

GAO

Report to the Ranking Minority
Member, Subcommittee on Seapower
and Expeditionary Forces, Committee
on Armed Services, House of
Representatives

August 2007

DEFENSE ACQUISITIONS

Navy Faces
Challenges
Constructing the
Aircraft Carrier
Gerald R. Ford within
Budget



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Highlights

Highlights of [GAO-07-866](#), a report to the Ranking Minority Member, Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, House of Representatives

Why GAO Did This Study

The Navy is investing over \$3 billion to develop technologies for a new type of aircraft carrier—the Ford class—and it expects to spend almost \$11 billion to design and construct the USS *Gerald R. Ford* (CVN 78)—the lead ship of the class. New technologies are to improve the carrier's performance and reduce crew size. The Navy requested authorization of CVN 78 in its fiscal year 2008 budget. GAO was asked to assess the Navy's ability to meet its goals for developing the new carrier. Specifically, this report assesses (1) the extent to which technology development could affect the capability and construction of CVN 78, (2) the status of efforts to achieve design stability, and (3) the challenges to building CVN 78 within budget. To accomplish this, our work includes analysis of test reports, development schedules, and ship progress reviews; interviews with Navy and other officials; and examinations of cost estimates and our own past work.

What GAO Recommends

GAO recommends that the Department of Defense (DOD) take actions to improve the realism of CVN 78's budget estimate, improve the Navy's cost surveillance capability, and schedule carrier-specific tests of the dual band radar. DOD partially concurred with our recommendations. This report also contains matters for congressional consideration to ensure that CVN 78 is budgeted at the likely cost of the ship.

www.gao.gov/cgi-bin/getrpt?GAO-07-866.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Paul Francis at (202) 512-4841 or francispg@gao.gov.

DEFENSE ACQUISITIONS

Navy Faces Challenges Constructing the Aircraft Carrier *Gerald R. Ford* within Budget

What GAO Found

Delays in technology development may lead to increases in CVN 78's planned construction costs and potential reductions in the ship's capability at delivery. CVN 78's success depends on on-time delivery and insertion of fully mature and operational technologies in order to manage construction costs and enhance ship capabilities. Technologies that are highly integrated into the construction sequence or provide vital capabilities for the ship to carry out its mission are the most critical in achieving this goal. While the Navy has mitigated the impact of some technologies, such as the nuclear propulsion and electric plant, three systems—the electromagnetic aircraft launch system (EMALS), the dual band radar, and the advanced arresting gear—have faced problems during development that may affect the ship's construction costs.

The Navy has made significant progress in maturing the ship's design. With about 70 percent of the ship design complete, design appears on track to support the construction schedule. A structured design approach and a lengthy construction preparation contract have enabled the program to perform more work prior to construction than on previous carriers. The program, however, may face challenges completing more detailed phases of design because of the tight schedule remaining for development of the ship's critical technologies, which in turn could impede the design process—and construction—of CVN 78.

Artist's Rendition of CVN 78



Source: Navy.

Costs for CVN 78 will likely exceed the budget for several reasons. First, the Navy's cost estimate, which underpins the budget, is optimistic. For example, the Navy assumes that CVN 78 will be built with fewer labor hours than were needed for the previous two carriers. Second, the Navy's target cost for ship construction may not be achievable. The shipbuilder's initial cost estimate for construction was 22 percent higher than the Navy's cost target, which was based on the budget. Although the Navy and the shipbuilder are working on ways to reduce costs, the actual costs to build the ship will likely increase above the Navy's target. Third, the Navy's ability to manage issues that affect cost suffers from insufficient cost surveillance. Without effective cost surveillance, the Navy will not be able to identify early signs of cost growth and take necessary corrective action.

Contents

Letter		1
	Results in Brief	2
	Background	4
	Remaining Work on Key Technologies Poses Risks to Ship Cost and Capability	11
	The Navy Has Made Significant Design Progress, but Sustained Progress Depends on Technology Development	25
	Costs for CVN 78 Will Likely Exceed Budget	32
	Conclusions	41
	Recommendations for Executive Action	42
	Matters for Congressional Consideration	43
	Agency Comments and Our Evaluation	43

Appendix I	Scope and Methodology	46
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Appendix II	Comments from the Department of Defense	48
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Appendix III	GAO Contact and Staff Acknowledgments	52
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Tables

Table 1: Major Events in the Development of Future Aircraft Carriers	6
Table 2: CVN 78 Critical Technologies	8
Table 3: Extent of Potential Impact on the Construction Sequence	13
Table 4: Critical Technologies' Impact on Ship Capability	14
Table 5: Matrix of the Impact of Critical Technologies	15
Table 6: Schedule of Key Events Relating to EMALS	17
Table 7: Challenges Faced by the EMALS Program in Meeting Program Requirements	18
Table 8: Schedule of Key Events Relating to Dual Band Radar	20
Table 9: Schedule of Key Events Relating to Advanced Arresting Gear	22
Table 10: Other Technologies That Affect the Construction Sequence	24

Table 11: Other Technologies That Affect CVN 78's Planned Capability	24
Table 12: Design Progress by Location on Ship	30
Table 13: Construction Labor Hour Change	34

Figures

Figure 1: CVN 78 Aircraft Carrier Currently in Development	4
Figure 2: CVN 78's Budgeted Cost	10
Figure 3: Product Model Design Process	26
Figure 4: Ship Design Status as of April 2007	28
Figure 5: Knowledge of Carrier Material Costs Prior to Construction Contract Award	38

Abbreviations

DOD	Department of Defense
DCAA	Defense Contract Audit Agency
DCMA	Defense Contract Management Agency
EMALS	electromagnetic aircraft launch system
JPALS	joint precision approach and landing system
NAVSEA	Naval Sea Systems Command
SAR	Selected Acquisition Report
SUPSHIP	Supervisor of Shipbuilding, Conversion and Repair

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United States Government Accountability Office
Washington, DC 20548

August 23, 2007

The Honorable Roscoe G. Bartlett
Ranking Minority Member
Subcommittee on Seapower and Expeditionary Forces
Committee on Armed Services
House of Representatives

The Navy is developing the Ford-class nuclear-powered aircraft carrier, which will serve as the future centerpiece of the carrier strike group. The Ford class is the successor to the Nimitz-class aircraft carrier designed in the 1960s. Until the establishment of the future aircraft carrier program, the Navy had not invested significantly in research and development to incorporate leading edge technologies into current carriers. The new carrier was designed to include a number of advanced technologies in propulsion, aircraft launch and recovery, and weapons handling. These technologies, along with an expanded and improved flight deck, are designed to increase operational efficiency and enable higher sortie rates while at the same time reducing manpower requirements for the ship and air wing as compared with current aircraft carriers. The Navy is investing over \$3 billion to research and develop technologies for the new class of carriers, and it expects to spend almost \$11 billion to design the class and construct the lead ship, USS *Gerald R. Ford* (CVN 78).

The Navy requested authorization of CVN 78 as part of its fiscal year 2008 budget and plans to fund the carrier in fiscal years 2008 and 2009. Given the carrier's sizable investment and the Navy's long-standing problem of cost growth on shipbuilding programs, you asked us to assess the Navy's ability to meet its goals for developing the CVN 78 aircraft carrier. Specifically, we assessed (1) the extent to which technology development could affect the capability and construction of CVN 78, (2) the status of efforts to achieve design stability, and (3) the challenges to building CVN 78 within budget.

To address the first objective, we developed a matrix based on the degree to which CVN 78's technologies could have an impact on the optimum capability and construction of the ship. We categorized technologies based on our analysis of key program documents, including test reports, development schedules, and ship progress reviews. To supplement our analysis, we visited contractors and test sites where the ship's major technologies are being developed and tested. To assess the Navy's progress in achieving design stability, we examined the ship's design

requirements and analyzed design maturity metrics captured in the shipbuilder's integrated master schedule. Finally, we examined the ship's estimated costs and identified cost challenges by examining the ship's budget; Navy, independent, and shipbuilder cost estimates; ship progress reviews; defense contract audit reports; and GAO's past work on shipbuilding cost growth. To address all of the above objectives, we held discussions and attended briefings with Department of Defense (DOD), Navy, and CVN 78 program officials, as well as the shipbuilder and developers of CVN 78's critical technologies. We conducted our analysis from July 2006 to June 2007 in accordance with generally accepted government auditing standards.

Results in Brief

As a result of a substantial investment of time and money, the Navy has reduced the risks associated with a number of essential technologies, including the nuclear propulsion and electric plant. At this time, several technical risks that could lead to increased construction costs and potentially result in capability reductions still remain. In particular, the electromagnetic aircraft launch system (EMALS), the advanced arresting gear, and the dual band radar face key tests with little margin for resolving problems before they begin to disrupt the optimal CVN 78 construction schedule and increase ship costs. If key systems arrive late, more labor cost may be incurred because of inefficient work-arounds and schedule delays. EMALS and the advanced arresting gear are vital to meeting key capabilities and must be delivered to the shipyard on time to maintain the construction schedule. The dual band radar enables a smaller island structure on the deck of the carrier, facilitating the ship's increased sortie generation rate. All three systems have experienced schedule delays because of technical and other challenges. Demanding tests lay ahead for all three systems:

- In November 2007, the EMALS program will begin testing a production-representative system, including a critical generator component that will be field-tested for the first time.
- Land-based testing of a dual band radar prototype is expected to begin in December 2008, but will not demonstrate full power output critical to meeting requirements. Specific testing has not yet been planned for all carrier-unique capabilities, including a number of air traffic control scenarios.
- Testing of the advanced arresting gear, including, for the first time, the software control system, is scheduled to begin in 2008.

The Navy has made significant progress in maturing the ship's design. The shipbuilder has completed about 67 percent of the ship's design, and design efforts are on track to support the construction schedule. A structured design approach and a lengthy construction preparation contract have enabled the program to perform more work prior to construction than on previous carriers. The program, however, may face challenges completing more detailed phases of design because of delays in the development of the ship's critical technologies, which in turn could impede the design process—and construction—of CVN 78.

Costs for CVN 78 will likely exceed the budget for several reasons. First, the Navy's cost estimate that underpins the budget is optimistic. For example, the Navy estimates that CVN 78 will be built with fewer labor hours than were needed for the previous two carriers. Second, the Navy's target cost for ship construction may not be achievable. The Navy established a cost target for the shipbuilder based on the budget. The shipbuilder's initial cost estimate for construction was 22 percent higher than the Navy's cost target. The Navy and the shipbuilder are working to reduce costs by incentivizing capital improvements, removing noncritical capabilities to save costs, and introducing other production efficiencies. However, experience on other shipbuilding programs suggests that actual construction costs will increase above the cost target as a result of labor inefficiencies and late material deliveries. Third, the Navy may not have the management tools necessary to identify and react to early signs of cost growth because current contractor cost performance reports do not have meaningful performance measurements, the Navy's on-site Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP) does not have an independent cost surveillance capability. Given CVN 78's magnitude, managing cost growth will be essential to the Navy's ability to execute its 30-year shipbuilding plan. Decisions the Navy makes on CVN 78's budget this year and next year will determine whether and to what extent overruns will require offsets in the budgets for future fiscal years.

We are making several recommendations to the Secretary of Defense aimed at ensuring that the budget for CVN 78 is executable and at improving technology development efforts. We are also making recommendations to improve the Navy's management of shipyard performance and early recognition of issues that may affect cost. DOD agreed with most of our recommendations, but did not agree with all recommended actions aimed at ensuring that the budget for CVN 78 is executable. Therefore, future cost growth beyond the budget remains likely. As a result, this report also contains matters for congressional

consideration to ensure that CVN 78 is budgeted at the likely costs of the ship.

Background

The Ford-class nuclear aircraft carriers are intended to replace the USS *Enterprise*—the Navy’s first nuclear-powered aircraft carrier—and the Nimitz-class carriers. The Ford class will serve as the premier forward asset for crisis response and early decisive striking power in a major combat operation. The first Ford-class carrier—CVN 78—is scheduled for delivery to the fleet in September 2015. Figure 1 depicts an artist’s rendition of CVN 78.

Figure 1: CVN 78 Aircraft Carrier Currently in Development



Source: Navy.

Delivery of CVN 78 is an important step in maintaining the Navy's force of operational carriers. The Navy outlined its strategy of sustaining a force of 11 operational carriers and achieving a force of 313 ships in its long-range shipbuilding plan.¹ This plan outlines future ship construction rates, fiscal constraints, and force structure requirements that the Navy envisions over the next 30 years. In the near term, the Navy plans to significantly increase its rate of construction and introduce several new classes of ships, including the Ford class. The Navy recognizes that the success of the plan will depend on its ability to control shipbuilding costs.

