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Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress

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Summary

The Navy has been procuring Arleigh Burke (DDG-51) class Aegis destroyers since FY1985. The two DDG-51s requested for procurement in FY2017 are to be the 75th and 76th ships in the class. The 10 DDG-51s programmed for procurement in FY2013-FY2017 (in annual quantities of 3-1-2-2-2) are being procured under a multiyear-procurement (MYP) contract. One of the DDG-51s funded in FY2016 is to be the first of a new DDG-51 design variation called the Flight III design, which is to incorporate a new and more capable radar called the Air and Missile Defense Radar (AMDR).

As part of its action on the Navy's FY2016 budget, Congress provided \$1 billion in unrequested procurement funding to help pay for a DDG-51 that would be in addition to those being procured under the 10-ship MYP contract for FY2013-FY2017. The Navy, in its budget submission, notes this additional \$1 billion in funding for the DDG-51 program, but does not show the additional DDG-51 in its shipbuilding plan. The \$433 million in procurement funding that would be needed to complete the cost of this additional DDG-51 is, however, included as the second item on the Navy's FY2017 unfunded requirements list (i.e., the list of FY2017 programs that the Navy desires, but for which it did not have sufficient funding in FY2017).

The Navy estimates the combined procurement cost of the two DDG-51s requested for procurement in FY2017 at \$3,393.9 million. The ships have received a total of \$182.6 million in prior-year advance procurement (AP) funding. The Navy's proposed FY2017 budget requests the remaining \$3,211.3 million needed to complete the ships' estimated combined procurement cost. The Navy's proposed FY2017 budget also requests \$16.0 million in so-called cost-to-complete procurement funding to cover cost growth on DDG-51s procured in FY2011. The Navy's proposed FY2017 budget also requests \$271.8 million in procurement funding to complete construction of Zumwalt (DDG-1000) class destroyers procured in prior years, and \$144.4 million in research and development funding for development work on the AMDR.

Potential FY2017 issues for Congress concerning destroyer procurement include the following:

- whether to approve, reject, or modify the Navy's FY2017 procurement funding requests for the DDG-51 and DDG-1000 programs, and the Navy's FY2017 research and development funding request for the AMDR program;
- whether to provide some or all of the \$433 million in procurement funding needed to complete the funding for the additional DDG-51 that was partially funded with \$1 billion in FY2016;
- whether to provide the Navy with authority for entering into an MYP contract for DDG-51s to be procured in FY2018-FY2022;
- continued cost growth in the DDG-1000 program;
- cost, schedule, and technical risk in the Flight III DDG-51 program;
- issues raised in a January 2016 report from DOD's Director of Operational Test and Evaluation (DOT&E)—DOT&E's annual report for FY2015; and
- the lack of an announced Navy roadmap for accomplishing three things in the cruiser-destroyer force: restoring ship growth margins; introducing large numbers of ships with integrated electric drive systems or other technologies that could provide ample electrical power for supporting future electrically powered weapons; and introducing technologies for substantially reducing ship operating and support (O&S) costs.

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Introduction

This report presents background information and potential oversight issues for Congress on the Navy's Arleigh Burke (DDG-51) and Zumwalt (DDG-1000) class destroyer programs. The Navy's proposed FY2017 budget requests funding for the procurement of two DDG-51s. Decisions that Congress makes concerning destroyer procurement could substantially affect Navy capabilities and funding requirements, and the U.S. shipbuilding industrial base.

Background

Strategic and Budgetary Context

For an overview of the strategic and budgetary context in which the DDG-51, DDG-1000, and other Navy shipbuilding programs may be considered, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by (name redacted) .

DDG-51 Program

The DDG-51 program was initiated in the late 1970s.¹ The DDG-51 (**Figure 1**) is a multi-mission destroyer with an emphasis on air defense (which the Navy refers to as anti-air warfare, or AAW) and blue-water (mid-ocean) operations. DDG-51s, like the Navy's 22 Ticonderoga (CG-47) class cruisers,² are equipped with the Aegis combat system, an integrated ship combat system named for the mythological shield that defended Zeus. CG-47s and DDG-51s consequently are often referred to as Aegis cruisers and Aegis destroyers, respectively, or collectively as Aegis ships. The Aegis system has been updated several times over the years. Existing DDG-51s (and also some CG-47s) are being modified to receive an additional capability for ballistic missile defense (BMD) operations.³

The first DDG-51 was procured in FY1985. A total of 74 have been procured through FY2016, including 62 in FY1985-FY2005 and 12 in FY2010-FY2016.⁴ During the period FY2006-FY2009, the Navy procured three Zumwalt (DDG-1000) class destroyers (see discussion below) rather than DDG-51s.⁵ The first DDG-51 entered service in 1991, and a total of 62 were in service

¹ The program was initiated with the aim of developing a surface combatant to replace older destroyers and cruisers that were projected to retire in the 1990s. The DDG-51 was conceived as an affordable complement to the Navy's Ticonderoga (CG-47) class Aegis cruisers.

² A total of 27 CG-47s were procured for the Navy between FY1978 and FY1988; the ships entered service between 1983 and 1994. The first five, which were built to an earlier technical standard, were judged by the Navy to be too expensive to modernize and were removed from service in 2004-2005.

³ The modification for BMD operations includes, among other things, the addition of a new software program for the Aegis combat system and the arming of the ship with the SM-3, a version of the Navy's Standard Missile that is designed for BMD operations. For more on Navy BMD programs, CRS Report RL33745, *Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress*, by (name redacted) .

⁴ The ten DDG-51s procured in FY2010-FY2015 include one in FY2010, two in FY2011, one in FY2012, three in FY2013, one in FY2014, and two in FY2015.

⁵ The Navy had planned to end DDG-51 procurement permanently in FY2005 and procure Zumwalt (DDG-1000) class destroyers thereafter. In July 2008, however, the Navy announced that it had changed its mind—that it wanted to halt procurement of DDG-1000s and resume procuring DDG-51s. The Navy announced this change in its plans at a July 31, 2008, hearing before the Seapower and Expeditionary Forces subcommittee of the House Armed Services Committee. In explaining their proposed change in plans, Navy officials cited a reassessment of threats that Navy forces are likely to face in coming years. As a result of this reassessment, Navy officials stated, the service decided that destroyer (continued...)

as of the end of FY2014. DDG-51s are built by General Dynamics' Bath Iron Works (GD/BIW) of Bath, ME, and Huntington Ingalls Industries' Ingalls Shipbuilding (HII/Ingalls) of Pascagoula, MS.

Figure I. DDG-51 Class Destroyer



Source: Navy file photograph accessed October 18, 2012, at http://www.navy.mil/view_image.asp?id=134605.

The DDG-51 design has been modified over time. The first 28 DDG-51s (i.e., DDGs 51 through 78) are called Flight I/II DDG-51s. The next 45 DDG-51s (i.e., DDGs 79 through 123) are referred to as Flight IIA DDG-51s. The Flight IIA design, first procured in FY1994, implemented a significant design change that included, among other things, the addition of a helicopter hangar. One of the DDG-51s funded in FY2016 is to be the first of a new Flight III version of the DDG-

(...continued)

procurement over the next several years should emphasize three mission capabilities—area-defense AAW, BMD, and open-ocean ASW. Navy officials also stated that they want to maximize the number of destroyers that can be procured over the next several years within budget constraints. Navy officials stated that DDG-51s can provide the area-defense AAW, BMD, and open-ocean ASW capabilities that the Navy wants to emphasize, and that while the DDG-1000 design could also be configured to provide these capabilities, the Navy could procure more DDG-51s than reconfigured DDG-1000s over the next several years for the same total amount of funding. In addition, the Navy by 2008-2009 no longer appeared committed to the idea of reusing the DDG-1000 hull as the basis for the Navy's planned CG(X) cruiser. If the Navy had remained committed to that idea, it might have served as a reason for continuing DDG-1000 procurement.

The Navy's FY2010 budget, submitted in May 2009, reflected the Navy's July 2008 change in plans: the budget proposed truncating DDG-1000 procurement to the three ships that had been procured in FY2007 and FY2009, and resuming procurement of Flight IIA DDG-51s. Congress, as part of its action on the FY2010 defense budget, supported the proposal: The FY2010 budget funded the procurement of one DDG-51, provided advance procurement funding for two DDG-51s the Navy wants to procure in FY2011, completed the procurement funding for the third DDG-1000 (which was authorized but only partially funded in FY2009), and provided no funding for procuring additional DDG-1000s.

51 design that is to feature a new and more capable radar called the Air and Missile Defense Radar (AMDR).

As part of its action on the Navy's FY2013 budget, Congress granted the Navy authority to use a multiyear procurement (MYP) contract for DDG-51s to be procured FY2013-FY2017.⁶ The Navy awarded the contract on June 3, 2013.⁷ The Navy plans to use an engineering change proposal (ECP) to shift from the Flight IIA design to the Flight III design during this MYP contract.

