United States Government Accountability Office

GAO

Testimony

Before the Subcommittee on Projection Forces, Committee on Armed Services, House of Representatives

For Release on Delivery
Expected at 3:30 p.m. EDT
Tuesday, July 19, 2005

DEFENSE ACQUISITIONS

Progress and Challenges Facing the DD(X) Surface Combatant Program

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Highlights

Highlights of GAO-05-924T, a testimony before the Subcommittee on Projection Forces, House of Representatives Committee on Armed Services

Why GAO Did This Study

In April 2002, the Department of the Navy launched the DD(X) Destroyer program to develop a stealthy, multi-mission ship that would provide advanced land attack capability to support forces ashore and contribute to military dominance in shallow coastal waters. Numbers and costs for the DD(X) have changed since the inception of the program. According to the program's official cost estimate, the first ship is expected to cost $3.3 billion, with per unit costs decreasing as production progresses.

DD(X) is approaching Milestone B and critical design review—two key decision points that will shape the future of both the program and the Navy itself. This testimony focuses on (1) the challenges the DD(X) program is expected to encounter, (2) the program's approach and progress in managing attendant risks, and (3) potential consequences if program progress falls short of expectations.

www.gao.gov/cgi-bin/getrpt?GAO-05-924T.

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

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DEFENSE ACQUISITIONS

Progress and Challenges Facing the DD(X) Surface Combatant Program

What GAO Found

Demanding requirements and time frames present substantial challenges for the DD(X) program. DD(X)'s revolutionary design and automated operations require multiple technological advances. For example, to carry out its primary mission of land attacks, DD(X) must be able to strike land targets from distances of up to 83 nautical miles (about 96 miles)—a capability requiring a level of accuracy and range not yet achieved in naval gunfire. To meet DD(X)'s stealth requirements, new materials, designs, and construction processes are being developed, including a radical hull design that reduces the ship's signature by sloping out—not in—from the ship's deck to the waterline. In addition, many traditionally manned functions will be automated to appreciably cut crew size and reduce operational costs. At the same time, the DD(X) program has imposed a tight schedule—one that calls for concurrent development, design, and construction.

To reduce risk in the DD(X) program, the Navy is building 10 engineering development models that represent the ship's most critical subsystems and technologies. While use of these models is a sound approach, planned testing of the models continues through system design and, in some cases, into detailed design and construction, creating risk. Any problems identified through testing could require design changes and result in delays and cost increases. Past GAO work shows that demonstrating technological maturity—that is, the technology has been shown to perform in its intended environment—at the start of system design and development is key to reducing risk and meeting cost, schedule, and performance objectives. In addition, the models are not identical in design to the subsystems that will actually be installed on the first ships and thus will require additional work to reach the final design.

The consequences of not meeting the challenges facing the DD(X) program are significant. If the program fails to demonstrate capabilities, develop software, or integrate subsystems as planned, these activities will be pushed into the later stages of design and construction. In these stages, the cost of work and delays is much higher and the schedule much less forgiving than in earlier stages. At the same time, the Navy must compete for funding with other programs, while supporting existing platforms and deployments, in a time when the discretionary budget is constrained. In light of the risks framed by the DD(X)'s challenges, decision makers should consider potential trade-offs in advance, including accepting reduced mission performance, increased costs, delayed shipyard work, and/or additional manning. It would be prudent to consider the palatability of such trade-offs now before authorizing the construction of the first ship—a commitment the Navy plans to make by the end of this fiscal year.

Mr. Chairman and Members of the Subcommittee,

I am pleased to be here today to discuss the Department of the Navy's DD(X) Destroyer program, part of the family of future surface combatants. The DD(X) is being developed as a next-generation multi-mission destroyer. It is intended to provide advanced land attack capability to support forces ashore and contribute to military dominance in the shallow coastal water environment known as the littorals. The DD(X) program began in April 2002 with the award of a design and development contract to Northrop Grumman Ship Systems. Since that time, the program has been developing key technologies and a system design to meet the requirements established by the Navy. Currently DD(X) is approaching key decisions on design and acquisition strategy that will shape the future of both the program and the Navy itself.

We have published two previous reports on technology development in the DD(X) program.[1] Today I would like to discuss (1) the challenges the DD(X) is expected to meet, (2) the program's approach and progress in managing attendant risks, and (3) potential consequences if program progress falls short of expectations.

Summary

The DD(X) program faces a steep challenge that is framed by demanding requirements and a tight schedule imposed by industrial base concerns. Several demands have been made of the DD(X) program, including multiple missions, with a focus on land attack; stealth; manning levels of less than half of the predecessor *Arleigh Burke* destroyer; and a construction schedule that must address industrial base priorities. To meet these demands, the DD(X) will employ revolutionary designs and automated operations, requiring multiple technological advances, to be accomplished on a schedule that calls for concurrent development, design, and construction.

