United States Government Accountability Office

Report to Congressional Requesters

September 2013

FORD-CLASS CARRIERS

Lead Ship Testing and Reliability Shortfalls Will Limit Initial Fleet Capabilities

GAO-13-396

GAO Highlights

Highlights of GAO-13-396, a report to congressional requesters

September 2013

FORD-CLASS CARRIERS

Lead Ship Testing and Reliability Shortfalls Will Limit Initial Fleet Capabilities

Why GAO Did This Study

The Navy plans to spend over $43 billion to produce three Ford-class aircraft carriers. The lead ship, CVN 78, is under construction, and preparation work is underway for the second, CVN 79. These ships will feature new technologies designed to increase capability and reduce crew size. GAO was asked to evaluate the progress of the Ford class. This report examines (1) technical, design, and construction challenges to delivering the lead ship within budget and schedule estimates; (2) the Navy's test strategy for demonstrating CVN 78's required capabilities; and (3) actions the Navy is taking to improve CVN 79 cost outcomes. GAO analyzed documents related to mission requirements, acquisition plans and performance, and testing strategies, and interviewed Department of Defense (DOD) and contractor officials.

What GAO Recommends

GAO recommends the Secretary of Defense take several actions aimed at ensuring Ford-class carrier acquisitions are supported by sound requirements and a comprehensive testing strategy, including conducting a cost-benefit analysis of required capabilities and associated costs. GAO is also recommending actions to improve the Navy's knowledge about CVN 79 capabilities and costs before beginning contract negotiations. DOD concurred with one recommendation, partially concurred with three others, and did not concur with the recommendation to defer CVN 79's detail design and construction contract award. GAO maintains that DOD's current schedule for awarding this contract undermines the government's negotiating position.

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What GAO Found

The Navy faces technical, design, and construction challenges to completing *Gerald R. Ford* (CVN 78) that have led to significant cost increases and reduced the likelihood that a fully functional ship will be delivered on time. The Navy has achieved mixed progress to date developing CVN 78's critical technologies, such as a system intended to more effectively launch aircraft from the ship. In an effort to meet required installation dates aboard CVN 78, the Navy has elected to produce some of these systems prior to demonstrating their maturity—a strategy that GAO's previous work has shown introduces risk of late and costly design changes and rework, and leaves little margin to incorporate additional weight growth in the ship. In addition, progress in constructing CVN 78 has been overshadowed by inefficient out-of-sequence work, driven largely by material shortfalls, engineering challenges, and delays developing and installing critical technology systems. These events are occurring in a constrained budget environment, even as lead ship costs have increased by over 22 percent since construction authorization in fiscal year 2008—to $12.8 billion. Additional increases could follow due to uncertainties facing critical technology systems and shipbuilder underperformance.

The Navy's strategy for providing timely demonstration of CVN 78 capabilities is hampered by post-delivery test plan deficiencies, Joint Strike Fighter aircraft delays, and reliability shortfalls affecting key ship systems. Additional risk is introduced due to the Navy's plan to conduct integration testing of key systems with the ship at the same time as initial operational test and evaluation (IOT&E). This strategy will constrain opportunities to implement timely, corrective actions if problems are discovered with key ship systems. In addition, significant discoveries during IOT&E could delay demonstration of ship capabilities. The Joint Strike Fighter, intended to operate with the carrier, has faced delays, and there is the likelihood of costly retrofits to the ship to accommodate the aircraft after CVN 78 is delivered to the Navy. But even after the ship commissions, several key ship systems will continue to face significant reliability shortfalls that will likely increase costs to the government and limit the ship's mission effectiveness. The extent of these limitations will not be known until after IOT&E. GAO contemplated making a recommendation to delay CVN 78 commissioning until the ship successfully completes IOT&E. However, based on additional information provided by DOD, GAO decided not to include this recommendation in the report.

The Navy and shipbuilder are implementing process improvements aimed at reducing the cost of the follow-on ship, *John F. Kennedy* (CVN 79), ahead of the main construction contract award for that ship, currently planned for September 2013. CVN 79 is to be of nearly identical design to CVN 78. The shipbuilder plans to employ a new, more efficient build strategy, but remaining technical and design risks with the lead ship could interfere with the Navy's ability to achieve its desired cost savings for CVN 79. These uncertainties also affect the soundness of the Navy's current CVN 79 cost estimate, which is optimistic. These factors, when coupled with the existing sole source environment for aircraft carrier construction, may compromise the government's negotiating position for CVN 79.

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Abbreviations

DFARS	Defense Federal Acquisition Regulation Supplement
DOD	Department of Defense
EMALS	electromagnetic aircraft launch system
HSLA 65	high strength low alloy steel
HSLA 115	high strength toughness steel
IOT&E	initial operational test and evaluation
JPALS	joint precision approach and landing system
TRL	technology readiness level

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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September 5, 2013

The Honorable Carl Levin
Chairman
Committee on Armed Services
United States Senate

The Honorable John McCain
Ranking Member
Subcommittee on Seapower
Committee on Armed Services
United States Senate

The Navy is developing the Ford-class nuclear powered aircraft carrier to serve as the future centerpiece of the carrier strike group, which combines different types of ships together to gain and maintain sea control. The Ford class is the successor to the Nimitz-class aircraft carrier designed in the 1960s. The Ford class carriers will introduce several advanced technologies that are intended to create operational efficiencies while enabling higher sortie rates (operational flights by aircraft, such as the Joint Strike Fighter) with reduced manpower compared to current carriers. The Navy plans to invest over $43 billion to develop, design, construct, and test three Ford class carriers. At present, the lead ship, Gerald R. Ford (CVN 78), is under construction, and initial construction activities are underway for the first follow-on ship, John F. Kennedy (CVN 79).

In 2012, the Navy reported a significant increase in its budget estimate for construction of the lead ship. That ship is now expected to cost $12.8 billion—a $1.3 billion increase since 2011. This cost growth has led to concerns about the Navy's ability to deliver the three Ford-class aircraft carriers as planned and with the promised levels of capability.

In light of these developments, you asked us to review the Navy's acquisition of the Ford class. Specifically, we (1) assessed technical, design, and construction challenges the Navy faces in delivering the lead ship, CVN 78, within current budget and schedule estimates; (2) evaluated whether the Navy's post-delivery test and evaluation strategy for CVN 78 will provide timely demonstration of required capabilities; and (3) identified actions the Navy is taking to improve cost outcomes for the first follow-on ship, CVN 79, ahead of that ship's upcoming contract award for detail design and construction.

To assess technical, design, and construction challenges the Navy faces in delivering CVN 78 within current budget and schedule estimates, we reviewed Department of Defense (DOD) and contractor documentation to identify technology development, design stability, and construction activities. This documentation included Navy technology readiness assessments and briefings, ship and key subsystem test plans, and contract performance reports. To evaluate whether the Navy's post-delivery test and evaluation strategy for CVN 78 will provide timely demonstration of required capabilities, we reviewed the Navy's draft revision to the CVN 78 test and evaluation master plan, Joint Strike Fighter performance reports and briefings, and reliability data for key CVN 78 systems. To identify actions the Navy is taking to improve cost outcomes for CVN 79 ahead of that ship's detail design and construction contract award, we reviewed shipbuilder reports on lessons learned constructing CVN 78, the Navy's request for proposals for CVN 79 detail design and construction, and CVN 79 construction plans. To corroborate information for each of these objectives, we interviewed DOD officials and contractor representatives responsible for Ford-class carrier requirements, development, acquisition, and testing. A more detailed description of our scope and methodology is presented in appendix I.

We conducted this performance audit from June 2012 to September 2013 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The Navy intends for Ford-class nuclear-powered aircraft carriers to serve as premier forward assets for crisis response and provide early striking power during major combat operations. The Ford-class is expected to feature a number of improvements over existing aircraft carriers that the Navy believes will improve the combat capability of the carrier fleet while simultaneously reducing acquisition and life cycle costs. These improvements include the following:

- increased sortie generation rates for the aircraft being deployed from the carrier,
- a near threefold increase in electrical generating capability,

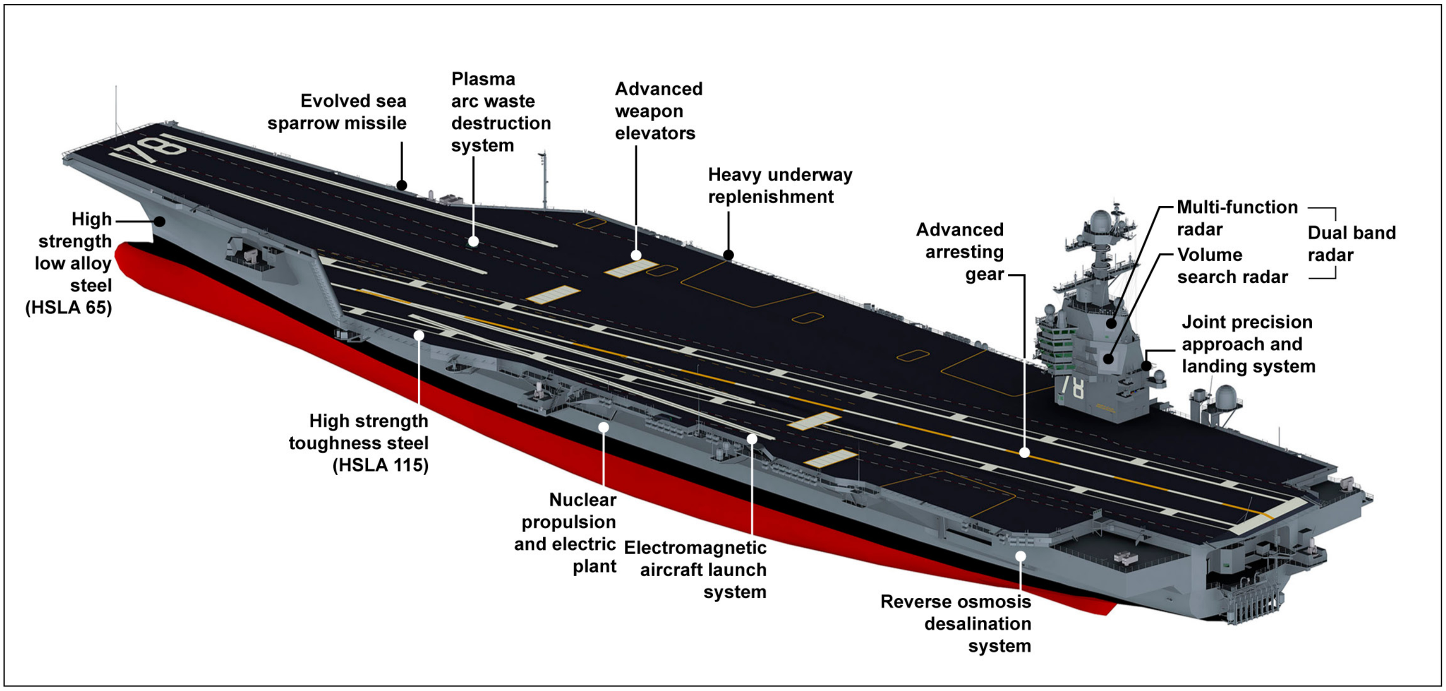
- increased operational availability, and
- increased service life margins for weight and stability to support future configuration changes to the ship over its expected 50-year service life.

To facilitate these capability and efficiency gains, the Navy is developing 13 new, critical technologies for installation on Ford-class carriers.[1] For example, the ship includes a new electromagnetic aircraft launch system (EMALS) to propel aircraft off the ship, an advanced arresting gear to recover the aircraft, and an improved anti-aircraft missile system. It also includes a new dual band radar, which integrates two radars operating on different frequency bands to provide air traffic control, ship self-defense, and other capabilities. Other technologies are intended to improve the ship's propulsion, supply (replenishment), water generation, and waste disposal systems.

Aside from their own intrinsic capabilities, these technologies are also intended to permit the Navy to implement favorable design features into the ship. Key design features include 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. The Navy is managing these technology development activities across several different program offices and contractors, using quarterly integrated product team meetings to track progress. Figure 1 highlights the location of the 13 critical technologies on the ship.

[1]DOD acquisition guidance defines a technology element as "critical" if the system being acquired depends on this technology element to meet its operational requirements (within acceptable cost and schedule limits) and if the technology element or its application is either new or novel or in an area that poses major technological risk during detailed design and demonstration.

Figure 1: Critical Technologies on the Ford-Class Aircraft Carrier



Source: GAO (presentation); Navy (image).

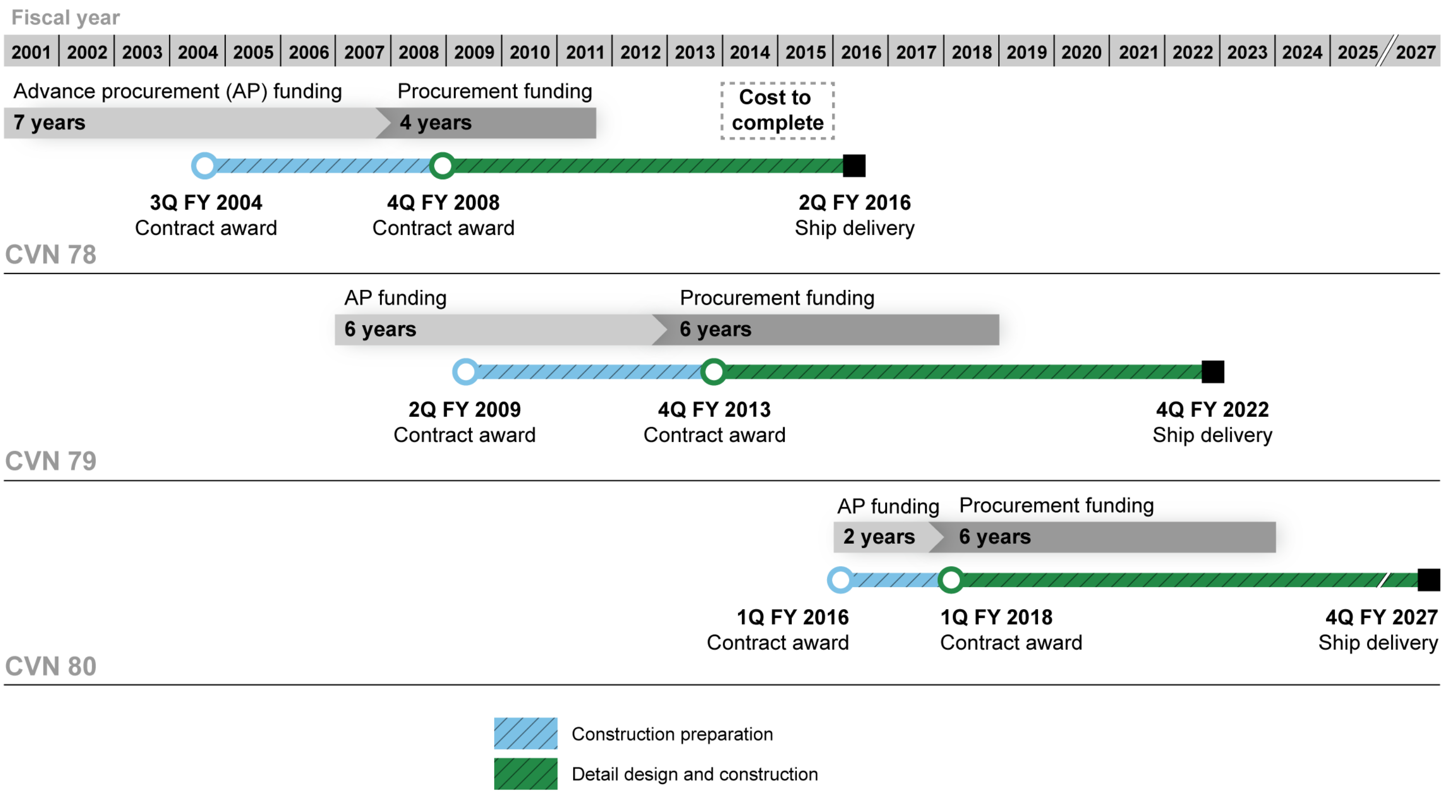
The Navy's strategy for acquiring a new class of carriers has changed from its initial concept. Initially, the Navy employed an evolutionary acquisition strategy, with technology improvements planned to be introduced gradually with each successive carrier. The Navy established the CVN(X) program in 1998 in support of this concept. Under the CVN(X) program, introduction of new technologies would be spread over three ships, beginning with the final Nimitz-class carrier, CVN 77, which was authorized in fiscal year 2001 to begin construction, and continuing over two, new design CVN(X) class carriers. In 2002, however, DOD decided to restructure the CVN(X) program (renamed as CVN 21) and accelerated plans for introducing new technologies on the first ship of the new class. To support this acceleration, in 2004 the Navy increased its planned research, development, test, and evaluation funding for the program from $2.3 billion to $4.3 billion.[2] In 2006, the Secretary of the Navy named the lead ship of the program (CVN 78) Gerald R. Ford, thus initiating the Ford class.

Due to their vast size and complexity, aircraft carriers require funding for design, long-lead materials (such as nuclear propulsion plant components), and construction over many years. To accomplish these activities, the Navy awards contracts for two phases of construction—construction preparation and detail design and construction—underpinned by advance procurement and procurement funding. Additional funding, termed “cost to complete” funding, may be needed to cover unexpected cost growth that occurs during construction.

Figure 2 outlines the Navy’s budgeting and contracting strategies for the Ford class. As indicated in the figure, construction preparation contracts can be awarded several years after advance procurement funds are in place, to allow for procurement of long-lead materials.

[2]The Navy further increased this total to $4.4 billion in 2005, which continues to reflect the approved funding baseline for research, development, test, and evaluation investments in the program. To date, the Navy has received over $3.7 billion to support these activities, with remaining funding scheduled through fiscal year 2022.