Starting with the lead ship, the Ford class features 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. Some of the improvements include the following:

- increased sortie generation rates,
- a near three-fold increase in electrical generating capability,
- increased operational availability, and
- increased service life margins (e.g., weight and stability) to support future changes.

These improvements are made possible through a number of design features, including an enlarged flight deck; a smaller, aft-positioned island with fewer rotating radars; and a flexible ship infrastructure to accommodate future changes to the ship.

The Navy's strategy for acquiring a new class of carriers has changed since the initial concept was determined. The Navy established the CVN(X) program in 1998 after deciding that the next class of carriers would be nuclear-powered and feature a large deck, with over 75 aircraft. Initially, the Navy employed an evolutionary acquisition strategy, with technology improvements introduced gradually with each successive carrier. In 2002 the Navy established the CVN 21—or 21st century—aircraft carrier program and decided to use a Nimitz hull on all carriers, but accelerate the

¹The Navy plans to increase its inventory to 12 aircraft carriers beginning in 2019. See *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2008*.

introduction of new technologies on the first lead ship. Follow-on ships will largely repeat the lead ship design, with some modifications. In 2006 the Navy decided to delay awarding a contract for construction of the first two ships by 1 year in order to meet other Navy priorities, thereby shifting lead ship delivery. This delay will reduce the Navy’s inventory to 10 aircraft carriers in 2013 and 2014—1 below its force requirement.

The Navy requested authorization of CVN 78 in its fiscal year 2008 budget request, with funding split over 2 years. Table 1 outlines the major events in the development of future aircraft carriers.

Table 1: Major Events in the Development of Future Aircraft Carriers

Year	Events
1993	<ul style="list-style-type: none"> Navy establishes a carrier working group to investigate the requirements and available technologies and systems for a new class of aircraft carriers.
1998	<ul style="list-style-type: none"> CVN(X) evolutionary design approach established.
2000	<ul style="list-style-type: none"> Integrated process and product development contract awarded to Northrop Grumman Newport News. Design begins on the new propulsion system. CVN(X) program reaches Milestone 1.
2002	<ul style="list-style-type: none"> CVN(X) changes to the CVN 21 program following the Navy’s decision to eliminate an evolutionary strategy.
2003	<ul style="list-style-type: none"> Construction contract award date shifted from 2006 to 2007.
2004	<ul style="list-style-type: none"> CVN 21 program receives approval for Milestone B, the point for entry into the system development and demonstration phase of the DOD acquisition system. Navy awards a construction preparation contract to Northrop Grumman Newport News.
2005	<ul style="list-style-type: none"> Fabrication of the lead ship (CVN 78) begins.
2006	<ul style="list-style-type: none"> Construction contract award date shifted from 2007 to 2008. Construction preparation contract extended by 1 year until 2008. Secretary of the Navy names CVN 78 USS <i>Gerald R. Ford</i>—initiating the Ford class. Congress establishes a cost cap of \$10.5 billion for CVN 78 procurement in the Defense Authorization Act for Fiscal Year 2007 (Pub. L. No. 109-364§122 (2006)).
2007	<ul style="list-style-type: none"> Navy requests authorization of CVN 78 construction in its 2008 budget request. Defense Acquisition Board program review (expected). Updated Navy and DOD independent cost estimates were expected in support of the review.
2008	<ul style="list-style-type: none"> CVN 78 construction contract award to Northrop Grumman Newport News.
2010	<ul style="list-style-type: none"> CVN 78 keel lay.
2012	<ul style="list-style-type: none"> Construction contract award for CVN 79.
2015	<ul style="list-style-type: none"> CVN 78 delivery.

Source: Navy data.

CVN 78 Critical Technology Development

A number of new technologies will be installed on CVN 78. These technologies will enable CVN 78 to achieve its capability enhancements. The Navy identifies 16 critical technologies—technologies that it defines as new or novel that the ship depends on to meet development, production, employment, and operations² (see table 2). The number of critical technologies changes when the Navy decides to remove a technology from the ship or if it determines that a technology warrants additional attention. The Navy recently removed a dynamic armor protection system from the CVN 78 design, deferring this technology to follow-on ships and is currently considering identifying CVN 78's electronic warfare and command and control systems as critical technologies.

²The Navy recently removed the 1,100-ton air-conditioning plant and the aviation data management control system from its critical technologies list because they are no longer considered developmental systems.

Table 2: CVN 78 Critical Technologies

Technology	Capability improvement
1,100-ton air-conditioning plant	Greater cooling capability with fewer units than the legacy system.
Advanced arresting gear	Recovers current and future aircraft, lighter than the legacy system, software controls reduce manning.
Advanced weapons elevator	Elevators that use moving electromagnetic fields instead of cabling. Allows elevator shaft to use horizontal doors to close off magazines. Reduces manning and maintenance costs.
Aviation data management control system	Optimizes weapons inventory and arrangement. Interfaces new technologies such as EMALS and the advanced arresting gear for operation and management purposes.
Dual band radar—multifunction radar and volume search radar	Integrates two radars operating on different frequency bands: <ul style="list-style-type: none">• volume search radar: long-range searches to detect small targets.• multifunction radar: horizon/surface search and tracking.
Evolved Sea Sparrow missile for CVN 21	Supports raid requirement with a data link between combat systems and missiles.
EMALS	Replaces steam catapult. Uses an electrically generated, moving magnetic field to propel aircraft to launch speed.
Heavy underway replenishment	Quicker shipboard replenishment through reinforced steel beams that increase ship separation (180 to 300 ft.) and load transport (5,700 lbs to 12,000 lbs).
High-strength low-alloy steel 65 and 115	Lightweight steel reduces ship weight.
Joint precision approach and landing system (JPALS)	Global positioning system technology allows for all-weather, day-night landings.
Nuclear propulsion and electric plant	Converts energy into electricity. Provides 2.8 times more electrical generating capacity than previous carrier class.
Plasma arc waste destruction system	Uses extreme temperatures to convert 6,800 lbs/day of paper, cardboard, plastic, cloth, wood, incidental food, metal, and glass into gaseous emissions.
Reverse osmosis desalination system	Desalinates water without requiring a steam distribution system and creates potable water.
Shipboard weapons loader	Self-powered, self-charging munitions loader intended to lift up to 3,000 lbs in sea states 5 or 6.

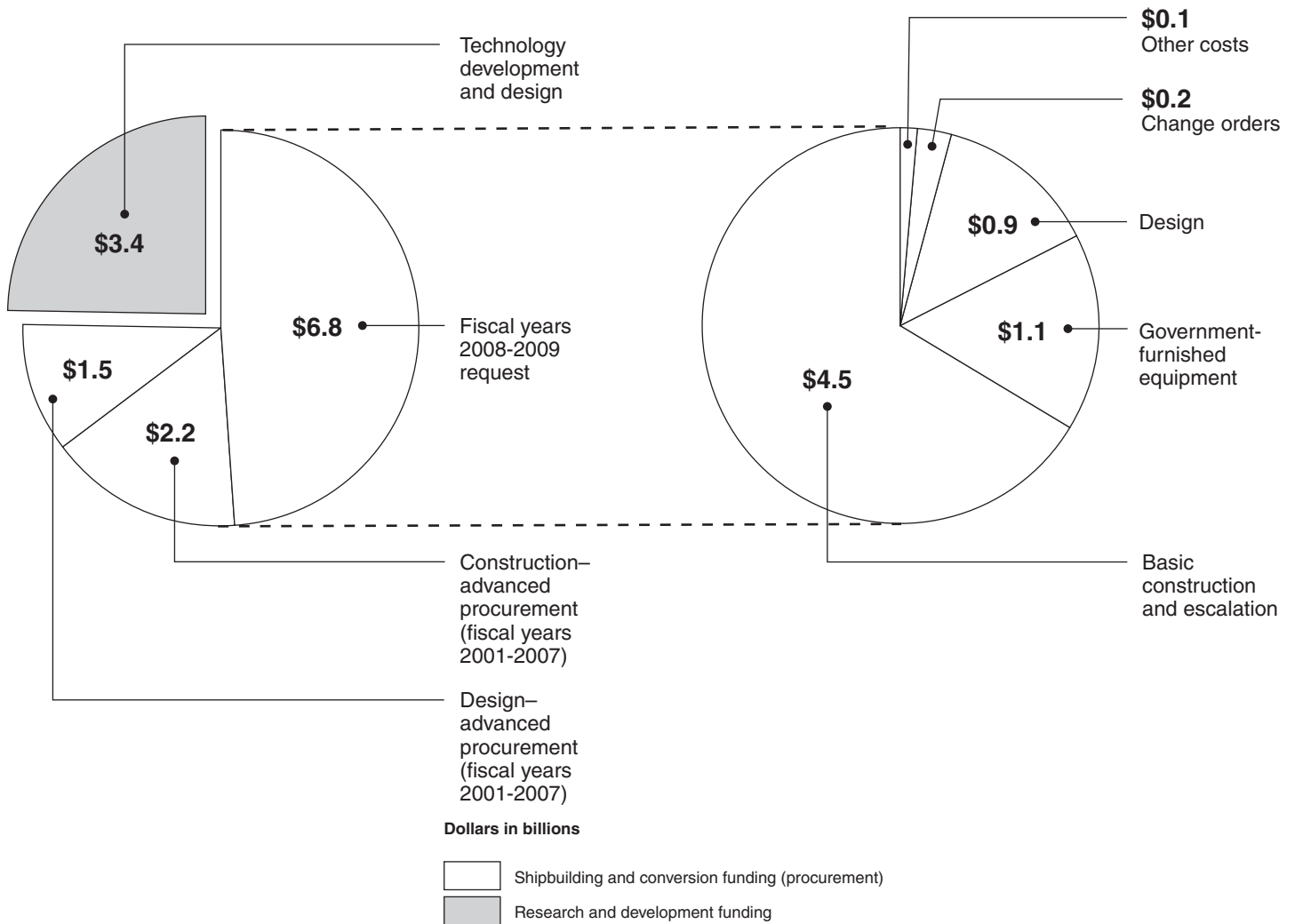
Source: Navy data.

The Navy tracks the status of critical technologies through quarterly integrated product team meetings with the various program offices and developers responsible for systems that will be installed on the ship.

CVN 78 Acquisition Costs

CVN 78's current total acquisition cost is estimated at \$13.9 billion, including funding for research and development, and design of the ship class. The Navy is spending approximately \$3.4 billion over several years on research and development of technologies and ship design. Of this amount, approximately \$1.8 billion is to develop the ship's propulsion system. To date, the Navy has received almost \$3.7 billion in advanced procurement funding. The Navy estimates a total shipbuilding budget of \$10.5 billion, including \$8.1 billion for CVN 78 construction and \$2.4 billion for ship class design. The Navy requested \$2.7 billion in fiscal year 2008 and plans to request \$4.1 billion in fiscal year 2009, thereby fully funding construction of the ship. Figure 2 outlines CVN 78's budgeted costs.

Figure 2: CVN 78's Budgeted Cost



Source: GAO analysis of Navy data.

The Navy's budget for CVN 78 is based largely on an initial life cycle cost estimate developed in 2004 to support the Milestone B acquisition decision. An independent DOD cost estimate performed that same year estimated the cost of CVN 78 at \$13.8 billion, \$1.3 billion higher than the Navy estimate. DOD leadership approved an amount between the two estimates, establishing a Milestone B cost estimate of \$13.1 billion for a fiscal year 2007 ship procurement. The Navy's fiscal year 2008 budget request of \$13.9 billion is based on the Milestone B estimate, adjusted

upward to include inflation, additional funding for government-furnished equipment, and the 1-year delay in the program.³

Unlike previous carriers, which were budgeted for in the first year of construction, funding for CVN 78 construction is split over 2 fiscal years. By funding the ship over multiple years, the Navy hopes to mitigate potential disruptions to other programs that can be caused by a large budget outlay in a single year. In the event that CVN 78's costs grow above the budget for fiscal years 2008 and 2009, the Navy will need to seek additional funding. Funds will be transferred from other programs or obtained through a prior year completion request, a mechanism used to fund cost growth for ships budgeted in prior years.

Remaining Work on Key Technologies Poses Risks to Ship Cost and Capability

Delays in technology development may lead to increases in CVN 78's planned construction costs and potential reductions in the ship's capability at delivery. CVN 78's success depends on on-time delivery and insertion of fully mature and operational technologies in order to manage construction cost and enhance ship capabilities. Technologies that are highly integrated into the construction sequence or provide vital capabilities for the ship to carry out its mission are the most critical in achieving this goal. While the Navy has mitigated the impact of some technologies, such as the nuclear propulsion and electric plant, three systems—EMALS, the dual band radar, and the advanced arresting gear—have faced problems during development that may eventually affect the ship's construction costs. Upcoming critical tests must be executed as planned in order for these systems to remain on schedule.