Key to the management of risk is the building of 10 engineering development models that represent the ship's most critical subsystems and technologies. Progress is being made on each, and the delay in the decision to authorize the first ship has allowed additional work to be

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[1] GAO, *Progress of the DD(X) Destroyer Program*, GAO-05-752R (Washington, D.C.: June 14, 2005); GAO, *Defense Acquisitions: Challenges Facing the DD(X) Destroyer Program*, GAO-04-973 (Washington, D.C.: Sept. 3, 2004).

completed. Tests of several engineering development models resulted in successful demonstration of key components and progress toward final testing. In other models, tests identified technical problems that will need to be overcome before ship installation or that have led to changes in the ship design. Although the use of engineering development models is a good approach, the timing for their completion entails risk. Our work on successful commercial and defense product developments shows that demonstrating mature technology at the start of system development is key to reducing risk and meeting cost, schedule, and performance objectives. In the case of DD(X), testing of the engineering development models continues into system design and some extend into detailed design and construction. In addition, the models are not identical in design to the subsystems that will actually be installed on the first ships and thus will require additional work to reach the final design.

The Navy has developed a structured approach for meeting the challenging demands of the DD(X). At the same time, it must be recognized that these challenges are, to some extent, conflicting and do not have much give in them. They may not be simultaneously achievable regardless of the acquisition strategy. To the extent that the large scope of activities remaining for the DD(X) do not go as planned, work—in the form of demonstrating capabilities, developing software, integrating subsystems, and actual fabrication—will travel to the later stages of design and construction. In these stages, the cost of work and delays is much higher and the schedule much less forgiving than in earlier stages. In light of the risks framed by the DD(X)'s challenges, decision makers will have to be prepared to make difficult trade-offs. These could include accepting reduced mission performance, increased costs, delayed shipyard work, and/or additional manning. It is advisable that the palatability of such trade-offs be discussed now before the upcoming commitment to authorize construction of the first ship is made.

Background

The DD(X) program is currently in the system design phase, approaching two key decision points. One is Milestone B, when the Navy will decide on whether to authorize the award of a detail design and construction contract for production of the lead ship(s). Milestone B was planned for March 2005 but has been delayed several times and is now expected to take place before the end of the fiscal year. The other key decision point is the critical design review, scheduled for September 2005. This review is intended to demonstrate the design maturity of the ship and its readiness to proceed to production. Following these decisions, a contract will be awarded for detailed design and construction. Fabrication is planned to start in 2008. The Navy's most recent cost estimate places the cost of the first ship at $3.3 billion, with per unit costs decreasing as production progresses.[2]

The DD(X) Challenge: Deliver Unprecedented Performance on a Tight Schedule

The DD(X) program faces a steep challenge that is framed by demanding requirements and a tight schedule imposed by industrial base concerns. Several demands have been made of the DD(X) program. First, the DD(X) is required to perform not only its primary mission of land attack, but also anti-submarine, anti-aircraft, and mine warfare tasks. For the land attack mission alone, the ship must be able to precisely strike land targets from distances of up to 83 nautical miles, a capability requiring a level of accuracy and range not yet seen in naval gunfire. Second, the DD(X) must meet stealth requirements, which affects the destroyer's signature across all spectrums (infrared, radar cross section, and acoustic). Third, to reduce operational costs, crew size must be at least half of historical levels, requiring the automation and computerization of many traditionally manned functions. Finally, to manage shipyard workloads, the Navy believes construction of the DD(X) must begin in 2008.

To meet these demands, performance and schedule objectives, the DD(X) will employ revolutionary designs and automated operations, requiring multiple technological advances, to be accomplished on a schedule that calls for concurrent development, design, and construction. To meet stealth requirements, completely new materials, designs, and construction processes are being developed, including a revolutionary hull design—the tumblehome hull form—which widens as it approaches the waterline. Another departure from traditional shipbuilding design is the peripheral vertical launch system, which situates missile enclosures peripherally instead of centrally. Several new technologies are being developed to provide the needed weaponry, radars, signature reduction, fire suppression, and propulsion. Advances in automation are necessary to replace many manpower-intensive tasks. For example, the advanced gun system will be completely automated, requiring crew only for the command to fire and replenishment of its magazines. Fire suppression will also be highly automated. This level of sophistication necessitates a large software development effort—14 to 16 million lines of code.

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[2] The quoted estimate assumes alternating production at two shipyards beginning in fiscal year 2007.

DD(X) Acquisition Strategy Requires Completing Technology Maturity During Detail Design and Construction

To reduce risk in the DD(X) program and demonstrate the ship's 12 technologies, the Navy is building 10 engineering development models that represent the ship's most critical subsystems. The development models are described in table 1.