Figure 2: Ford Class Budgeting and Contracting Strategies



Source: GAO analysis of Navy documentation.

Note: FY = fiscal year; AP = advance procurement. Unlike other ships, for which the Navy typically funds detail design and construction over 1 or 2 years, Congress has authorized Ford-class carrier constructions to be funded in annual increments lasting up to 6 years. The Navy can vary the amount of funds it budgets for each increment on a year-to-year basis to account for evolving work needs and cost changes in the program.

In September 2008, the Navy awarded a $4.9 billion cost-reimbursement contract for detail design and construction of CVN 78 to Newport News Shipbuilding. Cost-reimbursement contracts, also known as cost-plus contracts, provide for payment of allowable incurred costs, to the extent prescribed in the contract. This contract type places most of the risk on the government, which may pay more than budgeted should incurred costs be more than expected when the contract is signed.

The Navy expects to largely repeat the lead ship design for CVN 79, with minor modifications, and to construct that ship under a fixed-price incentive contract with the shipbuilder. Fixed-price incentive contracts place increased risk on the contractor, which generally bears some responsibility for increased costs of performance, including full responsibility once the contract's ceiling is exceeded. These contracts include a negotiated target cost, target profit, and a formula for sharing the risk of cost overruns between the buyer and the seller (sometimes referred to as a shareline).[3] Upon completion of performance, if the costs incurred by the contractor have exceeded the target cost, then application of the formula results in the contractor receiving a profit that is less than the target profit, and may result in a net loss for the contractor. The Navy has not yet determined the design parameters and contract type for CVN 80.

Congress has previously expressed concern about Ford-class carrier costs. The John Warner National Defense Authorization Act for Fiscal Year 2007 included a provision that established (1) a procurement cost cap for CVN 78 of $10.5 billion, plus adjustments for inflation and other factors, and (2) a procurement cost cap for subsequent Ford-class carriers of $8.1 billion each, plus adjustments for inflation and other factors.[4]

Further, in August 2007, we reported that delays in Ford class technology development could increase lead ship construction costs and lead to potential reductions in capability at delivery. In addition, we found that although the Navy had made considerable progress maturing CVN 78's design, significant schedule pressures in development of the ship's critical technologies could impede completion of the detailed phases of design and potentially disrupt construction. We also found that the Navy's cost estimate used to develop the CVN 78 budget was optimistic. We recommended actions to improve the realism of the CVN 78 budget estimate, improve the Navy's cost surveillance capability, and schedule carrier-specific tests of the dual band radar.[5] The Navy addressed some, but not all, of our recommendations.

[3]The target cost is the pre-established cost of the contracted goods/services that is a reasonable prediction of the final incurred costs. Target profit is the pre-established profit that the contractor will earn if the negotiated final cost of the contracted goods/services is the same as the target cost.

[4]Pub. L. No. 109-364, § 122.

[5]GAO, *Defense Acquisitions: Navy Faces Challenges Constructing the Aircraft Carrier Gerald R. Ford within Budget*, GAO-07-866 (Washington, D.C.: Aug. 23, 2007).

As is typical for all ships, Ford-class carrier construction is conducted over several phases:

- **Block fabrication**: Metal plates are welded together into elements called blocks. Blocks are the basic building units for a ship, and when completed they will form completed or partial compartments, including accommodation spaces, engine rooms, and storage areas.

- **Assembly and outfitting of blocks**: Blocks are generally outfitted with pipes, brackets for machinery or cabling, ladders, and any other equipment that may be available for installation at this early stage of construction. This allows a block to be installed as a completed unit when it is welded to the hull of the ship. Installing equipment at the block stage of construction is preferable because access to spaces is not limited by doors or machinery, unlike at later phases.

- **Block erection**: Blocks are welded together to form grand blocks, which are then erected with other grand blocks in a drydock.

- **Launch**: Once the ship is watertight and the decision is made to launch—or float the ship in water—the ship is then towed into a quay or dock area where final outfitting and testing of machinery and equipment such as main engines will occur. Afterwards, the ship embarks on sea trials where performance is evaluated against the contractually required specifications and overall quality is assessed.

- **Delivery**: Following sea trials, the shipyard delivers the ship to the buyer (Navy).

- **Commissioning**: Following delivery, the act or ceremony of commissioning a ship marks its entry into active service.

DOD acquisition policy requires major defense acquisition programs, including shipbuilding programs, to execute and complete developmental testing, reliability growth testing, initial operational test and evaluation (IOT&E), and live-fire testing activities:

- **Developmental testing** is intended to assist in the maturation of products, product elements, or manufacturing or support processes. For ship technologies, developmental testing typically includes robust land-based testing activities prior to introducing the technology to a maritime environment.

- **Reliability growth testing** is an integral part of the systems engineering process for a weapon system. Simply stated, reliability is the ability of a system and its parts to perform its mission without failure, degradation, or demand on the support system under a prescribed set of conditions. Program managers are responsible for developing reliability growth curves for weapon systems, which outline a series of intermediate goals that are tracked through test and evaluation events until minimum reliability requirements are satisfied. In addition, program managers and operational test agencies are responsible for assessing and reporting on the reliability growth required for a system to achieve its minimum reliability requirements during IOT&E. The Navy measures reliability for key CVN 78 systems in terms of mean (average) time between failures and average number of cycles between critical mission failures. [6]

- **IOT&E**—a major component of operational testing—is intended to assess a weapon system's capability in a realistic environment when maintained and operated by sailors, subjected to routine wear-and-tear, and employed in combat conditions against a simulated enemy who fights back. During this test phase, the ship is exposed to as many actual operational scenarios as possible—a process that reveals the weapon system's capabilities under stress. IOT&E for CVN 78 will take place after the shipbuilder completes construction and delivers the ship to the Navy.

- **Live-fire testing** provides timely assessment of the survivability and/or lethality of a weapon system as it progresses through its design and development. For ships, two major components of this testing are the full-ship shock trial and total ship survivability trial. The Navy defines a full-ship shock trial as an at-sea trial conducted to identify any unknown weakness in the ability of the ship to withstand specified levels of shock from underwater explosions. The Navy defines a total ship survivability trial as an at-sea, scenario-based assessment of the ability of the ship and crew to control damage, reconfigure, and attempt to reconstitute mission capability after damage.

[6]DOD defines mean time between failures as, for a particular interval, the total functional life of a population of an item divided by the total number of failures (requiring corrective maintenance actions) within the population. The definition holds for time, rounds, miles, events, or other measures of life unit (such as cycles).

DOD also establishes two key milestones for introducing new weapon systems, including ships, to the warfighter: initial operational capability and full operational capability.

- **Initial operational capability** (or initial capability) for a weapon system is, in general, attained once some units and/or organizations in the force structure scheduled to receive the system have received it and have the ability to employ and maintain it. For CVN 78, initial capability closely follows the completion of combat system ship qualification trials, which are a series of technical and training events conducted aboard newly commissioned warships.

- **Full operational capability** (or full capability) generally represents the point when all units and/or organizations in the force structure scheduled to receive the system have received it and have the ability to employ and maintain it. For CVN 78, full capability closely follows the completion of joint task force exercises, which are designed to test the carrier's ability to operate in hostile, complex environments alongside other U.S. and coalition forces. The purpose of these exercises is to prepare the carrier for an upcoming deployment.

In addition, DOD acquisition policy requires the development of a life cycle cost estimate for weapon systems. A cost estimate is a summation of individual cost elements—using established methods and valid data—to estimate the future costs of a program, based on what is known today. Cost estimates are necessary for many reasons: to support decisions about funding one program over another, to develop annual budget requests, to evaluate resource requirements at key decision points, and to develop performance measurement baselines. The management of a cost estimate involves continually updating the cost estimate with actual data as they become available, revising the estimate to reflect changes, and analyzing differences between estimated and actual costs. The Navy completed its initial life cycle cost estimate for CVN 78 in 2004, which largely underpinned initial budget requests for that ship. Since that time, the Navy has periodically updated that cost estimate and also recently developed a cost estimate for CVN 79 detail design and construction.

Finally, the Defense Federal Acquisition Regulation Supplement (DFARS) requires certain contracts, to include the Ford class contract, to include a clause requiring the contractor to maintain a government-validated earned value management system and to provide monthly contract performance reports to the government.[7] Earned value management is a program management tool for assessing cost and schedule performance. It goes beyond simply comparing budgeted costs to actual costs. It measures the value of work accomplished in a given period and compares it with the planned value of work scheduled for that period and with the actual cost of work accomplished. By using the metrics derived from these values to understand performance status and to estimate cost and time to complete the work, earned value management can alert program managers to potential problems sooner than expenditures alone can.

Technology, Design, and Construction Challenges Pose Risk to Lead Ship Cost and Schedule Outcomes

While construction of CVN 78 is more than halfway complete, the Navy and shipbuilder must still overcome significant technology development, design, and construction challenges in order to deliver a fully functional ship to the fleet at the currently budgeted cost of $12.8 billion and the February 2016 delivery date. However, several critical technologies—provided to the shipbuilder by the Navy—have encountered developmental delays and, subsequently, have not yet reached a level of maturity that will enable them to be effectively incorporated onto the ship. These delays are most evident in the land-based test programs for these technologies, which are lagging significantly behind schedule. At the same time, the ship's design stability—a key factor in controlling future cost growth—is contingent on critical technologies maturing in the configurations currently anticipated. In addition, construction inefficiencies at the shipyard have delayed—and threaten additional delays to—ship launch and delivery. These combined challenges and uncertainties suggest that more cost growth could occur for CVN 78.

[7]DFARS subpart 234.201 and section 252.234-7002. DOD's earned value management implementation policy includes requirements that for cost-reimbursable and/or incentive fee contracts valued at or above $50 million, (1) a DOD contracting officer must formally validate and accept a contractor's earned value management system at contract award and throughout contract performance and (2) the contractor must provide monthly contract performance reports to DOD.

Some Critical Technologies Are Mature, but Others Face Significant Land-Based Testing Delays

At present, the Navy assesses 7 of CVN 78's 13 critical technologies as mature, meaning that they have been proven in an operational environment. The shipbuilder has begun installing the remaining 6 technologies on the ship even though their capabilities are not yet fully proven. This strategy introduces the risk of late and costly design changes aboard the ship. Specifically, progress continues to lag for several systems that are integral to the ship achieving its intended mission capabilities.

Our previous work has shown that good acquisition outcomes are achieved through a knowledge-based approach to product development that demonstrates high levels of knowledge before significant commitments are made.[8] In essence, knowledge supplants risk over time. In this approach, developers make investment decisions on the basis of specific, measurable levels of knowledge at critical junctures before investing more money and advancing to the next phase of acquisition. Shipbuilding programs are no exception. As we have previously reported, leading commercial ship buyers and shipbuilders retire program risks, including technology risk, prior to signing a contract.[9] Demonstrating the maturity of critical technologies—by testing representative prototypes in realistic environments—is a key component to reducing these risks.

DOD uses technology readiness levels (TRL) to describe the maturity of critical technologies in programs. Technologies with TRLs below 6 are at a stage of development where only components or a basic proof of concept of the system have been validated. Technologies developed into representative prototypes and successfully tested in a relevant environment meet requirements for TRL 6. Technologies developed into actual system prototypes (full form, fit, and function) and tested in an operational environment meet requirements for TRL 7. We have previously reported that TRL 7 constitutes low risk for starting a product development and, for shipbuilding programs, should be achieved for individual technologies prior to detail design contract award.[10] Consequently, our assessment of CVN 78 technologies refers to

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[8]GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-11-233SP (Washington, D.C.: Mar. 29, 2011).

[9]GAO, *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009).

[10]GAO-09-322.

technologies that have reached TRL 6 and TRL 7 as approaching maturity and as mature, respectively. Technologies exceeding TRL 7 represent actual systems that have been proven to work in final form and under expected (TRL 8) or actual (TRL 9) mission conditions. Table 1 summarizes the planned capabilities and development status of current Ford-class technologies and DOD's assessment of TRLs since contract award in 2008.

Table 1: Planned Capabilities and Development Status of Ford-class Critical Technologies

Technology	Capability improvement	2008 TRL	2013 TRL	Development status
Volume Search Radar (part of dual band radar)	Volume search radar includes long-range, above-horizon surveillance and air traffic control capabilities. The dual band radar permits reduced manning and higher sortie generation rates aboard CVN 78 via anticipated operational availability increases and size reductions to the ship's island.	5	6	Technical deficiencies have slowed development, and key functions, including air traffic control capabilities, remain undemonstrated. For land-based testing, the Navy is employing a prototype design that will not demonstrate the higher-voltage output needed to meet ship requirements. At present, the first test of a fully configured volume search radar is scheduled for fiscal year 2016 aboard CVN 78. Following this testing, the Navy expects the radar will reach maturity (TRL 7) in fiscal year 2017.
Multifunction Radar (part of dual band radar)	Multifunction radar includes horizon search, surface search and navigation, and missile communications. This system facilitates reduced manning through anticipated improvements in operational availability.	6	7	Although the Navy has assessed the system as mature since 2010, it restarted land-based testing of this radar in fiscal year 2013 to demonstrate certain CVN 78-specific functionalities that the Navy previously deferred. New tests have employed prototype test articles and, beginning in fiscal year 2014, will employ a production unit system. The Navy plans to transition to shipboard testing in fiscal year 2014 to complete requirements verifications not addressed at the land-based test site and to integrate the system with the CVN 78 volume search radar.

Technology	Capability improvement	2008 TRL	2013 TRL	Development status
Advanced Arresting Gear	Advanced arresting gear recovers current and future aircraft and contributes to increased sortie generation rate and reduced manning.	5	6	Developmental test failures led to system redesigns. Navy is presently executing the first phase of land-based testing concurrent with system production and installation on CVN 78. The system is scheduled to arrest its first aircraft in June 2014. The Navy anticipates system maturity (TRL 7) in fiscal year 2015.
Electromagnetic Aircraft Launch System (EMALS)	EMALS uses an electrically generated moving magnetic field to propel aircraft, which places less physical stress on aircraft as compared to steam catapult launchers. The system is a contributor to CVN 78's planned sortie generation rate and reduced manning, in part because of Navy expectations about EMALS's increased operational availability.	6	6	EMALS land-based testing is proceeding concurrently with system production and installation on CVN 78. To date, EMALS has successfully launched a wide range of aircraft using a single launcher and 4 motor generators. The shipboard system will employ a more complex configuration of 4 launchers and 12 generators sharing a power interface. EMALS is scheduled to mature (TRL 7) in fiscal year 2014 following aircraft compatibility and environmental testing.
Advanced Weapons Elevators	These elevators rely on electromagnetic fields to move instead of cables. Capability improvements include an expected 200 percent greater load capacity than legacy carrier elevators. Advanced weapons elevators facilitate reduced manning and enable higher sortie generation rates.	5	6	Prior to installation on the ship, system testing was limited to factory tests of the first production unit in a configuration that was unrepresentative of shipboard doors, hatches, and ramps. Planned tests aboard CVN 78 will verify system performance against load requirements and under casualty (degraded) conditions. The Navy anticipates system maturity (TRL 7) in fiscal year 2014.
Evolved Sea Sparrow Missile Joint Universal Weapons Link	This system supports anti-air warfare. The system provides capability to defeat high-density raids and facilitates reduced manning aboard the ship.	4	6	The Navy expects this technology to mature (TRL 7) in fiscal year 2014 following completion of qualification and integration tests, to include integration with CVN 78's multifunction radar.

Technology	Capability improvement	2008 TRL	2013 TRL	Development status
Joint Precision Approach and Landing System (JPALS)	JPALS is a global positioning system technology allowing for all-weather, day and night aircraft landings. JPALS is expected to become the primary landing system for F-35C Joint Strike Fighter aircraft on all carriers, including the Ford class. JPALS permits reduced manning.	6	6	Shore-based flight tests of the system are ongoing. Shipboard flight testing is scheduled to begin in fiscal year 2013, which the Navy expects will mature the system to TRL 7. Technical risks include operations within electronic jamming environments.
Heavy Underway Replenishment Receiving Station	This system provides quicker shipboard replenishment (supply) than legacy underway replenishment systems. The system facilitates F-35C power module replacement and higher sortie generation rates for the Ford class.	6	7	In fiscal year 2013, the Navy matured the system by completing a full-scale transfer of 12,000-pound loads to a CVN 78 prototype receiving station in accordance with required conditions. Although CVN 78 will have this capability installed, the Navy's plan to install this system on supply ships has slipped 8 years.
Plasma Arc Waste Destruction System	This system uses extreme temperatures to convert 6,800 pounds per day of plastic and other waste into gaseous emissions. It facilitates reduced manning aboard the ship.	7	7	System maturity was achieved in 2007 following engineering development model testing that satisfied all performance objectives. A similar system was tested on a cruise ship.
Nuclear propulsion/ electric plant	The system converts energy into electricity, providing a nearly three-fold increase in power generation over the Nimitz-class plant. The plant design also facilitates manning reductions and preservation of service life weight and stability allowances.	7	8	The Navy matured the system in 2004 and it is now installed aboard CVN 78. Currently, the Navy and shipbuilder are conducting flushing/hydrostatic testing, control system testing, and electric plant testing. Plans call for this system to demonstrate initial capability in December 2014.
Reverse Osmosis Desalinization System	This system desalinates water without a steam distribution system, facilitating reduced manning and improved weight and stability allowances.	7	8	System maturity was achieved in 2003 following over 1,800 hours of prototype testing. Following later shock, vibration, and maintainability tests, first unit qualifications were completed in 2010.
High Strength Toughness Steel (HSLA 115)	HSLA 115 is stronger and lighter than legacy ship steel types and comprises the CVN 78 flight deck. HSLA 115 improves weight and stability allowances.	7	8	HSLA 115 completed prototype and first article qualification testing in fiscal years 2007 and 2008, respectively. The Navy has assessed the system as mature since 2007. Since then, the shipbuilder has successfully constructed CVN 78 flight deck sections using HSLA 115.

