong, 2023, para. 3). He believed that "the technological challenges involved…are not nearly so formidable as the organizational resistance" in moving the Navy away from "the platforms that have dominated its thinking and shaped its internal "tribes" since the Second World War" (Ong, 2023, para. 20). He identified that some programs had already been "doomed by the assumption that untested technology…would enable the ships to supplant current, well-honed capabilities," but can provide "lessons regarding the need to define coherent, attainable goals, the need to avoid rapidly introducing premature technologies, and how not to manage acquisition" (Ong, 2023, para. 21). Ultimately, Dr. Savitz indicated that there is a need to make strategic changes through "the gradual introduction of new technologies and adaptation over decades, reflecting the experience of past naval transformations" (Ong, 2023, para. 21).

CVN 79 was 90% complete in December 2023, on track for the updated delivery date of July 2025 with the program reporting that the change to the delivery strategy was a decision using "lessons learned from CVN 78, which had more post-delivery work than expected, resulting in schedule delays and cost growth" (GAO, 2024b, p. 132). The Navy now anticipated a "decrease [in] the time required to resolve discrepancies discovered during the ship's trials" (GAO, 2024b, p. 132). Additionally, program officials reported to the GAO that the "change did not result in new program costs," despite the FY24 budget requesting additional funding (GAO, 2024b, p. 132).

CVN 80 was also 36% complete, but experiencing delays due to "ongoing industrial base challenges," including "supply chain delays, as well as challenges with shipyard and vendor workforces" (GAO, 2024b, p. 132). A root cause was identified as "a smaller, inexperienced workforce that is less efficient at completing work…after many skilled, senior workers retired during the COVID-19 pandemic," and while the shipbuilder was working on mitigating actions it was "unlikely to improve CVN 80 construction performance because they are not yet in place" (GAO, 2024b, p. 132). The program had previously reported an identified risk that if launch of CVN 80 moved "beyond the working schedule milestone date of May 2027, then delays would cascade directly to CVN 81" (DON, 2024, p. 15). However, the program reported that CVN 81 was still on schedule for keel laying in 2026 with delivery in 2032, stating that they "do not expect industrial base issues to affect CVN 81, based on planned shipyard improvements" (GAO, 2024b, p. 132).

IOT&E remains incomplete as "operational requirements necessitated changing CVN 78's original test plan timeline around the operational deployment" and a revision was developed in July 2024 replacing the "original two-phase structure with a more incremental approach" (DOT&E, 2025, p. 212). However, approval of the updated plan was "withheld…due to an insufficiently articulated reliability, maintainability, logistics, and availability (RMLA) data collection strategy" (DOT&E, 2025, p. 213). Along with the updated RMLA collection strategy, test plan updates were also needed for "operational testing of the Ford class's capability to support F-35 and CMV-22, along with the self-defense capabilities of CVN 79 and follow-on carriers," as "the most significant changes to CVN 79 and beyond are related to the combat system and design changes to support F-35" (DOT&E, 2025, p. 213). In fact, CVN 79 and follow-on ships have six changes for sensors and weapons systems related to combat systems and SSDS (Table 10; DOT&E, 2025).

Table 10. Ford Class Combat Systems. Adapted from DOT&E (2025).

| CVN 78 | Follow-on Ships |
|---|---|
| Dual Band Radar (DBR) | SPY-6(V)3 Enterprise Air Surveillance Radar (EASR) Fixed Variant, the SPQ-9B Horizon Search Radar, and Mk 9 Tracker Illuminator System |
| SSDS Mk 2 Mod 6 with Baseline 10 Combat Management System | SSDS Mk 2 Mod 6 with Baseline 12 upgrade |
| AN/USG-2B Cooperative Engagement Capability (CEC) Tracking, Data Fusion, and Distribution System | AN/USG-2B CEC Block II upgrade |
| Rolling Airframe Missile (RAM) Block 2 | RAM Block 2A and 2B upgrade |
| Evolved Sea Sparrow Missile (ESSM) Block 1 | ESSM Block 1 and 2 upgrade |
| Close-In Weapon System (CIWS) Search Radar in Stand-Alone Mode | CIWS Search Radar integrated with AN/USG-2B CEC and SSDS |