Table 1: Description of Engineering Development Models

Engineering development models	Description
Advanced gun system	Will provide long-range fire support for forces ashore through the use of unmanned operations and the long-range land attack projectile.
Integrated deckhouse and apertures	A composite structure that integrates apertures of radar and communications systems.
Dual band radar	Horizon and volume search improved for performance in adverse environments.
Integrated power system	Power system that integrates power generation, propulsion, and power distribution and management.
Total ship computing environment	Provides single computing environment for all ship systems to speed command while reducing manning.
Peripheral vertical launch system	Multipurpose missile launch system located on the periphery of the ship to reduce damage to ship systems.
Integrated undersea warfare system	System for mine avoidance and submarine warfare with automated software to reduce workload.
Infrared mockup	Seeks to reduce ship's heat signature in multiple areas.
Hull form	Designed to significantly reduce radar cross section.
Autonomic fire suppression system	Intended to reduce crew size by providing a fully automated response to fires.

Source: DD(X) program office and contractors.

The engineering development models are the most significant aspect of the program's risk reduction strategy. They represent a disciplined process for generating the information needed for development. In using engineering development models, the Navy seeks to achieve increasing levels of technology maturity by first defining the requirements and risks of a developmental technology and then executing a series of tests to reduce these risks and prove the utility of a technology. It is these tests that provide confidence in a technology's ability to operate as intended. Once the technology is demonstrated, the subsystem can be integrated into the ship's system design. The progress of technology maturity is recorded and communicated clearly through the use of established metrics,[3] affording the program manager and others readily available information for use in decision making. While engineering development models provide the Navy with vital information on the progress of technologies, the models are being completed later than they should, putting more pressure on the remainder of the program.

Our reviews of commercial and Department of Defense acquisition programs have identified a number of specific practices that ensure that high levels of knowledge are achieved at key junctures in development and used to make investment decisions. The most important practice is achieving a high level of technology maturity at the start of system development. A technology reaches full maturity when its performance is successfully demonstrated in its intended environment. Maturing a technology to this level before including it into system design can reduce risk by creating confidence that a technology will work as expected and allows the developer to focus on integrating mature technologies into the ship design. This improves the ability to establish realistic cost, schedule, and performance objectives as well as the ability to meet them. Including the technologies in the system design before reaching maturity raises the risk of discovering problems late and can increase the cost and time needed to complete design and fabrication.

The DD(X) program is based on a concurrent schedule that calls for developing and testing key subsystems during system design and into detailed design. The schedule for DD(X) and its attendant development models is shown in figure 1. Most of the testing of the development models takes place during the program's system design, which culminates in critical design review. In some cases, the testing of development models continues through the start of DD(X) construction. If problems are found in testing, as has been the case with other programs, they could result in changes in the design, delays in product delivery, and increases in product cost.

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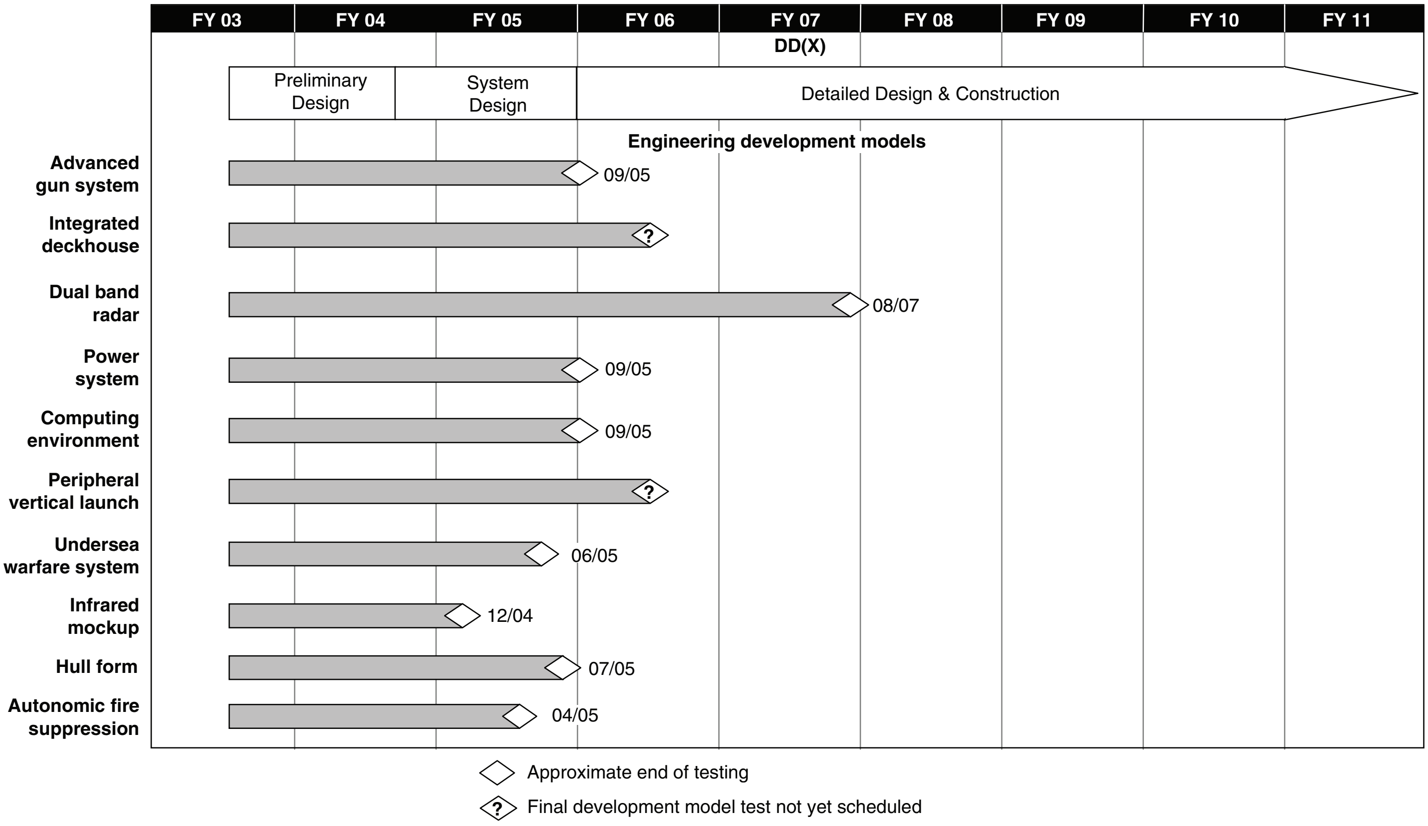
[3] One metric utilized by the DD(X) program office is technology readiness levels. This metric incorporates many of the factors that determine technology maturity, including form, fit, and function, into a single digit numerical score.