Technology	Capability improvement	2008 TRL	2013 TRL	Development status
High Strength Low Alloy Steel (HSLA 65)	HSLA 65 is stronger and lighter than legacy ship steel types, and is used in bulkhead and deck constructions. HSLA 65 improves weight and stability allowances.	8	9	HSLA 65 was rated TRL 8 in 2004 and is currently employed aboard a Nimitz class carrier. CVN 78, however, represents the first widespread application of HSLA 65 on a Navy ship.

Source: GAO analysis of Navy and contractor documentation.

Note: TRL refers to technology readiness level. The TRLs outlined in the table reflect DOD's estimates of maturity. Additionally, the Navy has removed several systems from the ship that it had previously tracked as critical technologies. For example, the Navy deferred CVN 78's planned dynamic armor protection system to future carriers as a cost-savings measure.

As indicated in the table, the Navy has largely retired the risks posed by the reverse osmosis desalinization, plasma arc waste destruction, and nuclear propulsion/electric plant systems. These technologies are currently at TRL 7 or higher and were mature even before the CVN 78 contract award for detail design and construction. However, other critical technologies were immature at contract award and still must undergo extensive testing before reaching maturity. These technologies moved through development with lower-than-desired levels of knowledge and subsequently faced technical, design, and production challenges. For example, three systems integral to the ship's ability to execute its mission assignments—the volume search radar, advanced arresting gear, and EMALS—were immature at CVN 78 detail design and construction contract award in 2008. These systems continue to experience disruptions in development and delays in the land-based testing that is needed to assess their levels of maturity. In contrast to the knowledge-based approach used by leading commercial ship buyers, the Navy, in an effort to meet required installation dates aboard CVN 78, elected to produce these systems prior to demonstrating their maturity. More information about the status of these three critical technologies follows:

- **Volume search radar**: Prior to the CVN 78 detail design contract award, the Navy had only built, tested, and integrated prototype components of the volume search radar in controlled laboratory environments. As we previously reported, these tests revealed deficiencies related to key components of the radar.[11] Under the Navy's 2008 program schedule, the volume search radar was to be developed and tested as part of the Zumwalt-class destroyer program

[11]GAO, *Defense Acquisitions: Navy Faces Challenges Constructing the Aircraft Carrier Gerald R. Ford within Budget*, GAO-07-866 (Washington, D.C.: Aug. 23, 2007).

and was expected to approach maturity following land-based testing in fiscal year 2009. The radar would then participate in combat system integration testing with the other major component of the dual band radar, the multifunction radar, and eventually demonstrate maturity as part of Zumwalt-class destroyer at-sea testing in fiscal year 2014. In 2010, however, to reduce Zumwalt-class construction costs, the Navy removed the volume search radar from the destroyer program and suspended remaining land-based testing, leaving key Ford-class testing requirements unaddressed. The Navy subsequently transferred remaining development work to the Ford class program and planned to resume land-based testing in fiscal year 2012 using an actual production unit of the radar—but contracting delays pushed the start of this testing out to fiscal year 2013. As a result of this delay, and the Navy's desire not to slow down the current radar installation schedule for CVN 78, remaining land-based testing will be completed in fiscal year 2014, 4.5 years later than originally planned, using a less capable developmental radar array than the actual production configuration that will be installed on CVN 78. The Navy has also scheduled shipboard testing beginning in fiscal year 2016 to complete additional volume search radar testing not executed on land. This testing schedule increases the risk that discovery of problems with the system will trigger costly design changes and rework aboard the ship.

- **Advanced arresting gear**: Prior to CVN 78's detail design contract award, the advanced arresting gear completed early verification tests to prove out the system's concept, along with some component testing. Under the Navy's 2008 program schedule, this system was scheduled to execute the following land-based testing program: (1) extended reliability testing in fiscal year 2009 to demonstrate integration of high risk subcomponents and produce reliability growth data; (2) environmental qualification testing between fiscal years 2009 and 2011, which would verify the system's suitability; (3) jet car track site testing—where the system arrests jet-engine-propelled vehicles that travel down a railway with different physical loads and speeds—between fiscal years 2010 and 2011 to validate the system's full range of performance; and (4) runway arrested landing site testing between fiscal years 2011 and 2012, which would verify aircraft compatibility and performance with the system. Progress has proven slower than anticipated, however. Deficiencies affecting five major components, plus software, have contributed to several redesigns of the system since 2007. Most recently, the Navy and its contractor redesigned and remanufactured the energy absorbing "water twister" components of the system, which turned out to be costly, time consuming processes that have delayed installation of these units aboard the ship.[12] Consequently, the Navy has delayed the start of runway arrested landing site testing—required to mature the advanced arresting gear technology—until fiscal year 2014. Under this revised testing schedule, the Navy now expects to complete land-based developmental testing, 2.5 years later than initially planned, by fiscal year 2015—after it has installed the full system aboard CVN 78.

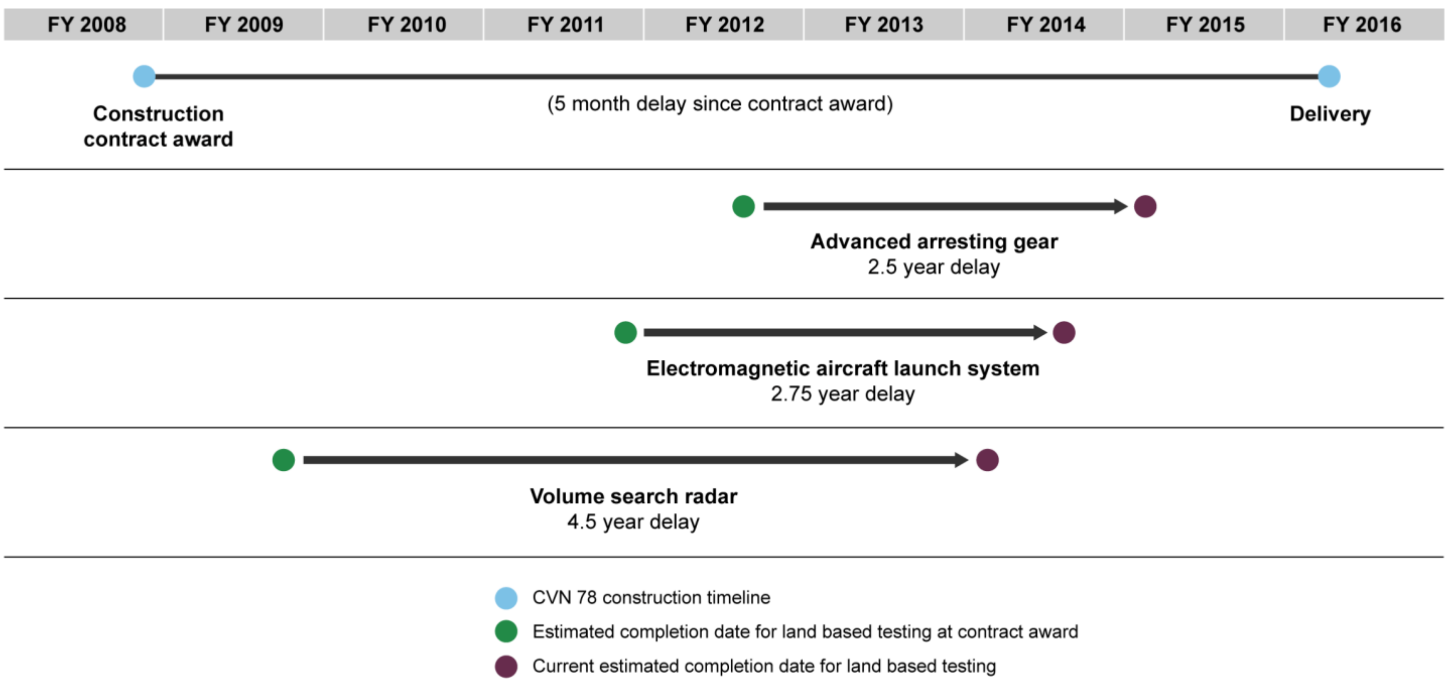
- **EMALS:** Unlike the other critical technologies discussed above, this system was approaching maturity prior to the CVN 78 detail design contract award because the Navy had built and tested competitive prototypes of the system as part of the contractor selection process for EMALS development in 2004. Under the Navy's 2008 program schedule, land-based testing for the system was scheduled to occur between fiscal years 2008 and 2011. However, technical issues affecting the EMALS power interface and conversion systems, among other deficiencies, have slowed progress. The Navy's 2012 development schedule calls for land-based testing to continue into fiscal year 2014, which, upon completion, the Navy expects will mature the EMALS technology. In the meantime, however, significant numbers of EMALS components have already been produced, delivered to the shipbuilder, and installed on CVN 78—even though the functional requirements, performance, and suitability of the system remain unproven.

Although the Navy has encountered land-based testing delays totaling 2.5 to 4.5 years each for the volume search radar, advanced arresting gear, and EMALS critical technologies, it has elected to not adjust the CVN 78 construction schedule to compensate for these delays. As a result, the Navy and its shipbuilder are constructing CVN 78 with less knowledge about the ship's critical technologies than it deemed appropriate at contract award in 2008. As the disparity between land-based testing and construction schedules persists—or worsens—the Navy faces significant risk of unbudgeted cost growth arising from technical discoveries late in construction. Figure 3 illustrates changes to the CVN 78 construction

[12]Water twisters are energy-absorbing water brakes that convert kinetic energy to heat through fluid turbulence. They operate automatically during aircraft arrestment and adjust automatically to accommodate aircraft of varying weights, engaging speeds, and off-center arrestments within the specified performance limits of the system.

schedule and to land-based testing programs for critical technologies that have been incurred since the 2008 detail design and construction contract award.

Figure 3: Delays to the CVN 78 Construction Schedule and Land-Based Test Programs for Critical Technologies Since 2008



Source: GAO analysis of Navy documentation.

Note: FY = fiscal year.

Design Stability Contingent on Technologies Maturing As Planned

Since the CVN 78 contract was awarded in 2008, the Navy and shipbuilder have made progress stabilizing and completing the Ford-class design. The Ford class represents the first time that the shipbuilder has used a 3D, computer-aided design product model to generate the design of an entire aircraft carrier. The product model generates a detailed design, allowing engineers to visualize the arrangement of spaces and systems. The design is also fed into a simulated 3D environment that allows engineers, planners, and construction workers to validate the design and build strategy by conducting virtual "walkthroughs." These tests validate elements of the design prior to construction, thereby avoiding potentially costly rework.

In our work on shipbuilding best practices, we found that achieving design stability before start of fabrication is a key step that leading shipbuilders and ship buyers follow to ensure their vessels deliver on-time, within planned costs, and with planned capabilities.[13] Leading commercial firms assess a ship design as stable once all basic and functional design activities have been completed. Basic and functional design refers to two-dimensional drawings and 3D computer-aided models (when employed) that fix the ship's hull structure; set the ship's hydrodynamics; route all major distributive systems including electricity, water, and other utilities; and identify the exact positioning of piping and other outfitting within each block of the ship. At the point of design stability, the shipbuilder has a clear understanding of the ship structure as well as electrical, piping, and other systems that traverse individual blocks of the ship. To achieve design stability, shipbuilders need suppliers (also called vendors) to provide complete, accurate system information prior to beginning basic design. This vendor-furnished information describes the exact dimensions of a system or piece of equipment going into a ship, including space and weight requirements, and also requirements for power, water, and other utilities that will have to feed the system.

The CVN 78 shipbuilder completed its 3D product model in November 2009—over a year after the construction contract was awarded. At contract award, 76 percent of the model was complete and the shipbuilder had already begun construction of at least 25 percent of its structural units under the previous construction preparation contract. While the model is now considered functionally complete, maintaining design stability depends on the critical technologies discussed above fitting within the space, weight, cooling, and power reservations allotted them. To date, evolving information about the attributes of these technologies has produced a weight/stability configuration for CVN 78 that leaves little margin to incorporate additional weight growth high up in the ship without making corresponding weight trade-offs elsewhere or compromising the future growth potential of the ship.[14] Shipbuilder representatives have recently expressed concern about this possibility, particularly regarding additional design changes to critical technologies

[13]GAO-09-322.

[14]In designing and constructing a new ship, the Navy seeks to preserve "service life allowances"—room for weight growth after the vessel enters service—in order to provide room to take on new, heavier equipment over the ship's life cycle. The Navy generally sets service life allowances for a new ship's overall weight and for its vertical center of gravity (stability). For the Ford class carrier, these minimum margins are 5.0 percent of full load displacement in long tons and 1.5 feet, respectively.

still in development—including the volume search radar, advanced arresting gear, and EMALS technologies. According to shipbuilder representatives, additional weight growth to the advanced arresting gear was of particular concern and could trigger a need for future structural and space modifications around the installed system. Further, until the advanced weapons elevators, joint precision approach and landing system, and evolved sea sparrow missile weapons link each demonstrate maturity, the likelihood of additional design changes to CVN 78 persists.

In addition, as construction progresses, the shipbuilder is discovering “first-of-class” type design changes, which it will use to update the model prior to the follow-on ship construction. To date, several of these design changes have related to EMALS configuration changes, which have required electrical, wiring, and other changes within the ship. Although the Navy reports that these EMALS-related changes are nearing completion, it anticipates additional design changes stemming from remaining advanced arresting gear development and testing. In total, over 1,200 anticipated design changes remain to be completed (out of nearly 19,000 planned changes). According to the Navy, many of these 19,000 changes were programmed into the construction schedule early on—a result of the government’s decision at contract award to introduce improvements during construction to the ship’s warfare systems, which are heavily dependent on evolving commercial technologies.

Construction Progress Slowed by Inefficiencies that Could Delay Delivery of the Ship

As of April 2013, the shipbuilder had erected 95 percent of the ship’s structural units and had achieved a key milestone of installing the ship’s island (command tower) onto the flight deck. Nevertheless, the ship was only 56 percent complete in April 2013, as compared to the builder’s planned 62 percent completion rate at that point in construction. As a result of these construction delays, the Navy and shipbuilder recently elected to delay CVN 78’s launch and delivery by 4 months each.

Ships are ideally designed and constructed using the most cost efficient sequence for construction, called the optimal sequence. Typically, an optimal construction sequence includes designing and building the ship from the bottom up, maximizing the work completed in shipyard shops, and minimizing tasks performed when the ship is already in the water, which tend to be costlier than tasks completed on land. As a general shipbuilding rule, the earlier a particular task can be performed in the production plan, the fewer labor hours it will consume. The sequence is outlined in the shipbuilder’s integrated master schedule, which links all of the detailed construction tasks based on key event dates.

By comparison, progress constructing CVN 78 has been constrained by inefficient out-of-sequence work driven largely by material shortfalls, engineering challenges, and delays developing and installing certain critical technology systems (provided by the Navy to the shipbuilder for installation). These outcomes are consistent with those experienced by other Navy shipbuilding programs that began lead ship constructions prior to maturing critical technologies, stabilizing their designs, or both.[15] Key examples of construction issues with the CVN 78 include the following:

- **Material shortfalls**: CVN 78 has experienced significant shortages of developmental valves throughout the ship due to delayed vendor deliveries. These valves are crucial for installing the ship's chilled water system, which provides air conditioning and cooling for electronic systems, as well as other distributive piping systems. To mitigate the impact of valve delinquencies, the shipbuilder installed temporary metal spool pieces in place of missing valves in order to continue construction work for piping systems. Installing the valves later, out-of-sequence, required additional labor hours to complete. According to shipbuilding representatives, their vendor base for valves did not have sufficient experience developing and manufacturing new Navy ship system valves, and consequently encountered difficulties meeting Navy and shipbuilder specifications. To improve vendor performance, the shipbuilder provided on-site engineering and procurement assistance. The shipbuilder reports that suppliers have now delivered over 90 percent of the required valves and that most of the spool piece installations have been replaced with actual valves.

- **Engineering challenges**: The shipbuilder's use of HSLA 65 thin steel plating for ship decks—intended to reduce weight in the ship's design—excessively warped and flexed during construction, which contributed to lower than desired levels of pre-outfitting and additional disruption to build processes. In an effort to compensate for the warping and flexing, the shipbuilder erected scaffolding around ship blocks to secure the assemblies. This scaffolding facilitated some pre-outfitting improvements, but produced corresponding cost increases and schedule delays. In addition, ship welders experienced

[15] GAO-09-322 and GAO, *Defense Acquisitions: Assessments of Selected Weapons Programs*, GAO-10-388SP (Washington, D.C.: Mar. 30, 2010). Program examples include the Littoral Combat Ship, Zumwalt-class destroyer (DDG 1000), America-class amphibious assault ship (LHA 6), San Antonio-class amphibious transport dock (LPD 17), and Seawolf-class attack submarine (SSN 21).

substantial difficulty early on working this new plate steel because it was thinner than what had traditionally been used on aircraft carriers.

The Navy and shipbuilder have also experienced other engineering challenges, including late delivery of accurate construction drawings and instructions to shipworkers. In many instances, the shipbuilder produced construction drawings—derived from the ship's 3D product model—that lacked sufficient detail necessary for efficiently installing critical components within the ship. This lack of comprehensive, detailed construction drawings contributed to inefficient work delays and restarts.

- **Critical technology system delays**: Advanced arresting gear delivery delays to date have caused the shipbuilder to modify the planned arresting gear engine room loading sequence. Instead of being built in one piece in the yard and hoisted into place as originally envisioned, arresting gear components will be installed in sequence, including through a hole cut in the flight deck. This strategy has caused additional work and interfered with the construction of other ship features in some areas, such as duct work and cabling. Further, late dual band radar equipment deliveries have required the shipbuilder to cut open previously closed areas of the ship to allow loading of equipment. Additional delays, as well as rework or retrofits on installed components, remain possible as these developmental systems continue to progress through testing.