The Navy is implementing a program for modernizing all DDG-51s (and CG-47s) so as to maintain their mission and cost effectiveness out to the end of their projected service lives.⁸ Older CRS reports provide additional historical and background information on the DDG-51 program.⁹

DDG-1000 Program

The DDG-1000 program was initiated in the early 1990s.¹⁰ The DDG-1000 is a multi-mission destroyer with an emphasis on naval surface fire support (NSFS) and operations in littoral (i.e., near-shore) waters. The DDG-1000 is intended to replace, in a technologically more modern form, the large-caliber naval gun fire capability that the Navy lost when it retired its Iowa-class battleships in the early 1990s,¹¹ to improve the Navy's general capabilities for operating in defended littoral waters, and to introduce several new technologies that would be available for use on future Navy ships. The DDG-1000 was also intended to serve as the basis for the Navy's now-canceled CG(X) cruiser.¹²

The DDG-1000 is to have a reduced-size crew of 142 sailors (compared to roughly 300 on the Navy's Aegis destroyers and cruisers) so as to reduce its operating and support (O&S) costs. The ship incorporates a significant number of new technologies, including an integrated electric-drive propulsion system¹³ and automation technologies enabling its reduced-sized crew.

With an estimated full load displacement of 15,482 tons, the DDG-1000 design is roughly 63% larger than the Navy's current 9,500-ton Aegis cruisers and destroyers, and larger than any Navy

⁶ For more on MYP contracts, see CRS Report R41909, *Multiyear Procurement (MYP) and Block Buy Contracting in Defense Acquisition: Background and Issues for Congress*, by (name redacted) and (name redacted) .

⁷ "DDG 51 Multiyear Procurement Contract Awarded," *Navy News Service*, June 3, 2013, accessed July 1, 2013, at http://www.navy.mil/submit/display.asp?story_id=74583. See also Mike McCarthy, "Navy Awards Multi-Year Contracts For Destroyers," *Defense Daily*, June 4, 2013: 1.

⁸ For more on this program, see CRS Report RS22595, *Navy Aegis Cruiser and Destroyer Modernization: Background and Issues for Congress*, by Ronald O'Rourke.

⁹ See CRS Report 94-343, *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, by Ronald O'Rourke (April 25, 1994; out of print and available directly from the author), and CRS Report 80-205, *The Navy's Proposed Arleigh Burke (DDG-51) Class Guided Missile Destroyer Program: A Comparison With An Equal-Cost Force Of Ticonderoga (CG-47) Class Guided Missile Destroyers*, by Ronald O'Rourke (November 21, 1984; out of print and available directly from the author).

¹⁰ The program was originally designated DD-21, which meant destroyer for the 21st Century. In November 2001, the program was restructured and renamed DD(X), meaning a destroyer whose design was in development. In April 2006, the program's name was changed again, to DDG-1000, meaning a guided missile destroyer with the hull number 1000.

¹¹ The Navy in the 1980s reactivated and modernized four Iowa (BB-61) class battleships that were originally built during World War II. The ships reentered service between 1982 and 1988 and were removed from service between 1990 and 1992.

¹² For more on the CG(X) program, see **Appendix B**.

¹³ For more on integrated electric-drive technology, see CRS Report RL30622, *Electric-Drive Propulsion for U.S. Navy Ships: Background and Issues for Congress*, by Ronald O'Rourke.

destroyer or cruiser since the nuclear-powered cruiser *Long Beach* (CGN-9), which was procured in FY1957.

The first two DDG-1000s were procured in FY2007 and split-funded (i.e., funded with two-year incremental funding) in FY2007-FY2008; the Navy’s FY2017 budget submission estimates their combined procurement cost at \$9,072.0 million. The third DDG-1000 was procured in FY2009 and split-funded in FY2009-FY2010; the Navy’s FY2017 budget submission estimates its procurement cost at \$3,666.2 million.

As shown in **Table 1** below, the estimated combined procurement cost for all three DDG-1000s, as reflected in the Navy’s annual budget submission, has grown by \$3,761.1 million, or 41.9%, since the FY2009 budget (i.e., the budget for the fiscal year in which the third DDG-1000 was procured).

Table 1. Estimated Combined Procurement Cost of DDG-1000, DDG-1001, and DDG-2002

In millions, rounded to nearest tenth, as shown in annual Navy budget submissions

	Estimated combined procurement cost (millions of dollars)	Change from prior year’s budget submission	Cumulative change from FY2009 budget submission
FY2009 budget	8,977.1	—	—
FY2010 budget	9,372.5	+395.4 (+4.4%)	+395.4 (+4.4%)
FY2011 budget	9,993.3	+620.8 (+6.6%)	+1,016.2 (+11.3%)
FY2012 budget	11,308.8	+1,315.5 (+13.2%)	+2,331.7 (+26.0%)
FY2013 budget	11,470.1	+161.3 (+1.4%)	+2,493.0 (+27.8%)
FY2014 budget	11,618.4	+148.3 (+1.3%)	+2,641.3 (+29.4%)
FY2015 budget	12,069.4	+451.0 (+3.9%)	+3,092.3 (+34.4%)
FY2016 budget	12,288.7	+219.3 (+1.8%)	+3,311.6 (+36.9%)
FY2017 budget	12,738.2	+449.5 (+3.7%)	+3,761.1 (+41.9%)

Source: Table prepared by CRS based on data in annual Navy budget submissions.

Some of the cost growth in the earlier years in the table was caused by the truncation of the DDG-1000 program from seven ships to three, which caused some class-wide procurement-rated costs that had been allocated to the fourth through seventh ships to be reallocated to the three remaining ships.

The Navy states that the cost growth shown through FY2015 in the table reflects, among other things, a series of incremental, year-by-year movements away from an earlier Navy cost estimate for the program, and toward a higher estimate developed by Cost Assessment and Program Evaluation (CAPE) office within the Office of the Secretary of Defense (OSD). As one consequence of a Nunn-McCurdy cost breach experienced by the DDG-1000 program in 2010 (see “2010 Nunn-McCurdy Breach, Program Restructuring, and Milestone Recertification” in **Appendix A**), the Navy was directed to fund the DDG-1000 program to CAPE’s higher cost estimate for the period FY2011-FY2015, and to the Navy’s cost estimate for FY2016 and beyond. The Navy states that it has been implementing this directive in a year-by-year fashion with each budget submission since 2010, moving incrementally closer each year through FY2015 to CAPE’s higher estimate. The Navy stated in 2014 that even with the cost growth shown in the table, the DDG-1000 program as of the FY2015 budget submission was still about 3% *below* the

program's rebaselined starting point for calculating any new Nunn-McCurdy cost breach on the program.¹⁴

All three ships in the DDG-1000 program are to be built at GD/BIW, with some portions of each ship being built by HII/Ingalls for delivery to GD/BIW. Raytheon is the prime contractor for the DDG-1000's combat system (its collection of sensors, computers, related software, displays, and weapon launchers). The Navy awarded GD/BIW the contract for the construction of the second and third DDG-1000s on September 15, 2011.¹⁵

For additional background information on the DDG-1000 program, see **Appendix A**.

Surface Combatant Construction Industrial Base

All cruisers, destroyers, and frigates procured since FY1985 have been built at General Dynamics' Bath Iron Works (GD/BIW) shipyard of Bath, ME, and Huntington Ingalls Industries' Ingalls Shipbuilding (HII/Ingalls) of Pascagoula, MS. Both yards have long histories of building larger surface combatants. Construction of Navy surface combatants in recent years has accounted for virtually all of GD/BIW's ship-construction work and for a significant share of HII/Ingalls' ship-construction work. (HII/Ingalls also builds amphibious ships for the Navy.) Navy surface combatants are overhauled, repaired, and modernized at GD/BIW, HII/Ingalls, other private-sector U.S. shipyards, and government-operated naval shipyards (NSYs).

Lockheed Martin and Raytheon are generally considered the two leading Navy surface combatant radar makers and combat system integrators. Lockheed is the lead contractor for the DDG-51 combat system (the Aegis system), while Raytheon is the lead contractor for the DDG-1000 combat system, the core of which is called the Total Ship Computing Environment Infrastructure (TSCE-I). Lockheed has a share of the DDG-1000 combat system, and Raytheon has a share of the DDG-51 combat system. Lockheed, Raytheon, and Northrop competed to be the maker of the AMDR to be carried by the Flight III DDG-51. On October 10, 2013, the Navy announced that it had selected Raytheon to be the maker of the AMDR.

The surface combatant construction industrial base also includes hundreds of additional firms that supply materials and components. The financial health of Navy shipbuilding supplier firms has been a matter of concern in recent years, particularly since some of them are the sole sources for what they make for Navy surface combatants.

FY2017 Funding Request

The Navy estimates the combined procurement cost of the two DDG-51s requested for procurement in FY2017 at \$3,393.9 million. The ships have received a total of \$182.6 million in prior-year advance procurement (AP) funding. The Navy's proposed FY2017 budget requests the remaining \$3,211.3 million needed to complete the ships' estimated combined procurement cost. The Navy's proposed FY2017 budget also requests \$16.0 million in so-called cost-to-complete procurement funding to cover cost growth on DDG-51s procured in FY2011. The Navy's proposed FY2017 budget also requests \$271.8 million in procurement funding to complete construction of Zumwalt (DDG-1000) class destroyers procured in prior years, and \$144.4

¹⁴ Source: Navy briefing for CRS and the Congressional Budget Office (CBO) on the DDG-1000 program, April 30, 2014.

¹⁵ See, for example, Mike McCarthy, "Navy Awards Contract for DDG-1000s," *Defense Daily*, September 16, 2011: 3-4.

million in research and development funding for development work on the AMDR. The funding request for the AMDR is contained in Program Element (PE) 0604522N (“Air and Missile defense Radar (AMDR) System”), which is line 123 in the Navy’s FY2017 research and development account.