Due to the changes, the Navy is now "in development of an enterprise test strategy that will coordinate ship self-defense evaluation of multiple ship classes, including the Ford-class, as modified in CVN 79 and follow-on carriers" (DOT&E, 2025, p. 213). SSDS and CEC systems are separate programs of record, requiring coordination "between the CVN 78 TEMP Revision F and the yet-to-be-approved Enterprise TEMP 1910" (DOT&E, 2025, p. 213–214). Additionally, DOT&E brought up the issue of ship berthing, stating that "sufficient berthing is not installed…to conduct combat operations with all hands assigned a bed, due to a lack of berthing capacity for embarked units" (DOT&E, 2025, p. 215). The Navy's Shipboard Habitability Program requires a 10% growth allowance over the service life of a ship but if "the ship and its embarked units were each at 100 percent manning, the ship would have a shortfall of 159 beds," which "could increase as the air wing diversifies to include CMV-22, F-35, and MQ-25" (DOT&E, 2025, p. 215). Two of the current recommendations from DOT&E for the program to resolve these issues are to "re-examine manning and berthing for future ships of the class" and finish an updated TEMP that "provides the test strategy and test resources to determine operational effectiveness of new and/or upgraded capabilities on CVN 79" (DOT&E, 2025, p. 216).

The current expectation from the Navy is for an approved update to the TEMP prior to delivery of CVN 79 (DOT&E, 2025).

As of 2024, the program schedule is to deliver CVN 79 in 2025, CVN 80 in 2029, and CVN 81 in 2032. Due to construction delays, delivery of CVN 80 was eventually shifted 18 months in FY25 budget documents to September 2029 (Shelbourne, 2024). Consideration for the purchase of the next two-ship buy, CVN 82/83, was also impacted, with a potential shift from 2028 to 2030 for CVN 82. The decision to delay purchase of CVN 82 had previously been of concern to HII, with HII executives advocating for "two carrier block buys, with three years of advance procurement funding ahead of each ship award, and a schedule that builds the carriers on four-year centers to both maintain the workforce and the supplier base" (Shelbourne, 2024, para. 7). According to HII and the suppliers, a delay from 2028 to 2030 "could cause workforce shortages, cold production lines, and higher costs," and a survey of suppliers by ACIBC found that purchasing CVN 82 after FY28 could cause 40% of suppliers to reduce their workforce through layoffs (Shelbourne, 2024, para. 9). The ACIBC chairwoman, Lisa Papini, stated that the current trend of carrier procurement at six years or more between starts was viewed as negative for business by 71% of suppliers, and "argued for a consistent shipbuilding plan from the Navy so suppliers can plan for future work" (Shelbourne, 2024, para. 13).

# V. CONCLUSIONS AND RECOMMENDATIONS

The Ford-class program has suffered substantial cost growth, schedule delays, and performance and reliability concerns. The program has been managed under a single MDAP in what is now the MCA pathway and has attempted various acquisition strategies with tailoring within that singular pathway. However, the program has also been reactive to externally directed changes to the acquisition strategies and management of the program. While there has been considerable focus placed on improving the accuracy of cost estimating and managing cost growth during construction, further research is needed into the root cause issues surrounding the program management framework and acquisition strategy decisions. This research enables additional assessment into recommendations for the future of the program to improve the underlying issues for all three of the triple constraint of cost, schedule, and performance and the cascading impacts from the interconnections between them.

## A. CONCLUSIONS

A review of the literature identified a lack of guidance on how the Ford-class program could tailor the MCA pathway for more effective program management. Analyzing the program constraints, priorities, and the impacts on acquisition strategy decision making allows for an assessment of the requirements needed by tailoring to provide recommendations for enabling actions.

### 1. Impact of Initial Constraints and Priorities on the Acquisition Strategy

All of the potential shipbuilding constraints as assessed by RAND in 2011 have been impacting the Ford program from the very start of research into a replacement for the Nimitz and the analysis of alternatives, naturally pushing the program toward a constrained design process (Table #; Drezner et al.). Additionally, the constraints had conflicting pressure on which between cost, schedule, and performance should be the priority.