The construction inefficiencies suffered by CVN 78 have only recently begun to materialize in the form of schedule delays. Recently revised Navy and shipbuilder plans now call for the ship to be launched in November 2013 at a 70 percent completion level—a total lower than what is found among leading commercial shipbuilding programs, which complete as much as 95 percent of the ship before launch.[16] Executing these plans requires completion of certain shipbuilding activities prior to the scheduled launch date. For example, the establishment of the chilled water system—necessary to support the ship's energization of the electrical distribution system for launch—is several weeks behind schedule. As launch gets delayed, so, too, does the shipbuilder's post-launch test program for key systems. Since this testing program is synched closely with ship delivery, the 4-month delay to the planned July

[16] GAO-09-322.

2013 launch date has produced a corresponding delay in delivering the ship to the Navy.

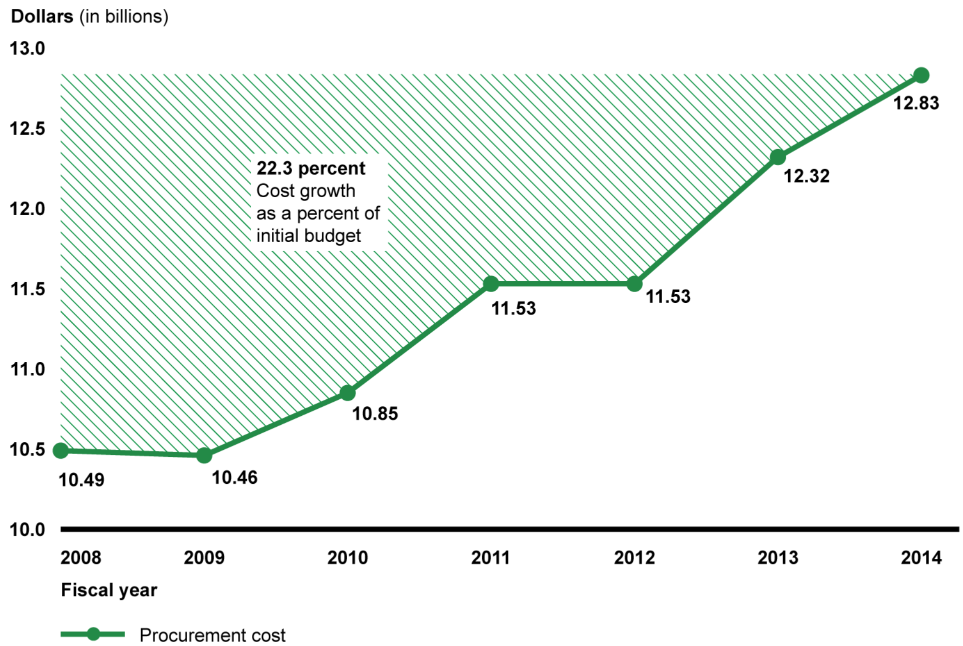
Lead Ship Costs Will Likely Exceed Current Budget Estimates

Since CVN 78 construction was authorized with the contract award in fiscal year 2008, the Navy has consistently increased its procurement budget for the ship to account for cost growth as construction has progressed. Budgeted costs have grown to $12.8 billion, compared to the Navy's initial $10.5 billion procurement budget request. This total represents an increase of $2.3 billion, or 22.3 percent, and includes almost $1.4 billion in future years' funding (fiscal years 2014 and 2015) to cover the anticipated cost growth. It also exceeds the $10.5 billion legislative cost cap on the program, which the Navy is currently seeking to amend as part of its fiscal year 2014 budget submission.[17]

Figure 4 outlines the evolution of CVN 78 procurement costs.

[17] In 2010, the Secretary of the Navy, using authority granted him by subsection (b) of section 122 of the John Warner National Defense Authorization Act for Fiscal Year 2007, increased the cost cap for CVN 78 to $11.755 billion. Pub. L. No. 109-364. The Navy's fiscal year 2014 budget proposal seeks to amend the statutory cost cap imposed by subsection (a)(1) of that section to the program manager's current estimate at completion of $12.887 billion.

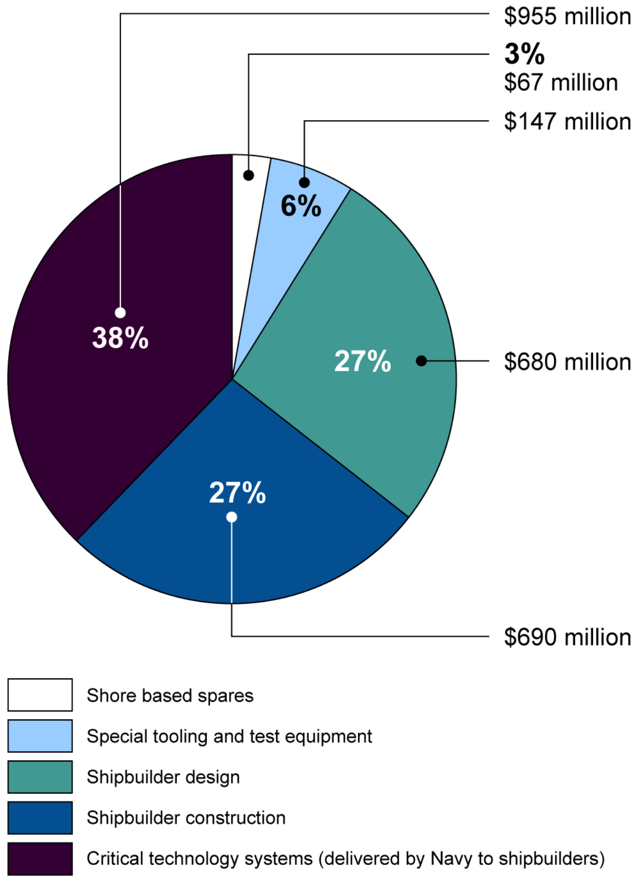
Figure 4: CVN 78 Procurement Cost History



Source: GAO analysis of Navy documentation.

As figure 5 highlights, CVN 78 cost growth to date is primarily attributable to cost increases with acquiring critical technology systems provided to the shipbuilder by the Navy, although the shipbuilder detail design and construction inefficiencies discussed above also account for considerable growth.

Figure 5: CVN 78 Procurement Cost Growth Drivers as of June 2012



Source: GAO analysis of Navy documentation.

Note: The Navy has identified $141 million in miscellaneous cost reductions for the ship that partially offset the cost growth identified in the figure.

We further analyzed the reasons for the 38 percent procurement cost growth in the critical technology systems aboard the ship. Table 2 shows that the cost growth is largely attributable to the dual band radar (volume search and multifunction radars), advanced arresting gear, and EMALS acquisitions.

Table 2: CVN 78 Procurement Cost Growth Since Fiscal Year 2008 for Selected Critical Technology Systems

Dollars in millions

System	Fiscal year 2008 budget	Fiscal year 2014 budget	Difference in cost	Cost growth as a percent of fiscal year 2008 budget
EMALS	$317.7	$742.6	$424.9	133.7%
Dual band radar	201.9	484.0	282.1	139.7
Advanced arresting gear	75.0	168.6	93.6	124.8
Total	**$594.6**	**$1395.2**	**$800.6**	**134.6%**

Source: GAO analysis of Navy documentation.

The Navy has taken steps to limit cost growth for EMALS and the advanced arresting gear, which are being developed and produced under contracts separate from the CVN 78 detail design and construction contract. Most notably, in 2010, the Navy negotiated firm fixed-price contracts for production of these systems for CVN 78.[18] According to the Navy, these contracts have helped cap cost growth for these systems and have incentivized more timely deliveries to the shipyard. While EMALS is farther along in development than both the dual band radar and advanced arresting gear systems, all have experienced significant cost growth, and costs are likely to increase, given the remaining work needed to fully develop, test, and integrate the systems on CVN 78. This potential for additional cost growth is also apparent based on the Navy's experience with the most recent Nimitz-class carrier, CVN 77. That ship experienced cost growth during its system integration, even though that effort employed mostly nondevelopmental systems.

Aside from the risk of cost growth stemming from the integration of critical technology systems into the ship, the shipbuilder's cost and schedule performance under the detail design and construction contract suggests additional overruns are looming. Our review of the contractor's earned value management data for the program indicates that shipbuilder cost pressures remain high and additional costs are likely, especially as key

[18]Firm fixed-price contracts provide a firm price to the government. This contract type places the risk on the contractor, which generally bears the responsibility of increased costs of performance.

developmental items are integrated onto the ship.[19] We reviewed 18 months of earned value management data for the CVN 78 ship program during the period of July 2011 through December 2012. During this time, the shipbuilder increased its estimate of the number of labor hours required to construct CVN 78 from 44.4 million to 47.3 million. Consequently, the shipbuilder's budgeted cost grew substantially, from $4,758 million to $5,266 million (an increase of $508 million).[20] Our analysis shows that, as of December 2012, the contractor was forecasting an overrun at contract completion of over $913 million. This cost growth is attributable to the shipbuilder not accomplishing work as planned. The Navy has largely, but not fully, funded this cost growth within CVN 78's $12.8 billion procurement budget.

Further, the Navy's current budget estimate of $12.8 billion for completing CVN 78 is optimistic because it assumes the shipbuilder will maintain its current level of performance throughout the remainder of construction. This assumption is inconsistent with historical Navy shipbuilding experiences for recent lead ships, which have suffered from performance degradation late in construction. Our previous work has shown that the full extent of cost growth does not usually manifest itself until after the ship is more than 60 percent complete, when key systems are being installed and integrated.[21] In April 2013, the ship was 56 percent complete. The Director of DOD's Cost Assessment and Program Evaluation office and the Congressional Budget Office—as well as Navy cost analysts and a Navy-commissioned expert panel—have also projected higher than budgeted procurement costs for CVN 78, with cost estimates ranging from $13.0 to $14.2 billion.

Additional CVN 78 cost growth could also place the Navy's long-term shipbuilding plan at risk. Previously, we have reported on this plan, which the Navy revises annually, and its significant weaknesses.[22] A key tenet

[19]The earned value data we reviewed are limited to the main CVN 78 detail design and construction contract and do not fully account for the integration of critical technology systems onto the ship platform.

[20]Budget at completion is the sum of all estimated budgets, representing the cumulative value of the budgeted cost of the work scheduled over the life of the project.

[21]GAO, *Defense Acquisitions: Realistic Business Cases Needed to Execute Navy Shipbuilding Programs,* GAO-07-943T (Washington, D.C.: July 24, 2007).

[22]GAO, *Defense Acquisitions: Challenges Associated with the Navy's Long-Range Shipbuilding Plan*, GAO-06-587T (Washington, D.C.: Mar. 30, 2006).

underpinning this plan is that the Navy will be able to maintain cost control over its major shipbuilding acquisition programs. Yet, the budgets for many ships, including CVN 78, have already proven inadequate to cover the costs required to complete their constructions. To compensate, the Navy must shift funds away from other priorities—including future ship constructions—or request additional funds from Congress to pay for this cost growth. Analysis of the Navy's fiscal year 2014 long-term shipbuilding plan shows that Ford-class procurement costs alone are estimated to comprise approximately 14 percent of the Navy's total new ship construction budgets between fiscal years 2014 and 2018. Even a small percentage of cost growth on these ships could lead to the need for hundreds of millions of dollars in additional funding. Already, the Navy is programming $1.3 billion between fiscal years 2014 and 2015 to cover CVN 78 cost growth. To the extent that this cost growth continues for CVN 78 or follow-on ships, it may result in fewer ships acquired than planned in the near term.

Demonstration of Ship Capabilities after Delivery Is Limited by Test Plan Deficiencies and Reliability Shortfalls

Several factors are likely to hamper the Navy's plans to demonstrate CVN 78 capabilities after it accepts delivery of the ship. In particular, significant risk is introduced due to the Navy's plan to conduct integration testing of critical technologies concurrently with the ship's IOT&E. This strategy will constrain opportunities to implement timely, corrective actions if problems are discovered with key ship systems. If significant discoveries are made during IOT&E, initial deployment could be delayed. In addition, Joint Strike Fighter integration with CVN 78 remains in its infancy, with work to date limited to paper-based assessments and a single test with EMALS. Further, key ship systems face reliability shortfalls that the Navy does not expect to resolve until many years after CVN 78 commissioning, which will limit the ship's mission effectiveness during initial deployments and likely increase costs to the government.

Post-Delivery Test Plans Are Unlikely to Provide Timely Discovery of Deficiencies

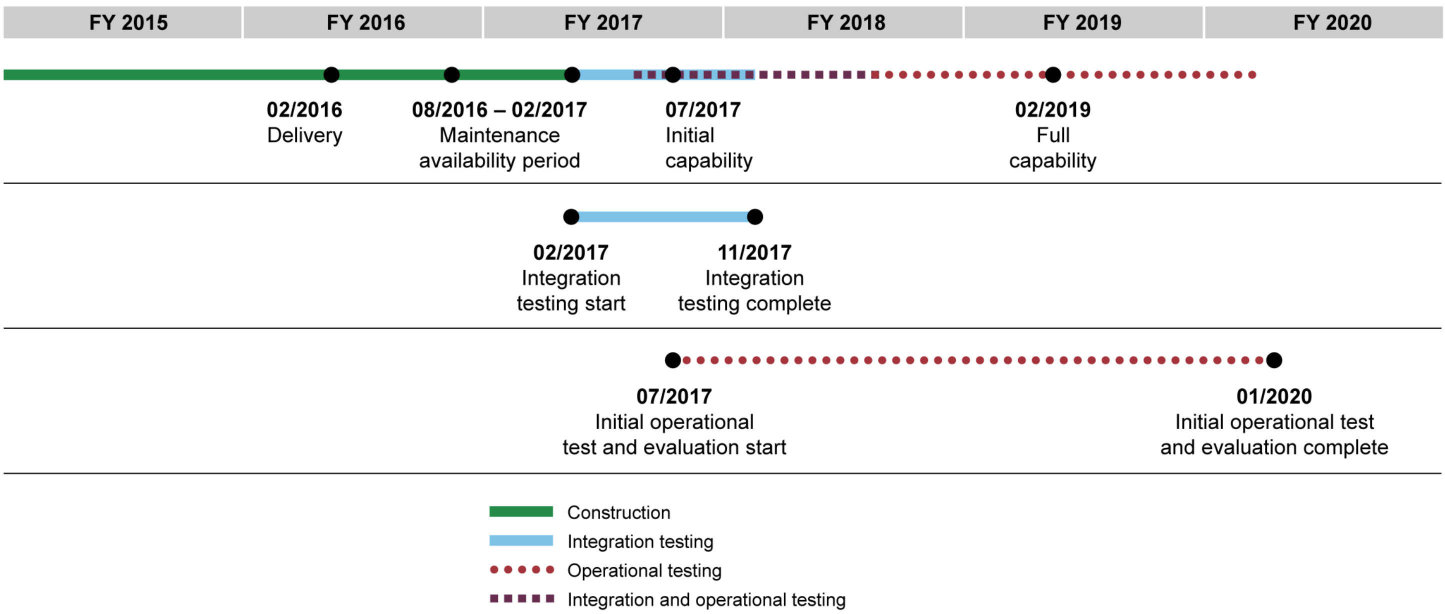
Following ship delivery in February 2016 and a brief maintenance period, the Navy plans to embark on two separate developmental and operational test phases for CVN 78 intended to demonstrate successful integration of key ship systems and overall effectiveness and suitability of the ship itself.[23] At present, the Navy anticipates requiring 10 months to complete the first phase—integration testing—and 32 months to complete the second phase—IOT&E. Further, in an effort to meet the lead ship's anticipated deployment schedule, the Navy plans to execute much of its integration testing concurrent with IOT&E. This concurrent strategy will constrain opportunities for the Navy to implement corrective actions to problems discovered in integration testing and risks introducing significant discovery during IOT&E—outcomes that could delay demonstration of ship capabilities. DOD and Navy operational test officials stated that they share these concerns. According to the Director, Operational Test and Evaluation's Test and Evaluation Master Plan Guidebook, premature commencement of IOT&E can waste scarce resources if testing is suspended or terminated early because of technical problems that should have been resolved prior to the start of this testing phase. This guidance further states that a system should demonstrate acceptable hardware and software performance during mission-focused developmental testing conducted in operationally realistic environments with the hardware and software to be used in IOT&E.[24]

Figure 6 illustrates how the Navy has sequenced its test plans for CVN 78, as outlined in the Navy's current post-delivery test schedule, and where they fall with regard to ship delivery, initial and full capability, and the planned initial deployment of the ship.

[23]The Navy's planned maintenance period for CVN 78 will be used to (1) install systems and equipment deferred during construction phase or not included in the construction contract, (2) install upgrades or improvements to existing systems, (3) correct new or previously identified construction deficiencies, and (4) perform maintenance.

[24]Director, Operational Test and Evaluation, *DOT&E TEMP Guidebook* (Washington, D.C.: Feb. 27, 2012).

Figure 6: CVN 78 Post-Delivery Testing Schedule and Key Milestones



Source: GAO analysis of Navy documentation.

Note: FY = fiscal year.