The Ship's Optimum Construction Sequence and Capability Depend on Technologies Being Delivered as Planned

In order for CVN 78 to deliver with its promised capability and within construction cost, the ship's technologies must be delivered as planned—on schedule, fully mature, and operational. EMALS, the dual band radar, and the advanced arresting gear warrant the most concern at this point because they have a high impact on both ship capability and construction schedule, have had difficulties during development that have absorbed much of their schedule margin, and have a significant amount of work to complete before they can demonstrate full maturity. Other technologies

³Government-furnished equipment includes technologies, electronics, weapons systems, propulsion, mechanical equipment, and other items, which are purchased by the Navy and installed by the shipbuilder.

are either further along in development or have less impact on capability and construction. The Navy has been actively managing technical risks on CVN 78 and has mitigated the risk on several technologies, such as the propulsion and electric plant, that have a high impact on both capability and construction.

The first key impact on the ship is the construction sequence. Ships are designed and constructed with an optimal sequence—that is, the most cost-efficient sequence to construct the ship. This includes designing and building the ship from the bottom up and maximizing the work completed in shipyard shops and minimizing tasks performed when the ship is already in the water, which tends to be costlier than tasks on land. This sequence is outlined in the shipbuilder’s integrated master schedule, which links all of the detailed construction tasks based on key event dates. The plan for installing CVN 78’s critical technologies takes advantage of construction efficiencies. If a technology does not arrive on time, the shipbuilder will have to work around the missing technology. Additional labor hours may be needed because spaces will be less accessible and equipment may require more time for installation. Certain technologies have an increased potential to affect the optimum construction sequence—and, consequently, are more likely to increase costs. Similarly, if areas of the ship require redesign, costs can increase and can significantly delay construction.

The degree to which technologies can affect construction and increase costs depends on the interrelationship of several factors—including the following:

- The date that technologies are first needed in the yard for installation. Technologies that are located low in the ship have earlier installation dates.
- The degree to which a technology is embedded in the ship’s design. CVN 78’s design is divided into 423 separate zones (75 for the propulsion plant and 348 for the platform). Although each zone is a separate design unit, there are dependencies among them, including technologies that cross multiple zones. Changes to one design zone must be applied to all dependent design zones. Problems with technologies that affect several zones can have a cascading effect on other areas of the ship.
- The extent of integration. For example, the dual band radar is highly integrated in the design of the island and enables the smaller island design. CVN 78 cannot install legacy radars without major redesign of the ship.

Table 3 shows the degree to which CVN 78's technologies can affect the ship's construction sequence.

Table 3: Extent of Potential Impact on the Construction Sequence

Technology	In-yard date	Total design zone impact	Deck location
High-strength low-alloy steel 65	2005	348	All decks
Nuclear propulsion and electric plant	2006	75	Below third deck
Reverse osmosis desalination system	2008	10	Below third deck
1,100-ton air-conditioning plant	2009	9	Below third deck
Advanced weapons elevator	2010	68	All decks
High-strength toughness steel 115	2010	15	Flight deck
EMALS	2011	48	Flight deck and above main deck
Advanced arresting gear	2011	18	Above main deck
Heavy underway replenishment	2011	6	Main deck
Plasma arc waste destruction system	2011	4	Main deck
Dual band radar (multifunction radar and volume search radar)	2012	9	Island
Evolved Sea Sparrow missile for CVN 21	2012	0	Flight deck
JPALS	2013	2	Island
Aviation data management control system	2013	0	Not applicable (N/A) (software)
Shipboard weapons loader	2015	1	Flight deck

Source: GAO analysis of Navy data.

The second key impact of CVN 78's critical technologies is on the ship's planned capability. CVN 78's capability is predicated on technologies meeting requirements. The ship's capability is based on technologies meeting five key performance parameters: sortie generation rates, manpower reduction, electric generation capacity, service weight and stability allowance, and interoperability. Table 4 describes the impact of critical technologies on the ship's capability.

Table 4: Critical Technologies' Impact on Ship Capability

Technology	Sortie generation rate enabler	Manpower reduction (in billets)^a	Other capability impact
1,100-ton air-conditioning plant	None	Maintenance reduction	N/A
Advanced arresting gear	High	41	50 tons lighter than the legacy system
Advanced weapons elevator	Moderate to high	Over 20	N/A
Aviation data management control system	Low	6	N/A
Dual band radar: multifunction radar and volume search radar	High ^b	28	Projected weight reduction, interoperability
EMALS	High	32	N/A
Evolved Sea Sparrow missile for CVN 21	None	0	Interoperability
Heavy underway replenishment	High	Decrease manpower surge time	N/A
High-strength low-alloy steel 65	None	0	700-ton projected weight reduction
High-strength toughness steel 115	None	0	175-ton projected weight reduction
JPALS	Low	Maintenance reduction	Interoperability
Nuclear propulsion and electric plant	Low	220 (includes reverse osmosis desalination system)	1350-ton projected weight reduction (includes reverse osmosis desalination system), electric generation
Plasma arc waste destruction system	None	Decrease trash sorting time	Reduction of trash and equipment weight
Reverse osmosis desalination system	None	See nuclear propulsion plant reduction	See nuclear propulsion plant, weight reduction
Shipboard weapons loader	Moderate	4-5 per loader	N/A

Source: GAO analysis of Navy data.

^aCVN 78's total system manpower requirements reflect a manpower billet reduction of 500 (threshold) and 900 (objective) compared to the last class of carriers.

^bThe dual band radar does not directly affect sortie generation rates, but it enables the smaller island design, which greatly affects sortie generation rates.

Technologies That Greatly Affect both Capability and Construction Will Have the Greatest Impact on the Ship if They Are Not Delivered as Planned

We categorized CVN 78’s technologies according to the degree they can affect the construction and capability of the ship (see table 5). Technologies in quadrant 1 affect both the construction sequence and capability of the ship—and would present the greatest risk to the cost and capability of the ship if not delivered as planned. Of the technologies in quadrant 1:

- The Navy has largely retired the risk posed by the nuclear propulsion and electric plant, the reverse osmosis desalination system, and the high-strength low-alloy steel 65.
- The design of the weapons elevator has been developed—but full-scale testing, scheduled for later this year, is needed to demonstrate a shipboard representative system.
- Significant risks remain in the development of EMALS, the dual band radar, and the advanced arresting gear.

Table 5: Matrix of the Impact of Critical Technologies

High impact on ship construction	Quadrant 2: Medium 1,100-ton air-conditioning plant	Quadrant 1: High Advanced arresting gear Dual band radar: volume search and multifunction radars EMALS Advanced weapons elevator High-strength low-alloy steel 65 Nuclear propulsion and electric plant Reverse osmosis desalination system
Low impact on ship construction	Quadrant 4: Low Aviation data management control system Evolved Sea Sparrow missile for CVN 21 High-strength toughness steel 115 Plasma arc waste destruction system	Quadrant 3: Medium Heavy underway replenishment JPALS Shipboard weapons loader
	Low impact on ship capabilities	High impact on ship capabilities

Source: GAO.

Early planning and testing of several CVN 78 critical technologies have mitigated risk, including some technologies with the highest impact on construction and capability. The Navy fully demonstrated:

- **Nuclear propulsion and electric plant.** Development began in 1998 and the overall design is complete. The Navy tested and qualified the system generator in 2005, and fabrication and installation of components are under way.
- **Reverse osmosis desalination system.** In 2003 units were successfully tested at a land-based test facility. The Navy is currently

evaluating units aboard an amphibious assault ship. The design is complete and the system is currently being manufactured.

- **High-strength low-alloy steel 65.** After testing finished in 2002, the Navy certified its use on naval ships in 2003. Steel is currently being used to fabricate the ship.
- **Plasma arc waste destruction system.** System is currently in use on a commercial cruise ship.

The Navy can also still choose not to install a number of the low-impact technologies, if they do not mature as planned, without significantly affecting the ability of the ship to meet minimum performance requirements. For example, the new weapons management system is a software upgrade; the Navy can opt to use legacy software—and the ship will still achieve threshold performance requirements. Similarly, the Navy is considering the use of new high-strength steel on the flight deck to reduce weight if ballistic testing proves successful. Steel currently scheduled for use on the ship is an acceptable backup.

EMALS, Dual Band Radar, and Advanced Arresting Gear Have Experienced Schedule Delays That Could Disrupt CVN 78's Construction Schedule

EMALS, the dual band radar, and the advanced arresting gear are each critical to realizing CVN 78's planned capability—and the Navy has committed to installing these technologies on the ship. Upcoming system testing of each technology is expected to demonstrate its capability. The ship's construction sequence, however, is at risk. While progress has been made in developing components, EMALS, the dual band radar, and the advanced arresting gear have encountered difficulties during development that have led to delays. Difficulties include achieving needed performance in key components, as well as reaching agreement with the Navy on systems engineering and other requirements. While each technology has passed critical design milestones, they now face demanding test and production schedules with little or no margin to address problems discovered in testing or manufacturing. If problems occur, EMALS and the advanced arresting gear will be hard pressed to meet their schedule for delivery to the shipyard. Problems with the dual band radar could have an immediate impact on the next generation destroyer (DDG 1000) program, but delays in producing radars for the first two DDG 1000 ships could cascade down to CVN 78—affecting delivery to the shipyard.

EMALS

EMALS is critical to meeting sortie generation rates and reducing manpower on the ship. The contractor has demonstrated the feasibility of using magnetic fields to launch aircraft on a land-based test bed designed to simulate a flight deck—but at half the length. Land-based tests are

scheduled to begin in February 2008 will demonstrate a ship-ready system. Table 6 outlines EMALS' schedule.

Table 6: Schedule of Key Events Relating to EMALS

2003	2004	2006	2007	2008	2009	2011
Developmental testing of competing systems on a half-length test bed.	Preliminary design competition completed, contractor begins system development.	Follow-up testing and evaluation.	Construction of a land-based test facility completed. Critical design review held.	High-cycle and land-based developmental testing on a full-length test bed.	Production start.	EMALS required in yard for carrier construction.

Source: Navy data.

The EMALS program finished its system integration phase over 15 months behind schedule and substantially above budget. Delays resulted from technical challenges, as well as difficulties meeting detailed Navy requirements.

Although progress has been made on many of EMALS' components, the system has faced technical challenges, largely because of failures with the prototype generator that stores the high power needed to propel the launchers. The prototype generator malfunctioned during integrated and follow-on testing. The contractor believes that the problem has been resolved through redesign of the prototype generator. The first tests of the redesigned generators are scheduled for 2008 at the contractor's facility, followed by full-scale testing of the EMALS prototype.

The contractor also faced challenges meeting the requirements involved with Navy ships. Ships, especially carriers, have complex requirements, largely because they operate at sea and must meet unique survivability requirements. The contractor has never produced a shipboard system—particularly one as highly integrated into the ship as EMALS—and underestimated the effort needed to meet Navy requirements. Additionally, the contractor received requirements after much of the system had already been designed. Specific challenges are summarized in table 7. According to the contractor, the company has taken action to address these problems, including hiring experts familiar with the Navy's processes.

Table 7: Challenges Faced by the EMALS Program in Meeting Program Requirements

Weight requirement	The contractor initially designed and tested EMALS in a configuration that minimized the system's weight. After the Navy defined the ship's survivability requirements, the system was reconfigured, separating EMALS components and increasing the use of cabling. EMALS weight increased above its margin, resulting in a reallocation of weight elsewhere on the ship and the redesign of a subsystem. EMALS is now within its revised weight allocation.
Electromagnetic environmental effects requirement^a	Due to the effects of electromagnets, EMALS may interfere with the operations of shipboard systems or ordnance—and potentially harm the ship or personnel. After EMALS' design was stable, a number of electromagnetic effect issues emerged. The program has now taken steps to examine potential interference by hiring an expert and creating an integrated product team to analyze electromagnetic effects. However, tests to understand potential electromagnetic effects have not yet started and the effort required to mitigate these effects remains unclear.
Shipboard requirements	Shipboard requirements evolved during EMALS' design process as the design of the ship became better known. The contractor designed one subsystem component, the power conversion system, to generic shock and vibration requirements while waiting for the Navy's final determination of requirements. The subsystem may need to be reconfigured in order to meet final shock and vibration requirements, but the redesign will not occur until production. According to the contractor, limited coordination with the shipyard contributed to delays in meeting requirements. Initially, requirements were communicated via the Navy, creating a lag in delivery time. The contractor now believes that coordination issues have been resolved through direct communication between the shipyard and the EMALS program.
Systems engineering^b	The contractor underestimated the extent that systems engineering is needed to integrate EMALS into other shipboard systems. The contractor had not previously worked on shipboard systems and lacked the necessary staff to address the Navy's systems engineering requirements. The contractor has now hired additional systems engineers to manage the requirements process.