The aircraft carrier force structure requirement determined in the DoD's 1993 Bottom-Up Review (BUR), and corresponding statutory requirement in 10 U.S. Code §

8062 to meet that force structure, placed significant pressure on maintaining a production schedule to align with the decommission of the oldest carriers. Additionally, the 1995 report on *Investment Strategy Options for the Navy's Aircraft Carrier Program* made clear that the constraints related to industrial base concerns were a major factor with Newport News Shipbuilding (NSS) as a sole source contractor to support construction with minimum production timelines and sustainable employment requirements. That constraint also placed additional pressure on schedule as a priority, although the tradeoff should not have been between a new carrier and nothing, but rather a new carrier or another Nimitz class ship while the new carrier design continued to develop.

Next, due to its significant cost, the foundational research itself was based around the idea of investment related to the aircraft carrier with a focus on affordability using cost as a priority. In fact, the language used in the initial DON 1996 Mission Need Statement (MNS) that the new ship be "as capable, but more affordable" than Nimitz indicates that the Navy at that time placed a greater emphasis on cost and schedule, rather than performance (para 2.e). This prioritization of cost and schedule was reflected in the initial strategy development by RADM Rittenour and Captain O'Hare (1997) from OPNAV and NAVSEA focusing on affordability with an emphasis on the force structure requirement as one of "the fundamental 'drivers'" of the program, balanced against the needs of "longer term war-fighting capability" (p. 25-26). They also correctly identified that due to being behind in starting R&D for new technology, there was a technical constraint on the timeline at which new capability could be achieved to meet the desired performance goals.

Based on the identified constraints and the priorities of cost and schedule, tailoring the acquisition strategy for incremental improvements on a schedule fitting the force structure and industrial base requirements was the correct decision based on the guidance at the time. It also was supported by their identification of "high levels of technological and fiscal risk" when programs attempt "'revolutionary' improvements in capability" (Rittenour & O'Hare, 1997, p. 26). However, a failure of the strategy development was in properly articulating those risks to military and civilian senior leaders to manage stakeholder priorities and the constraint of political pressure despite the substantial amount of research that had been conducted. This failure was initially demonstrated by the discussion surrounding getting "technology developed earlier to achieve savings sooner" which should have already been properly accounted for in the trade-off between prioritizing cost and schedule over performance in a cost-benefit analysis and risk assessment (Nathman, 1998, slide 11).

That discussion foreshadowed the inability to handle increased political pressure after the 2002 Defense Science Board (DSB) report called in to question the thoroughness of the Navy's planning and the SECDEF became involved. The acquisition strategy that had been tailored to manage the constraints and identified priorities of cost and schedule was not sufficient to articulate the previously identified high risk and overcome a new priority of schedule and performance. Despite then-SECDEF Rumsfeld making it clear that he understood there was risk involved, he placed pressure on what would be considered achievable and did not appear to consider the opinion of the then-PEO Carriers, RADM Dwyer (Castelli et al., 2002). The added pressure coming from the industrial base, including a letter from Congress to the SECDEF, provided sufficient pressure to force consideration of a change in the acquisition strategy from the initial tailoring conducted (Castelli et al., 2002).

Additionally, the reports that personnel within the Navy and from industry worked to convince leadership that the technology acceleration was possible on the same schedule rather than push back based on the previously established strategy is indicative of a failure in the original strategy development (Ma, 2003). Despite the acquisition strategy being tailored based on years of research and a clear understanding of risk, it did not have the proper acquisition structure backing it or sufficient supporting documentation to manage the stakeholder engagement. The issue may also have been compounded by the fact that turnover within the Navy meant the PEO Carriers dealing with the pressure was not the one who developed the initial strategy, as well as the involvement of industry experts with different motivations in terms of managing the cost, schedule, and performance constraints.

### 2. Utilization of Incremental Development, Evolutionary Acquisition, and Modular Open Systems Approach

The initial planning identified incremental development/evolutionary acquisition as the most effective strategy, but also regularly referenced modularity and system architecture as the enabling technical requirements. This was even prior to the development of what is now a requirement for MOSA rather than incremental development/evolutionary acquisition based on the later identification that modularity supports the principles necessary to provide capability faster while managing risk.

The use of language in the MNS such as “future upgrades,” “major functional elements,” “forward fit, and “retrofit” indicate that the Navy understood the necessity for improving the design architecture of the new ship while also maintaining requirements for sub-systems to interface with Nimitz class as well (DON, 1996, para 5.a). Following from the MNS, the program office leadership also clearly stated their understanding that the need for incremental development using modularity was based on the substantial 50-year life cycle of each new ship necessitating “a design that is easily modified to accept upgrades over the course of the ship’s service life” (Rittenour & O’Hare, 1997, p. 27).