Figure 1: DD(X) First Ship and Engineering Development Models Schedule



Sources: U.S. Navy (data); GAO (analysis and presentation).

As you can see, testing of some engineering development models continues through the detailed design and construction phase. Not shown here are the events that will follow tests of the development models. The development models demonstrate the technologies but are not identical in design to the subsystems that will actually be installed on the first ships. Tests performed with development models may also not demonstrate the full functionality of the systems needed for DD(X). In some cases, such as the dual band radar, substantial changes will be needed. Results of testing need to be analyzed and integrated into the final design, and production plans will need to be finalized and approved before the subsystems are manufactured. Testing of the final subsystems will take place before and after installation into the ship.

In responding to our September 2004 report,[4] the Department of Defense stated that it is appropriate to take a reasonable amount of risk in developing technologies for the lead ship of DD(X) given the long production time associated with shipbuilding. Yet DD(X) will proceed from the start of system development to initial capability in the same or less time as other major acquisition programs for which DOD does call for demonstration of technology maturity before development start. Table 2 gives time periods for DD(X) and DDG-51, as well as other nonshipbuilding systems.

Table 2: Comparison of Time from System Development to Initial Capability

System	Start of system development	Initial capability	Time elapsed
DD(X)	March 2004	January 2013	8 years, 10 months
DDG-51	March 1983	February 1993	9 years, 11 months
F/A-18E/F Super Hornet	May 1992	September 2001	9 years, 4 months
Expeditionary Fighting Vehicle	December 2000	September 2010	9 years, 9 months
Joint Strike Fighter	October 2001	March 2012	10 years, 5 months
F/A-22 Raptor	June 1991	December 2005	14 years, 6 months

Source: DOD (data); GAO (analysis and presentation).

Other shipbuilding programs have developed acquisition strategies that sought to mature key technologies before their inclusion into system design, especially if they are vital to the performance or design. The CVN-21 program had a risk-reduction strategy that defined a timeline for making decisions about a technology in line with the start of system design. One example of a technology that followed this strategy was the electromagnetic aircraft launching system, an advanced technology key to meeting system requirements. While there were other technologies not matured to levels as high as the launch system, the majority followed the risk-reduction strategy and had options to switch to an existing technology should development fail. The Navy tested the Virginia class submarine's nonpenetrating periscope at sea before including it into requirements, assuring that the submarine's design could benefit from that technology while reducing the risk it would delay design.

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[4] GAO, *Defense Acquisitions: Challenges Facing the DD(X) Destroyer Program*, GAO-04-973 (Washington, D.C.: Sept. 3, 2004).

Progress on Engineering Development Models

Much of the testing to this date has been for components of subsystems, for example tests on the turbine engines that supply electricity to the integrated power system. Tests of several engineering development models resulted in successful demonstration of key components and progress toward final testing. One example is the advanced gun system, which has been able to rapidly change design or correct deficiencies to meet requirements and demonstrate capability. In other cases, tests identified technical problems that will need to be overcome before ship installation or that have led to changes in the ship design. Examples include the integrated power system or the dual band radar. While these problems could be considered normal for any developmental program, especially when this many new technologies are being developed simultaneously, they are occurring as the program approaches a decision on starting detail design and construction.