Source: GAO analysis of EMALS contractor and Navy data.

^aElectromagnetic environmental effects refer to the impact of the electromagnetic environment on the operational capability of military forces, equipment, systems, and platforms. System electromagnetic effects can interfere with other systems, specifically causing undesirable responses, malfunctions, degradation of performance, or premature and undesired location, detection, or discovery by enemy forces.

^bSystems engineering is a technical management tool that provides the knowledge necessary to translate requirements into specific, achievable capabilities. Tasks include defining what the customer wants, turning the requirements into specific functions, and identifying technical and design solutions to achieve system functionality.

Challenges to date have led to schedule delays and cost growth. Without the 1-year delay in the ship's schedule, it would have been unlikely that EMALS would have met the ship's installation date. Even with an additional year of development, it may be difficult to deliver EMALS components. To meet ship installation dates for EMALS' components, the contractor eliminated all schedule margin, normally reserved for addressing unexpected issues. As a result, the schedule cannot accommodate unanticipated testing or production problems. While the contractor believes that problems during system integration have been resolved and EMALS' delivery schedule can be met, challenges remain:

-
- **Demonstrating shipboard-ready system.** Demanding tests lay ahead. An integrated full-scale prototype will undergo over 4 months of testing. These tests will be the first demonstrations of the redesigned prototype generator and the first time the system will be tested with actual aircraft. With no margin for delays, any problems encountered during testing will likely prevent an on-time delivery to the shipyard.
 - **Demonstrating program requirements.** In order to stay on schedule, the program shifted a number of key test events, including maintainability testing, to the production phase. This introduces additional risk to EMALS production if problems are discovered during testing. Additionally, tests of electromagnetic interference and shock and vibration could lead to redesign of some components—which may result in additional delays.
 - **Producing a shipboard-ready system.** EMALS' contractor has traditionally been involved in projects aimed at research and development—not producible systems. Converting EMALS design into producible, affordable components, with established test and quality controls, may prove challenging. The contractor recently opened a new production facility in Mississippi to control production costs. The contractor acknowledges the risk associated with manufacturing EMALS components at a new facility inexperienced with production, but believes it has taken steps to mitigate the risks through training and manufacturing automation.

Dual Band Radar

The dual band radar, composed of two systems (the multifunction and volume search radars), is being developed and tested as part of the DDG 1000 program. The Navy initially intended to install the dual band radar on CVN 77—the last carrier of the Nimitz class. When it was clear that the radar would not mature in time for ship delivery, the Navy chose to use legacy radars on CVN 77 and delay initial installation until CVN 78. Use of legacy radars, however, necessitated the redesign of CVN 77's island structure. Key events in the development of the dual band radar can be seen in table 8.

Table 8: Schedule of Key Events Relating to Dual Band Radar

2006	2007	2008	2009	2010	2011	2012
Multifunction radar completes at-sea testing.	Preliminary volume search radar “string” testing complete. Volume search radar begins land-based testing.	Volume search radar completes land-based testing. Dual band radar begins integrated testing.	Dual band radar completes integrated testing. Dual band radar integrated with power system.	First dual band radar delivered to DDG 1000.	Second dual band radar delivered to DDG 1000.	Third dual band radar required in yard for carrier construction.

Source: Navy data.

Development and testing of the multifunction radar have progressed further than the volume search radar. Land-based and at-sea testing of the multifunction radar prototype demonstrated the radar’s key functions—clutter rejection and firm tracking range.

The volume search radar has encountered difficulties developing key components of the transmit-receive units, the individual radiating elements that are the essence of the radar. Specifically, critical circuit technology experienced failures during testing and could not reliably operate at the radar’s voltage needed to meet requirements. The contractor believes it has identified a solution, and is currently pursuing two design iterations that it believes will improve the reliability of the circuit while also achieving greater affordability. However, the redesigned circuit technology has not been included in testing of the volume search radar. In an effort to maintain schedule, the contractor is only testing the radar at a reduced voltage. Upcoming land-based testing of the volume search radar prototype and integrated testing of the dual band radar will not demonstrate the higher-voltage output necessary to meet ship requirements. The contractor does not anticipate testing the complete radar system, with the redesigned circuit technology, until production unit testing in 2010—shortly before the dual band radar is required for DDG 1000 installation. Moreover, the volume search radar will not be fully demonstrated until operational testing on DDG 1000 in 2013. Problems discovered during testing may not only affect DDG 1000, but may affect installation on CVN 78 scheduled to begin in 2012.

Dual band radar testing must occur as planned in order to meet the radar production schedule. Testing of the volume search radar at a land-based test facility is now currently planned to begin in September 2007, followed by integration with the multifunction radar and testing as the dual band radar now scheduled to begin in December 2008. Further, the construction

of the land-based test facility is over 8 months behind schedule. In order to maintain the current test schedule, the Navy moved testing of the volume search radar to a different site. The dual band radar is scheduled to complete integrated testing at the land-based test site in 2009—after production of the radars is scheduled to begin in 2008. This concurrency introduces additional risk if problems are discovered during testing. Upcoming land-based testing will not include tests designed to demonstrate all carrier-specific capabilities. The dual band radar was initially designed to meet both destroyer and aircraft carrier requirements, including air traffic control. Although the contractor is obligated to meet air traffic control requirements, the prototype for the volume search radar—the key component in air traffic control—is not designed to demonstrate air traffic control in short ranges. The Navy decided to waive minimum requirements for the volume search radar prototype as long as the CVN 78 production unit radar satisfied these requirements. Testing to verify all aspects of the air traffic control capability, however, has not yet been planned, but the Navy anticipates that the radar will demonstrate this capability by the end of fiscal year 2012. This leaves little to no time to incorporate any necessary upgrades into CVN 78’s air traffic control capabilities prior to the radar’s delivery date to the shipyard.

Additionally, electromagnetic effects with the dual band radar and other major electronic systems involved in aircraft operations are not yet fully understood. In particular, if the multifunction radar is not restricted during flight landings, it could interfere with an aircraft-landing radar during aircraft approach and could result in a major accident on the flight deck. The Navy has identified this as the highest risk of electromagnetic interference. Any interference between the multifunction radar and aircraft landing systems will be engineered to remove the threat of flight deck accidents. The Navy plans to conduct studies to further evaluate electromagnetic effects, but has not yet determined how it will address these concerns. It may be necessary to relocate antennas or make other changes to the ship’s topside to isolate interference of the radars.

Further development of CVN 78’s integrated warfare system is needed to ensure its operation with the dual band radar. The warfare system is composed of the ship’s command and control, mission planning, air traffic control, and self-defense systems. The dual band radar is a critical element of CVN 78’s warfare system because it provides the ship’s surveillance and air traffic control capability. Available carrier electronic warfare and command and control systems, however, cannot function on CVN 78 because they were not designed to interface with the dual band radar. The Navy plans to modify the current carrier command and control system by

integrating modules from the DDG 1000 total ship computing system, which was designed to function with the dual band radar. While the Navy has developed a plan for upgrading the command and control system, a solution for the electronic warfare system has not yet been identified. The electronic warfare system used on existing carriers cannot operate effectively with the dual band radar. The electronic warfare system being developed for the DDG 1000 can operate with the dual band radar, but is designed only to meet the destroyer's surveillance requirements—not CVN 78's electronic attack requirements. The Navy is currently drafting a plan to develop an electronic warfare system for CVN 78.

Advanced Arresting Gear

The Navy plans to install the advanced arresting gear on not only Ford-class carriers, but anticipates retrofitting the system on current carriers. The advanced arresting gear successfully completed early verification tests that proved the system's concept, and tested a number of components. Integrated testing of simulated aircraft loads is scheduled to begin in 2008, and is expected to demonstrate aircraft arresting capability on a land-based test site. See table 9 for key events in the development of the advanced arresting gear.

Table 9: Schedule of Key Events Relating to Advanced Arresting Gear

2003	2007	2008	2010	2011	2012
Arresting gear contract awarded to begin technology development.	Complete design of hardware and software components.	Complete system testing of simulated aircraft loads.	Complete testing of live aircraft landings.	Arresting gear required in the yard to begin CVN 78 installation.	Arresting gear scheduled for backfit into a Nimitz-class carrier for operational testing.

Source: Navy data.

Similar to the EMALS program, the contractor faced difficulties meeting the Navy's requirements for the system, a fact that contributed to program schedule delays.⁴ The Navy and the contractor disagreed on the necessary format of design drawings to meet the Navy's requirements. The contractor underestimated the number of drawings required at critical design review. The schedule slipped due to late delivery of drawings, and critical design review was delayed by over 5 months. Additionally, changes in the Navy's requirements in shock and vibration led to redesign of a major subsystem.

⁴The same contractor is responsible for developing EMALS and the advanced arresting gear.

While components have been tested, future tests are critical for demonstrating system performance, including software functionality. Unlike the legacy landing system, the advanced arresting gear uses a software control system to regulate the arresting process and prepare the system for incoming aircraft. The contractor recently completed software system design, but the software system has not yet been tested. Upcoming land-based testing is expected to demonstrate the ability of the software control system using simulated aircraft loads as well as live aircraft.

Even if testing is successful, the advanced arresting gear may not meet its delivery date to the shipyard. Schedule delays have slipped the program's production decision and delivery for CVN 78 by 6 months. Timely delivery of the arresting gear is necessary to save shipyard labor hours. Unlike with previous carriers, the shipbuilder plans to install the arresting gear prior to laying the flight deck. If the arresting gear is delivered after installation of the flight deck, the shipbuilder will expend additional labor hours lowering the system into place through a hole cut in the deck and welding the deck back together. The Navy believes that the delivery schedule can be met if the system is delivered to the shipyard in pieces and test events are consolidated. Specifically, the Navy will increase the rate of test cycles during testing to eliminate schedule margin. Compressing test events, however, introduces additional risk because there will be limited time to address any failures that may occur during testing prior to the start of production.

Other Technologies May Disrupt the Ship's Construction Sequence or May Not Be Fully Capable at Ship Delivery

Additional testing is necessary to ensure that other technologies needed early in construction will operate as intended. Technologies responsible for achieving future carrier capabilities such as heavy underway replenishment and JPALS may not be fully available at ship delivery, requiring the installation of additional legacy technologies or increasing expected ship manpower.

Some technologies with early installation dates still require testing to demonstrate a shipboard-ready system. Table 10 highlights two technologies developed by the shipbuilder—the advanced weapons elevator and air-conditioning plant—that have not yet demonstrated a full prototype but are required in the yard early in ship construction.

Table 10: Other Technologies That Affect the Construction Sequence

Advanced weapons elevator	Elevators that use moving magnetic fields and no cabling is a new technology—never previously used in any application. In 2005, the shipbuilder demonstrated the elevator’s functionality through testing of a model representing a quarter of the elevator. A shipboard representative prototype is currently in production, and full-scale testing is scheduled for later this year. The elevators will not be tested at sea until CVN 78 qualification testing, shortly before ship delivery.
1,100-ton air-conditioning plant	Since the components are readily available and used on ships and shore-based applications, the Navy considers this technology a low risk. The shipbuilder will not demonstrate a full prototype until fiscal year 2008—after fabrication of shipboard units is already under way. An air-conditioning plant of this size has never been used on a ship before. If any unexpected problems arise during testing, little time remains for resolution prior to ship installation.

Source: GAO analysis of Navy and shipbuilder data.

Other technologies do not affect construction, but could affect CVN 78’s planned capability at ship delivery. For example, if the shipboard weapons loader is not ready at ship delivery, additional manpower will be needed to install aircraft weapons, and the ship’s sortie generation rates will be affected. Although weapons loaders are not required until 2015, the system is still in early development and requirements continue to be modified. In addition, the ability to achieve enhanced ship capability provided by the heavy underway replenishment system and JPALS depends upon the reciprocal installation on other platforms (see table 11). Without these enhancements, the carrier will only perform at legacy capability.