The research conducted by the Naval Research Advisory Committee (NRAC) during the AOA reinforced a support for MOSA as well, with their findings that “modular architecture and a common source of electric power are essential” (Weldon et al., 1997, p. 6). The NRAC study also concurred with a need to plan for changes far in the future, stating that a modular design to achieve their “reconfigurability” requirement was the best approach to enable “cost effective” upgrades as each ship would likely operate with “several generations of aircraft, C4I, and [hull, mechanical, and electrical (HM&E)] technologies” over their full service life (Weldon et al., 1997, p. 41). The third part of the AOA reportedly investigated multiple new designs and designs modified from CVNX-1 when planning for CVNX-2, but it is unclear how that analysis took into consideration the emphasis on modular architecture from the earlier studies (DOT&E, 2002, p. 175).

Starting from a Nimitz class base design from the 1960s with CVN 77 would likely necessitate a large amount of incremental improvement to achieve the leap forward from CVNX-1 to CVNX-2 in line with the initial AOA research. While the previously stated belief was that using an incremental development approach would mean an "all-new carrier design…might eventually emerge," there was never any specific Spirals, Increments, or Blocks reported as part of the program the way guidance for incremental development was written at the time (O'Rourke, 1998, p. 3). Instead, the program continued to reference the transition plan between CVN 77 of the Nimitz class to CVX 1 and CVX 2 from the new class, with each ship naturally being an increment due to the build process. In fact, there is almost no reference to increments or modularity related to the program at all following the Systems Requirement Review (SRR) in 2001.

The decision to essentially jump straight from CVN 77 to CVNX-2 would indicate there was not sufficient planning to support the need for CVNX-1 in between to improve modularity and support upgrades over the long term. That planning would be more in line with the current MOSA guidance requiring MDAPs to describe "the evolution of capabilities that will be added, removed, or replaced in future increments" and would have been the supporting documentation needed to prevent the change in acquisition strategy (OUSD[A&S], 2021, p. 26). Instead, while the program did incorporate new technologies developed through other programs and repeatedly refer to the potential to off ramp to existing technology as a fallback, there were also multiple reports that some technologies were too integral to the design to change, indicating an overconfidence in achieving early design stability without properly leveraging modular architecture principles.

Lack of clarity in the development and design modifications to the CVN 78 design for CVN 79, 80, and 81 based on upgrades to EASR , integration of F-35C capabilities, and the other "additional capabilities …that will drive future modifications" approved by the Navy Resources and Requirements Review Board also indicate a utilization of MOSA and incremental development principles without the necessary structure and planning to properly leverage them. Other shipbuilding programs within the Navy are reported as MDAP Increments and managed as Blocks or Flights, such as the Arleigh Burke class destroyer Flight II or Virginia class submarine Block V (GAO, 2024b). Under an MDAP increment or sub-program, a separate baseline would need to be established for each increment and could properly set expectations between the program and stakeholders (AcqNotes, 2022).

A lack of clear expectations and early planning for when and how modifications will be made forces the program to be reactive, like in the examples where the CVN 79 delivery strategy was changed to meet an NDAA mandate or where a TEMP update became necessary "to determine operational effectiveness of new and/or upgraded capabilities on CVN 79" the same year as planned delivery (DOT&E, 2025, p. 216). Not effectively using MOSA as the strategy to achieve incremental improvements has also contributed to a lack of stakeholder confidence in future upgrades and prevented the program from countering the belief that it is always more cost effective to include a capability during production as opposed to as a later upgrade, despite it being apparent from program initiation that capabilities will need to be added over the long life cycle of each ship (Werner, 2019).

### 3. Critical Technology Integration and Performance

Despite the late change in acquisition strategy prior to Milestone B, there was still a great deal of confidence in the ability of the program to manage the risk involved with pulling technology forward. This confidence was based on the feeling in the program that the risk mitigation measures in place were sufficient despite the clear understanding at the time that it is not the best practice to proceed with immature technology. However, the primary focus of the risk mitigation planning was on the timing of off ramping an immature technology to a mature fall back, and it was already apparent prior to the Milestone B decision that there was no intention of deviating from some of the critical technologies like EMALS (Ma, 2003). Additionally, the secondary focus of the risk mitigation was a reliance on construction sequencing allowing time for further development concurrently with construction, but there was obvious pressure to continue moving forward with an immature technology and avoid being "disruptive to the design" once construction began (Ma, 2003).