Issues for Congress

FY2017 Funding Request

One issue for Congress is whether to approve, reject, or modify the Navy’s FY2017 procurement funding requests for the DDG-51 and DDG-1000 programs, and the Navy’s FY2017 research and development funding request for the AMDR program. In assessing this question, Congress may consider various factors, including whether the Navy has accurately estimated the cost of the work to be done.

\$433 Million for Additional DDG-51

Another issue for Congress is whether to provide some or all of the \$433 million in procurement funding needed to complete the funding for the additional DDG-51 that was partially funded with the additional \$1 billion provided in FY2016. As mentioned earlier, the \$433 million needed to complete funding for the additional DDG-51 is the second item on the Navy’s FY2017 unfunded requirements list (URL). In assessing whether to provide some or all of the \$433 million, Congress may consider various factors, including the role this ship would play in fulfilling the terms of a 2002 memorandum of understanding (MOU) among the Navy, GD/BIW, and what is now HII/Ingalls concerning the allocation of DDG-51s and LPD-17 class amphibious ships, the industrial-base impact of procuring an additional DDG-51, the operational value of an additional DDG-51, and the potential impact, in a situation of constraints on defense funding, on other Navy or DOD programs of providing this funding for the DDG-51 program.

Authority for Multiyear Procurement in FY2018-FY2022

Another issue for Congress is whether to provide, as part of Congress’s action on the Navy’s FY2017 budget, authority for entering into an MYP contract for DDG-51s to be procured in FY2018-FY2022. The Navy has not requested such authority as part of its FY2017 budget submission; the Navy plans to request the authority next year, as part of its FY2018 budget submission. The practice in the Navy’s surface ship community (and other parts of DOD) has been to request MYP authority coincident with what would be the first fiscal year of the MYP contract. The practice in the Navy’s submarine community, however, has been to request MYP authority one year in advance of what would be the first year of the MYP contract, because the submarine community has found it useful, in terms of negotiating the terms of the contract, to start the negotiating process a year ahead of the planned start of the contract itself.

Cost Growth in DDG-1000 Program

Another issue for Congress is the continued cost growth in the DDG-1000 program shown in **Table 1**. Potential oversight questions for Congress include the following: What are the causes of this cost growth? Does the Navy expect the cost growth to continue past FY2017? What is the Navy doing to end this cost growth and bring DDG-1000 procurement costs under control?

Flight III DDG-51: Cost, Technical, and Schedule Risk

Another issue for Congress concerns cost, technical, and schedule risk for the Flight III DDG-51.

March 2016 GAO Report

A March 2016 Government Accountability Office (GAO) report assessing selected DOD acquisition programs stated the following in its assessment of the DDG-51 program:

The Navy continues Flight III design activities, including the award of the detail design contracts in February 2015 and completion of a preliminary design review in September 2015. Flight III and AMDR development is concurrent, which could affect ship construction if delays occur in AMDR development or production. In addition to AMDR, Flight III changes include, among other things, upgrades to the ship's electrical plant. Power conversion modules and new generators similar to those developed for the DDG 1000 class are to supply the increased power needed for AMDR. The DDG 1000 program had issues in developmental testing of its electrical system, and additional modifications are required for Flight III. The Flight III design also includes configuration changes to increase weight and stability margins, which determine how much new equipment can be incorporated into the ship. The Navy stated that it believes that the new equipment's additional weight will not adversely affect Flight III performance, but the ship's internal space is a risk that it is monitoring. The addition of AMDR and system upgrades will account for the majority of the increased margins and may limit the ability to introduce future upgrades.

The Navy plans to modify, using an engineering change proposal, the existing Flight IIA multiyear procurement contracts in order to construct the first three Flight III ships rather than awarding new contracts. In February 2015, the Navy submitted a report to Congress on the engineering change proposal, reiterating that the low to moderate risks associated with AMDR and the proposed system upgrades justifies its execution within the next year. The Navy plans to award construction of the first Flight III ship in the third quarter of fiscal year 2016 and two follow-on ships in fiscal year 2017.¹⁶

Regarding the AMDR specifically, the report stated:

Technology and Design Maturity

AMDR's four critical technologies—digital-beamforming, transmit-receive modules, software, and digital receivers/exciters—are nearing full maturity, and the program is expected to deliver its first radar to DDG 51 Flight III, as scheduled, in spring 2020. The contractor completed developmental testing of an early prototype consisting of key subsystems in July 2012. In April 2015, the program office completed a critical design review, with 100 percent of design drawings finalized and releasable. To support initial integration between the radar and the combat system, the AMDR contractor developed and delivered an AMDR simulator to the combat system contractor in September 2015. The AMDR contractor is also developing a radar emulator—scheduled to be completed in spring 2016—that is intended to support system testing and early combat system software integration. The simulator and emulator are expected to help inform the program's knowledge of the radar and combat system interface performance prior to a 6-month risk reduction test period planned for the second half of fiscal year 2017.

Additionally, the contractor has built and tested a second prototype at its facility, which is a single 14-foot S-band radar array—the final configuration for DDG 51 Flight III ships

¹⁶ Government Accountability Office, *Defense Acquisitions[:] Assessments of Selected Weapon Programs*, GAO-16-329SP, March 2016, p. 122.

will be a four-faced array. In July 2016, this prototype is expected to be delivered to the Navy's Pacific Missile Facility (PMF) in Hawaii for testing in a more representative environment. The Navy has allotted 15 months in the AMDR schedule to install this asset at the lab and complete test activities prior to a low-rate initial production decision in September 2017. This production decision will be made prior to combat system integration and test, so any design issues identified through testing will have to be addressed during production.

The AMDR program includes significant software development, which is being completed in four builds. The software approach includes upfront requirements and architecture analysis for each build, as well as continuous integration of new software and automated testing to ensure functionality and performance. The first two already completed developed basic infrastructure, anti-air warfare, and ballistic missile defense capabilities. The third and fourth builds are intended to provide the full extent of radar capabilities, including debris detection and mitigation and advanced discrimination of missile threats. Build three is scheduled to be completed in January 2016 and the final build completion is planned for September 2016. The Navy also has approved plans to upgrade the combat system for integration with AMDR, but the requirements for the upgrade have not yet been defined. The interface between AMDR and the combat management system will require a significant software development effort, with software builds expected to be completed in fiscal year 2021.

Other Program Issues

In 2013, DOT&E disapproved AMDR's Test and Evaluation Master Plan because of operational realism concerns, noting that use of an unmanned AMDR- and Aegis-equipped self-defense test ship is needed to ensure adequate operational testing. No decision has been made on whether a test ship will be used for the testing. If a test ship is used, early DOD estimates suggest that operational testing costs will increase by \$300 to \$400 million.

Program Office Comments

In commenting on a draft of this assessment, the Navy stated they intend to complete the requirements for the upgrade of the combat system for integration with AMDR by the fall of 2016. The program also provided technical comments, which were incorporated as appropriate.¹⁷

October 2015 CBO Report

An October 2015 Congressional Budget Office (CBO) report on the cost of the Navy's shipbuilding programs stated:

The Navy's strategy for meeting the combatant commanders' goal that future ballistic missile defense capabilities exceed those provided by existing DDG-51s—and for replacing 11 Ticonderoga class cruisers when they are retired in the 2020s—is to substantially modify the design of the DDG-51 Flight IIA destroyer, creating a Flight III configuration. That change would incorporate the new Air and Missile Defense Radar (AMDR), now under development, which will be larger and more capable than the radar on current DDG-51s. The effective operation of the AMDR in the new Flight III configuration, however, will require an increase in the ships' capacity to generate electrical power and their ability to cool major systems.

¹⁷ Government Accountability Office, *Defense Acquisitions[:] Assessments of Selected Weapon Programs*, GAO-16-329SP, March 2016, p. 90.

With those changes and associated increases in the ships' displacement, CBO expects that the average cost per ship over the entire production run would be \$1.9 billion in 2015 dollars, or about 15 percent more than the Navy's estimate of \$1.7 billion. Costs could be higher or lower than CBO's estimate, however, depending on the eventual cost and complexity of the AMDR and the associated changes in the ship's design to integrate the new radar.¹⁸

Flight III DDG-51: Issues Raised in January 2016 DOT&E Report

Another issue for Congress concerns issues raised in a January 2016 report from DOD's Director of Operational Test and Evaluation (DOT&E)—DOT&E's annual report for FY2015. Regarding the Flight III DDG-51 program, the report stated:

Assessment

- DOT&E's position continues to be that the Navy's operational test programs for the AMDR, Aegis Combat System, ESSM [Evolved Sea Sparrow Missile] Block 2, and DDG 51 Flight III Destroyer programs are not adequate to fully assess their self-defense capabilities. They are also not adequate to test the following Navy-approved DDG 51 Flight III, AMDR, Aegis Combat System, and ESSM Block 2 requirements.

- The AMDR Capability Development Document (CDD) describes AMDR's IAMD [integrated air and missile defense] mission, which requires AMDR to support simultaneous defense against multiple ballistic missile threats and multiple advanced anti-ship cruise missile (ASCM) threats. The CDD also includes an AMDR minimum track range Key Performance Parameter.

- The DDG 51 Flight III Destroyer has a survivability Key Performance Parameter requirement directly tied to meeting a self-defense requirement threshold against ASCMs described in the Navy's Surface Ship Theater Air and Missile Defense Assessment document of July 2008. It clearly states that area defense will not defeat all the threats, thereby demonstrating that area air defense will not completely attrite all ASCM raids and individual ships must be capable of defeating ASCM leakers in the self-defense zone.