In 2012, the Navy added the integration testing component to the CVN 78 post-delivery schedule in recognition of concerns raised by the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation and the Director, Operational Test and Evaluation, that under previous testing plans, developmental systems would not be tested with one another until IOT&E. Previously, the CVN 78 program office planned to rely on developmental testing of individual systems as a means to establish confidence in the interoperability of capabilities ahead of IOT&E—a strategy assessed as high risk by DOD and Navy operational testers. Earlier testing of developmental systems with one another—above and beyond testing individual systems separately—is beneficial and can provide earlier demonstration of interoperability and combined capabilities, including measured performance against ship requirements ahead of IOT&E. Under the integrated testing approach, for example, the dual band radar will be required to conduct near-simultaneous air traffic control and self-defense operations, using both the multifunction radar and the volume search radar. On CVN 78, these operations will occur in an environment where multiple antennas and arrays are emitting and receiving transmissions, and multiple loads are placed upon the ship's power and cooling systems. Incompatibility between the dual band radar and other elements of the ship's combat system could endanger mission execution. To date, however, the Navy has not defined the scope or activities that will be covered by the new integration testing phase, which is planned to begin in February 2017, or the resources required to execute this testing. CVN 78 program officials told us they are defining these items as part of the updated Ford-class test and evaluation master plan, which is scheduled to be approved shortly before CVN 79 detail design and construction contract award in September 2013. Until integration testing scope and activities are clarified, and resource requirements are defined, the sufficiency of this testing and availability of necessary schedule and funding remains unknown.

Further, the aforementioned developmental testing delays facing critical technology systems also threaten the Navy's integration testing plans for CVN 78. In the draft revision to the Ford class test and evaluation master plan, program officials stated a willingness to defer developmental test events for critical technologies to the integration testing phase, should remaining land-based testing activities not progress at planned rates. Already, the program has deferred certain tests of the volume search radar from land to sea. To the extent that the Navy defers additional critical technology tests planned over the next 4 years, CVN 78's current integration testing schedule will face increased disruption, and the revised test and evaluation master plan may prove unexecutable.

In addition, live-fire test and evaluation plans for CVN 78 remain unclear. In 2004, the Navy and the Director, Operational Test and Evaluation, reached agreement that two major components of live-fire test and evaluation—full-ship shock trial and total ship survivability trial—would occur as part of CVN 78 post-delivery tests and trials. However, in 2012, the Navy modified its live-fire testing plans for the Ford class, citing resource constraints facing the lead ship, and deferred this testing to the first follow-on ship, CVN 79. The Director, Operational Test and Evaluation disagreed with this proposed strategy, expressing concern that delaying the testing to CVN 79 would cause a 5- to 7-year delay in obtaining data critical to evaluating Ford class survivability and would preclude timely modification of subsequent ships. On this basis, the Director rescinded approval of the Navy's alternative life-fire test and evaluation plan and recommended that the Navy plan and budget for adequate live-fire testing on CVN 78. Although the Navy's draft test and evaluation master plan appears to take steps toward addressing the Director's concerns—stating plans to conduct a total ship survivability trial following CVN 78 delivery—shock trial plans remain linked to CVN 79. According to CVN 78 program officials, the Navy continues to work with the Director, Operational Test and Evaluation to provide a robust modeling, simulation, and analysis process to better understand the survivability characteristics of the Ford class. However, these program officials also state that they expect the Defense Acquisition Board to ultimately decide the Ford class's live-fire test and evaluation strategy as part of its planned program review later this year ahead of the detail design and construction contract award for CVN 79.[25]

Delayed Availability of Joint Strike Fighter Aircraft Has Hampered Integration Efforts

The Ford-class is designed to accommodate the new Joint Strike Fighter carrier variant aircraft (F-35C), but aircraft development and testing delays have affected integration activities on CVN 78. These integration activities include testing the F-35C with CVN 78's EMALS and advanced arresting gear system and testing the ship's storage capabilities for the F-35C's lithium-ion batteries (which provide start-up and back-up power), tires, and wheels.

While the Navy has engaged in paper-based assessments to define F-35C integration requirements—and plans to incorporate necessary design changes ahead of scheduled CVN 78 deployment—actual integration testing of F-35C and CVN 78 system hardware and software remains in its infancy. To date, F-35C aircraft have participated in only one test with EMALS, and have not completed any tests with the advanced arresting gear system. Joint Strike Fighter program officials state that prior to deploying aboard CVN 78, F-35C aircraft will need to complete multiple qualification tests, on the order of 60 advanced arresting gear arrestments and 80-100 EMALS launches at the Navy's land-based testing site in Lakehurst, New Jersey.

Previously, F-35C initial capability was scheduled to occur prior to the shipbuilder's delivery of CVN 78 to the Navy in 2016. However, as a result of F-35C developmental delays, the Navy will not field the aircraft until at least 2017—one year after CVN 78 delivery. As a result, the Navy has deferred critical F-35C integration activities, which introduces risk of system incompatibilities and costly retrofits to the ship after it is delivered to the Navy.

[25]The Defense Acquisition Board is DOD's senior-level forum for advising the Under Secretary of Defense for Acquisition, Technology, and Logistics on critical decisions concerning major defense acquisition programs, such as the Ford-class carrier.

As Table 3 illustrates, the CVN 78 design baseline includes several F-35C-required accommodations to facilitate integration, and the Navy is evaluating modifications to other aspects of the ship design so as to better accommodate F-35C aircraft.

Table 3: F-35C Integration Requirements with CVN 78

Requirements incorporated in existing CVN 78 design	Requirements for which design solutions remain under development
Aircraft electrical servicing station upgrade	Jet blast deflector modifications
Ordnance work center	Third deck level noise abatement
Autonomic Logistics Information System	Lithium-ion battery handling and stowage facility
Joint Precision Approach and Landing System	Pilot equipment and helmet stowage
Heavy underway replenishment system (supports F-35C power module)	Seat shop modifications
Modifications to various rooms including ready rooms (areas where aircraft pilots mission plan) and a secure tactical briefing room	
Carrier intelligence center mission planning facility	

Source: GAO analysis of Navy documentation.

Reliability Shortfalls Facing Key Systems Will Constrain Ship Capabilities during Initial Deployments

Reliability is a key driver of system performance, directly affecting the amount of time that individual systems are online and mission capable. Reliability also drives life cycle costs related to manning, repairs, and sparing. When systems demonstrate low reliability, they can risk costing more than planned and not delivering the intended capability to the warfighter. DOD acquisition policy requires program managers to analyze, plan, track, and report on reliability for their systems—including taking steps to improve it, as needed—at intervals throughout the acquisition process.[26]

Reliability Shortfalls Prevalent in Key Ford Class Systems

The Navy's business case for Ford class carriers hinges on improved capabilities—particularly the ship's increased sortie generation rates—and reduced manning requirements, as compared to legacy Nimitz-class carriers. Together, these requirements are intended to position the Navy to field more capability in the fleet at a lower operating cost. At present,

[26]Under Secretary of Defense for Acquisition, Technology, and Logistics, *Reliability Analysis, Planning, Tracking, and Reporting*, Directive Type Memorandum 11-003 (Washington, D.C.: Mar. 21, 2011).

however, the Navy projects that the dual band radar, advanced arresting gear, EMALS, and advanced weapons elevators will all fall well short of their required reliability rates ahead of CVN 78 IOT&E. High reliability is a key attribute that underpins the contributions that these systems are intended to make toward Ford-class sortie generation rates and manning levels.

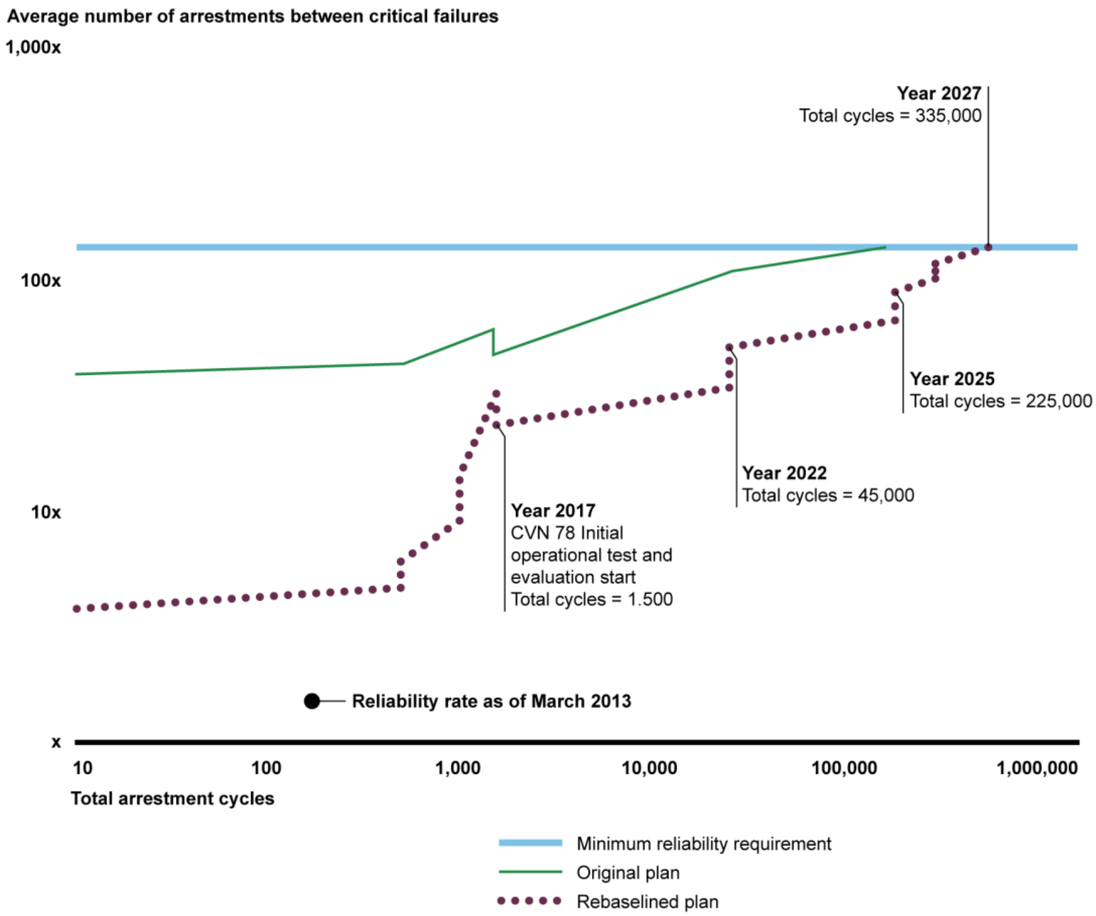
Navy's Reliability Growth Plans Optimistic and Insufficient to Meet Operational Testing Criteria

For the advanced arresting gear and EMALS, the Navy has outlined reliability growth curves, which illustrate the anticipated positive improvement in system reliability in future years due to implementation of corrective actions to system design, operation or maintenance procedures, or manufacturing processes. However, developmental testing to date has demonstrated that reliability for both of these systems was much lower than the Navy initially estimated. This shortfall has undermined the effectiveness of the Navy's initial reliability improvement plans. In response to these realities, the Navy crafted new curves for each system, which assumed lower reliability at the start. However, these more realistic starting points were offset by more optimistic assumptions about the pace of reliability gains in coming years. Therefore, the revised reliability growth curves project (1) sharp increases in system reliability in coming years and (2) achievement of required reliability levels within roughly the same amount of time as under initial plans—scenarios that may not be underpinned by sound methodologies. According to Navy officials, reliability growth projections for the advanced arresting gear and EMALS technologies are generated using a DOD growth planning methodology—called the Duane methodology—coupled with historical aircraft data from relevant points in development. However, DOD's handbook on reliability growth management notes certain drawbacks to the Duane methodology, including with how growth curves are calculated within that model.[27] Specifically, Duane's assumptions about the rate of reliability growth, which date back to 1981, have since been shown to be unrealistic. Further, Duane's methodology for estimating regression makes no allowance for variation. Subsequently, the handbook outlines several alternative models to Duane to use when projecting reliability growth for a system.

[27]DOD, *Handbook: Reliability Growth Management*, MIL-HDBK-189C (Aberdeen Proving Ground, Md.: Jun. 14, 2011).

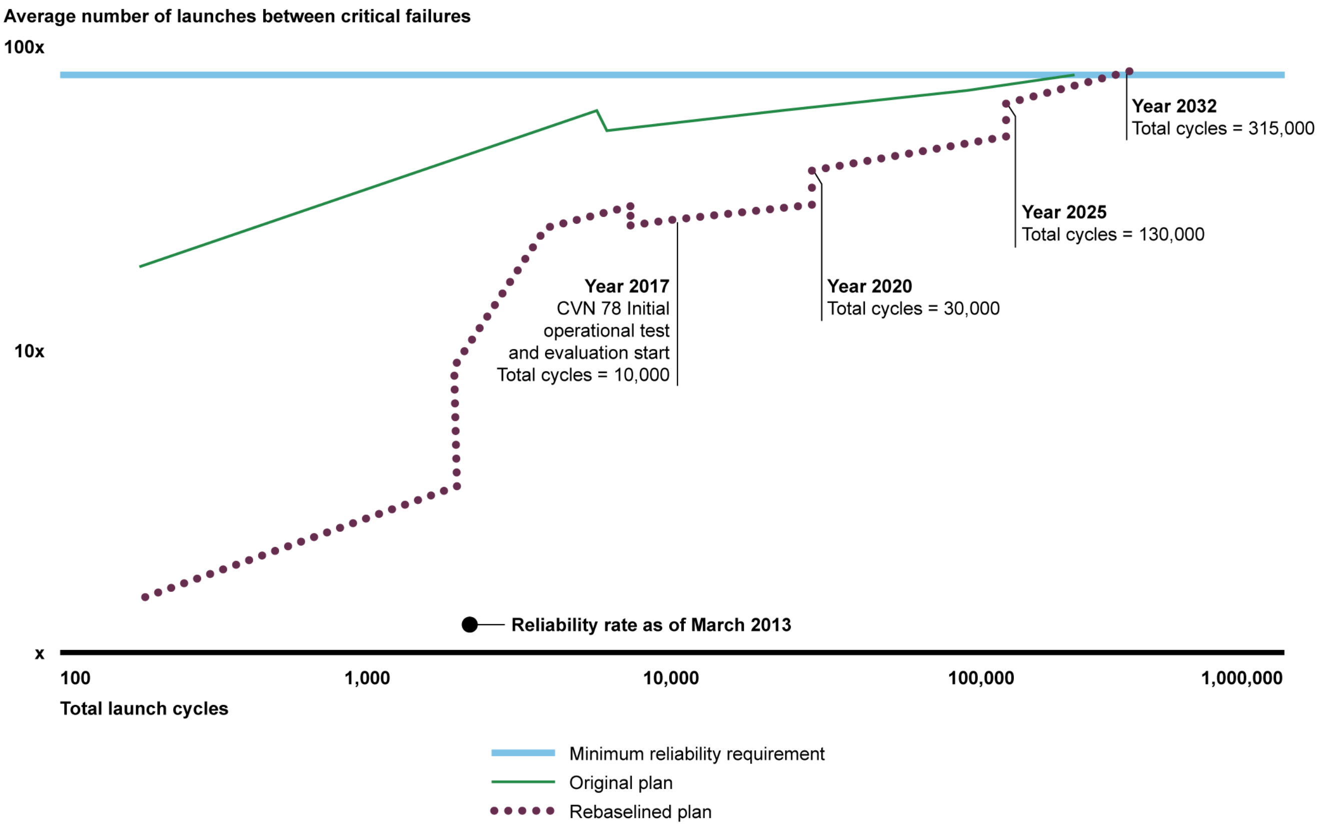
The validity of the Navy's updated growth curves is further undermined by recent reliability data on the advanced arresting gear and EMALS, which show continued underperformance against growth estimates. Although these technologies are assessed as approaching maturity (TRL 6), as discussed above, TRL criteria do not account for reliability performance. The Navy measures advanced arresting gear and EMALS reliability in terms of the average number of arrestments and launches, respectively, that the systems can complete prior to failing. The total number of arrestments and launches that these two systems complete over time are referred to as cycles. Figures 7 and 8 highlight the Navy's reliability growth projections, and current reliability performance, for the advanced arresting gear and EMALS technologies. As the figures show, neither of these systems is scheduled to reach its required rate of reliability until many years after CVN 78 is scheduled to complete IOT&E.

Figure 7: Advanced Arresting Gear Reliability Performance and Growth Projections



Source: GAO analysis of Navy reliability growth plans.

Figure 8: Electromagnetic Aircraft Launch System Reliability Performance and Growth Projections



Source: GAO analysis of Navy documentation.

Note: Reliability growth projections and the minimum reliability requirement for the electromagnetic aircraft launch system are both based on a single launcher configuration as currently employed at the Navy's land-based test site.

While the Navy also anticipates reliability growth testing for the dual band radar and advanced weapons elevators, program officials have not yet completed plans for demonstrating this growth. Further, Navy officials stated that reliability requirements for these two systems continue to evolve, noting, in particular, that reliability metrics for the dual band radar were recently invalidated based on evolving analysis from their subject matter experts. As a result, the planned reliability of each system at key points, including CVN 78 IOT&E, is unknown. For the dual band radar, however, Navy program officials state that they are collecting reliability data during first unit production and factory testing—a phase that typically produces high failure rates over limited run times. Additional data collection opportunities for dual band radar include land-based testing, shipyard testing, and post-delivery testing and trials for CVN 78. According to Navy officials, data collected during shipboard testing will support a reliability assessment of the dual band radar.

In addition, the ship itself has operational availability requirements that are linked to the reliability performance of its individual systems, such as EMALS and the advanced arresting gear. The projected reliability shortfalls for these key systems—even under the Navy's optimistic assumptions—could delay CVN 78's planned entry into IOT&E in 2017. The Navy's draft test and evaluation master plan for the program identifies various entrance criteria that it must meet before initiating IOT&E. In particular, these criteria include a requirement that testing and analysis demonstrate that the ship's reliability will meet or exceed program requirements. The criteria further stipulate that adequate reliability data be available (or planned) to enable evaluation of current versus predicted reliability growth progress. During land-based and shipboard developmental testing, the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation will conduct assessments that consider testing progress to date as well as the risks associated with the ship's capability to meet operational suitability and effectiveness goals (including reliability). These assessments will be based, in part, on the IOT&E entrance criteria outlined in the program's test and evaluation master plan. Ultimately, the Under Secretary of Defense for Acquisition, Technology, and Logistics will make the determination as to CVN 78's readiness for IOT&E.