Table 11: Other Technologies That Affect CVN 78’s Planned Capability

Heavy underway replenishment	The system is a modification of current replenishment technology. The design is complete, and land-based testing of a full-scale shipboard system is scheduled to conclude this year. However, the system’s improved capability will not be achieved unless it is also outfitted on logistics ships that replenish the carrier. Heavy underway replenishment is not installed on logistic ships currently in the fleet, and it is unclear when logistic ships with this capability will be delivered.
JPALS	The program is still in early development, and it is unclear when JPALS will be inserted into the carrier air wing. Until installation, the carrier will use legacy systems to land aircraft. This will require additional design to accommodate the installation of legacy radars on the carrier’s smaller island structure. JPALS is the primary landing system for the Joint Strike Fighter. While a backup landing system will be installed on the Joint Strike Fighter, it will be less capable to land aboard the carrier during inclement weather compared to other aircraft.

Source: GAO analysis of Navy and shipbuilder data.

The Navy Has Made Significant Design Progress, but Sustained Progress Depends on Technology Development

The Navy has completed the basic design of the ship and the shipbuilder is currently developing the detailed design. Given the amount of design work to be performed, it appears that CVN 78's design will be more complete than that of the previous carrier at construction contract award. Progress in designing the ship is due in part to a structured design approach and an extended construction preparation period that enables the shipbuilder to perform more work prior to construction than on previous carriers. With about 67 percent of the ship's design complete, the shipbuilder appears on track to support the construction schedule. However, the program may face challenges in maintaining its design schedule because of delays in the development of the ship's critical technologies. Such delays in technology development could impede completion of design and interfere with construction of CVN 78.

Significant Design Development Is Being Performed Prior to Construction Contract Award

The Navy has already completed the basic design of the ship. In 2004, the Navy completed the Operational Requirements Document, a necessary step in the acquisition process. This document outlines the requirements that the ship must possess to perform its mission. The Navy also certified the ship's specifications, a key event in the design process that defines the technical requirements that the ship must fulfill. After certification, the ship is under configuration control and any changes must be approved by Navy management. The basic design of the ship was approved through general arrangement and block/system diagram drawings, which describe the use of space and location of systems within the ship, including the location of compartments, ductwork and cabling, and the height of decks. The shipbuilder is currently designing more detailed phases of the ship and generating the drawings needed for construction.

A structured design approach enables the shipbuilder to more efficiently and effectively design CVN 78. For the first time, the shipbuilder is using a computer-aided design product model to generate the design of an entire carrier.⁵ The product model generates a detailed design, allowing engineers to visualize spaces. The design is also fed into a simulated three-dimensional environment that allows engineers to test the design by conducting a virtual "walk-through." This validates elements of design prior to construction, thereby avoiding potentially costly rework.

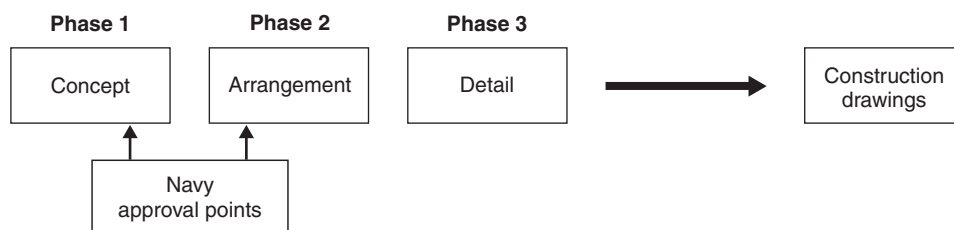
⁵This approach has been used to design previous ships and select sections of CVN 77.

Each of the ship's design zones go through the three phases of the product model: concept, arrangement, and detail (see fig. 3). The phases build on each other, progressively adding more detail to the design. The final phase enables the shipbuilder to order all necessary material.

- **Concept phase** defines the primary structures of the design zone, including structures, gratings, ladders, and passageways.
- **Arrangement phase** adds the form, fit, and function of components, including piping and cables. Data are gathered during this phase to generate material estimates and the schedule for ordering long-lead materials.
- **Detail phase** provides all design zone attributes, including part numbers, vents, drains, and other detailed information.

After completion of the detail phase, construction drawings are developed. Once construction drawings are released, work on building the ship can begin.

Figure 3: Product Model Design Process



Source: Navy.

The product model gives greater visibility into the progress of design, allowing tracking of design zones through each stage of design. The Navy has approval points in each phase of design, including critical design reviews at the end of the arrangement phase and a review of significant design changes made in the detail phase. In addition, the shipbuilder tracks the progress of design zones measured against an established design schedule. The shipbuilder can use the product model to assess the impact that a delay in one phase of design will have on other design zones or on the construction schedule.

Using this approach, the shipbuilder has completed approximately 67 percent of the ship's design, including almost all of the propulsion plant (see fig. 4 and table 12). Despite weight increases in some key technologies, design is within threshold requirements for weight, stability,

and sortie generation rates. According to the shipbuilder, the product model creates design efficiencies, but without the 1-year slip in schedule, it would have been more difficult for the design to keep pace with the construction schedule.

Figure 4: Ship Design Status as of April 2007

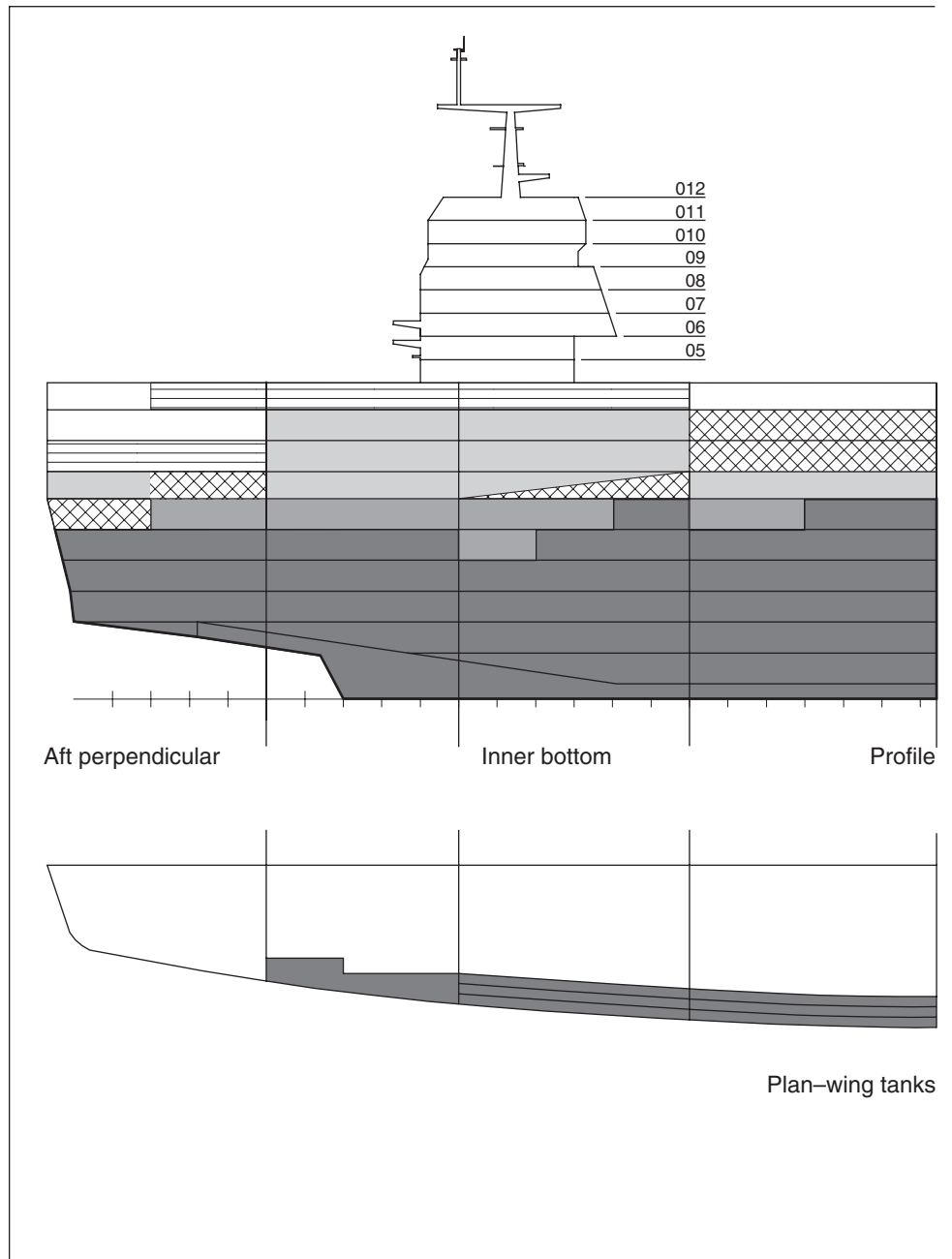


Table 12: Design Progress by Location on Ship

Data as of April 2007

Location	Percent complete in design product model design phase		
	Concept	Arrangement	Detail
Whole ship	84%	70%	55%
Below third deck	100	99	98
Third deck to main deck	100	99	62
Main deck and above	59	19	1
Miscellaneous trunk and elevators	83	67	11

Source: Northrop Grumman Newport News.

Progress in developing the ship's design is also due to a lengthier preparation period than was the case on previous carriers. Under the contract for construction preparation, the shipbuilder is not only designing the ship but procuring long-lead materials and fabricating parts of the ship. The Navy has had more time to prepare for CVN 78 construction than previous carriers. The shipbuilder will have 44 months to prepare, compared to just 28 months for CVN 77, an increase of 16 months, or 57 percent.⁶

The extended length of the preparation period and the improved design process are allowing the shipbuilder to perform more work on CVN 78 prior to the award of the construction contract than has been performed on previous carriers. The shipbuilder estimates that 75 percent of ship design will be completed prior to construction contract award in January 2008. In comparison, design of CVN 77 was largely incomplete at construction award, even though much of the design was rolled over from the previous ship. With more design complete, the shipbuilder is better able to estimate its material needs. By contract award, the shipbuilder expects to have contracted for or quotes received on approximately 70 percent of total material costs, compared to about 55 percent for CVN 77. Design progress also facilitates construction work. The shipbuilder is fabricating more of the ship prior to construction award than on previous carriers. Approximately 13 percent of construction units for CVN 78 are expected to be complete prior to contract award, compared to just 3 percent of units for CVN 77.

⁶This is partially a result of the 1-year delay in CVN 78's construction schedule.

Delays in Developing Critical Technologies Could Impede Design Progress

Despite design progress to date, the shipbuilder may not be able to complete design on schedule if it does not receive technical information required to complete design or if ship technologies are not delivered as planned.

The Navy is required to deliver technical information to the shipbuilder, including power needs, weight requirements, and critical interfaces of various technology-dependent systems. Without this information, the shipbuilder cannot complete the design of the ship. Up until now the shipbuilder has established the general parameters of the technologies and has not needed the technical information. The shipbuilder is now beginning more detailed phases of design that require finalized technical information in order to complete design. The Navy is already experiencing delays in transmitting information to the shipbuilder, including delays in delivering data on 110 items for the advanced arresting gear, 11 for the dual band radar, and 76 for EMALS. According to the shipbuilder, these delays have not significantly affected the schedule. However, the availability of some of the technical information is dependent upon the Navy completing design and testing of key technologies. Because the development schedule for some technologies has slipped, the date that the Navy can deliver technical information to the shipbuilder may also slip. Further delays in completing testing and stabilizing design for critical systems such as EMALS and the dual band radar could in turn delay when the Navy can deliver technical information about these systems to the shipyard, thus affecting the design schedule. Moreover, the Navy has not yet defined the electronic warfare system. As a result, the system's interfaces with the ship—like power, cooling water, and air-conditioning—are not yet known, affecting the shipbuilder's ability to complete detailed design phases.

Some of CVN 78's technologies have not completed testing. Problems discovered during testing may lead to redesign, which could result in changes to other sections of the ship. For example, weight increases for EMALS and the advanced arresting gear affected the ship's weight and stability margin, leading the shipbuilder to compensate for weight elsewhere on the ship. While the ship is currently within threshold, redesign of ship systems could affect other sections of the ship that have already completed design. Moreover, the physical characteristics of the electronic warfare system are not yet known because the system remains undefined. According to the Navy's commander for operational test and evaluation, the weight and stability effects on the ship will remain uncertain until the system is determined.

Costs for CVN 78 Will Likely Exceed Budget

Costs for CVN 78 are likely to exceed the Navy's budget because the cost estimate that underpins the budget is optimistic, and more specifically, the target cost for construction of the ship may not be achievable. The budget includes a target cost for ship construction, as well as costs for government-furnished equipment and other expenses. While the Navy and the shipbuilder are working to reduce costs through the use of incentive fees, capital improvements, and other initiatives, costs will likely exceed the budget if

- key technology-dependent systems are delivered late;
- labor efficiencies are not realized;
- materials are delayed, resulting in labor-intensive work-arounds; or
- material costs exceed estimates.