- The ESSM Block 2 CDD has a requirement to provide self-defense against incoming ASCM threats in clear and jamming environments. The CDD also includes an ESSM Block 2 minimum intercept range Key Performance Parameter.

- Use of manned ships for operational testing with threat representative ASCM surrogates in the close-in, self-defense battlespace is not possible due to Navy safety restrictions because targets and debris from intercepts pose an unacceptable risk to personnel at ranges where some of the engagements will take place. The November 2013 mishap on the USS Chancellorsville (CG 62) involving an ASCM surrogate target resulted in even more stringent safety constraints.

- In addition to stand-off ranges (on the order of 1.5 to 5 nautical miles for subsonic and supersonic surrogates, respectively), safety restrictions require that ASCM targets not be flown directly at a manned ship, but at some cross-range offset, which unacceptably degrades the operational realism of the test.

- Similar range safety restrictions will preclude manned ship testing of eight of the nine ASCM scenarios contained in the Navy-approved requirements document for the Aegis Modernization Advanced Capability Build 16 Combat System upgrade. Restrictions also

¹⁸ Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2016 Shipbuilding Plan*, October 2015, p. 27.

preclude testing of the AMDR minimum track range requirement against threat representative ASCM threat surrogates at the land-based AMDR Pacific Missile Range Facility test site.

- To overcome these safety restrictions for the LHA 6, Littoral Combat Ship, DDG 1000, LPD 17, LSD 41/49, and CVN 78 ship classes, the Navy developed an Air Warfare/ Ship Self-Defense Enterprise Modeling and Simulation (M&S) test bed, which uses live testing in the close-in battlespace with targets flying realistic threat profiles and manned ship testing for other battlespace regions, as well as soft-kill capabilities to validate and accredit the M&S test bed. The same needs to be done for the DDG 51 Flight III Destroyer with its AMDR, as side-by-side comparison between credible live fire test results and M&S test results form the basis for the M&S accreditation. Without a Self-Defense Test Ship (SDTS) with AMDR and an Aegis Combat System, there will not be a way to gather all of the operationally realistic live fire test data needed for comparison to accredit the M&S test bed.

- Since Aegis employs ESSMs in the close-in, self-defense battlespace, understanding ESSM's performance is critical to understanding the self-defense capabilities of the DDG 51 Flight III Destroyer.

- Past DOT&E annual reports have stated that the ESSM Block 1 operational effectiveness has not been determined. The Navy has not taken action to adequately test the ESSM's operational effectiveness.

- The IOT&E for ESSM Block 2 will be conducted in conjunction with the DDG 51 Flight III Destroyer, AMDR, and Aegis Combat System operational testing.

- Specifically, because safety limitations preclude ESSM firing in the close-in self-defense battlespace, there are very little test data available concerning ESSM's performance, as installed on Aegis ships, against supersonic ASCM surrogates.

- Any data available regarding ESSM's performance against supersonic ASCM surrogates are from a Ship Self-Defense System-based combat system configuration, using a completely different guidance mode or one that is supported by a different radar suite.

- The cost of building and operating an Aegis SDTS, estimated to be about \$350 Million, is small when compared to the total cost of the AMDR development/procurement and the eventual cost of the 22 (plus) DDG 51 Flight III ships that are planned for acquisition (\$55+ Billion). Even smaller is the cost of the SDTS compared to the cost of the ships that the DDG 51 Flight III Destroyer is expected to protect (approximately \$450 Billion in new ship construction over the next 30 years). If DDG 51 Flight III Destroyers are unable to defend themselves, these other ships are placed at substantial risk.

- The modification/upgrades being planned for the DDG 51 Flight III are significant enough to warrant an assessment of the impact of these changes on ship survivability. The Navy has unofficially indicated the DDG 51 Flight III LFT&E strategy will include Component Shock Qualification, a Total Ship Survivability Trial, and a Full Ship Shock Trial. Other LFT&E program particulars are still under discussion to ensure DDG 51 Flight III adequately addresses survivability requirements against operationally relevant threats and recoverability requirements.

Recommendations

- Status of Previous Recommendations. The Navy has not addressed the following four previous recommendations. The Navy should:

1. Program and fund an SDTS equipped with the AMDR, ESSM Block 2, and DDG 51 Flight III Aegis Combat System in time to support the DDG 51 Flight III Destroyer and ESSM Block 2 IOT&Es.

2. Modify the AMDR, ESSM Block 2, and DDG 51 Flight III Test and Evaluation Master Plans to include a phase of IOT&E using an SDTS equipped with the AMDR and DDG 1 Flight III Combat System.

3. Modify the AMDR, ESSM Block 2, and DDG 51 Flight III Test and Evaluation Master Plans to include a credible M&S effort that will enable a full assessment of the AMDR, ESSM Block 2, and DDG 51 Flight III Combat System's self-defense capabilities.

4. Comply with the DEPSECDEF direction to develop and fund a plan, to be approved by DOT&E, to conduct at-sea testing of the self-defense of the DDG 51 Flight III Destroyer with the AMDR, ESSM Block 2, and Aegis Combat System.

• FY15 Recommendations. The Navy should:

1. Provide program funding for an Aegis-equipped self-defense test ship to support adequate operational testing of the AMDR, Aegis Combat System, ESSM Block 2, and DDG 51 Flight III Destroyer programs as soon as possible so as not to disrupt the ESSM Block 2 development schedule.

2. Provide DOT&E the DDG 51 Flight III LFT&E Strategy for approval prior to the end of FY16 in coordination with the Test and Evaluation Master Plan.¹⁹

Lack of Roadmap for Accomplishing Three Things in Cruiser-Destroyer Force

Another issue for Congress concerns the lack of an announced Navy roadmap for accomplishing three things in the cruiser-destroyer force:

- restoring ship growth margins;
- introducing large numbers of ships with integrated electric drive systems or other technologies that could provide ample electrical power for supporting future electrically powered weapons; and
- introducing technologies (such as those for substantially reducing ship crew size) for substantially reducing ship operating and support (O&S) costs.

The Navy's pre-2008 plan to procure DDG-1000 destroyers and then CG(X) cruisers based on the DDG-1000 hull design represented the Navy's roadmap at the time for restoring growth margins, and for introducing into the cruiser-destroyer force significant numbers of ships with integrated electric drive systems and technologies for substantially reducing ship crew sizes. The ending of the DDG-1000 and CG(X) programs in favor of continued procurement of DDG-51s leaves the Navy without an announced roadmap to do these things, because the Flight III DDG-51 will not feature a fully restored growth margin, will not be equipped with an integrated electric drive system or other technologies that could provide ample electrical power for supporting future electrically powered weapons, and will not incorporate features for substantially reducing ship crew size or for otherwise reducing ship O&S costs substantially below that of Flight IIA DDG-51s. One option for addressing this issue would be to further modify the DDG-51 design. Another would be to initiate a program to design a new cruiser or destroyer class.

¹⁹ Department of Defense, *Director, Operational Test and Evaluation, FY 2015 Annual Report*, January 2016, pp. 194-195.

Legislative Activity for FY2017

Summary of Congressional Action on FY2017 Funding Request

Table 2 summarizes congressional action on the Navy’s FY2017 procurement funding requests for the DDG-51 and DDG-1000 programs, and its research and development funding request for the Air and Missile Defense Radar (AMDR).

Table 2. Congressional Action on FY2017 Funding Request

Millions of dollars, rounded to nearest tenth

	Request	Authorization			Appropriation		
		HASC	SASC	Conf.	HAC	SAC	Conf.
DDG-51 procurement	3,211.3	3,644.3	3,261.1		3,644.3	3,614.8	
DDG-51 cost to complete	16.0	16.0	16.0		16.0	16.0	
DDG-1000 procurement	271.8	271.8	271.8		271.8	271.8	
AMDR research and development (PE 0604522N, line 123)	144.4	144.4	144.4		144.4	144.4	

Source: Table prepared by CRS based on Navy’s FY2017 budget submission and committee and conference reports.

Notes: **HASC** is House Armed Services Committee; **SASC** is Senate armed Services Committee; **HAC** is House Appropriations Committee; **SAC** is Senate Appropriations Committee; **Conf.** is conference agreement.

FY2017 National Defense Authorization Act (H.R. 4909/S. 2943)

House

The House Armed Services Committee, in its report (H.Rept. 114-537 of May 4, 2016) on H.R. 4909, recommends the funding levels shown in the HASC column of **Table 2**.

H.Rept. 114-537 states:

Arleigh Burke-class destroyer

The budget request included \$3.21 billion for two Arleigh Burke-class destroyers.

The committee notes that the Consolidated Appropriations Act, 2016 (Public Law 114–113) included \$1.00 billion for a third Arleigh Burke-class destroyer in fiscal year 2016 but these funds are insufficient to procure the entire ship. The committee also notes that the Chief of Naval Operations included \$433.0 million on his fiscal year 2017 unfunded requirements list in order to fully fund the balance of this Arleigh Burke-class destroyer.

Therefore, the committee recommends \$3.64 billion, an increase of \$433.0 million, for procurement of an additional Arleigh Burke-class destroyer. (Page 20)

Senate

The Senate Armed Services Committee, in its report (S.Rept. 114-255 of May 18, 2016) on S. 2943, recommends the funding levels shown in the SASC column of **Table 2**.

Section 123 of S. 2943 as reported states:

SEC. 123. Certification on ship deliveries.