The program consistently fell behind reported projections in maturity levels leading up to production despite continuing to emphasize the use of "established processes to mitigate cost, schedule, and development risk" (GAO, 2008, p. 66). These projections indicate there was overconfidence in those processes and the use of integrated product team meetings was insufficient, requiring the added oversight of an OSD directed team until greater maturity was reached in 2012 (GAO, 2013a). The risk management plan had been briefed as including “identified decision points…linked to key events in the platform design schedule and the technology development schedule” or use the fallbacks to meet the “ship delivery schedule constraints” (GAO, 2004, p. 44). However, it is not clear what milestones they were anticipating individual technologies reaching to achieve the maturity projection and what metrics were used at those decision points to not actually utilize the fallback technology. The later adjustments to testing and production timelines of sub-systems to prevent impacts to construction, and the fact that CVN 78 continued all the way through launch and delivery with immature technology, indicate that the risk mitigation measures were not sufficient to manage the technical risk in the program.

Reliability growth concerns for AAG and EMALS also represent a disconnect between a technology reaching maturity based on TRLs and the reliability and maintainability levels needed to achieve a KPP. The original schedule goal of completing IOT&E by 2020 does not align with the reliability goals of 2027 for AAG and 2032 for EMALS identified in 2013 and indicates that the sortie generation rate KPPs do not properly account for reliability and availability metrics. The independent review team designated by USD(AT&L) in 2017 to “identify and mitigate potential technology risks for follow-on ships” based on “key subsystem deficiencies” represented a lack of confidence in the planning and structure used to manage those critical technologies (GAO, 2017a, p. 96).

There is also a disconnect present in performance expectations based on the importance placed on critical technologies enabling sortie generation rates as a KPP and the deferral of F-35C integration. Although F-35C integration was a lower priority for the program through development of the lead ship due to the lagging F-35C program, it became a higher priority for Congressional oversight for CVN 79 before the program had planned (Werner, 2019). This disconnect in performance priorities represents a gap in the utilization of KPPs to set stakeholder expectations for the program. The KPPs for sortie generation rate numbers are not necessarily tied to a specific air wing capability, and the net-ready KPP is a new mandatory requirement focused on information system interoperability rather than for interoperability with aircraft; however, Congress viewed F-35C interoperability as important enough to mandate a change to the CVN 79 delivery strategy (DAU, 2025).

Due to management as a single program within the MCA pathway, there is only a singular APB with one set of KPPs based off planning for the lead ship with the note that these KPPs are for all follow-on ships as well and updated estimates for follow-on ship performance will be reported when necessary. At the same time, there is a requirement for updated testing of CVN 79 capabilities due to changes from the base design of the lead ship (DOT&E, 2025). CVN 80/81 have also received approval for "additional capabilities …that will drive future modifications" and will likely require further test and evaluation (DON, 2018, p. 10). It is unclear what mechanisms within the current structure of the program will be used to determine how and when new KPPs and testing requirements will be developed and applied, as the long life span of the ships and program will require.

Additionally, there is a lack of reporting on new critical technologies since the maturation of those incorporated in the original design, as there is no mention of any new critical technologies being monitored for the follow-on ships. It is also unclear how the current structure of the program supports monitoring and maturation of future critical technologies that will need to be incorporated to achieve future capability requirements and possible KPP updates.

### 4. Changes to Constraints and Acquisition Strategy Updates

The program has continued to suffer all of the same constraints that the RAND study in 2011 determined will force shipbuilding into an undesirable build process, impacting attempts by the program to proactively make acquisition strategy changes and tailor requirements to achieve improvements for follow-on ships. The force structure and statutory requirements remain unchanged despite further studies by the Navy into future fleet composition and strategic focus, necessitating the same schedule pressure to align with inactivation/decommissioning timelines. Planning for follow-on ships was made with expected improvements from stabilizing the design with CVN 78 and gaining efficiencies in the production process. Assessments by the GAO and the year-on-year reporting from the program indicate that improvements have been minimal. Program efforts leading to the CAPEX dry dock improvements and two-ship build strategy will hopefully mitigate some of the industrial base constraints to achieve cost savings.