Advanced Gun System

The advanced gun system is a large caliber, unmanned gun system designed to fire long-range projectiles in support of land attack missions, such as strikes at specific targets or suppressing fire in support of ground troops. The DD(X) design calls for two gun systems with approximately 300 rounds in each magazine, as well as an additional 320 rounds in an auxiliary magazine. Because the gun system provides supporting fire for land attack, a fundamental mission objective of the DD(X), it needs to be able to quickly and accurately hit a substantial number of land-based targets from a significant distance. The system consists of the mount (the gun together with its housing and movement mechanisms), a fully automated magazine, and a munition known as the long-range land attack projectile. A schedule of key events for the advanced gun system can be seen in table 3.

Table 3: Schedule of Key Events Relating to Advanced Gun System

2004	2005	2006 and beyond
October: Virtual testing of gun system **Second quarter**: Component testing begins **December**: First munition guided flight test	**First quarter**: Component testing ends **April:** Factory acceptance testing of the magazine **January–February**: Munition guided flight tests **May**: Factory acceptance testing of the mount **May**: Long-range land attack projectile preliminary design review **July**: Land-based testing of the mount and magazine **April–September:** Further guided flight tests of munition	**To be determined**: Munition firing from gun system

Source: U.S. Navy (data); GAO (analysis and presentation).

In October 2004 the advanced gun system was tested using a physics-based software model that included the software functionality for all major components of the advanced gun system and incorporated the results of physical testing. Results met or exceeded expectations for response time, rate of fire, sustained rate of fire, range, and pallet unloading rate. The contractor has begun verifying the results through testing of physical components. In April, the magazine component of the advanced gun system successfully completed factory acceptance testing by demonstrating its ability to meet requirements and has been shipped to Dugway, Utah, for integration into further land-based tests. In May, the mount component completed similar testing. Land-based tests scheduled to begin in mid-July will demonstrate the entire firing sequence of the advanced gun system. However, these tests will not demonstrate the ability of the gun system to communicate target information to the munition or the ability to move the gun side to side. The munition will not be tested with the gun until after ship installation.

The munition for advanced gun system, known as long-range land attack projectile, has completed four flight tests at Point Mugu, California; and has successfully demonstrated launch, tail fin deployment, canard deployment, rocket motor ignition, global positioning system acquisition, and some flight maneuvers. The first guided flight test failed when the canards deployed improperly and controlled flight was lost. The issue was identified, corrected, and successfully resolved in later flight tests. The current schedule calls for completion of an additional three flight tests by the end of September 2005. Flight testing of the munition will continue after critical design review.

Recently, the design of the advanced gun system was changed to support ease of production for DD(X). The advanced gun system will now be constructed as a single modular unit, transported to the shipyard, and installed as a block. This redesign has added some weight, which has been accounted for in the current design.

Integrated Deckhouse and Apertures

Integrated deckhouse and apertures refers to the superstructure on the deck of the ship and the openings in which radar, sensor, and communication equipment are placed. The deckhouse is dependant on the use of recently developed composite materials to meet requirements for weight. A major focus of deckhouse design is to reduce the ship's radar cross section signature. A separate technical challenge, referred to as co-site interference, involves placing apertures in precise locations to ensure the signals from the multitude of antennas do not interfere with one another. The contractor, Northrop Grumman, is building two test articles to fulfill requirements for the testing of the deckhouse. One is a fire and shock test article that will be subjected to underwater explosions; the other is an integrated deckhouse article that will be tested for radar cross section and antenna placement. A schedule for key events for the integrated deckhouse can be seen in table 4.

Table 4: Schedule of Key Events Relating to Integrated Deckhouse

2004	2005	2006 and beyond
August: Begin antenna predelivery tests **November**: Begin fire and shock testing (postponed)	**February**: End antenna predelivery tests **March**: Shielding effectiveness tests **April:** Lightning-protection tests **June**: Co-site interference tests **July**: End fire and shock testing (postponed) **September**: Radar cross section tests	**To be determined**: Fire and shock testing (postponed)

Source: U.S. Navy (data); GAO (analysis and presentation).

Construction on the fire and shock test article continues to be delayed due to questions about the material properties of the composites involved, and lack of adequate test facilities. Further time is needed to conduct analysis of composite properties regarding issues such as structural strength, corrosion, toxicity of fumes when composites catch fire, and ability to bind composites with the steel hull. The program office states that the ability of the deckhouse design to meet requirements will continue to be analyzed in support of the critical design review. In addition, facilities for shock testing of large-scale articles, such as those needed for testing of the deckhouse, are not available until 2006. Testing of the fire and shock article has been delayed until the next contract period, after DD(X) critical design review.

Since May 2004, a series of changes involving equipment, antenna size, and positioning have been made to the deckhouse, which has caused changes in the placement of apertures. The integrated deckhouse test article was scheduled to begin testing for radar cross section in May, including all deckhouse antennas and the multifunction radar (half of the dual band radar system), and for co-site interference in June.