(a) In general.—The delivery of the USS JOHN F. KENNEDY (CVN–79), the USS ZUMWALT (DDG–1000), and any other new construction ship that employs a multiple phase delivery scheme shall be deemed to occur at the completion of the final phase of construction.

(b) Certification requirement.—Not later than January 1, 2017, the Secretary of the Navy shall certify that ship delivery dates have been adjusted in accordance with subsection (a). The certification shall include the ship hull numbers and delivery date adjustments. The adjustments shall be reflected in the budget of the President submitted under section 1105(a) of title 31, United States Code, as well as Department of Defense Selected Acquisition Reports.

Regarding Section 123, S.Rept. 114-255 states:

Certification on ship deliveries (sec. 123)

The committee recommends a provision that would require the Secretary of the Navy to deem ship delivery to occur at the completion of the final phase of construction. The Secretary would be required to submit a certification to the congressional defense committees not later than January 1, 2017 that certifies ship delivery dates have been adjusted, including the ship hull numbers and delivery date adjustments. The adjustments would be reflected in the budget of the President submitted under section 1105(a) of title 31, United States Code, as well as Department of Defense Selected Acquisition Reports.

The committee notes that justification materials, which accompanied the President’s fiscal year 2016 and 2017 budgets, as well as Department of Defense Selected Acquisition Reports for the CVN–78 class aircraft carrier program, list the delivery date of USS John F. Kennedy (CVN–79) as June 2022. However, the Navy plans to deliver this ship in two phases. Phase I delivery, scheduled to complete in June 2022, will deliver the ship with full propulsion capability, aircraft launch and recovery systems, and safe to sail navigation systems. Phase II delivery, scheduled to complete in September 2024, will add the remaining electronics and ordnance equipment, including the Ship Self-Defense System, weapons systems, and Enterprise Air Search Radar. The committee believes CVN–79 delivery should be deemed to occur at the end of Phase II delivery.

Similarly, the committee understands all three ships in the Zumwalt-class will employ a dual delivery approach with hull, mechanical, and electrical (HM&E) systems delivery at the shipbuilder in Maine and combat systems activation in California. In the case of USS Zumwalt (DDG–1000), HM&E delivery is scheduled for 2016 and combat systems activation is scheduled for 2018. The committee notes the President’s fiscal year 2017 budget lists April 2016 as the delivery date. The committee believes Zumwalt-class delivery should be deemed to occur at the completion of the dual delivery approach, following combat systems activation.

The committee is concerned the variance in the Navy’s definition of ship delivery may obscure oversight of the program’s schedule, including whether or not a project has breached its threshold delivery date. The committee is also concerned Navy ships are being delivered in various degrees of completion and then, after a period of availabilities and shakedowns, possibly several years later, the ship is delivered to the fleet for operations. CVN–79 and the Zumwalt-class programs illustrate this practice.

Therefore, the committee also directs the Comptroller General of the United States to submit a report, not later than March 1, 2017, that includes analysis and recommendations regarding the Navy’s process for fully delivering ships from the time the Navy takes custody of the vessel until the vessels are fully complete and ready for operations. This review should examine the Navy’s cost and schedule milestones throughout this process and how these milestones are reported to decision makers and

oversight agencies. The review should also propose a common definition and criteria for Navy ship deliveries, including the associated dates. (Pages 9-10)

S.Rept. 114-255 also states:

Arleigh Burke-class destroyers

The budget request included \$3.2 billion in line item 9 of Shipbuilding and Conversion, Navy for procurement of Arleigh Burkeclass destroyers (DDG–51). The committee notes an additional destroyer was provided for in the National Defense Authorization Act for Fiscal Year 2016 (Public Law 114–92), which included incremental funding authority, and the Department of Defense Appropriations Act for Fiscal Year 2016 (Public Law 114–113), which included \$1.0 billion in funding. The committee further notes an additional \$433.0 million is required to fully fund this additional destroyer. Therefore, the committee recommends an increase of \$49.8 million to this program to provide the next increment of funding for the additional fiscal year 2016 Arleigh Burke-class destroyer. (Page 24)

S.Rept. 114-255 also states:

DDG–51 destroyer production gap

The committee is concerned a production gap may occur between the current DDG–51 multi-year procurement contract, which concludes with the procurement of two ships in fiscal year 2017, and the follow-on contract scheduled to begin in fiscal year 2018. The committee notes a previous production gap in this program resulted in increased costs for both construction shipyards, as well as the broader vendor base. The committee urges the Secretary of the Navy to prevent a DDG–51 production gap to the maximum extent practicable.

Therefore, the committee directs the Secretary of the Navy to submit a report to the Committees on Armed Services of the Senate and House of Representatives with the fiscal year 2018 budget request that provides a plan to prevent a DDG–51 production gap or, should the Secretary be unable to prevent a gap, provide mitigation options. (Page 32)

FY2017 DOD Appropriations Act (H.R. 5293/S. 3000)

House

The House Appropriations Committee, in its report (H.Rept. 114-577 of May 19, 2016) on H.R. 5293, recommends the funding levels shown in the HAC column of **Table 2**.

Senate

The Senate Appropriations Committee, in its report (S.Rept. 114-263 of May 26, 2016) on S. 3000, recommends the funding levels shown in the SAC column of **Table 2**. The net increase of \$403.5 million recommended for DDG-51 procurement includes an increase of \$433 million to complete funding for the procurement of the additional DDG-51 that was partially funded in FY2016, and a decrease of \$29.5 million for “Budget document disparity: Change orders reduction from two ships requested for fiscal year 2017.” (Page 98)

Appendix A. Additional Background Information on DDG-1000 Program

This appendix presents additional background information on the DDG-1000 program.

Program Origin

The program known today as the DDG-1000 program was announced on November 1, 2001, when the Navy stated that it was replacing a destroyer-development effort called the DD-21 program, which the Navy had initiated in the mid-1990s, with a new Future Surface Combatant Program aimed at developing and acquiring a family of three new classes of surface combatants:²⁰

- **a destroyer called DD(X)** for the precision long-range strike and naval gunfire mission;
- **a cruiser called CG(X)** for the air defense and ballistic missile mission; and
- **a smaller combatant called the Littoral Combat Ship (LCS)** to counter submarines, small surface attack craft (also called “swarm boats”), and mines in heavily contested littoral (near-shore) areas.²¹

On April 7, 2006, the Navy announced that it had redesignated the DD(X) program as the DDG-1000 program. The Navy also confirmed in that announcement that the first ship in the class, DDG-1000, is to be named the *Zumwalt*, in honor of Admiral Elmo R. Zumwalt, the Chief of Naval operations from 1970 to 1974. The decision to name the first ship after Zumwalt was made by the Clinton Administration in July 2000, when the program was still called the DD-21 program.²²

New Technologies

The DDG-1000 incorporates a significant number of new technologies, including a wave-piercing, tumblehome hull design for reduced detectability,²³ a superstructure made partly of large sections of composite (i.e., fiberglass-like) materials rather than steel or aluminum, an integrated electric-drive propulsion system,²⁴ a total-ship computing system for moving information about

²⁰ The DD-21 program was part of a Navy surface combatant acquisition effort begun in the mid-1990s and called the SC-21 (Surface Combatant for the 21st Century) program. The SC-21 program envisaged a new destroyer called DD-21 and a new cruiser called CG-21. When the Navy announced the Future Surface Combatant Program in 2001, development work on the DD-21 had been underway for several years, while the start of development work on the CG-21 was still years in the future. The current DDG-1000 destroyer CG(X) cruiser programs can be viewed as the descendants, respectively, of the DD-21 and CG-21. The acronym SC-21 is still used in the Navy’s research and development account to designate the line item (i.e., program element) that funds development work on both the DDG-1000 and CG(X).

²¹ For more on the LCS program, see CRS Report RL33741, *Navy Littoral Combat Ship (LCS)/Frigate Program: Background and Issues for Congress*, by (name redacted) .

²² For more on Navy ship names, see CRS Report RS22478, *Navy Ship Names: Background for Congress*, by Ronald O’Rourke.

²³ A tumblehome hull slopes inward, toward the ship’s centerline, as it rises up from the waterline, in contrast to a conventional flared hull, which slopes outward as it rises up from the waterline.

²⁴ For more on integrated electric-drive technology, see CRS Report RL30622, *Electric-Drive Propulsion for U.S. Navy Ships: Background and Issues for Congress*, by Ronald O’Rourke.

the ship, automation technologies enabling its reduced-sized crew, a dual-band radar, a new kind of vertical launch system (VLS) for storing and firing missiles, and two copies of a 155mm gun called the Advanced Gun System (AGS). The AGS is to fire a new rocket-assisted 155mm shell, called the Long Range Land Attack Projectile (LRLAP), to ranges of more than 60 nautical miles. The DDG-1000 can carry 600 LRLAP rounds (300 for each gun), and additional rounds can be brought aboard the ship while the guns are firing, creating what Navy officials call an “infinite magazine.”

Planned Quantity

When the DD-21 program was initiated, a total of 32 ships was envisaged. In subsequent years, the planned total for the DD(X)/DDG-1000 program was reduced to 16 to 24, then to 7, and finally to 3.

Construction Shipyards

Under a DDG-1000 acquisition strategy approved by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L) on February 24, 2004, the first DDG-1000 was to have been built by HII/Ingalls, the second ship was to have been built by GD/BIW, and contracts for building the first six were to have been equally divided between HII/Ingalls²⁵ and GD/BIW.