The other program efforts to tailor delivery requirements for CVN 79 led to a similar outcome seen with the changes to the original acquisition strategy. A misalignment between the stakeholder and program priorities in cost, schedule, and performance resulted in political factors becoming the most significant constraint that the program could not overcome. The fiscal constraint of the cost cap and the schedule pressure of the force structure requirement, both statutory requirements from Congress, indicate the priority of cost and schedule in the short term related to production. The long service life of the ship and planned upgradeability of the design supporting performance as a priority in the long term. However, the program again had a mandated change to the strategy based on performance becoming a priority over schedule.

Similar to the outcome seen from a late shift in priority to performance with the lead ship, the mandated change caused cascading impacts to the schedule including a delay to CVN 80. That in turn limits the effectiveness of previous mitigation efforts for industrial base concerns, as the delays cause suppliers to lose confidence in the consistency of shipbuilding efforts and reduce their workforce and production capacity and once again drive increased costs for the program (Shelbourne, 2024). This event mirroring the changes to the original acquisition strategy indicates that despite the program's best efforts to plan and tailor updates to the acquisition strategy, there was the same outcome. There remains the same lack of structure to align expectations between the program and stakeholders, support the existing planning efforts, and prevent changing conditions that shorten the program's planning and decision windows leading to cascading impacts.

## B. RECOMMENDATIONS

The Ford-class program has attempted to manage the complexity of the aircraft carrier shipbuilding process but seen poor outcomes primarily due to external pressure, despite following approved policy and procedure. The program has tailored the timing and sequence of reviews and program events in accordance with Navy guidance related to tailoring. However, the tailored acquisition strategies have not been sufficient to mitigate external constraints and provide mechanisms to control internal constraints.

PEO Carriers currently has program offices for CVN 78 Class Aircraft Carriers (PMS 378), In-Service Aircraft Carriers (PMS 312), and Aircraft Carrier Inactivation and Disposal (PMS 368), with support from the Carrier Planning Activity (CPA) for life cycle planning of maintenance and modernization (SECNAV, 2025). The Ford program is also utilizing a singular MCA pathway, in a perpetual EMD phase since the Milestone B in 2004 with no planned Milestone C. This utilization of the MCA pathway means that the program is in EMD but still conducting activities from all phases for the various ships, participating in AOAs for future modifications, conducting technology maturation for design changes to follow-on ships, and managing the transition of ships into an operational status. The AAF is not being leveraged effectively to prevent the risks presented by concurrent technology development, design, and construction.