Ship Likely to Deploy without Required Capabilities

Because of the development and testing delays and reliability deficiencies affecting key systems, CVN 78 will likely face operational limitations that extend past commissioning and into initial deployments. Thus, the ship will likely deploy without meeting its key sortie generation rate and reduced manning requirements. In the National Defense Authorization Act for Fiscal Year 2010, Congress gave the Navy a temporary waiver that lowered the statutory requirement for the minimum number of operational aircraft carriers from 11 to 10 during the period between the then-planned inactivation of the USS Enterprise (CVN 65) and commissioning into active service of CVN 78, currently planned for March 2016.[28] The temporary waiver granted to the Navy on its number of operational aircraft carriers ends on the date that CVN 78 is commissioned into the fleet. However, because of the magnitude of its operational deficiencies, it is unlikely that CVN 78 will adequately fill the capability gap created by the inactivation of CVN 65 for some time. For example, between February and June 2011, CVN 65 aircraft completed flight operations in support of Operation Enduring Freedom that totaled 2,970 combat missions and a 99.1 percent sortie completion rate.[29] Further, of the 112 days that the ship was on station for these operations, only 18 days were consumed performing maintenance.

Until the ship completes IOT&E, the full scope of CVN 78's operational limitations remains unclear. In the interim, the Navy is evaluating adding extra spares and maintenance personnel to the ship for initial deployments—at a presently unknown, additional cost to the government—to help offset some of these reliability shortfalls. The Navy also plans to conduct reliability testing for these systems as their development progresses to support updated reliability analyses and assessments.

In January 2013, the Joint Requirements Oversight Council issued a memorandum encouraging program managers and other acquisition executives—in coordination with requirements sponsors—to request requirements relief when major performance requirements for a system appear out of line with an appropriate cost-benefit analysis. According to the memo, requirements that do not provide the best return on investment for warfighters should be considered for reevaluation. The memorandum further highlighted the pressures that DOD faces from increased fiscal constraints, noting the importance of providing cost effective capability to warfighters, consideration of risk-informed trades throughout the life cycle

[28]Pub. L. No. 111-84, § 1023(a). The number of the Navy's operational carriers has changed over time. The National Defense Authorization Act for Fiscal Year 2006 amended the U.S. Code to require that the Navy have no fewer than 12 operational aircraft carriers. Pub. L. No. 109-163, § 126(a), amending section 5062 of title 10 of the U.S. Code. The following year, in the John Warner National Defense Authorization Act for Fiscal Year 2007, Congress reduced the number of required operational aircraft carriers to 11. Pub. L. No. 109-364, § 1011(a).

[29]Operation Enduring Freedom is the ongoing United States-led operation that conducts counter-terrorism operations in Afghanistan and elsewhere.

of programs, and, when needed, revisitation of previously validated requirements at the joint and component levels.

DOD last validated CVN 78 requirements in 2007—well before important knowledge was gained about the capabilities of key ship technologies. These requirements include a 25 percent increase in sortie generation rate above Nimitz class capabilities—performance contingent on the advanced arresting gear and EMALS maturing as planned. In addition, the dual band radar, advanced arresting gear, and EMALS together are projected to reduce manning requirements by over 100 people, as compared to the Nimitz class. While the Navy continues to assess reliability growth for these technologies, it has not yet considered the costs and benefits of maintaining current requirements versus modifying them. Such analysis could affect the Navy's investment priorities in the program over the long term. For example, trade-off assessments could inform decisions about the soundness and effect of less strenuous sortie generation rate requirements on the warfighter's mission versus the costs associated with the approximately 15-year effort needed to reach current minimum requirements.

Lead Ship Unknowns Complicate the Navy's Ability to Determine Follow-on Ship Cost Outcomes

The Navy and shipbuilder are implementing changes to the build strategy for CVN 79 aimed at reducing that ship's costs before the construction contract is awarded, currently planned for September 2013. These changes include increased time allotted to construct the ship and in-yard construction process improvements. Remaining technical and design risks with CVN 78, however, could interfere with the Navy's ability to achieve its desired cost savings for CVN 79. These uncertainties also affect the Navy and contractor's ability to assess the likely CVN 79 costs ahead of contract award and, when coupled with the existing sole source environment for aircraft carrier construction, compromise the government's negotiating position for CVN 79.

Planned Improvements to Follow-on Ship Construction Are Complicated by Lead Ship Uncertainties

The Navy and its shipbuilder have learned valuable lessons from CVN 78 construction that have the potential to improve cost outcomes for the construction of the first follow-on ship, CVN 79. The shipbuilder plans to employ a new build strategy for CVN 79 that (1) allots more time to fund and construct the ship compared to CVN 78 and (2) implements process improvements aimed at completing more work earlier in the build process—steps that the Navy anticipates will achieve construction efficiency improvements as compared to CVN 78. However, remaining technical and design risks in the program could undermine the Navy's ability to realize cost savings on CVN 79.

Changes to Funding Profile and Construction Schedule

In its fiscal year 2012 budget, the Navy programmed CVN 79 construction funding over a 4-year period beginning in fiscal year 2013. However, as part of its fiscal year 2013 budget, the Navy revisited this strategy and requested congressional authority to extend Ford-class construction funding, including for CVN 79, across 6 years for each ship. Congress approved this strategy change as part of the National Defense Authorization Act for Fiscal Year 2013.[30] As table 4 illustrates, this strategy allows the Navy to request less funding in the near term for CVN 79 construction, but also reflects a $1.1 billion increase in cost as compared to the fiscal year 2012 budget estimate for the ship. According to CVN 78 program officials, roughly half of this increase is a direct result of the increased build duration, whereas the remaining half is attributable to (1) design, construction, and critical technology system pricing changes and (2) shipyard and supplier base effects, including growth in overhead and inflation estimates.

Table 4: Comparison of CVN 79 Procurement Funding Strategies Outlined in the Navy's Fiscal Year 2012, 2013, and 2014 Budget Submissions

Then-year dollars in millions

Budget Submission	Prior funding received	Fiscal Years							Total
		2012[a]	2013[b]	2014	2015	2016	2017	2018	
Fiscal year 2012	$2,778.1	$554.8	$1,942.4	$1,920.3	$2,030.9	$1,026.5	-	-	**$10,253.0**
Fiscal year 2013	$2,773.1	$554.8	$608.2	$666.1	$2,999.1	$979.4	$1,823.8	$1,006.5	**$11,411.0**
Fiscal year 2014	$2,773.1	$554.8	$608.2	$944.9	$1,834.1	$1,235.6	$1,496.0	$1,891.8	**$11,338.4**

Source: GAO analysis of Navy budget documentation.

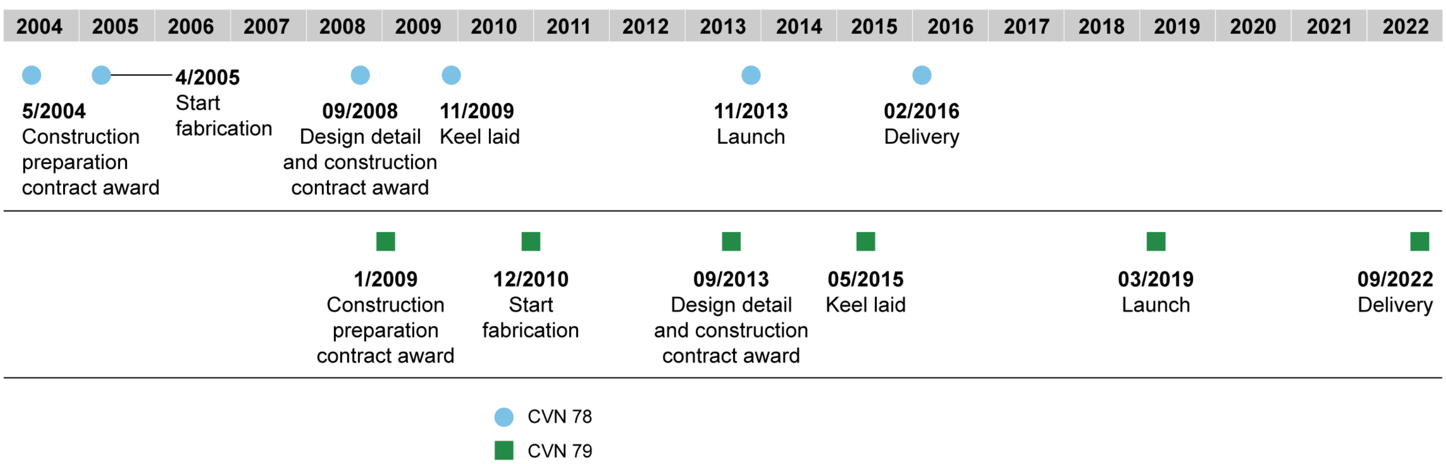
[a]The Navy's fiscal year 2012 budget provided the final installment of advance procurement funding for CVN 79.

[b]The Navy's fiscal year 2013 budget provided the first increment of procurement funding for CVN 79.

[30]Pub. L. No. 112-239, § 121. Based on the Navy's existing funding profile for CVN 78, the provision, in practice, only applies to CVN 79 and CVN 80. The new 6-year funding strategy is the latest in a series of funding plans in the Ford class program. Previously, Congress authorized the Navy to fund Ford-class carrier constructions over periods of 4 years each. Pub. L. No. 109–364, § 121. Congress later amended this authorization to permit funding periods totaling 5 years for each carrier. Pub. L. 112–81, § 124.

The Navy's decision to fund CVN 79 construction over 6 years was coupled with a decision to increase the build time for the ship as compared to CVN 78.[31] According to the Navy, it will use the additional time to improve CVN 79's construction sequence and implement cost reduction initiatives. Further, Ford class shipbuilders report that the increased time afforded to CVN 79 construction provides additional opportunities to apply lessons learned from lead ship construction. The Navy expects the combined savings from these actions to more than offset the increased costs associated with extending the funding of the ship by 2 years. Figure 9 compares CVN 78 and CVN 79 construction schedules.

Figure 9: Schedule of CVN 78 and CVN 79 Construction Milestones



Source: GAO analysis of Navy documentation.

[31]The Navy has not yet established a construction schedule for CVN 80.

Process Improvements

Planned process improvements for CVN 79

- Increasing levels of planned preoutfitting and modular construction beyond what was planned and accomplished for CVN 78. This is expected to decrease the total number of erectable units and support more efficient construction.
- Moving more planned work—including complex ship assemblies—from the ship to shop environment, which is expected to increase efficiency and yield labor reductions.
- Implementing common integrated work packages to bundle information and increase craftsmen productivity.
- Various producibility improvements based on CVN 78 learning. For example, reducing the number and extent of welded pipefitting to eliminate component costs.
- Increasing overall ship completion levels at each key construction milestone event.
- Completing whole ship bill of material—a list of all materials required to complete construction—by time of contract award. This is expected to improve supply chain management and facilitate bulk purchases.

Source: GAO analysis of Navy and shipbuilder data.

As part of CVN 79 construction, the shipbuilder plans to implement process improvements aimed at reducing the labor hours—and cost—required to construct the ship, as compared to CVN 78. The sidebar outlines several examples of key improvements planned.

The core of the shipbuilder's strategy for CVN 79 is moving more planned work—including complex ship assemblies—earlier in the build process so that it can be completed in shipyard workshops. Generally, the earlier work can be sequenced in the build process, the more efficiently it can be completed. As we have previously reported, shipbuilders often describe a general "1-3-8" rule where work that takes 1 hour to complete in a workshop takes 3 hours to complete once the steel panels have been welded into blocks, and 8 hours to complete after a block has been erected and/or after the ship has been launched.[32]

Potential Disruptions from Late Testing Discoveries

Although the Navy and shipbuilder expect CVN 79's design to be virtually the same as that of the lead ship—another step toward improving follow-on ship outcomes—remaining developmental and design risks in the program could undermine the actual realization of cost savings. As discussed above, these risks are exemplified by key ship systems not progressing through their land-based test programs at the pace the Navy anticipated—delays largely attributable to persisting technical deficiencies. Navy and shipbuilder efforts to resolve these deficiencies on CVN 78—concurrent with follow-on ship construction—are likely to lead to redesign and potentially costly out of sequence work or rework for CVN 79. If these discoveries and fixes disrupt CVN 79 construction and offset

[32] GAO-09-322.

planned improvements, they could jeopardize the Navy's ability to complete the ship within planned cost and schedule estimates.

Lead Ship Uncertainties Limit Visibility on Follow-on Ship Costs in Sole Source Environment

The Navy's cost estimate for CVN 79 detail design and construction is closely linked to CVN 78 outcomes and reflects an expectation that the shipbuilder will deliver the lead ship within current labor hour estimates. One key component of the CVN 79 cost estimate is a Navy assumption that 15 percent fewer labor hours will be required to construct the follow-on ship as compared to the lead ship. This estimate is also underpinned by expectations that the shipbuilder's current level of performance will persist between now and lead ship delivery. Further, the Navy's budget for CVN 79 is predicated on even higher performance gains than those forecast in the cost estimate—notably, 20 percent fewer labor hours in construction as compared to CVN 78. Yet, as we previously detailed, the Navy's understanding of the costs required to construct and deliver CVN 78 remains incomplete. These knowledge gaps add risk and uncertainty to CVN 79 cost and budget estimates.

The Navy plans to award a fixed-price incentive type contract for CVN 79 detail design and construction, as compared to CVN 78's cost-plus incentive contract.[33] A fixed-price incentive contract provides for adjusting profit and establishment of a final contract price by application of a formula (sometimes referred to as a shareline) based on the relationship of total final negotiated cost to total target cost. A fixed-price incentive contract includes a ceiling (maximum) price that constrains the government's exposure to potential cost growth. For CVN 79, the Navy's request for proposal stipulated a 120 percent (of target cost) ceiling price and a 50/50 cost shareline between the government and the contractor (shipbuilder) for cost increases above target cost, although final contract terms are subject to change pending completion of negotiations between the government and shipbuilder.

Because the Ford-class shipbuilder represents the only domestic entity capable of constructing, testing, and delivering nuclear-powered aircraft carriers, the government's contract negotiating position is compromised. Contracting in this sole source environment, the government lacks the leverage it would have in a competitive environment to negotiate lower

[33]A cost-plus incentive contract is a cost-reimbursement contract that provides for an initially negotiated fee to be adjusted by a formula based on the relationship of total allowable costs to total target costs.

costs or capability enhancements. Similarly, the shipbuilder's proposed price will not be influenced by competition and, as such, is likely to account for the remaining technical and design risks facing the Ford class program. For example, in a previous solicitation for Littoral Combat Ship constructions, potential shipbuilders submitted proposals which were priced significantly higher than the Navy's expectations. Even in light of the competition in this case, contractor officials stated that the fixed-price terms the Navy sought prompted a forthright assessment of remaining program risks—including technical, design, and funding uncertainties—and subsequent pricing of that risk in their proposals.[34] Alternatively, Navy officials report that the CVN 79 shipbuilder could propose to remove high-risk items from the contract's shareline or move to renegotiate the planned cost-sharing terms altogether. For example, in Zumwalt-class destroyer contract negotiations, the Navy and its shipbuilder reached agreement to remove work from the scope of the lead ship's construction contract and to include a special incentive fee associated with construction and delivery of the ship's innovative, composite-material deckhouse, which had never before been manufactured.[35]

Conclusions

The Navy awarded a multibillion dollar contract for detail design and construction of CVN 78 in 2008, even in light of substantial technology development risks and an overly optimistic budget. Now, nearly 5 years later, the cost of the lead ship has increased by more than $2.3 billion and many risks still remain which are likely to lead to further cost increases before the ship is completed. Although the ship is now more than half constructed, and promises significant capability increases over existing carriers, it is still grappling with land-based testing delays and system reliability deficiencies for critical government-provided technologies, a high-risk operational testing strategy, potentially unachievable performance requirements, and cost estimating uncertainties. Further complicating matters, the Navy is attempting to manage these challenges within an operational environment that is pressuring it to deliver CVN 78 to the fleet with haste.

[34]GAO, *Defense Acquisitions: Navy's Ability to Overcome Challenges Facing the Littoral Combat Ship Will Determine Eventual Capabilities*, GAO-10-523 (Washington, D.C.: Aug. 31, 2010).

[35]The Zumwalt-class destroyer's deckhouse is a structure that integrates the ship's radar and communications systems.

Congress granted the Navy a temporary waiver from the requirement to have 11 operational aircraft carriers in the fleet. Under the terms of the waiver, the waiver period ends at the planned CVN 78 commissioning in March 2016. As it stands, the Navy will not be positioned to deliver a fully capable ship at that time. For example, recent Navy decisions to introduce shipboard integration testing after lead ship delivery will provide valuable insights and facilitate identification of any deficiencies of integrated ship systems. However, because of the overlapping timing of this testing with IOT&E—as well as with deferred developmental tests for ship systems—the Navy will not have time to incorporate potentially significant results of the testing before CVN 78 likely deploys. Further, reliability shortfalls facing key Ford-class systems cloud the Navy's ability to forecast when, or if, current sortie generation rate and manning requirements for the ship will be met—analysis that could inform decisions on cost and requirements trade-offs in the program, both within DOD and by Congress.