The deckhouse has experienced some problems remaining within its margins for weight. To reduce weight, the program has made a number of changes to the design including modifications to fragmentation protection, and redesigned power and cooling systems for the radars and other components. The program office states that the deckhouse is now in compliance with its weight budget.

Dual Band Radar

The dual band radar monitors airborne and surface activities, guides weaponry to targets, and conducts environmental mapping. The dual band radar is made up of two major radar systems, the multifunction radar and the volume search radar, unique technologies that are brought to bear jointly on a range of critical tasks to improve overall depth and quality of battlespace vision. The volume search radar specializes in providing information on aircraft, missiles, and other activities in the vast, open sky environment. In contrast, the multifunction radar is designed to monitor airspace at horizon or near the surface levels for threats such as low-flying antiship cruise missiles. Key events for the dual band radar can be seen in table 5.

Table 5 - Schedule of Key Events Relating to Dual Band Radar

2004	2005	2006	2007 and beyond
September–October: Multifunction radar tests for clutter rejection and sensitivity	**September**: Multifunction radar cross section tests	**February**: Integration and test of volume search radar array **February-May**: Multifunction radar at sea tests **May**: Engineering development model “string” test for the volume search radar **June**: Volume search radar Array delivery	**August**: Dual band radar land-based tests **To be determined**: Continued development of volume search radar to meet requirements

Source: U.S. Navy (data); GAO (analysis and presentation).

Testing and development of the multifunction radar is proceeding well. There have been a number of design changes, including a power/cooling system redesign that reduced weight. These changes will be validated in land based tests with the volume search radar in August 2007. Tests of the multifunction radar’s clutter rejection capabilities and firm track range, two key functions required for demonstration, have been proven in demonstrations with realistic targets. In a simulated scenario, the multifunction radar has demonstrated the ability to guide an Evolved Sea Sparrow Missile against an inbound cruise missile. Testing of the radar’s ability to communicate with one of its own outbound missiles will take place in 2007, when the fully assembled dual band radar undergoes land-based tests. A significant risk remaining is ensuring that the shape and placement of the multifunction radar meets radar cross section requirements.

The transmit/receive units, the individual radiating elements that are the essence of the volume search radar, encountered difficulties when a key component failed in testing. Officials believe they have identified a solution to the problem, but a further design iteration is needed to fully satisfy performance requirements for the engineering development model. Additional iterations of design will be necessary before ship installation.

The schedule for construction of the dual band radar is already challenging, with the radar for the first DD(X) scheduled for placement after the ship is already afloat. Additional delay in development of the volume search radar could affect the schedule for ship construction.

Integrated Power System

The integrated power system centrally generates and distributes power to the ship for all functions, including propulsion. This design allows greater flexibility in power use and will allow the integration of high-energy weapons in the future. The integrated power system consists of three primary components: turbine generator sets, a power distribution system, and propulsion motors. A significant technical challenge is development of the propulsion motors, which are used to turn the shaft and propeller. To reduce risk the program carried two designs of propulsion motor, the permanent magnet motor and the advanced induction motor. A schedule of events for the integrated power system can be seen in table 6.

Table 6: Schedule of Key Events Relating to Integrated Power System

2004	2005	2006 and beyond
October: Main turbine generator set factory acceptance test **October**: Advanced induction motor factory acceptance test **November**: Auxiliary turbine generator factory acceptance test	**January**: Auxiliary turbine generator factory acceptance test **January**: Permanent magnet motor test failure **July-September**: Land-based testing of integrated power system	**To be determined**: Full power load test **To be determined**: Integration and testing with ship control system

Source: U.S. Navy (data); GAO (analysis and presentation).

The program has completed initial testing on propulsion motors for DD(X). The program carried two designs of propulsion motor, the permanent magnet motor and the advanced induction motor. The program preferred to use the permanent magnet motor due to its ability to meet requirements with less weight and noise, but carried the advanced induction motor as a backup. Recently, the permanent magnet motor failed to demonstrate the speed needed to produce the required power. The advanced induction motor tested successfully in October 2004 and has now been selected as the propulsion motor for DD(X). Carrying a backup to a critical new technology is a smart strategy and paid off on the propulsion motor. This change does have has implications for design as the advanced induction motor is heavier and less efficient than the permanent magnet motor, will require more space, and operates at a different voltage. It will take two advanced induction motors linked together to replace one permanent magnet motor.

Navy officials stated that the advanced induction motor will be tested this summer to 18.25 megawatts, half of what the ship requires per propeller and half of what the permanent magnet motor was to demonstrate. The advanced induction motor will also demonstrate half of the torque needed per propeller. While two advanced induction motors will be needed to turn one shaft in the final design, program officials state that there is little risk in simply adding a second motor to reach full power. During demonstrations this summer, the advanced induction motor will also be tested for integration with the power distribution system.