In February 2005, Navy officials announced that they would seek approval from USD AT&L to instead hold a one-time, winner-take-all competition between HII/Ingalls and GD/BIW to build all DDG-1000s. On April 20, 2005, the USD AT&L issued a decision memorandum deferring this proposal, stating in part, “at this time, I consider it premature to change the shipbuilder portion of the acquisition strategy which I approved on February 24, 2004.”

Several Members of Congress also expressed opposition to Navy’s proposal for a winner-take-all competition. Congress included a provision (§1019) in the Emergency Supplemental Appropriations Act for 2005 (H.R. 1268/P.L. 109-13 of May 11, 2005) prohibiting a winner-take-all competition. The provision effectively required the participation of at least one additional shipyard in the program but did not specify the share of the program that is to go to the additional shipyard.

On May 25, 2005, the Navy announced that, in light of Section 1019 of P.L. 109-13, it wanted to shift to a “dual-lead-ship” acquisition strategy, under which two DDG-1000s would be procured in FY2007, with one to be designed and built by HII/Ingalls and the other by GD/BIW.

Section 125 of the FY2006 defense authorization act (H.R. 1815/P.L. 109-163) again prohibited the Navy from using a winner-take-all acquisition strategy for procuring its next-generation destroyer. The provision again effectively requires the participation of at least one additional shipyard in the program but does not specify the share of the program that is to go to the additional shipyard.

On November 23, 2005, the USD AT&L granted Milestone B approval for the DDG-1000, permitting the program to enter the System Development and Demonstration (SDD) phase. As part of this decision, the USD AT&L approved the Navy’s proposed dual-lead-ship acquisition

²⁵ At the time of the events described in this section, HII was owned by Northrop Grumman and was called Northrop Grumman Shipbuilding (NGSB).

strategy and a low rate initial production quantity of eight ships (one more than the Navy subsequently planned to procure).

On February 14, 2008, the Navy awarded contract modifications to GD/BIW and HII/Ingalls for the construction of the two lead ships. The awards were modifications to existing contracts that the Navy has with GD/BIW and HII/Ingalls for detailed design and construction of the two lead ships. Under the modified contracts, the line item for the construction of the dual lead ships is treated as a cost plus incentive fee (CPIF) item.

Until July 2007, it was expected that HII/Ingalls would be the final-assembly yard for the first DDG-1000 and that GD/BIW would be the final-assembly yard for the second. On September 25, 2007, the Navy announced that it had decided to build the first DDG-1000 at GD/BIW, and the second at HII/Ingalls.

On January 12, 2009, it was reported that the Navy, HII/Ingalls, and GD/BIW in the fall of 2008 began holding discussions on the idea of having GD/BIW build both the first and second DDG-1000s, in exchange for HII/Ingalls receiving a greater share of the new DDG-51s that would be procured under the Navy's July 2008 proposal to stop DDG-1000 procurement and restart DDG-51 procurement.²⁶

On April 8, 2009, it was reported that the Navy had reached an agreement with HII/Ingalls and GD/BIW to shift the second DDG-1000 to GD/BIW, and to have GD/BIW build all three ships. HII/Ingalls will continue to make certain parts of the three ships, notably their composite deckhouses. The agreement to have all three DDG-1000s built at GD/BIW was a condition that Secretary of Defense Robert Gates set forth in an April 6, 2009, news conference on the FY2010 defense budget for his support for continuing with the construction of all three DDG-1000s (rather than proposing the cancellation of the second and third).

Procurement Cost Cap

Section 123 of the FY2006 defense authorization act (H.R. 1815/P.L. 109-163 of January 6, 2006) limited the procurement cost of the fifth DDG-1000 to \$2.3 billion, plus adjustments for inflation and other factors. Given the truncation of the DDG-1000 program to three ships, this unit procurement cost cap appears moot.

2010 Nunn-McCurdy Breach, Program Restructuring, and Milestone Recertification

On February 1, 2010, the Navy notified Congress that the DDG-1000 program had experienced a critical cost breach under the Nunn-McCurdy provision. The Nunn-McCurdy provision (10 U.S.C. 2433a) requires certain actions to be taken if a major defense acquisition program exceeds (i.e., breaches) certain cost-growth thresholds and is not terminated. Among other things, a program that experiences a cost breach large enough to qualify under the provision as a critical cost breach has its previous acquisition system milestone certification revoked. (In the case of the DDG-1000 program, this was Milestone B.) In addition, for the program to proceed rather than be terminated, DOD must certify certain things, including that the program is essential to national

²⁶ Christopher P. Cavas, "Will Bath Build Second DDG 1000?" *Defense News*, January 12, 2009: 1, 6.

security and that there are no alternatives to the program that will provide acceptable capability to meet the joint military requirement at less cost.²⁷

The Navy stated in its February 1, 2010, notification letter that the DDG-1000 program's critical cost breach was a mathematical consequence of the program's truncation to three ships.²⁸ Since the DDG-1000 program has roughly \$9.3 billion in research and development costs, truncating the program to three ships increased to roughly \$3.1 billion the average amount of research and development costs that are included in the average acquisition cost (i.e., average research and development cost plus procurement cost) of each DDG-1000. The resulting increase in program acquisition unit cost (PAUC)—one of two measures used under the Nunn-McCurdy provision for measuring cost growth²⁹—was enough to cause a Nunn-McCurdy critical cost breach.

In a June 1, 2010, letter (with attachment) to Congress, Ashton Carter, the DOD acquisition executive (i.e., the Under Secretary of Defense for Acquisition, Technology and Logistics), stated that he had restructured the DDG-1000 program and that he was issuing the certifications required under the Nunn-McCurdy provision for the restructured DDG-1000 program to proceed.³⁰ The letter stated that the restructuring of the DDG-1000 program included the following:

- A change to the DDG-1000's design affecting its primary radar.
- A change in the program's Initial Operational Capability (IOC) from FY2015 to FY2016.
- A revision to the program's testing and evaluation requirements.

Regarding the change to the ship's design affecting its primary radar, the DDG-1000 originally was to have been equipped with a dual-band radar (DBR) consisting of the Raytheon-built X-band SPY-3 multifunction radar (MFR) and the Lockheed-built S-band SPY-4 Volume Search Radar (VSR). (Raytheon is the prime contractor for the overall DBR.) Both parts of the DBR have been in development for the past several years. An attachment to the June 1, 2010, letter stated that, as a result of the program's restructuring, the ship is now to be equipped with "an upgraded multifunction radar [MFR] and no volume search radar [VSR]." The change eliminates the Lockheed-built S-band SPY-4 VSR from the ship's design. The ship might retain a space and weight reservation that would permit the VSR to be backfitted to the ship at a later point. The Navy states that

As part of the Nunn-McCurdy certification process, the Volume Search Radar (VSR) hardware was identified as an acceptable opportunity to reduce cost in the program and thus was removed from the current baseline design....

Modifications will be made to the SPY-3 Multi-Function Radar (MFR) with the focus of meeting ship Key Performance Parameters. The MFR modifications will involve

²⁷ For more on the Nunn-McCurdy provision, see CRS Report R41293, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, by (name redacted) .

²⁸ Source: Letter to congressional offices dated February 1, 2010, from Robert O. Work, Acting Secretary of the Navy, to Representative Ike Skelton, provided to CRS by Navy Office of Legislative Affairs on February 24, 2010.

²⁹ PAUC is the sum of the program's research and development cost and procurement cost divided by the number of units in the program. The other measure used under the Nunn-McCurdy provision to measure cost growth is average program unit cost (APUC), which is the program's total procurement cost divided by the number of units in the program.

³⁰ Letter dated June 1, 2010, from Ashton Carter, Under Secretary of Defense (Acquisition, Technology and Logistics) to the Honorable Ike Skelton, with attachment. The letter and attachment were posted on InsideDefense.com (subscription required) on June 2, 2010.

software changes to perform a volume search functionality. Shipboard operators will be able to optimize the SPY-3 MFR for either horizon search or volume search. While optimized for volume search, the horizon search capability is limited. Without the VSR, DDG 1000 is still expected to perform local area air defense....

The removal of the VSR will result in an estimated \$300 million net total cost savings for the three-ship class. These savings will be used to offset the program cost increase as a result of the truncation of the program to three ships. The estimated cost of the MFR software modification to provide the volume search capability will be significantly less than the estimated procurement costs for the VSR.³¹

Regarding the figure of \$300 million net total cost savings in the above passage, the Navy during 2011 determined that eliminating the SPY-4 VSR from the DDG-1000 increased by \$54 million the cost to integrate the dual-band radar into the Navy's new Gerald R. Ford (CVN-78) class aircraft carriers.³² Subtracting this \$54 million cost from the above \$300 million savings figure would bring the net total cost savings to about \$246 million on a Navy-wide basis.

A July 26, 2010, press report quotes Captain James Syring, the DDG-1000 program manager, as stating: "We don't need the S-band radar to meet our requirements [for the DDG-1000]," and "You can meet [the DDG-1000's operational] requirements with [the] X-band [radar] with software modifications."³³

An attachment to the June 1, 2010, letter stated that the PAUC for the DDG-1000 program had increased 86%, triggering the Nunn-McCurdy critical cost breach, and that the truncation of the program to three ships was responsible for 79 of the 86 percentage points of increase. (The attachment stated that the other seven percentage points of increase are from increases in development costs that are primarily due to increased research and development work content for the program.)