As the Navy looks ahead to its planned detail design and construction contract award for CVN 79, it will be important to avoid repeating the mistakes of the past. Staying within budget will require the Navy to retire significant technical risks mainly by completing land-based testing for critical technologies before negotiating a contract with the shipbuilder. The results of this important testing will allow the government and shipbuilder to gain clearer insights on the capabilities of each system and, subsequently, better position the government to avoid paying a costly risk premium within the planned, fixed-price incentive contract. Further, the Navy's current CVN 79 cost and budget estimates are overly optimistic in that they do not take into account remaining developmental and design risks with the lead ship. A more realistic assessment of CVN 79 costs would put the government in a better negotiating position, even within the existing sole source environment. Until these issues are resolved, the Navy cannot be confident that the CVN 79 capabilities it desires can be attained at the most advantageous price to the taxpayer.

Recommendations for Executive Action

We recommend the Secretary of Defense direct the Secretary of the Navy to take the following five actions:

To ensure Ford-class carrier acquisitions are supported by sound requirements and a comprehensive testing strategy, and to promote the introduction of reliable, warfighting capable ships into the fleet, take the following actions prior to accepting delivery of CVN 78:

- Conduct a cost-benefit analysis on (1) currently required capabilities, including increased sortie generation rates and reduced manning and (2) the time and money needed to field systems to provide these capabilities, in light of known and projected reliability shortfalls for critical systems. This analysis should be informed by demonstrated system performance from land-based testing, including updated reliability growth projections, and should identify trade space among competing cost, schedule, and performance parameters. The analysis should also consider whether the Navy should seek requirements relief from the Joint Requirements Oversight Council, to the extent necessary, to maximize its return on investment to the warfighter. The Navy should report the results of this analysis to Congress within 30 days of CVN 78 commissioning.

- Update the Ford class program's test and evaluation master plan to account for developmental testing outcomes experienced since 2013 and ensure that sufficient time is allotted post-delivery to complete developmental testing activities deferred from land to sea prior to initiating integration testing.

- Adjust the planned post-delivery test schedule to ensure that system integration testing is completed prior to entering initial operational test and evaluation.

To improve the Navy's ability to manage the costs and schedule of CVN 79 detail design and construction, take the following actions:

- Defer the CVN 79 detail design and construction contract award until land-based testing for critical, developmental ship systems including the dual band radar, advanced arresting gear, and EMALS is completed.

- During the recommended deferral period, update the Navy's CVN 79 cost estimate on the basis of actual costs and labor hours associated with CVN 78 construction to determine whether the preliminary information and assumptions remain relevant and accurate.

Agency Comments and Our Evaluation

We provided a draft of this report to DOD for comment. In its written comments, which are reprinted in appendix II, DOD concurred with one of our recommendations, partially concurred with three recommendations, and did not concur with one recommendation. Additionally, we removed one recommendation from our final report based on new information that

DOD provided. DOD also provided technical comments that we incorporated into the report, as appropriate.

DOD partially concurred with our recommendation to conduct a cost-benefit analysis on Ford-class capability requirements and the time and money needed to field systems to provide these capabilities. While DOD agreed that seeking requirements relief from the Joint Requirements Oversight Council is a potential long term solution if certain systems do not meet stated capabilities, it disagreed that a cost-benefit analysis is needed within 30 days of CVN 78 commissioning. In its comments, DOD stated that it does not anticipate major requirements changes for the ship and offered that the most cost-effective path forward in the program is to complete construction of the existing design. However, DOD noted that after measuring CVN 78 warfighting capabilities through planned developmental and operational testing and following lead ship delivery, it intends to identify mitigations for any systems that do not meet stated capabilities, which could include seeking requirements relief from the Joint Staff. Under DOD's proposed approach, the process of measurement and mitigation would conceivably extend into 2020, when CVN 78 is scheduled to complete IOT&E. This strategy is unnecessarily concurrent—particularly since the Navy has already identified several significant, long-term limitations that will face the ship. We believe the knowledge gained from developmental testing—coupled with additional study and evaluation leading up to CVN 78 delivery in 2016—would provide a strong foundation for conducting a cost-benefit analysis of the ship's current required capabilities. Waiting until IOT&E is completed may be too late to make effective tradeoffs among cost, schedule, and performance. Further, such analysis could provide a sound basis for investment decisions related to CVN 80, prior to that ship's planned detail design and construction contract award in late 2017.

DOD concurred with our recommendation to update the Ford class program's test and evaluation master plan prior to delivery of CVN 78. DOD cited its current efforts to update the program's test and evaluation master plan as being responsive to our recommendation. According to DOD, the revised plan is expected to include three phases of land-based developmental testing followed by two phases of integration testing for shipboard systems. The first integration testing phase is scheduled to commence three months prior to CVN 78 delivery, to be followed by the second integration testing phase beginning in 2017. Although DOD expressed confidence that its planned testing strategy would provide ample time for developmental and integration testing prior to operational testing, it did not directly address our recommendation related to ensuring that sufficient time is allotted to complete certain land-based testing activities that have been deferred to sea prior to beginning integration testing. Further, the extent to which additional testing will be deferred to sea remains unknown, as it hinges on land-based developmental testing outcomes leading up to CVN 78 delivery in 2016. Consequently, DOD's current update of the test and evaluation master plan will be structured around assumptions about future land-based testing outcomes that may or may not come to fruition.

DOD partially concurred with our recommendation to adjust the planned post-delivery test schedule for CVN 78 to ensure that system integration testing is completed prior to entering IOT&E. In its comments, DOD presented a plan under which warfare and non-warfare systems will separately complete integration testing prior to entering into their respective operational testing phases. However, this plan shows that when non-warfare system operational testing is scheduled to begin, integration testing of the warfare systems will be just past halfway complete. As we point out in our report, concurrency in integration and operational test schedules will constrain opportunities for the Navy to implement any needed corrective actions stemming from problems identified in the integration testing. Further, given the strong linkage between non-warfare and warfare systems, this overlap poses risk to the test program. For instance, ship warfare systems such as the dual band radar, EMALS, and advanced arresting gear require cooling and power from non-warfare systems aboard the ship. Subsequently, until these warfare systems are fully integrated and developmentally tested with the non-warfare systems upon which they rely, the Navy cannot be confident that the ship is ready to enter IOT&E.

DOD did not agree with our recommendation to defer the CVN 79 detail design and construction contract award until land-based testing for critical, developmental ship systems is completed. In its comments, DOD responded as if we had recommended a total work stoppage for CVN 79—a drastic measure inconsistent with our recommendation. As we noted in this report, the Navy has contracted for construction preparation activities for this ship since 2009. That ongoing contract provides a vehicle for continuing limited CVN 79 construction work into the future—while allowing time for land-based testing activities to regain traction and retire risks—and precludes any need for a detail design and construction contract in the near term. In its response, DOD noted that an extension of the CVN 79 construction preparation contract would require use of fiscal year 2014 funds for additional bid and proposal efforts. In response to our further inquiry on this matter, the Navy stated the costs would be on the order of $5-10 million and acknowledged there are no known legal or regulatory impediments to a limited extension of the construction preparation contract. According to the Navy, under an extension of the construction preparation contract, building and outfitting of structural units and the procurement of materials could continue. Retiring remaining risks in land-based testing will improve the Navy and shipbuilder's ability to assess the likely CVN 79 costs before the planned detail design and construction contract is awarded. We continue to believe that, in light of the existing sole source environment for aircraft carrier construction, a delay in awarding the CVN 79 detail design and construction contract—by extending the construction preparation contract—would improve the government's negotiating position for the ship.

DOD partially concurred with our recommendation to update the Navy's CVN 79 cost estimate on the basis of actual costs and labor hours associated with CVN 78 construction. We recommended that this update take place following deferral of the CVN 79 detail design and construction contract award—an action DOD did not agree to take, as discussed above. Nonetheless, DOD stated that it plans to have an updated independent cost estimate prepared by the Office of Cost Assessment and Program Evaluation ahead of the CVN 79 detail design and construction contract award. According to DOD, this cost estimate will take into account actual costs and labor hours associated with CVN 78 construction.

DOD did not concur with our recommendation on delaying the commissioning of CVN 78 that was included in the draft report that we sent to DOD for comment. We made the decision to remove this recommendation based on information DOD provided about unintended consequences associated with delaying the commissioning of the ship, including potential issues related to how a noncommissioned ship would operate effectively within the Navy's chain of command. The intent of the draft recommendation was to highlight the operational limitations that will be associated with the ship when it is commissioned, but DOD noted in its response that the ship will not be designated operationally ready until testing and trials are completed—an estimated 34 months after delivery. Until the ship is judged operationally ready, it will lack the ability to conduct assigned operations for which it is designed.

Further, DOD disagreed with our finding that, when it is commissioned, CVN 78 will have significant operational limitations due to the expected reliability rates of key technologies, including EMALS, advanced arresting gear, dual band radar, and advanced weapons elevator systems. DOD stated that these systems are designed and engineered to be highly reliable. However, DOD did not address the significant evidence we present in this report demonstrating that these systems are projected to experience reliability deficiencies well into future years. For instance, the Navy now estimates that the advanced arresting gear and EMALS will not demonstrate their minimum required reliabilities until 2027 and 2032, respectively. High reliability from these and other ship systems is key to enabling the Ford class to achieve its planned capabilities. DOD also outlined the Navy's disagreement with our findings related to the effect that land-based testing delays have had on the development of certain critical technologies within the Ford-class program. The response asserts that our report overstates the cost, schedule, and technical risks associated with these delays. According to the response, the system designs for EMALS, advanced arresting gear, and dual band radar have progressed to the point where the Navy expects that any future changes will be internal to each system and independent of the ship interface. As a result, the Navy concludes that the ship's design is stable. We disagree. As we have documented in this report, the Navy's knowledge deficit about these systems is evidenced by the significant land-based testing delays that EMALS, advanced arresting gear, and volume search radar (a dual band radar component) have encountered. Tests to date have uncovered a multitude of deficiencies that the Navy did not anticipate when it developed its CVN 78 and CVN 79 construction schedules. These outcomes have prompted Navy decisions to produce the systems prior to achievement of stable designs—a strategy that risks costly retrofits and rework aboard CVN 78 before and after ship delivery. In light of the considerable testing scope that remains for each of these developmental technologies, we do not share the Navy's confidence that all future design changes to these systems will be independent of the overall ship design.

We are sending copies of this report to interested congressional committees, the Secretary of Defense, and the Secretary of the Navy. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or mackinm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report.

Michele Mackin
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

This report evaluates the Navy's acquisition of Ford-class aircraft carriers. Specifically, we (1) assessed technical, design, and construction challenges the Navy faces in delivering the lead ship, CVN 78, within current budget and schedule estimates; (2) evaluated whether the Navy's post-delivery test and evaluation strategy for CVN 78 will provide timely demonstration of required capabilities; and (3) identified actions the Navy is taking to improve cost outcomes for the first follow-on ship, CVN 79, ahead of contract award for detail design and construction.

To assess challenges the Navy faces delivering CVN 78, we reviewed Department of Defense (DOD) and contractor documents that address technology development efforts including technology readiness assessments, test reports, program schedules and briefings, and reports to Congress. We also witnessed testing of the electromagnetic aircraft launch system (EMALS) and the advanced arresting gear critical technologies at the Navy's land-based test site in Lakehurst, New Jersey, and we visited the Nimitz-class carrier USS Harry S. Truman (CVN 75) to improve our understanding of the capability improvements and technical innovations planned for introduction aboard CVN 78. In our review, we relied on DOD's selection of critical technologies and its determination of the demonstrated levels of maturity. Although we did not validate the technology readiness levels (TRL) that DOD assigned to Ford-class critical technologies, we did seek to clarify the TRLs in those cases where information existed that raised concerns. To identify design changes and to understand the impact of these changes to CVN 78 construction, we reviewed quarterly ship production progress conference briefings, contract performance reports, and program schedules and briefings. We also evaluated Navy and contractor documents outlining cost and schedule parameters for CVN 78 including budget submissions, contracts, contract performance reports, reports to Congress, and program schedules and briefings. We also relied on our prior work evaluating the Ford-class program and shipbuilding best practices to supplement the above analyses.[1] To further corroborate documentary evidence and gather additional information in support of our review, we conducted interviews with relevant Navy and contractor officials responsible for managing the technology development, design, and

[1]GAO, *Defense Acquisitions: Navy Faces Challenges Constructing the Aircraft Carrier Gerald R. Ford within Budget*, GAO-07-866 (Washington, D.C.: Aug. 23, 2007); and *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009).

construction of CVN 78, such as the Program Executive Office, Aircraft Carriers; CVN 78 program office; Newport News Shipbuilding (a division of Huntington Ingalls Industries) (CVN 78 shipbuilder); Supervisor of Shipbuilding, Conversion, and Repair officials; Aircraft Launch and Recovery program office; General Atomics (EMALS and advanced arresting gear prime contractor); Program Executive Office, Integrated Warfare Systems; Above Water Sensors program office; Integrated Combat Systems program office; and Raytheon Integrated Defense Systems (dual band radar prime contractor). We also held discussions with the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics; Office of the Director, Cost Assessment and Program Evaluation; Office of the Director, Operational Test and Evaluation; Office of the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation; Office of the Deputy Assistant Secretary of the Navy for Ship Programs; Office of the Chief of Naval Operations' Air Warfare directorate; Office of the Commander, Navy Operational Test and Evaluation Force; Naval Sea Systems Command's Nuclear Propulsion and Cost Engineering and Industrial Analysis offices; Naval Air Warfare Center—Aircraft Division; and the Defense Contract Audit Agency.

To evaluate whether the Navy's post-delivery test and evaluation strategy for CVN 78 will provide timely demonstration of required capabilities, we analyzed (1) development schedules and test reports for CVN 78 critical technologies; (2) construction, delivery, and testing schedules and reports for CVN 78; and (3) the Navy's December 2012 draft revision to the CVN 78 test and evaluation master plan to identify concurrency among developmental, integration, and operational testing plans. Further, we reviewed Joint Strike Fighter reports and program briefings to identify plans for integrating that aircraft with CVN 78. We also reviewed the draft CVN 78 test and evaluation master plan, reliability data and growth curves for key ship systems, program briefings, and DOD guidance to identify and assess the impact of reliability shortfalls on CVN 78 capabilities. To further corroborate documentary evidence and gather additional information in support of our review, we held discussions with Navy and contractor officials and DOD agencies responsible for managing development and reliability growth for key CVN 78 systems, ship integration testing, and operational testing, including the Program Executive Office, Aircraft Carriers; CVN 78 program office; Newport News Shipbuilding; Aircraft Launch and Recovery program office; Program Executive Office, Integrated Warfare Systems; Above Water Sensors program office; Office of the Director, Operational Test and Evaluation; Office of the Deputy Assistant Secretary of Defense for Developmental

Test and Evaluation; Office of the Commander, Navy Operational Test and Evaluation Force; Naval Air Warfare Center—Aircraft Division; and the Joint Strike Fighter joint program office.

To identify actions the Navy is taking to improve cost outcomes for CVN 79 ahead of detail design and construction contract award, we reviewed shipbuilder reports detailing lessons learned constructing CVN 78, the Navy's request for proposals for detail design and construction of CVN 79, CVN 79 construction plans and reports, program briefings, Navy budget submissions, and our prior work.[2] To supplement our analysis and gain additional visibility into the Navy's actions for improving CVN 79 outcomes, we interviewed officials from the Program Executive Office, Aircraft Carriers; CVN 78 program office; CVN 79 and CVN 80 program office; Newport News Shipbuilding; Office of the Director, Cost Assessment and Program Evaluation; and Naval Sea Systems Command's Contracting and Cost Engineering and Industrial Analysis offices.

We conducted this performance audit from June 2012 to September 2013 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[2] GAO-07-866 and GAO-09-322.

Appendix II: Comments from the Department of Defense

THE ASSISTANT SECRETARY OF DEFENSE
3015 DEFENSE PENTAGON
WASHINGTON, DC 20301-3015

ACQUISITION

071113

Ms. Michele Mackin
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Ms. Mackin:

This is the Department of Defense response to the GAO Draft Report, GAO-13-396, 'FORD-CLASS CARRIERS: Lead Ship Testing and Reliability Shortfalls Will Limit Initial Fleet Capabilities,' dated June 6, 2013 (GAO Code 121076). The Department acknowledges receipt of the draft report.

As more fully explained in the enclosure, the Department non-concurs with recommendations 4 and 5, concurs with recommendation 2, and partially concurs with recommendations 1, 3, and 6.

The Department appreciates the opportunity to comment on the draft report. For further questions concerning this report, please contact Mr. Jack Evans, Deputy Director, Naval Warfare, 703-614-3170.

Sincerely,

Katrina McFarland

Enclosure:
As stated

GAO DRAFT REPORT DATED JUNE 6, 2013
GAO-13-396 (GAO CODE 121076)

"FORD-CLASS CARRIERS: LEAD SHIP TESTING AND RELIABILITY SHORTFALLS WILL LIMIT INITIAL FLEET CAPABILITIES"

DEPARTMENT OF DEFENSE COMMENTS

Navy Statement on GAO Finding: Some Critical Technologies Are Mature, but Others Face Significant Land Based Testing Delays

The Navy agrees that delays have occurred in land based testing of some critical technologies, but does not agree with the impact and conclusions GAO has drawn from those delays.

System Functional Demonstration land based testing of the Electromagnetic Aircraft Launch System (EMALS) commenced in September 2010. Since then EMALS has demonstrated its full operational range and proved system functionality through 134 aircraft launches, 2,324 deadload launches (as of February 2013) and thousands of no load launches. The EMALS system design is stable with low risk that future testing will discover any significant deficiencies requiring design changes that could impact ship construction.