Factory acceptance tests on turbine generators were performed to demonstrate their ability to produce the power needed for DD(X). The design for DD(X) requires two main turbine generators and two auxiliary turbine generators that are tested to similar requirements. The main turbine generator set, a Rolls-Royce MT-30 turbine and a generator produced by Curtiss-Wright, was tested in October 2004. Due to limitations of contractor facilities, the turbine engine and the generator were tested separately. Some problems with heat were experienced in testing of the turbine engine, but program officials have stated these issues have been resolved. The program tested two different turbine engines for the auxiliary generator sets, a Rolls-Royce MT-5 and a General Electric LM-500. Both turbine generator sets demonstrated they were able to produce the power necessary and actually produced more power than predicted.

Design of the power distribution system was also changed to reduce weight and improve performance. According to officials, the Navy will use a system it has been developing called “integrated fight through power,” which includes the use of solid state components and rapid switching technologies.

Total Ship Computing Environment

Program officials estimate that DD(X) will require 14 to 16 million lines of new and reused software code. The total ship computing environment, which accounts for a large portion of the software, will provide a common architecture for major ship systems to facilitate integration and to speed command and control while reducing manning. A schedule of events for the total ship computing environment can be seen in table 7.

Table 7: Schedule of Events Relating to Total Ship Computing Environment

2003	2004	2005	2006 - 2009
September: Preliminary design review	**May**: Critical design review **June**: Software release 1 certification	**March**: Software release 2 certification **May-September**: Land-based tests **September**: Software release 3 certification	Completion of remaining 3 software releases

Source: U.S. Navy (data); GAO (analysis and presentation).

While not a physical technology, the magnitude of software development for DD(X) still needs time for development, design, testing, and correction like the other engineering development models. An engineering development model for the computing environment is being developed for testing and includes three of six software releases. These three releases include the critical infrastructure functionality needed, as well as some functionality for anti-air, undersea, and land attack missions. To prove the functionality of the computing environment, it will be tested in a software integration center and connected with data from other engineering development models.

Computing environment development plans include many of the software best practices identified in our past work, including developing software in an evolutionary environment, following disciplined development process, and using meaningful metrics to measure progress. While robust development plans are in place, the computing environment is on a tight schedule that continues beyond the start of construction and has limited margin for correction of defects found in testing. While the total ship computing environment has not experienced significant challenges thus far, a demanding effort lies ahead. About three-quarters of the software development effort occurs during the detail design and construction phase.

Additional engineering development models

Our review of the remaining engineering development models has been less extensive. Nonetheless, I would like to highlight a few aspects of these systems.

The peripheral vertical launch system consists of the missile launcher, referred to as the advanced vertical launch system, and the enclosure for the launcher, referred to as the peripheral vertical launch system. The system is located on the sides of the ship to improve survivability, rather than the more traditional central positioning. A demonstration in May 2004 to test the peripheral vertical launch system against expected threats resulted in destruction of the test article that necessitated redesign and further testing. A second test replicating the same conditions with the new design and representative materials was held in June 2005.

The integrated undersea warfare system is used to detect mines and submarines in the littorals and consists of medium and high-frequency arrays, towed arrays, and decision-making software to reduce workload. Tests for the demonstration of mine warfare systems were scheduled for May, and were to take place on a vessel modified to carry DD(X) sonar and processing equipment. Submarine warfare tests were scheduled for June. According to program officials, at-sea tests of algorithms for antisubmarine warfare, a key component in reducing manning, have been changed to laboratory testing due to a lack of test ships. Significant advances in the automation of submarine detection and tracking may be required to meet manpower goals.

As a part of requirements for signature management, the DD(X) program seeks to reduce the heat signature of the ship using material treatments on the deckhouse and passive air cooling for engine exhaust. The use of subsystems or materials to reduce heat signature has changed due to design trade-offs for performance, weight, and cost. A sheeting water system for the hull has been deleted from the ship design and replaced with an alternate system. Program officials have determined that further testing of exhaust suppressors for the main turbine generator is no longer necessary. Program officials stated that the operational requirements are still achievable using the new design.

DD(X) uses a radically new hull design to reduce the radar cross section of the ship. Development also includes design of a new propeller. Scale models of the hull form are currently being tested for factors like resistance, efficiency of the propeller, and capsize probability. Development of the software model used to predict hull form behavior is continuing.

The autonomic fire suppression system utilizes new technologies, such as smart valves, flexible hosing, nozzles, sensors, and autonomic operations to reduce the crew and time needed for damage control. This system is vital for meeting requirements for ship survivability and manning. Testing for the system was performed on two Navy test ships and has been successful. An initial test aboard the ex-Peterson, a former destroyer used as a test ship, successfully demonstrated the system's ability to detect damage and control fires. Tests aboard the ex-Shadwell, another larger test ship, demonstrated the same abilities for specific ship environments. Because the exact components used in testing aboard the ex-Shadwell may not be the ones used in ship construction, Navy officials state that it is unclear how the engineering development model will translate into final ship design.