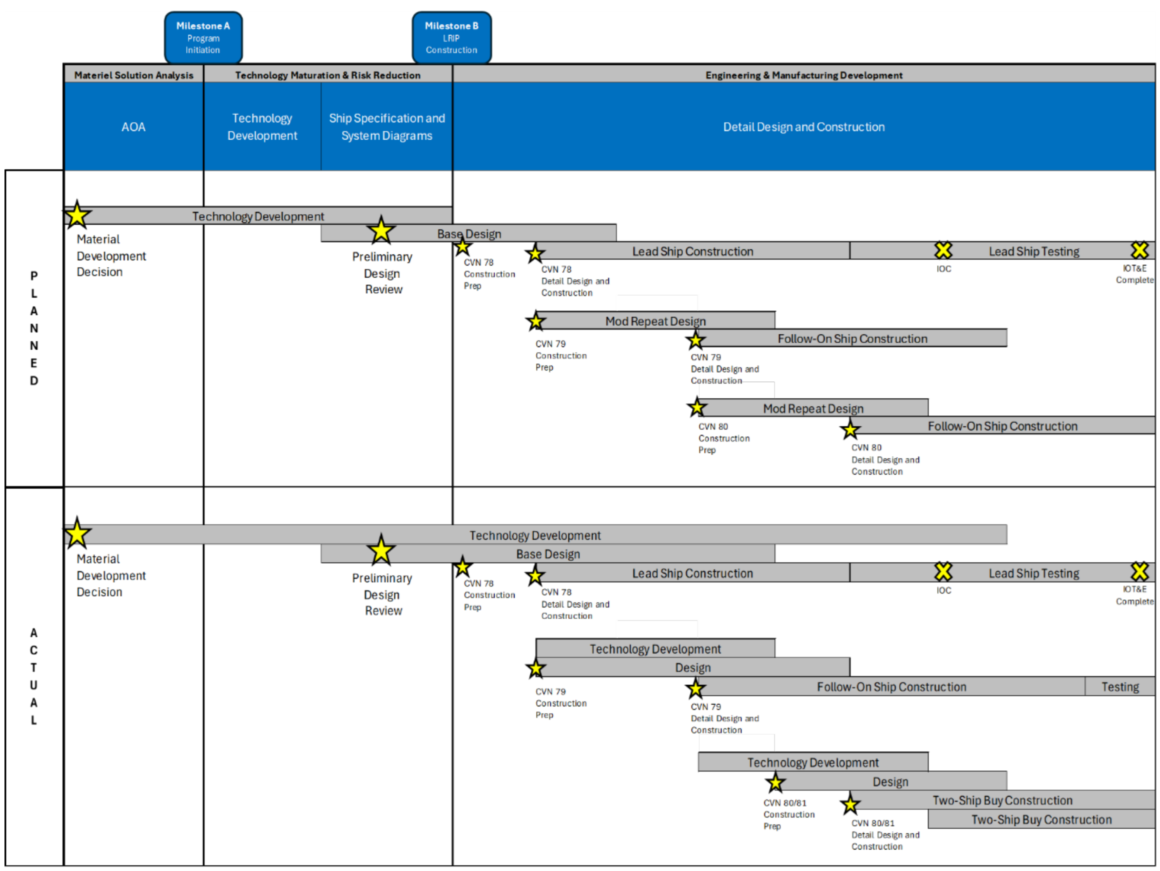



Figure 21. Ford Class Design/Build Process within MCA Pathway.

Changes are recommended to the program's utilization of the MCA pathway and the organization of responsibilities within the program offices and support staff under PEO Carriers to provide a framework that supports mitigating the constraints on the shipbuilding design and build process. The tailoring of the MCA pathway and reorganization should support the following based on the case study analysis of the program:

- Set expectations between stakeholders for cost, schedule, and performance priorities
- Limit impacts of leadership turnover on long term planning
- Enforce more thorough reporting requirements for oversight to improve the confidence of stakeholders
- Emphasize delivery of incremental capability over the long service life of each ship
- Provide mechanism for changing KPPs and the planning for subsequent test and evaluation requirements
- Provide structure for continuous technology development, including cost-benefit analysis of technology investment based on cost-benefit analysis of forward fit or inclusion in production, and backfit to operational ships
- Enforce decision gates for technology integration to maintain design stability and follow best practices for technology maturation

In order to support these actions, it is recommended that PEO Carriers split the CVN 78 program into sub-programs for each ship or set of ships to be managed as MDAP Increments, and create an additional program office to conduct continuous technology development and integration, including management of sub-programs for sub-system technologies in development through PEO Carriers like EMALS and coordination for technology developed through other programs like AAG, SSDS, and JPALS (see Figure 22).