Advanced Arresting Gear (AAG) testing to date includes extended reliability tests, deadload commissioning tests, environmental qualification testing, and initial system performance testing. AAG completed over 350 deadload arrestments and successfully demonstrated the full operational range. The remaining test events include several hundred deadload arrestments, approximately 600 aircraft arrestments, continued environmental testing, and demonstration of system maintenance procedures. Remaining tests are expected to complete in September 2015. Although AAG land based testing is behind schedule, all currently identified hardware and software design changes will either be incorporated prior to equipment delivery to the ship or corrected onboard the ship prior to certification testing. The system design has matured to the extent that future changes are expected to be internal to the system architecture (both hardware and software) and independent of the ship interface.

The Dual Band Radar (DBR) land based testing schedule, which includes the S-band SPY-4 Volume Search Radar (VSR) and X-band SPY-3 Multi-Function Radar (MFR), is on track. The MFR underwent extensive testing since contract award in 1999 to include land based testing in 2003 and at sea testing on the Self-Defense Test Ship (SDTS) in 2006. The testing, completed while installed on the SDTS, was essential to production decisions and gave insight into the operational environment. The VSR development produced an engineering development model that was installed and tested at Port Hueneme, CA in 2007. The MFR and VSR were integrated and tested separately at Wallops Island until late 2009, when both systems were integrated to form the DBR. DBR land based testing was conducted in 2010 and has resumed along with combat system integration testing in 2013. This testing, scheduled to complete December 2014, will conclude in advance of shipboard testing. The last significant DBR design modification was identified over two years ago, and is being resolved through software updates and internal Government Furnished Equipment (GFE) cabinet modifications; with minimal impact to the ship's design. Based on historical land based integration testing of similar systems at Wallops Island, there is a very high probability that all identified issues will be mitigated or corrected through software or internal GFE equipment modifications, with no impact to the ship's design stability or construction schedule.

The ship's design is stable. As stated above, EMALS, AAG and DBR system designs have matured to the extent that any future changes are expected to be internal to the system's architecture (both hardware and software), and independent of the ship interface. The cost, schedule, and technical risks associated with delayed land based testing have been overstated in the GAO draft report.

Department of Defense Responses to Specific GAO Recommendations

RECOMMENDATION 1: To ensure Ford-class carrier acquisitions are supported by sound requirements and a comprehensive testing strategy, and to promote the introduction of reliable, warfighting capable ships into the fleet, GAO recommends the Secretary of Defense direct the Secretary of the Navy to take the following action prior to accepting delivery of CVN 78:

Conduct a cost-benefit analysis on (1) currently required capabilities, including increased sortie generation rates and reduced manning and (2) the time and money needed to field systems to provide these capabilities, in light of known and projected reliability shortfalls for critical systems. This analysis should be informed by demonstrated system performance from land-based testing, including updated reliability growth projections, and should identify trade space among competing cost, schedule, and performance parameters. The analysis should also consider whether the Navy should seek requirements relief from the Joint Requirements Oversight Council, to the extent necessary, to maximize its return on investment to the warfighter. The Navy should report the results of this analysis to Congress within 30 days of CVN 78 commissioning.

DoD RESPONSE: Partial Concur. The Department agrees that seeking requirements relief from the Joint Requirements Oversight Council (JROC) is a potential long term mitigating solution if certain systems do not meet the stated capabilities. The Department disagrees that a cost-benefit analysis should be conducted and the results reported to Congress within 30 days of CVN 78 commissioning, as recommended. With 91% of the planned RDT&E investment in CVN 78 capability complete, major requirements changes are not anticipated. No additional RDT&E investments are planned in pursuit of additional capability or further improvements to performance. As testing has progressed, the Navy has continued to be mindful of the investments made to deliver new technology and complete testing compared to the capability improvement targets. At this point in CVN 78 construction, the most cost effective path forward is to complete construction of the existing design. The Navy intends to measure resultant CVN 78 performance and key performance parameters through a comprehensive test strategy including extensive developmental and operational testing phases. After measuring CVN 78 war fighting capabilities following lead ship delivery, any systems that do not meet stated capabilities will have mitigations identified. Those mitigations might include seeking requirements relief from the Joint Staff, if appropriate. For reference purposes this recommendation will be identified as item GAO-13-396-01.

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RECOMMENDATION 2: To ensure Ford-class carrier acquisitions are supported by sound requirements and a comprehensive testing strategy, and to promote the introduction of reliable, warfighting capable ships into the Fleet, GAO recommends the Secretary of Defense direct the Secretary of the Navy to take the following action prior to accepting delivery of CVN 78:

Update the Ford class program's test and evaluation master plan to account for developmental testing outcomes experienced since 2013 and ensure that sufficient time is allotted post-delivery to complete developmental testing activities deferred from land to sea prior to initiating integration testing.

DoD RESPONSE: Concur. The Department agrees that sufficient time should be allotted within the post-delivery test plan to account for Developmental Testing (DT) outcomes. The Program's Test and Evaluation Master Plan (TEMP 1610) is currently under revision. This revision includes five distinct Developmental Test phases which include Integrated Testing to accommodate developmental and operational test objectives and mitigate risk to operational testing and initial operational test and evaluation. The first three Developmental Testing/Integrated Testing (DT/IT) phases emphasize land-based testing of individual systems and ship-based systems, while the last two phases (Phase 4 and Phase 5) cover shipboard integrated systems testing. Phase 4 commences three months before ship's delivery. It includes six months of sea trials during the shakedown period and completes during the Post Shakedown Availability (PSA). Phase 5 begins after PSA and ends approximately nine months later following completion of combat systems testing. These DT/IT phases provide ample time for DT and associated integration testing to occur prior to operational testing. The revised TEMP 1610 also defines the Carrier Integrated Test Team and the Developmental Testing Working Group which evaluate test results, adjusts testing priorities and periodically updates the integrated post-delivery test and trials schedule. This approach was established based on recommendation received from, and in collaboration with the Navy and Office of the Secretary of Defense testing communities. For reference purposes this recommendation will be identified as item GAO-13-396-02.

RECOMMENDATION 3: To ensure Ford-class carrier acquisitions are supported by sound requirements and a comprehensive testing strategy, and to promote the introduction of reliable, warfighting capable ships into the fleet, GAO recommends the Secretary of Defense direct the Secretary of the Navy to take the following action prior to accepting delivery of CVN 78:

Adjust the planned post-delivery test schedule to ensure that system integration testing is completed prior to entering initial operational test and evaluation.

DoD RESPONSE: Partial Concur. As stated in the answer to Recommendation # 2, the Test and Evaluation Master Plan describe the roles of the Carrier Integrated Test Team and the Developmental Testing Working Group, which collaborate to assess test results and adjust the Post Delivery Test and Trials schedule periodically according to test outcomes. Developmental Testing (DT) and associated integration testing will occur prior to Operational Testing (OT). As shown in the figure below, Warfare Systems and Non-Warfare Systems DT and OT periods

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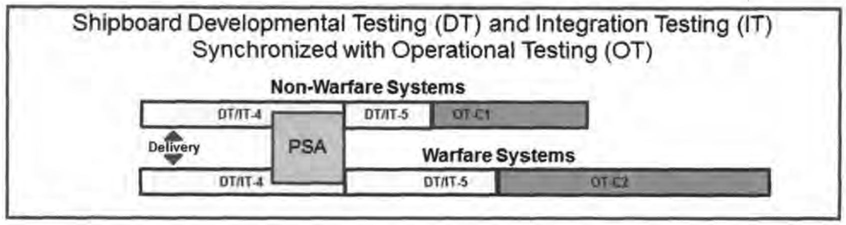
overlap, but in all cases DT, along with its associated integration testing, will occur prior to OT. For reference purposes this recommendation will be identified as item GAO-13-396-03.



This recommendation was removed from the final report. See page 51.

RECOMMENDATION 4: In recognition of the significant operational limitations that CVN 78 is expected to face following its planned March 2016 commissioning, particularly as reliability of key systems remains deficient, GAO recommends that the Secretary of Defense direct the Secretary of the Navy to take the following action:

Delay CVN 78 commissioning until the ship successfully completes initial operational test and evaluation, as determined by the operational testing community.

DoD RESPONSE: Non-Concur. The GAO assertion that CVN 78 will have significant operational limitations due to deficient reliability at commissioning is not valid. All CVN 78 systems including the Electromagnetic Aircraft Launch System (EMALS), the Advanced Arresting Gear (AAG), the Dual Band Radar (DBR), and the Advanced Weapons Elevator (AWE) are designed and engineered to be highly reliable and maintainable systems and to meet the ship's operational availability requirements.

The Navy applied the rigorous systems engineering processes that started with deriving the reliability requirement from Operational Availability requirement from the CVN 78 Operational Requirement Document, allocating reliability requirements at the subsystem and component level and, conducting testing, failure analyses, and corrective actions at these levels to engineer reliability into the systems. This rigorous process was also conducted at the system level including for EMALS, AAG, DBR and AWE. The failure reporting and corrective action system is maintained by the Navy throughout each system's life cycle. The Navy also is using the Reliability Growth Curve (RGC) as an effective tool to plan, illustrate, and report the progress of obtaining testing or operating time information to demonstrate statistical confidence that design reliability requirements have been met. Due to the nature of the statistical analysis, this data collection for ship systems frequently requires an extended data collection period which goes beyond the Initial Operational Test and Evaluation (IOT&E) period. The GAO recommendation is based solely on the availability of data to populate the RGC and improve the statistical confidence that the system will reach the reliability threshold before IOT&E, without consideration of the actual system reliability at delivery.

Additionally, the use of redundant reliable sub-systems (i.e. four EMALS catapults, four AAG arresting wires, three DBR arrays per horizon search and volume search function, multiple upper

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and lower stage weapons elevators) contributes to each system's ability to achieve the highest availability requirements.

It is a goal of the Navy's shipbuilding and modernization effort to deliver to the Fleet complete ships capable of supporting the Navy's primary mission and which are free from either contractor or government responsible deficiencies. A new ship undergoes extensive industrial testing during construction in the building yard. This testing is typically conducted by a team of shipbuilders, system providers, and Navy representatives, as a Ship Production Acceptance Test and Evaluation program under the auspices of a Total Ship Test Program. These industrial tests, which include an at-sea period known as Builder's Trials, are then followed by Acceptance Trials conducted at-sea by the President, Board of Inspection and Survey (INSURV) as an independent verification of a ship's readiness for acceptance prior to ship delivery by the shipbuilding contractor. Upon successful completion, INSURV provides the recommendation for accepting delivery of the ship and fleet introduction.

In addition to the pre-delivery tests and trials, certain number of tests and trials are still required to be conducted by the Navy after delivery, including the IOT&E. These tests and trials utilize specialized instrumentation, resources, ranges and facilities in order to demonstrate the ship's performance and mission capabilities in an operational environment while using the ship's crew during what is known as the Post- Delivery Tests and Trials (PDT&T) period.

Every NIMITZ class aircraft carrier delivered to the fleet underwent a PDT&T period, a post shakedown availability to correct deficiencies, and a crew training period resulting in ships being operationally ready an average of 25 months after commissioning. These events typically involved numerous periods at-sea to best evaluate ship performance. For CVN 78, the first ship of the GERALD R. FORD Class, additional testing and trials will result in 34 months between delivery and operational readiness. Longer periods between ship commissioning and completion of initial operational test and evaluation are typical for lead ships of the class given the more extensive test program. The period of time between commissioning and operational readiness for CVN 78 is factored into Fleet planning schedules.

Additionally, there are serious concerns with operating CVN 78 in a non-commissioned status for a prolonged period of time. Per Navy Regulations 8, a Commanding Officer is not designated until ship commissioning. Navy Regulations further state, "the prospective commanding officer of a ship not yet commissioned shall have no independent authority over the preparation of the ship for service by virtue of assignment to such duty, until the ship is commissioned and placed under his or her command." It is unclear how the ship and its crew would operate effectively within the Navy chain of command in a non-commissioned status. This GAO proposal would result in an unprecedented method of ship delivery and testing that is not prudent to pursue. For reference purposes this recommendation will be identified as item GAO-13-396-04.

RECOMMENDATION 5:
To improve the Navy's ability to manage the costs and schedule of CVN 79 detail design and construction, GAO recommends that the Secretary of Defense direct the Secretary of the Navy to take the following action:

Defer the CVN 79 detail design and construction contract award until land-based testing for critical, developmental ship systems including the dual band radar, advanced arresting gear, and EMALS is completed.

DoD RESPONSE: Non-Concur. The Department disagrees with GAO's contention that the Navy's ability to manage costs and schedule for CVN 79 would be improved by delaying award of the CVN 79 Detail Design and Construction (DD&C) contract until completion of land-based tests for certain systems on the first ship of the class, CVN 78. This would likely involve over a one year delay to CVN 79 construction plans. Any perceived cost avoidance resulting from waiting until completion of testing would be outpaced by real cost increases arising from the detrimental impacts of construction interruption, loss of momentum on cost improvement initiatives, required reissuance of a solicitation by Navy and submission of a proposal from the shipbuilder, interruption of planned material procurements, erosion of an experienced workforce, costs to retrain and rehire workforce once CVN 79 construction and planning efforts are restarted, and disruption of the fragile sub-vendor supplier base. In all, the risk reduction achieved due to the delay of the CVN 79 DD&C contract award does not justify the significant cost increase that would result.

With regard to the risk reduction that might be achieved by such a delay, the CVN 78 design already incorporates multiple design modifications resulting from the years of testing that has already occurred with the development systems. The Advanced Arresting Gear, Dual Band Radar, and Electromagnetic Aircraft Launching System designs have matured to the extent that future changes are expected to be internal to the system architecture (both hardware and software), and independent of the ship interface. There is little cost risk remaining for CVN 79 design and construction relative to these systems, which are design repeats from CVN 78. Lessons learned going forward on CVN 78 will likely involve the shipboard test program efforts. The CVN 79 test program is not slated to begin until 2018 or later. Therefore, the existing interval between CVN 78 and CVN 79 provides ample opportunity to implement CVN 78 lessons learned, including those identified through completion of the shipboard test program. In addition, the approach to CVN 79 construction underwent an extensive affordability review with significant changes that will reduce the cost of building the ship. CVN 79 construction will start with a complete design, a complete bill of materials, and an optimal build plan.

Advance Procurement funding for CVN 79 was first appropriated in Fiscal Year (FY) 2007. The National Defense Authorization Act for FY2010 authorized the initiation of advance construction efforts. Fabrication of the first construction units was begun in December 2010. In the time since, long lead time material procurement and advance construction authority has enabled the shipbuilder, Huntington Ingalls Industries – Newport News Shipbuilding (HII-NNS), to make significant progress in accordance with its build plan:

- Rollover of the CVN 78 design in the 3-D product model is 90% complete.
- Over 50% of contractor furnished, direct buy material has been placed on order; more than 40% of this amount has been received in the shipyard.

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- Fabrication has been started on 225 of 1,156 total construction units; of these, 97 are complete.
- 1,030 full-time equivalents are currently supporting the program.
- Approximately 50% of Government-Furnished Equipment (GFE) has been ordered, including all propulsion plant GFE.

The CVN 79 program established considerable positive momentum during the Construction Preparation (CP) phase of the program, and advance construction performance to date demonstrates the shipbuilder is well positioned to carry this momentum into the DD&C phase. Build strategy improvement initiatives identified in the recently submitted report to Congress on cost control measures are currently being implemented by the shipbuilder, and interruption of these ongoing efforts would increase costs. HII-NNS personnel would be released from the program due to the loss of this construction workload. The subsequent ramp back up and retraining of the workforce to support the delayed award would come with an attendant loss of program knowledge, loss of efficiency, and adverse cost impact. In addition, there would be cost implications to the VIRGINIA Class nuclear submarine work and CVN 68 Class refueling and complex overhaul work at HII-NNS due to the construction break between CVN 78 and CVN 79. To minimize the detrimental impact of complete interruption of these efforts, an extension of the existing CP contract and a continuation of advance construction efforts would be required utilizing FY 2014 procurement funding.

Furthermore, additional bid and proposal efforts needed to complete the CP Extension contract and to request, resubmit, and review the HII-NNS DD&C proposal would have to be repeated, adding further cost to the program.

Finally, following the truncation to the DDG 1000 program at three ships, CVN 79 will be the last ship to be outfitted with the Dual Band Radar. The current cost estimate for an FY 2014 procurement of DBR includes a premium to restart production at Raytheon. Delaying this procurement beyond FY 2014 would increase this premium. For reference purposes this recommendation will be identified as item GAO-13-396-05.

RECOMMENDATION 6: To improve the Navy's ability to manage the costs and schedule of CVN 79 detail design and construction, GAO recommends that the Secretary of Defense direct the Secretary of the Navy to take the following action:
During the recommended deferral period, update the Navy's CVN 79 cost estimate on the basis of actual costs and labor hours associated with CVN 78 construction to determine whether the preliminary information and assumptions remain relevant and accurate.

DoD RESPONSE: Partial Concur. Notwithstanding the Department's non-concur with the recommended deferral period detailed in the response to GAO Recommendation 5, the Department is planning to have an updated independent cost estimate prepared by the Office of Cost Assessment and Program Evaluation to support the Defense Acquisition Board Interim Program Review to be conducted prior to awarding the CVN 79 Detail Design and Construction contract. This independent cost estimate will take into account actual costs and labor hours associated with the CVN 78 construction. For reference purposes this recommendation will be identified as item GAO-13-396-06.

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Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Michele Mackin, (202) 512-4841 or mackinm@gao.gov

Staff Acknowledgments

In addition to the contact named above, key contributors to this report were Diana Moldafsky, Assistant Director; John Oppenheim, Assistant Director; Greg Campbell; Christopher R. Durbin; Laura Greifner; Kristine Hassinger; Karen Richey; W. Kendal Roberts; Charlie Shivers; Roxanna Sun; and Holly Williams.

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