Consequences of Not Meeting DD(X) Challenges Must Be Discussed Early

The Navy developed a structured approach for meeting the challenging demands of the DD(X) — multiple mission requirements, stealth, reduced manning, and industrial base timeframes. This strategy builds in some margins for risk, such as for additional weight and manning, should they become necessary. At the same time, it must be recognized that these challenges are, to some extent, conflicting and do not have much give in them. They may not be simultaneously achievable, regardless of the acquisition strategy.

The DD(X) strategy relies on multiple activities occurring concurrently to meet its schedule. To the extent things do not go as planned, work—in the form of demonstrating capabilities, developing software, integrating subsystems, and actual fabrication—will travel to the later stages of design and construction. In these stages, the cost of work and delays is much higher and the schedule much less forgiving than in earlier stages. In light of the risks framed by the DD(X)'s challenges, decision makers will have to be prepared to make difficult trade-offs. For example,

- If technologies do not perform as expected or have unintended consequences, such as additional weight, will the user accept lower performance or will more time and money be allocated to delivering required performance?
- If costs increase, will more money be provided or will performance trade-offs be considered to reduce cost?
- If the schedule will not allow the ship, as currently scoped, to be ready for in-yard fabrication, will scope be reduced to maintain schedule or will industrial base consequences attendant to a schedule delay be accepted?
- If the ship actually demands a larger crew than planned, can the manning be afforded and accommodated aboard ship or will workload be reduced to meet planned crew size?

In planning for such contingencies, there are a number of factors that should be considered. Earlier this year, we issued a report on cost growth experienced by previous shipbuilding programs.[5] One of the key factors in cost growth was the extent to which the maturity of design affects costs. In the course of doing this work, shipbuilders emphasized the importance

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

of properly sequencing work to achieve cost efficiency. They pointed out that the cost of performing a task increases if it is delayed further into the construction process. For example, one shipbuilder estimated that the same task performed early in the construction process at a steel, electrical or other shop is 3 times more expensive when delayed until assembling units or sections of the ship at the dock, and 8 times more expensive if the ship is afloat. According to another shipbuilder, before construction begins on a particular section of the ship, firm information is needed on equipment and components including such information as the dimensions, weight, and power and cooling requirements. When technologies are still being developed and tested, the Navy's ability to gather this information and finalize design is constrained. When firm information is not available and construction proceeds, the potential exists that work will not be done in the most efficient sequence and that changes will lead to redoing work already completed, increasing cost and delaying delivery.

Another factor is the DD(X) does not have fallback technologies that could mitigate changes to design and performance. The program has passed the decision point for inclusion of the two viable fallback technologies the program began with, a different hull form and the advanced induction motor. If the other technologies embodied in the engineering development models run into difficulties, they cannot be substituted. Thus, their consequences, whether in performance, weight, or manning, would have to be ameliorated through trade-offs.

When considering the possibility of cost growth, it must be taken into account that spending on the program comes at a time when the Navy is also procuring Virginia class submarines, Littoral Combat Ships, amphibious vessels, support vessels, and the last of the *Arleigh Burke* class destroyers. In addition to DD(X) the Navy is also developing new aircraft carriers and aircraft, and may soon start development of new cruisers and submarines. The Navy must compete for funding for these programs with other services, while simultaneously supporting existing platforms and deployments, at a time when the discretionary budget is constrained.

Finally, delays in the schedule for DD(X) construction would reduce the flow of work to the shipyards at the time that DDG-51 construction is drawing to a close. This could result in declining workloads, revenues, and employment levels.

As the cost, schedule, and capabilities of a program change, the business case for that program changes as well. The business case for DD(X), or a similar capability, has already changed multiple times since the Navy launched the future destroyer development effort in 1995. Originally, under the DD-21 program, the Navy planned to build 32 ships at an average cost of approximately $1 billion when the cost of development is also included. After the program transitioned to DD(X) the number of ships required changed repeatedly with numbers ranging from 24 ships to 16 to 8. The latest program baseline, released in April 2004, outlines a purchase of 8 ships at an average cost of around $2.9 billion with the inclusion of development costs.[6] A new life cycle cost estimate, released in March of 2005, presents different figures on number of ships and costs. Even this estimate does not reflect the current acquisition strategy proposed by the Navy. The Navy will have to decide what constitutes an acceptable business case for the DD(X) and at what point the business case becomes unacceptable.

It is important that these contingencies be confronted now and discussed because once the detail design and construction phase begins, it will be very difficult to change course on the program.

Thank you Mr. Chairman. I will be pleased to answer any questions.

Contact Information

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Individuals making key contributions to this testimony included Karen Zuckerstein, J. Kristopher Keener, and Marc Castellano.

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[6] Amounts are in fiscal year 2005 constant dollars.

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