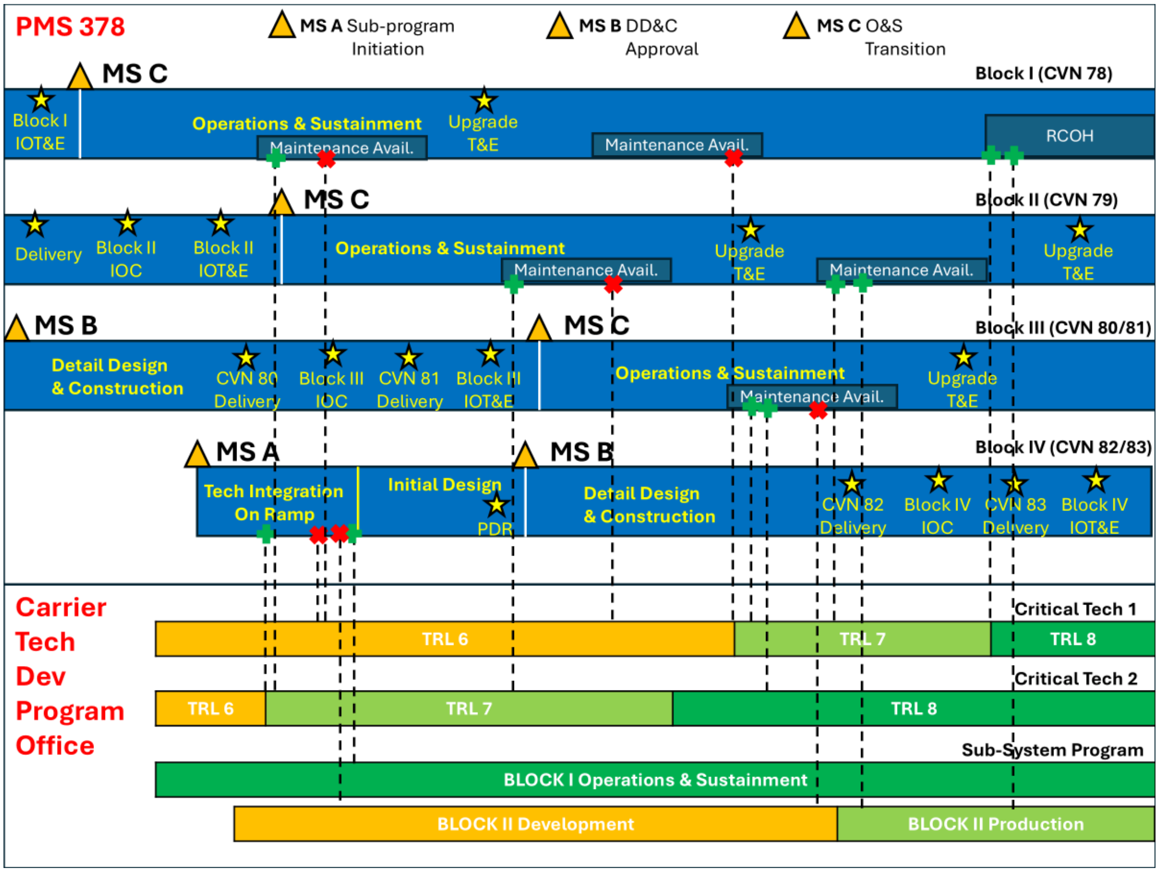



Figure 22. PEO Carriers Reorganization Model for Ford-Class Block Increments with Technology Integration.

The technology development office would manage continuous AOA and technology maturation activities with cost-benefit analysis conducted to determine the cost effectiveness of investments for inclusion in next increment production, backfit to operational carriers in a maintenance availability, or backfit during RCOH. Each sub-program would be initiated through a modified milestone decision with a window for technology integration into the design for a preliminary design review, enforcing decision gates for on ramps when a technology is mature vice an off ramp if still immature. A separate APB would be approved for each increment with tailoring of performance based on design modifications to have all or only some KPPs updated and a tailored test and evaluation schedule to match. Each increment would also then have its own cost estimation requirements and cost baseline.

Additional reporting requirements would then exist for each sub-program within the overall program, improving reporting for oversight. Priorities within the program could then be set for performance overall for PEO Carriers in the long-term, being differentiated clearly as a priority managed by the technology development office balanced against cost with schedule as a consideration for integration management to deliver incremental capability. Each ship sub-program would prioritize schedule for production timeline balanced against cost with the technology development office in a supporting role providing the understanding to stakeholders of how technical risk is being managed over each ship's service life for future capabilities. Expectations would be managed through the organizational structure that technology is being integrated at the right place and time in alignment with availability to manage risk while achieving cost effective upgrades. Older ships may actually receive new capabilities prior to the newest ship production based on timing but all stakeholders would have a clear idea of how obsolescence is being managed to close capability gaps.

In order to manage the added organizational complexity, PEO Carriers should leverage existing contract support from CACI and the digital engineering technology in development by NNS. NAVSEA has already contracted with CACI for program management support to PEO Carriers, to include supporting "Carrier Technology (CARTECH), New Technology, Science and Technology (S&T) Program Analysis, Small Business Innovative Research (SBIR) program, and other ongoing and emerging technology related efforts" and the reorganization will not necessarily add more requirements but simply reorganize for clearly delineated responsibilities in management and oversight (Naval Sea Systems Command [NAVSEA], 2020, p. 60). Additionally, PEO Carriers has already been utilizing an Integrated Digital Environment (IDE) supported by contract with CACI, and should be proactively working to incorporate the further capability provided by NNS' digital engineering Integrated Collaborative Environment to enable continuous technology development and integration in concert with the life cycle sustainment of multiple increments of ships in the class (NAVSEA, 2020).

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

www.acquisitionresearch.net