The Navy does not have an effective cost surveillance program in place to recognize and mitigate risks that could increase costs. Currently, the Navy is not able to measure shipbuilder performance because contractor performance reports are not informative. Because the Navy is not gaining insight into current performance, it is not benefiting from knowledge that could give insight into future costs under the construction contract.

The Navy's Cost Estimate May Be Optimistic

The Navy's cost estimate used to develop the budget for CVN 78 is optimistic, in part because it underestimates the cost of government-furnished equipment. Government-furnished equipment covers the costs for technologies and equipment items—such as ship weapon systems, electronics, and propulsion—purchased by the Navy and provided to the shipbuilder for installation on the carrier.⁷ Government-furnished equipment costs may increase because a number of critical technologies are still in development and their production costs are not as fully understood as those of systems that are currently fielded. For example, EMALS has experienced schedule slips during development, which could affect production costs. Navy cost analysts told us that they expect to increase EMALS costs in their updated cost estimate for CVN 78. Government-furnished equipment costs will also increase because costs associated with an additional aircraft landing radar are not included in the

⁷The costs are only to procure the equipment; development costs for the majority of the systems—with the exception of EMALS and the propulsion system—are captured under separately funded acquisition programs. While the costs for the equipment are the responsibility of the Navy, installation and integration costs are the responsibility of the shipbuilder.

current budget estimate. The radar, however, is necessary to land aircraft that are not equipped with the JPALS interface. The Navy intends to request additional funding for the radar in future budget years.

The Navy estimates that fewer labor hours will be needed to construct CVN 78 than for the previous two carriers—CVN 76 and CVN 77. The Navy developed its initial labor hour estimate by adjusting the average labor hours needed to construct previous carriers. This average, however, includes ships that were bought as part of two-ship procurements, which tend to be more cost-efficient due to economies of scale (see table 13). By contrast, independent cost analysts within DOD based their estimate on the construction experience of CVN 76, the last carrier delivered. CVN 76, like CVN 78, included unique changes to the design of the ship and required more labor hours to construct than previous carriers. Lead ships, like CVN 78, typically require more labor hours to construct than follow-on ships in the class. The Navy adjusted its estimate by 10 percent—the increase experienced for the lead ship of the Nimitz class. DOD cost analysts, however, estimated a higher percentage recognizing CVN 78's greater technological leap than the lead Nimitz-class carrier.⁸ The Navy believes that costs associated with the lead ship will be offset by design changes that make the ship easier to construct. Officials stated that efficiencies from investments in facilities, use of the product model, and design improvements should generate savings of some 2 million labor hours. However, our past work has found that labor hour savings based on efficiencies often did not materialize as expected.⁹ Savings expected through the use of a computer-assisted design process on CVN 77 were not achieved. DOD's independent cost analysts did not estimate efficiency savings for CVN 78 because their effects have not yet been demonstrated.

⁸ The final estimate approved by DOD leadership at Milestone B increased the labor hour estimate based on differences between DOD's independent cost estimate and the Navy's cost estimate. Even with this adjustment, estimated labor hours are still below the previous two carriers of the Nimitz class.

⁹ See GAO, *Defense Acquisitions: Improved Management Practices Could Help Minimize Cost Growth In Navy Shipbuilding Programs*, GAO-05-183 (Washington, D.C.: Feb. 28, 2005).

Table 13: Construction Labor Hour Change

Labor hours in millions

Hull	Total hours	Labor hour change	Type of ship buy	Contract award date
CVN 70	36.5	0	Single	April 1974
CVN 71	44.4	7.9	Single	September 1980
CVN 72	42.5	-1.9	Two	December 1982
CVN 73	38.4	-4.1	Two	December 1982
CVN 74	36.9	-1.5	Two	July 1988
CVN 75	36.5	-0.4	Two	July 1988
CVN 76	45.0	8.5	Single	December 1994
CVN 77	43.1	-1.9	Single	January 2001
CVN 78	Est. 42.7	-0.4	Single	Estimated January 2008

Source: GAO analysis of Navy data.

Note: Figures for CVN 78 do not include 25.9 million in nonrecurring labor hours and CVN 77 labor hours are based on Navy estimates at completion.

By optimistically estimating the costs to construct CVN 78, the Navy risks cost increases after construction has been funded and is well under way. Recent first-in-class ships have experienced particularly high cost growth—on average 27 percent¹⁰—partly because the total effort needed to build new designs and incorporate new technologies is not yet understood. One way to reduce the probability of unbudgeted cost growth is to present a confidence level for a cost estimate based on risk and uncertainty analyses. By conducting uncertainty analyses that measure the probability of cost growth, the Navy can identify a level of confidence for its estimates and determine whether program costs are realistically achievable. In an effort to better ensure realism in DOD budgets, a panel on acquisition reform established by the Deputy Secretary of Defense recommended that programs be budgeted to an 80 percent confidence level, meaning that a program has an 80 percent chance of achieving its estimated costs.¹¹ Navy cost analysts told us that they performed quantitative risk analyses and calculated a confidence level to test the validity of their cost estimate. However, the analyses for CVN 78 were well below an 80 percent confidence level. While there is room to debate what is the right level to

¹⁰We examined the average growth in construction budgets for all first-in-class ships built between 1996 and 2006.

¹¹Defense Acquisition Performance Assessment Panel, *Defense Acquisition Performance Assessment Report* (Washington, D.C.: January 2006).

use as a standard, the difference between an 80 percent confidence level and the one established for CVN 78 adds to the likelihood that costs will grow above budget.

Target Cost for Ship Construction May Not Be Achievable

The Navy established a target cost for construction based on the fiscal year 2008 budget request.¹² The Navy and shipbuilder are working to implement strategies that will reduce construction costs and minimize the risk of cost growth. However, despite the progress made to date, the shipbuilder may not be able to build the ship within its target cost.

In recent years, the Navy has had difficulty delivering ships within its initial target. Establishing a realistic cost target is especially difficult for first-in-class ships because uncertainty about costs is high. The Navy is taking action to encourage the shipbuilder to meet its target cost by initiating cost reduction efforts prior to negotiating the construction contract. For example, the Navy is taking the following steps:

- designing the ship to threshold capability requirements, rather than to objective requirements that are more costly to achieve;
- establishing incentive fees for capital improvements that will improve the efficiency of the shipyard; and
- awarding incentive fees in the current contract if the shipbuilder can progressively demonstrate reductions in its cost estimate for ship construction.

Initially, the shipbuilder's estimate was 22 percent higher than the Navy's cost target. The shipbuilder is identifying capabilities that can be removed from the ship while still meeting threshold requirements, such as eliminating one of the waste disposal systems from the ship. A dynamic armor protection system that was recently removed from CVN 78's design was a technology that the shipbuilder had suggested removing in order to save costs. The shipbuilder has also invested in a number of efforts that it believes will increase efficiency at the shipyard and lead to lower costs, including the following:

- upgrading the lift capacity of its crane,
- building a covered modular assembly facility that will allow larger sections of the ship to be assembled indoors, and

¹²The target cost for construction is based on the fiscal year 2008 budget request for basic construction and escalation, minus the cost of fees and facilities.

-
- cutting holes in steel plates early—during fabrication—which is expected to reduce labor hours associated with welding and pulling cable once construction of the ship begins in the dock.

While such initiatives have helped close the gap between the shipbuilder's estimate and the Navy's cost target by over 90 percent, the shipbuilder does not believe that the target is achievable without further capability trade-offs. The Navy believes it can further mitigate the risk of cost growth to the government by inserting a share line into the construction contract. However, even if the shipbuilder succeeds in reducing its cost estimate, experience indicates that the program is still at risk of exceeding the budget for construction. The shipbuilder's initial cost estimates for both CVN 76 and CVN 77 were higher than the Navy's target costs. During negotiations, the shipbuilder lowered its estimate to meet the cost target, and a share line was included in the contract to incentivize the shipbuilder to contain costs. Yet in both cases, costs grew not only above the negotiated contract price, but above the original estimate of the shipbuilder as well.

Higher costs for labor and material could also increase the likelihood that actual construction costs will exceed the target cost. Costs for the previous two carriers, CVN 76 and CVN 77, grew because more labor hours and material were needed to construct the ship than originally estimated. Additional labor hours will be needed for CVN 78 if labor hour savings do not materialize as expected. The shipbuilder estimates hundreds of thousands of labor hour savings based on new but untested initiatives. For example, the shipbuilder believes that the product model will generate efficiencies in pipe production that will result in savings of 400,000 shipboard labor hours. The shipbuilder also anticipates labor hour savings as a result of facilities enhancements and design improvements. However, the shipbuilder recognizes that it is difficult to accurately estimate the total labor hours that will be saved as a result of the new initiatives. Further, our past work on cost growth in shipbuilding programs has shown that labor hour savings based on untested efficiencies are often initially overestimated.¹³

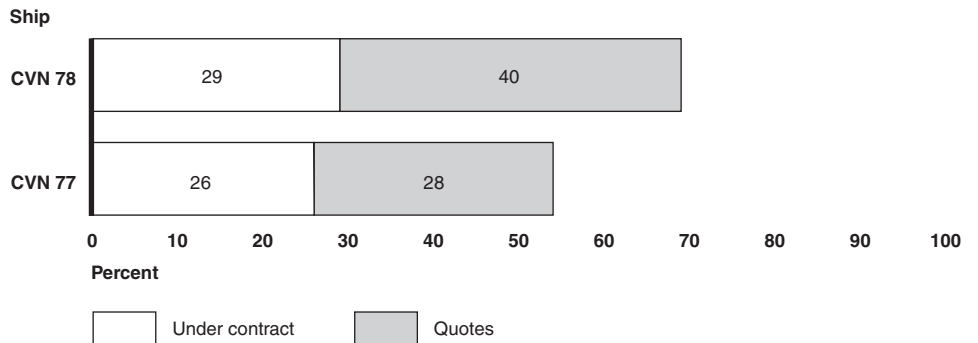
¹³We found that savings that were anticipated through the use of computer-assisted design and manufacturing for the LPD 17 amphibious transport ship were not achieved. Similar efficiencies estimated for the DDG 92 destroyer were also not initially achieved. See [GAO-05-183](#), 20.

Delays in receiving material may also result in additional labor hours. Late material delivery led to labor hour increases on both the CVN 76 and CVN 77. In both instances, when material did not arrive on time, the shipbuilder had to work around the missing items in order to maintain schedule—resulting in a less efficient construction sequence. The CVN 78 program is already beginning to experience slips in the delivery of material. According to the shipbuilder, while none of the delays to date are expected to disrupt the construction schedule, any further changes to the delivery of a number of EMALS and propulsion components will result in increased labor hours and costly work-arounds.

The CVN 78 program could reduce costs by improving labor practices at the shipyard. The Defense Contract Audit Agency (DCAA) measures the effectiveness of the shipbuilder's labor practices by analyzing the rate at which workers perform work versus non-work-related activity. More time spent on work-related activities will generate cost savings. DCAA has found that people assigned to new carrier construction work at a lower rate than suggested by DCAA and below the average of other shipyards constructing Navy ships. Improving the amount of time spent on work-related activity could decrease the number of hours required to build CVN 78 and result in savings of tens of millions of dollars.

Actual material costs for CVN 78 may exceed estimates and grow above target. Material costs have been significant drivers of cost growth on past carriers. For CVN 76 and CVN 77, cost growth was due partly to the shipbuilder basing its estimate on an incomplete bill of materials needed to construct the ship and a 15 percent increase in material prices. According to the shipbuilder, material requirements for previous carriers were developed by using the bill of materials from prior ships before the extent of design changes was well understood. The shipbuilder expects a more accurate material estimate for CVN 78, in part because a significant percentage of design will be completed prior to construction award. Further, the costs for materials are better understood because the shipbuilder is contracting for more material and receiving more actual quotes from suppliers prior to contract award than on previous carriers (see fig. 5). Quotes from vendors can help provide a greater degree of realism in material cost estimates.

Figure 5: Knowledge of Carrier Material Costs Prior to Construction Contract Award



Source: GAO analysis of Northrop Grumman Newport News data.

Despite the shipbuilder’s efforts to improve material cost estimates, the program is still at risk of cost growth. Over 70 percent of estimated material costs will not be under contract when the Navy awards the construction contract, leaving material costs vulnerable to market fluctuations.