Carter also stated in his June 1, 2010, letter that he had directed that the DDG-1000 program be funded, for the period FY2011-FY2015, to the cost estimate for the program provided by the Cost Assessment and Program Evaluation (CAPE) office (which is a part of the Office of the Secretary of Defense [OSD]), and, for FY2016 and beyond, to the Navy's cost estimate for the program. The program was previously funded to the Navy's cost estimate for all years. Since CAPE's cost estimate for the program is higher than the Navy's cost estimate, funding the program to the CAPE estimate for the period FY2011-FY2015 will increase the cost of the program as it appears in the budget for those years. The letter states that DOD "intends to address the [resulting] FY2011 [funding] shortfall [for the DDG-1000 program] through reprogramming actions."

An attachment to the letter stated that the CAPE in May 2010 estimated the PAUC of the DDG-1000 program (i.e., the sum of the program's research and development costs and procurement costs, divided by the three ships in the program) as \$7.4 billion per ship in then-year dollars (\$22.1 billion in then-year dollars for all three ships), and the program's average procurement unit cost (APUC), which is the program's total procurement cost divided by the three ships in the program, as \$4.3 billion per ship in then-year dollars (\$12.8 billion in then-year dollars for all three ships). The attachment stated that these estimates are at a confidence level of about 50%,

³¹ Source: Undated Navy information paper on DDG-51 program restructuring provided to CRS and CBO by Navy Office of Legislative Affairs on July 19, 2010.

³² Source: Undated Navy information paper on CVN-78 cost issues, provided by Navy Office of Legislative Affairs to CRS on March 19, 2012.

³³ Cid Standifer, "Volume Radar Contracted For DDG-1000 Could Be Shifted To CVN-79," *Inside the Navy*, July 26, 2010.

meaning that the CAPE believes there is a roughly 50% chance that the program can be completed at or under these cost estimates, and a roughly 50% chance that the program will exceed these cost estimates.

An attachment to the letter directed the Navy to “return for a Defense Acquisition Board (DAB) review in the fall 2010 timeframe when the program is ready to seek approval of the new Milestone B and authorization for production of the DDG-1002 [i.e., the third ship in the program].”

On October 8, 2010, DOD reinstated the DDG-1000 program’s Milestone B certification and authorized the Navy to continue production of the first and second DDG-1000s and commence production of the third DDG-1000.³⁴

March 2016 GAO Report

A March 2016 GAO report assessing selected major DOD weapon acquisition programs stated the following of the DDG-1000 program:

Technology Maturity

While 3 of the DDG 1000's 11 critical technologies are fully mature, the remaining 8 will not be demonstrated in a realistic environment until testing aboard the lead ship. Reliability of the ship's power conversion and distribution system—a key element of the integrated power system—was the top technical risk for completion of the sea trials required prior to delivery. The program believes that the integrated power system was successfully demonstrated during initial sea trials in December 2015. Issues with the power conversion and distribution system were due, in part, to the Navy's decision to not fully test and validate the performance of the system in a representative environment prior to installation on the ship. The Navy conducted land-based testing of the integrated power system with a configuration representing only half of the system, with plans to install the test equipment on DDG 1002, which it believed was the cost effective approach to risk reduction. As a result, the Navy reported that numerous issues with the power conversion and distribution system were discovered during land-based testing but not resolved before ship installation. Because land-based testing did not include testing to replicate shipboard power loads, power disturbances were discovered during shipboard testing.

The program reported that all mission system equipment for the first two ships has been delivered and installed, with mission system activation planned after lead ship delivery. The contract for the third ship's mission system equipment was awarded in December 2015. Testing of modifications to the multifunction radar to include a volume search capability is ongoing. Multiple tracking exercises with the multifunction radar were conducted at Wallops Island in 2015. A follow-on tracking exercise is planned in June 2016. According to program officials, software acceptance testing for the eighth and final software build for the total ship computing environment has been completed and will be accepted in January 2016. Low-rate initial production decision on the long range land attack projectile is planned for second quarter fiscal year 2016.

Design and Production Maturity

The DDG 1000 design is mature, but ongoing development and shipboard testing of technologies may result in design changes. As of December 2015, the program reported that construction of the three ships in the class was 98, 84, and 43 percent complete,

³⁴ Christopher J. Castelli, “Pentagon Approves Key Milestone For Multibillion-Dollar Destroyer,” *Inside the Navy*, November 22, 2010.

respectively. Program officials said delays to lead ship delivery were initially driven by challenges in completing electrical work, with the shipbuilder citing resource shortages and workforce turnover. Significant technical issues with activation and testing of the lead ship's hull, mechanical, and electrical systems have further delayed lead ship delivery. As of December 2015, the program reported that activation of the lead ship's hull, mechanical and electrical systems was 83 percent complete. The program also reported that initial sea trials in December 2015 demonstrated several ship systems including small boat operations, anchoring, integrated power system, and auxiliary systems and that primary risk reduction objectives were successfully met. Lead ship delivery is expected in April 2016.

Other Program Issues

Late delivery of the lead ship's hull, mechanical, and electrical systems delayed the start of mission system activation and verification that the ship can meet performance requirements. The current estimate for initial operating capability is September 2018, almost two years later than planned. A revision of the program's acquisition program baseline to account for these schedule delays has not yet been approved.

Program Office Comments

In commenting on a draft of this assessment, the Navy concurred with our findings and provided additional information. The Navy noted that the program has made significant progress in the test and activation phase as several ship systems were demonstrated during initial sea trials in December 2015. The Navy noted that analysis continues and any identified corrective actions will be prioritized to best support the continuing schedule of test and trial events. The Navy added that it continues to focus on delivery of the lead ship's hull, mechanical, and electrical systems; sail away and planning mission systems activation. The Navy also provided technical comments, which were incorporated where appropriate.³⁵

³⁵ Government Accountability Office, *Defense Acquisitions[:] Assessments of Selected Weapon Programs*, GAO-16-329SP, March 2016, p. 96.

Appendix B. Additional Background Information on CG(X) Cruiser Program

Background Information on CG(X) Program

The CG(X) cruiser program was announced by the Navy on November 1, 2001.³⁶ The Navy wanted to procure as many as 19 CG(X)s as replacements for its 22 CG-47s, which are projected to reach the end of their 35-year service lives between 2021 and 2029. The CG-47s are multi-mission ships with an emphasis on AAW and (for some CG-47s) BMD, and the Navy similarly wanted the CG(X) to be a multi-mission ship with an emphasis on AAW and BMD. The CG(X) was to carry the Air and Missile Defense Radar (AMDR), a new radar that was to be considerably larger and more powerful than the SPY-1 radar carried on the Navy's Aegis ships. Some press reports suggested that a nuclear-powered version of the CG(X) might have had a full load displacement of more than 20,000 tons and a unit procurement cost of \$5 billion or more.³⁷

The Navy's FY2009 budget called for procuring the first CG(X) in FY2011. Beginning in late 2008, however, it was reported that the Navy had decided to defer the procurement of the first CG(X) by several years, to about FY2017.³⁸ Consistent with these press reports, on April 6, 2009,

³⁶ The Navy on that date announced that it was launching a Future Surface Combatant Program aimed at acquiring a family of next-generation surface combatants. This new family of surface combatants, the Navy stated, would include three new classes of ships:

- a destroyer called the DD(X)—later redesignated DDG-1000—for the precision long-range strike and naval gunfire mission,
- a cruiser called the CG(X) for the AAW and BMD mission, and
- a smaller combatant called the Littoral Combat Ship (LCS) to counter submarines, small surface attack craft, and mines in heavily contested littoral (near-shore) areas.

The Future Surface Combatant Program replaced an earlier Navy surface combatant acquisition effort, begun in the mid-1990s, called the Surface Combatant for the 21st Century (SC-21) program. The SC-21 program encompassed a planned destroyer called DD-21 and a planned cruiser called CG-21. When the Navy announced the Future Surface Combatant Program in 2001, development work on the DD-21 had been underway for several years, but the start of development work on the CG-21 was still years in the future. The DD(X) program, now called the DDG-1000 or Zumwalt-class program, is essentially a restructured continuation of the DD-21 program. The CG(X) might be considered the successor, in planning terms, of the CG-21. After November 1, 2001, the acronym SC-21 continued for a time to be used in the Navy's research and development account to designate a line item (i.e., program element) that funded development work on the DDG-1000 and CG(X).

³⁷ For a discussion of nuclear power for Navy surface ships other than aircraft carriers, see CRS Report RL33946, *Navy Nuclear-Powered Surface Ships: Background, Issues, and Options for Congress*, by Ronald O'Rourke.

³⁸ Zachary M. Peterson, "Navy Awards Technology Company \$128 Million Contract For CG(X) Work," *Inside the Navy*, October 27, 2008. Another press report (Katherine McIntire Peters, "Navy's Top Officer Sees Lessons in Shipbuilding Program Failures," *GovernmentExecutive.com*, September 24, 2008) quoted Admiral Gary Roughead, the Chief of Naval Operations, as saying: "What we will be able to do is take the technology from the DDG-1000, the capability and capacity that [will be achieved] as we build more DDG-51s, and [bring those] together around 2017 in a replacement ship for our cruisers." (Material in brackets in the press report.) Another press report (Zachary M. Peterson, "Part One of Overdue CG(X) AOA Sent to OSD, Second Part Coming Soon," *Inside the Navy*, September 29, 2008) quoted Vice Admiral Barry McCullough, the Deputy Chief of Naval Operations for Integration of Capabilities and Resources, as saying that the Navy did not budget for a CG(X) hull in its proposal for the Navy's budget under the FY2010-FY2015 Future Years Defense Plan (FYDP) to be submitted to Congress in early 2009.