On the other hand, the shipbuilder’s system for managing and accounting for materials may inflate material costs.¹⁴ DCAA has found inadequacies in the shipbuilder’s system and identified eight deficiencies that could lead to increases in material costs. For example, DCAA has reported that the shipbuilder purchases material prematurely—before it is needed in construction—costing the government millions of dollars in annual inventory carrying costs. DCAA has also found that inappropriate transfers of material between different programs could increase material cost to the government. As a result of its findings, DCAA recommended withholding 10 percent of the shipbuilder’s billed material costs. If the shipbuilder improves its material management system, costs to the government may be reduced.

Instability of the workload at the shipyard may also lead to increased overhead costs and labor rates. Our past work, however, has shown that increases in overhead and labor rates are not major drivers of cost growth.¹⁵ Nevertheless, increases in overhead and labor rates often result

¹⁴The material management and accounting system is used to manage the purchase, use, and disposal of materials used to build the ship.

¹⁵We found that almost 50 percent of the cost increase in overhead dollars was related to a growth in labor hours. See [GAO-05-183](#), 16.

from changes in the workload at shipyards. For example, the CVN 77 program had to absorb a greater percentage of the shipyard's overhead costs because of delays in the CVN 78 program and changes in the carrier overhaul schedule. Labor rates increased on CVN 76 when workers were diverted to carrier overhauls. In order to maintain schedule, the shipyard made significant use of overtime, which is more expensive than normal hourly wages. The overhead and labor rates for CVN 78 could similarly be affected if changes are made to the schedule for overhauling current carriers or to construction of the Virginia-class submarine, which is also being built at the shipyard. Shipbuilders have reported that the procurement schedule or acquisition strategy for the Virginia-class submarine has changed 12 times in 10 years.

Insufficient Cost Surveillance Hinders the Navy's Ability to Manage Cost Growth

The Navy's approach to designing a substantial portion of the ship prior to the award of the construction contract award allows the Navy to gain insights that could be used to better inform the construction contract. The Navy, however, is not fully leveraging this knowledge because it lacks an effective surveillance capability that can capture and analyze current shipbuilder performance. Future government oversight may also be impeded if the Navy does not initiate adequate cost surveillance at the shipyard. Given the risk of cost growth, it is important that the Navy receive timely and informative cost performance reports that describe the shipbuilder's progress. Without such activity, the Navy is at risk of not identifying problems and taking corrective action promptly, allowing costs to grow.

The Navy may not be effectively managing the shipbuilder's current cost performance because earned value management data are not informative. Earned value management is a tool that provides the government and contractors with insight into technical, cost, and schedule progress on their contracts. Although the Navy has not yet contracted for construction, the shipbuilder is currently performing work that is equal to 30 percent of the total cost of the ship. The Navy, however, is not receiving objective data on the shipbuilder's cost and schedule performance, because the construction preparation contract is a cost-reimbursement contract that specifies a level of effort for a stated period of time—an approach typically reserved for work that does not produce end products, such as program management support. Since work under the contract is not divided into tasks that produce end results, there is no schedule against which progress can be measured. As a result, contractor cost performance reports do not show schedule variances, and cost variances are likely to be misleading because progress is not actually measured.

Navy officials recognize that contractor cost performance reports are not informative and told us that they evaluate the shipbuilder's performance using technical instructions, which direct the shipbuilder to accomplish certain work and include a period of performance and funding. Technical instructions, however, are not a sufficient tool for managing shipbuilder performance because they do not measure the value of work accomplished—that is, whether the shipbuilder is accomplishing tasks according to a planned budget and schedule. For example, one instruction, authorizing the shipbuilder to continue platform design efforts, has a period of performance of 1 year and funding of over \$200 million. However, the instruction does not include a detailed plan against which to measure performance, stating instead that all design products should be delivered according to the shipbuilder's integrated master schedule. In earned value management, progress can be readily measured because contracts are usually divided into smaller, more manageable tasks that are short in duration (e.g., between 4 and 6 weeks long), with specific start and finish dates and individual budgets. Progress on accomplishing technical instructions cannot be fully understood until over a year later—eliminating the Navy's ability to take early corrective action should problems arise. Moreover, the Navy cannot readily assess the shipbuilder's performance because the technical instructions do not have stable schedule benchmarks. The integrated master schedule changes periodically—creating a fluctuating program baseline. Recognizing a lack of insight into contractor performance, the Navy recently instituted monthly briefings designed to improve contractor oversight.

The Navy is missing an important opportunity to gain knowledge regarding shipbuilder performance prior to awarding the construction contract. Although ship construction is already under way—13 percent of the base units are expected to be finished prior to contract award—SUPSHIP is only minimally engaged in evaluating shipbuilder performance. SUPSHIP provides the Navy with unique insight into program performance because it is located at the shipyard, providing on-site contract administration and technical and business management. SUPSHIP is responsible for assessing contractor cost and schedule performance through a combination of on-site program surveillance and independent cost and schedule performance analyses. According to Navy officials, SUPSHIP traditionally assumes its responsibility when construction starts and will provide contract oversight after the award of the construction contract.

Future cost surveillance efforts, however, may not provide adequate oversight of shipyard costs. According to SUPSHIP's operating manual, a formal cost surveillance strategy is desirable because it ensures that

surveillance is effectively performed. However, neither the program office nor SUPSHIP has plans to develop a formal strategy for cost surveillance. In fact, SUPSHIP does not currently have the capability to conduct independent cost surveillance. According to officials, SUPSHIP is currently planning to develop this capability. Until then, the Navy will not have sufficient on-site representatives to analyze contractor cost data and verify that the data depict actual conditions and trends. Further, Navy officials have stated that they may not require variance analyses in the monthly contractor cost performance reports, only requiring reporting of variance analyses on a quarterly basis.¹⁶ Variance analyses describe the reasons for cost and schedule variances shown in the cost performance report and are important because they serve as an official, written record of the problems or actions taken by the shipbuilder to address them.¹⁷ Without monthly variance analyses, the Navy will miss timely information regarding root causes for cost and schedule problems and mitigation efforts—making it more difficult for managers to identify risk and take corrective action.

Conclusions

The Navy's ability to successfully execute its shipbuilding plan depends on improvements in the cost performance of individual programs. Since CVN 78 is the Navy's most expensive lead ship, its cost performance is essential to the plan—even a small percentage of cost growth corresponds to hundreds of millions of dollars. If CVN 78 follows historical cost growth patterns for lead ships, the Navy may be forced to sacrifice other aspects of its plan. The recognition of ship cost growth lags the initial budget requests for construction, such that cost growth is recognized and funded in later years at the expense of other ships vying for funding at that time. While construction of CVN 78 will be budgeted in fiscal years 2008 and 2009, the bulk of construction—and the recognition of actual cost—will occur in fiscal years 2010-2015. Thus, the steps the Navy takes between now and the fiscal year 2009 budget request to understand and plan for the likely costs of the ship will determine whether and how much cost growth will occur and require funding in those future years.

The Navy has made strides in reducing risk in the program. Construction risk has been minimized for key systems like the nuclear propulsion and

¹⁶In responding to a draft of this report, DOD stated that the Navy will require the shipbuilder to submit monthly cost performance reports.

¹⁷Variance analyses are provided in format 5 of the cost performance report.

electric system, and much of the ship's design has been completed. Yet substantial risk remains, which the budget may not accommodate. The budget is optimistic, with a target cost for construction that the Navy will in all likelihood exceed. Both the budget and schedule need to accommodate carrier-specific testing of the dual band radar. Delays in the development of key systems, most notably EMALS and the dual band radar, will likely have a cost impact on CVN 78 construction and—in the worst case—schedule. To avoid the cost growth experienced by other lead ships, coupled with the high opportunity cost of displacing other ships to pay for cost increases, the Navy is in the best position now to make decisions on establishing a realistic cost estimate and a corresponding budget for CVN 78 and to put into place the tools needed to monitor actual cost performance and react quickly to potential variances from estimates.

Recommendations for Executive Action

To provide more realism in the budget and minimize the likelihood of CVN 78 cost growth, we recommend that the Secretary of Defense:

- include in the fiscal year 2009 budget request a revised cost estimate that is based on updated Navy and independent DOD cost estimates and the actual progress in the program and
- provide Congress, along with the budget request:
 - a stated confidence level for the cost estimate;
 - results of tests of key systems and technologies;
 - schedule changes to test, production, or delivery dates for key systems; and
 - the impact of changes and test results of key systems on shipyard costs due to changes in work sequencing and workload management.

To improve shipyard management and promote early recognition of cost issues, we recommend that the Secretary of Defense

- develop an independent cost surveillance capability at the cognizant SUPSHIP and ensure that cost surveillance activities begin as soon as actual construction starts,
- require monthly cost performance reports that include contractor variance analyses, and
- require that earned value management captured in cost performance reports for construction and construction preparation contracts be made up of discrete measurable tasks so that true cost and schedule variances can be identified.

We also recommend that the Secretary of Defense identify and schedule carrier-specific tests to ensure that the dual band radar meets carrier-specific requirements.

Matters for Congressional Consideration

On the basis of DOD's response to our report, the department does not plan to update the independent cost estimate in support of the 2009 budget request or provide Congress a stated confidence level for the cost estimate along with the budget request. As a result, Congress will be asked to approve the fiscal year 2009 funding request for ship construction without the ship's most likely costs and without understanding DOD's confidence in its cost estimate. Accordingly, Congress should consider directing the Secretary of Defense to provide Congress, concurrent with the fiscal year 2009 budget request:

- certification that CVN 78 is budgeted at the most likely costs for the ship and
- a stated confidence level for the cost estimate.

Agency Comments and Our Evaluation

In written comments on a draft of this report, DOD agreed with our recommendation to identify and schedule carrier-specific testing of the dual band radar. DOD also concurred with our recommendations aimed at developing an independent cost surveillance capability at the cognizant SUPSHIP and strengthening earned value management analysis. DOD noted that the Navy has recently increased the number of people at SUPSHIP and expects further increases in fiscal year 2008. Some of the manning increases will be available for cost surveillance activities. In addition, DOD stated that SUPSHIP is currently increasing its oversight of the construction preparation contract for CVN 78 in advance of the construction contract award, including routine reviews of contractor earned value data.

DOD stated that it will require monthly cost performance reports that include variance analyses. The CVN 78 program office's initial decision to require quarterly cost performance reports would not have provided frequent formal reporting and review of contractor cost data necessary to manage a program of this size. DOD also agreed that data captured in cost performance reports should be composed of discrete measurable tasks and stated that the Navy plans to conduct a review of the program management baseline shortly after construction contract award to ensure that the shipbuilder has properly planned, scheduled, and resourced work. DOD noted that a similar review would also be conducted for the

construction preparation contract of the first follow-on carrier—CVN 79, but it is not clear if the baseline for this program will be made up of discrete measurable tasks. If this contract also specifies a level-of-effort approach, similar to the CVN 78 contract structure, the Navy may again have difficulty accurately assessing the shipbuilder's cost and schedule performance. Our recommendation was intended to apply to all construction and construction preparation contracts—and not just the contract for CVN 78. We have revised our recommendation to reflect this distinction.

In a draft of this report we recommended that DOD include in its fiscal year 2009 budget request a revised cost estimate that is based on updated Navy and independent DOD cost estimates and provide Congress with a confidence level for CVN 78 along with its budget request. DOD stated that the Navy revised its cost estimate for CVN 78 in support of the upcoming Defense Acquisition Board program review. DOD believes that this estimate validates the program budget for fiscal year 2008 and plans to update CVN 78's budget request for fiscal year 2009 to reflect the program's funding needs. Moreover, DOD did not agree to an updated estimate by the Cost Analysis Improvement Group—DOD's independent cost analysts. Nonetheless, the differences between the cost group's prior estimate and the Navy's current estimate remain. Consequently, the ship's budget levels for construction are likely to be insufficient.

DOD stated further that it does not routinely use confidence levels in developing cost estimates because the assumptions used to calculate confidence levels often lead to incorrect or misleading results. DOD also expressed concern about the use of high confidence levels in determining program budgets. We agree that confidence levels can be too low or too high, but the use of confidence levels is recognized as a best practice in cost estimating because it validates an estimate's realism. Moreover, DOD has previously agreed with our recommendation that the Navy develop confidence levels for all ship cost estimates and noted that the Navy trained its cost analysts in the use of risk and uncertainty analysis. In fact, Navy cost analysts established a confidence level for the CVN 78 cost estimate—the estimate that was used to determine the budget request. While DOD may believe this confidence level for CVN 78 is sufficient, it seems appropriate that Congress have the same information available as it decides what funds to provide for CVN 78's budget. In the absence of an updated independent cost estimate and the reservations expressed by DOD over confidence levels, we have included as matters for congressional consideration that the Secretary of Defense provide Congress, concurrent with the fiscal year 2009 budget request, a

certification that CVN 78 is budgeted at the most likely costs for the ship and a stated confidence level for the cost estimate.

We also recommended that DOD provide Congress with the results of tests of key systems and technologies; changes to test, production, or delivery schedules; and the impact of such changes to construction costs. DOD agreed, stating that such updates are provided in the annual Selected Acquisition Report (SAR). However, the SAR does not adequately address our recommendation because it provides only a high-level view of the program and does not provide the level of detail that is necessary to identify changes in schedule and understand the risk of cost growth. As we state in the report, technologies like EMALS are behind schedule and could affect the ship's construction schedule. However, neither the 2005 nor the 2006 SAR reports this fact—or even discusses EMALS at all. Consequently, the SAR alone does not provide Congress with sufficient information upon which to gauge the realism of the budget request and this does not fully address our recommendation.

DOD's written comments are included in their entirety in appendix II. The department also provided technical comments, which were incorporated into the report as appropriate.

As agreed with your office, unless you announce its contents, we will not distribute this report further until 30 days from its date. At that time, we will send copies to the Secretary of Defense, the Secretary of the Navy, and interested congressional committees. We will also make copies available to others on request. In addition, the report will be available at no charge on the GAO Web site at <http://www.gao.gov>.

Please contact me on (202) 512-4841 if you or your staff have any questions concerning this report. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made contributions to this report are listed in appendix III.



Paul L. Francis
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To assess the Navy's ability to meet its goals for CVN 78, we examined the Navy's progress in developing its critical technologies, stabilizing the ship's design, and estimating the cost of the ship. To examine the extent to which technology development could affect the construction and capability of CVN 78, we analyzed all the technologies that the Navy defined as critical technologies at the time we began our review. We developed a matrix based on the degree to which the optimum construction sequence and planned capability of the ship could be affected if technologies did not deliver as planned. To determine the impact on construction, we analyzed the in-yard and erect dates and examined the location, number of design zones, and interfaces for each technology. To determine the impact on ship capability, we analyzed ship requirements by reviewing the Operational Requirements Document, examining the development of sortie generation rates, and assessing the program's schedule for technology off-ramp decisions. We categorized each technology based on the results above and examined their degree of risk by analyzing key program documents. We analyzed, among other documents, CVN 21 Milestone B Risk Assessment Report, Critical Technology Integrated Product Team briefings, CVN 78 Program and Design Review briefings, technology test reports, critical design review checkout lists, risk matrices, Defense Contract Management Agency (DCMA) reports, and contractor cost performance reports for key technologies. To supplement our analysis, we visited contractors and test sites where the ship's major technologies are being developed and tested.

To evaluate the Navy's progress in achieving design stability, we reviewed the ship's design requirements and analyzed metrics captured in the integrated master schedule, including schedule delinquencies, key dates, receipt of government-furnished information, and progress in construction activity and material acquisition. We compared CVN 78's design process with GAO's knowledge-based acquisition methodology and past work on shipbuilding programs. We analyzed and compared CVN 78 design metrics with the experience of previous carriers, particularly CVN 77 and CVN 76. In conducting our analysis, we examined key documents, including Quarterly Ship Progress Reviews.

We assessed the challenges to building CVN 78 within budget by examining the Navy's budget request and cost estimates as well as recent shipyard cost performance. We analyzed the Navy's cost estimates by examining the Program Life Cycle Cost Estimate for CVN 78 and updates since the Milestone B decision in 2004. We compared the Navy's estimate with estimates from Department of Defense (DOD) independent cost analysts and our past work on shipbuilding cost growth. We evaluated the

ship's cost target by reviewing Defense Contract Audit Agency (DCAA) reports and examining the shipbuilder's cost-savings initiatives and cost performance on previous carriers. We assessed the Navy's practices for cost surveillance by analyzing the construction preparation contract, contractor cost performance reports, technical instructions, and Supervisor of Shipbuilding, Conversion and Repair's (SUPSHIP) Operating Manual. In addition, we reviewed, among other documents, Cost Analysis Requirements Description, business clearance memorandums, DOD's Earned Value Implementation Guide, and Naval Sea Systems Command's (NAVSEA) Cost Estimating Guide.

In conducting our analysis, we held discussions and attended briefings with the shipbuilder and officials from NAVSEA, including the CVN 21 Program Office; Naval Nuclear Propulsion Directorate; DDG 1000 Program Office; Program Executive Office, Integrated Warfare Systems; Cost Engineering and Industrial Analysis Division; Ship Design Integration and Engineering Division, Contracts Division; Naval Surface Warfare Center, Carderock; SUPSHIP, Newport News; as well Naval Air Systems Command, including the program offices for Aviation Support Equipment, Air Traffic Control and Combat Identification, and Aircraft Launch and Recovery. In addition, we interviewed officials from the Navy's Commander of Operational Test and Evaluation Force and DOD's Cost Analysis Improvement Group; DCAA in Newport News, Virginia; and DCMA in San Diego, California, Moorestown, New Jersey, and Tewksbury, Massachusetts.

We conducted our review from July 2006 through June 2007 in accordance with generally accepted government auditing standards.

Appendix II: Comments from the Department of Defense

Note: Page numbers in the draft report may differ from those in this report



ACQUISITION,
TECHNOLOGY
AND LOGISTICS

OFFICE OF THE UNDER SECRETARY OF DEFENSE
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AUG 03 2007

Mr. Paul L. Francis
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Mr. Francis:

This is the Department of Defense (DoD) response to the GAO Draft Report 07-866, "DEFENSE ACQUISITIONS: Navy Faces Challenges in Constructing USS Gerald R. Ford Aircraft Carrier within Budget," dated July 3, 2007, GAO Code 120576. The Department's comments on the recommendations are attached. I submitted separately a list of technical and factual errors for your consideration.

The Department partially concurs with recommendations 1 and 2, which relate to updating the current cost estimate and reporting the confidence level for the cost estimates, reporting the results of tests of key systems and technologies, and any associated impacts to the program, respectively.

The Department concurs with the other 4 recommendations, which relate to cost surveillance, monthly cost reporting, earned value management, and testing of the dual band radar system.

The Department appreciates the opportunity to comment on the draft report. Technical comments were provided separately. For further questions concerning this report, please contact Ms. Darlene Costello, Deputy Director, Naval Warfare, 703-697-2205.

Sincerely,

David G. Ahern
Director
Portfolio Systems Acquisition

Enclosure:
As stated



**GAO DRAFT REPORT DATED JULY 3, 2007
GAO-07-866 (GAO CODE 120576)**

**“DEFENSE ACQUISITIONS: NAVY FACES CHALLENGES IN
CONSTRUCTING USS GERALD R. FORD AIRCRAFT
CARRIER WITHIN BUDGET”**

**DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS**

RECOMMENDATION 1: The GAO recommends that the Secretary of Defense include in the fiscal year 2009 budget request a revised cost estimate that is based on updated Navy and independent DoD cost estimates and the actual progress in the program. (p. 42/GAO Draft Report)

DoD RESPONSE: Partially Concur. At Milestone B in April 2004, independent cost estimates were completed by both the Navy and the OSD Cost Analysis Improvement Group (CAIG). Reconciliation of these two estimates established the full funding level for the program and provided the basis for the program’s budget for award of the lead ship construction contract in fiscal year 2007. The Navy, with OSD concurrence, shifted the lead ship award year from fiscal year 2007 to fiscal year 2008 in the fiscal year 2006 budget request. The CAIG agreed with the changes to the Navy budget to reflect the one year move of the lead ship. In support of the upcoming Defense Acquisition Board (DAB) program review, now planned for fall, the Navy updated its Program Life Cycle Cost Estimate, confirming the program budget for the fiscal year 2008 lead ship award. The Navy update is based on progress of the program to date. While it is certainly feasible to update the CAIG independent cost estimate by the FY 2009 budget submission, there are currently no plans to do so because it is so early in the program that actual costs incurred to date will provide little insight in resolving the key differences in cost estimates since Milestone B, specifically in the areas of labor rates, material costs, and productivity levels. The fiscal year 2009 President’s Budget request will update the Department’s funding needs for the lead ship, CVN 78.

RECOMMENDATION 2: The GAO recommends that the Secretary of Defense provide congress along with the budget request: a stated confidence level for the cost estimate; results of tests of key systems and technologies; schedule changes to tests, production, or delivery dates for key systems; and the impact of changes and test results of key systems on shipyard costs due to changes in work sequencing and workload management. (p. 42/GAO Draft Report)

Attachment
Page 1 of 3

DoD RESPONSE: Partially concur. The Department does not concur with the specific request to include a stated confidence level for the cost estimate. The Department does not routinely calculate the quantitative confidence level associated with acquisition program life-cycle cost estimates for two reasons: 1) the Department frequently does not agree with the mathematical assumptions most often used to directly calculate quantitative estimates of confidence levels associated with acquisition cost estimates, particularly those developed in standard DoD work breakdown structures, making the results of these confidence calculations potentially incorrect and misleading; and 2) if quantitative confidence levels could be calculated correctly, the recent recommendations to budget to very high confidence levels associated with DoD cost estimates would be inefficient from a resource perspective when applied to the entire DoD acquisition portfolio. The Department partially concurs with the remaining recommendations. In its regularly submitted Selected Acquisition Reports, the CVN 21 Program provides updates on any significant impact to ship construction, cost, schedule, and performance which would include the areas recommended by GAO.

RECOMMENDATION 3: The GAO recommends that the Secretary of Defense develop an independent cost surveillance capability at the cognizant SUPSHIP and ensure that cost surveillance activities begin as soon as actual construction starts.
(p. 42/GAO Draft Report)

DoD RESPONSE: Concur. The Supervisor of Shipbuilding, Conversion, and Repair, Newport News (SUPSHIPNN) provides the Program Manager valuable on-site project management, engineering support, quality assurance, contract administration, and logistics support. SUPSHIPNN routinely reviews the contractor's earned value data, however, due to manpower constraints the project teams conducted the analysis whereas an independent analysis is preferred. The Navy recognized this and authorized manning increases of 50 people in fiscal year 2006 and another 30 people in fiscal year 2008. In addition to providing an independent organization for earned value analysis, the increased manpower allows for additional quality assurance monitoring, engineering review, production control, and oversight of business operations. SUPSHIPNN is currently increasing its engagement with construction preparation activities in advance of the ship construction contract award.

RECOMMENDATION 4: The GAO recommends that the Secretary of Defense require monthly cost performance reports that include contractor variance analyses.
(p. 43/GAO Draft Report)

DoD RESPONSE: Concur. In accordance with the Contract Performance Report (CPR) Data Item Description dated March 30, 2005, and the DoD/DCMA Earned Value Management Implementation Guide dated October 2006, the CVN 78 detail design and construction contract will require that CPRs be submitted monthly. The reports will

Attachment
Page 2 of 3

include the contractor's analysis of any cost or schedule variance in sufficient detail to permit effective oversight.

RECOMMENDATION 5: The GAO recommends that the Secretary of Defense require that Earned Value Management captured in cost performance reports be made up of discrete [ed.] measurable tasks so that true cost and schedule variances can be identified. (p. 43/GAO Draft Report)

DoD RESPONSE: Concur. Within 180 days of awarding the detail design and construction contract for CVN 78 and in accordance with DoD policy, the CVN 21 Program Office will conduct an Integrated Baseline Review (IBR). The review will ensure that the contractor has properly planned, scheduled, and resourced the contract scope of work and has established a program management baseline comprised of discrete work packages managed at the control account level. The IBR will establish the baseline for all subsequent earned value calculations, including cost and schedule variances. Similarly, the CVN 21 Program Office plans to conduct an IBR for the CVN 79 construction preparation contract.

RECOMMENDATION 6: The GAO recommends that the Secretary of Defense identify and schedule carrier specific tests to ensure that the dual band radar meets carrier-specific requirements. (p. 43/GAO Draft Report)

DoD RESPONSE: Concur. The dual band radar testing will be completed to verify the established performance requirements. Identification of the test requirements designed to specifically demonstrate any CVN-unique requirements not previously tested is in progress. The test requirements and the associated schedule will be documented in the CVN 78 Test and Evaluation Master Plan.

Attachment
Page 3 of 3

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Paul L. Francis (202) 512-4841

Staff Acknowledgments

Other contributors to this report were Assistant Director Karen Zuckerstein, Lisa L. Berardi, Diana Moldafsky, Moshe Schwartz, and Alyssa Weir.

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