An earlier report (Christopher P. Cavas, "DDG 1000 Destroyer Program Facing Major Cuts," *DefenseNews.com*, July 14, 2008) stated that the CG(X) would be delayed until FY2015 or later. See also Geoff Fein, "Navy Likely To Change CG(X)'s Procurement Schedule, Official Says," *Defense Daily*, June 24, 2008; Rebekah Gordon, "Navy Agrees CG(X) By FY-11 Won't Happen But Reveals Little Else," *Inside the Navy*, June 30, 2008.

Secretary of Defense Robert Gates announced—as part of a series of recommendations for the then-forthcoming FY2010 defense budget—a recommendation to “delay the CG-X next generation cruiser program to revisit both the requirements and acquisition strategy” for the program.³⁹ The Navy’s proposed FY2010 budget deferred procurement of the first CG(X) beyond FY2015.

Cancellation of CG(X) Program

The Navy’s FY2011 budget proposed terminating the CG(X) program as unaffordable. The Navy’s desire to cancel the CG(X) and instead procure Flight III DDG-51s apparently took shape during 2009: at a June 16, 2009, hearing before the Seapower Subcommittee of the Senate Armed Services Committee, the Navy testified that it was conducting a study on destroyer procurement options for FY2012 and beyond that was examining design options based on either the DDG-51 or DDG-1000 hull form.⁴⁰ A January 2009 memorandum from the Department of Defense acquisition executive had called for such a study.⁴¹ In September and November 2009, it was reported that the Navy’s study was examining how future requirements for AAW and BMD operations might be met by a DDG-51 or DDG-1000 hull equipped with a new radar.⁴² On December 7, 2009, it was reported that the Navy wanted to cancel its planned CG(X) cruiser and instead procure an improved version of the DDG-51.⁴³ In addition to being concerned about the projected high cost and immature technologies of the CG(X),⁴⁴ the Navy reportedly had concluded that it does not need a surface combatant with a version of the AMDR as large and capable as the one envisaged for the CG(X) to adequately perform projected AAW and BMD missions, because the Navy will be able to augment data collected by surface combatant radars with data collected by space-based sensors. The Navy reportedly concluded that using data collected by other sensors would permit projected AAW and BMD missions to be performed adequately with a radar smaller enough to be fitted onto the DDG-51.⁴⁵ Reports suggested that the

³⁹ Source: Opening remarks of Secretary of Defense Robert Gates at an April 6, 2009, news conference on DOD recommendations for the then-forthcoming FY2010 defense budget.

⁴⁰ Source: Transcript of spoken remarks of Vice Admiral Bernard McCullough at a June 16, 2009, hearing on Navy force structure shipbuilding before the Seapower subcommittee of the Senate Armed Services Committee.

⁴¹ A January 26, 2009, memorandum for the record from John Young, the then-DOD acquisition executive, stated that “The Navy proposed and OSD [the Office of the Secretary of Defense] agreed with modification to truncate the DDG-1000 Program to three ships in the FY 2010 budget submission.” The memo proposed procuring one DDG-51 in FY2010 and two more FY2011, followed by the procurement in FY2012-FY2015 (in annual quantities of 1, 2, 1, 2) of a ship called the Future Surface Combatant (FSC) that could be based on either the DDG-51 design or the DDG-1000 design. The memorandum stated that the FSC might be equipped with a new type of radar, but the memorandum did not otherwise specify the FSC’s capabilities. The memorandum stated that further analysis would support a decision on whether to base the FSC on the DDG-51 design or the DDG-1000 design. (Memorandum for the record dated January 26, 2009, from John Young, Under Secretary of Defense [Acquisition, Technology and Logistics], entitled “DDG 1000 Program Way Ahead,” posted on InsideDefense.com [subscription required].)

⁴² Zachary M. Peterson, “Navy Slated To Wrap Up Future Destroyer Hull And Radar Study,” *Inside the Navy*, September 7, 2009. Christopher P. Cavas, “Next-Generation U.S. Warship Could Be Taking Shape,” *Defense News*, November 2, 2009: 18, 20.

⁴³ Christopher J. Castelli, “Draft Shipbuilding Report Reveals Navy Is Killing CG(X) Cruiser Program,” *Inside the Navy*, December 7, 2009.

⁴⁴ Christopher J. Castelli, “Draft Shipbuilding Report Reveals Navy Is Killing CG(X) Cruiser Program,” *Inside the Navy*, December 7, 2009.

⁴⁵ Amy Butler, “STSS Prompts Shift in CG(X) Plans,” *Aerospace Daily & Defense Report*, December 11, 2009: 1-2.

new smaller radar would be a scaled-down version of the AMDR originally intended for the CG(X).⁴⁶

The Navy's February 2010 report on its FY2011 30-year (FY2011-FY2040) shipbuilding plan, submitted to Congress in conjunction with the FY2011 budget, states that the 30-year plan:

Solidifies the DoN's [Department of the Navy's] long-term plans for Large Surface Combatants by truncating the DDG 1000 program, restarting the DDG 51 production line, and continuing the Advanced Missile Defense Radar (AMDR) development efforts. Over the past year, the Navy has conducted a study that concludes a DDG 51 hull form with an AMDR suite is the most cost-effective solution to fleet air and missile defense requirements over the near to mid-term....

The Navy, in consultation with OSD, conducted a Radar/Hull Study for future destroyers. The objective of the study was to provide a recommendation for the total ship system solution required to provide Integrated Air and Missile Defense (IAMD) (simultaneous ballistic missile and anti-air warfare (AAW) defense) capability while balancing affordability with capacity. As a result of the study, the Navy is proceeding with the Air and Missile Defense Radar (AMDR) program....

As discussed above, the DDG 51 production line has been restarted. While all of these new-start guided missile destroyers will be delivered with some BMD capability, those procured in FY 2016 and beyond will be purpose-built with BMD as a primary mission. While there is work to be done in determining its final design, it is envisioned that this DDG 51 class variant will have upgrades to radar and computing performance with the appropriate power generation capacity and cooling required by these enhancements. These upgraded DDG 51 class ships will be modifications of the current guided missile destroyer design that combine the best emerging technologies aimed at further increasing capabilities in the IAMD arena and providing a more effective bridge between today's capability and that originally planned for the CG(X). The ships reflected in this program have been priced based on continuation of the existing DDG 51 re-start program. Having recently completed the Hull and Radar Study, the Department is embarking on the requirements definition process for these AMDR destroyers and will adjust the pricing for these ships in future reports should that prove necessary.⁴⁷

In testimony to the House and Senate Armed Services Committees on February 24 and 25, 2010, respectively, Admiral Gary Roughead, the Chief of Naval Operations, stated:

Integrated Air and Missile Defense (IAMD) incorporates all aspects of air defense against ballistic, anti-ship, and overland cruise missiles. IAMD is vital to the protection of our force, and it is an integral part of our core capability to deter aggression through conventional means....

To address the rapid proliferation of ballistic and anti-ship missiles and deep-water submarine threats, as well as increase the capacity of our multipurpose surface ships, we restarted production of our DDG 51 Arleigh Burke Class destroyers (Flight IIA series). These ships will be the first constructed with IAMD, providing much-needed Ballistic Missile Defense (BMD) capacity to the Fleet, and they will incorporate the hull, mechanical, and electrical alterations associated with our mature DDG modernization

⁴⁶ Cid Standifer, "NAVSEA Plans To Solicit Contracts For Air And Missile Defense Radar," *Inside the Navy*, December 28, 2009; "Navy Issues RFP For Phase II of Air And Missile Defense Radar Effort," *Defense Daily*, December 24, 2009: 4.

⁴⁷ U.S. Navy, *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2011*, February 2010, pp. 12, 13, 19. The first reprinted paragraph, taken from page 12, also occurs on page 3 as part of the executive summary.

program. We will spiral DDG 51 production to incorporate future integrated air and missile defense capabilities....

The Navy, in consultation with the Office of the Secretary of Defense, conducted a Radar/Hull Study for future surface combatants that analyzed the total ship system solution necessary to meet our IAMD requirements while balancing affordability and capacity in our surface Fleet. The study concluded that Navy should integrate the Air and Missile Defense Radar program S Band radar (AMDR-S), SPY-3 (X Band radar), and Aegis Advanced Capability Build (ACB) combat system into a DDG 51 hull. While our Radar/Hull Study indicated that both DDG 51 and DDG 1000 were able to support our preferred radar systems, leveraging the DDG 51 hull was the most affordable option. Accordingly, our FY 2011 budget cancels the next generation cruiser program due to projected high cost and risk in technology and design of this ship. I request your support as we invest in spiraling the capabilities of our DDG 51 Class from our Flight IIA Arleigh Burke ships to Flight III ships, which will be our future IAMD-capable surface combatant. We will procure the first Flight III ship in FY 2016.⁴⁸

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⁴⁸ Statement of Admiral Gary Roughead, Chief of Naval Operations, before the House Armed Services Committee on 24 February, 2010, pp. 10-11; and Statement of Admiral Gary Roughead, Chief of Naval Operations, before the Senate Armed Services Committee on 25 February 2010, pp. 10-11.

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