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

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Summary

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 procured DDG-51s from FY1985 through FY2005, and resumed procuring them in FY2010. The three DDG-51s requested for procurement in FY2019 are to be the 80th, 81st, and 82nd ships in the class. The Navy procured three DDG-1000s in FY2007-FY2009 and plans no further procurement of DDG-1000s.

The 13 DDG-51s planned for procurement in FY2018-FY2022 are to be procured under a multiyear procurement (MYP) contract that Congress approved as part of its action on the Navy's FY2018 budget. DDG-51s procured in FY2017 and subsequent years are being built to a new design (the Flight III DDG-51 design), which incorporates a new and more capable radar called the Air and Missile Defense Radar (AMDR) or SPY-6 radar.

The Navy estimates the combined procurement cost of the three DDG-51s requested for procurement in FY2019 at $5,292.7 million, or an average of $1,764.2 million each. The ships are to receive $39.4 million in prior-year (FY2018) Economic Order Quantity (EOQ) advance procurement (AP) funding (i.e., funding for up-front batch orders of components of DDG-51s to be procured under the FY2018-FY2022 MYP contract). The Navy's proposed FY2019 budget requests the following:

- the remaining $5,253.3 million in procurement funding needed to complete the estimated procurement cost for the three DDG-51s requested for FY2019;
- $391.9 million in additional EOQ AP funding for DDG-51s to be procured under the FY2018-FY2022 MYP contract;
- $54.0 million in cost-to-complete procurement funding to cover cost increases on DDG-51s procured in prior fiscal years; and
- $271.0 million in procurement funding to cover cost increases on Zumwalt (DDG-1000) class destroyers.

Issues for Congress for FY2019 for the DDG-51 and DDG-1000 destroyer programs include the following:

- whether to approve, reject, or modify the Navy's FY2019 funding requests for the DDG-51 and DDG-1000 programs;
- whether to provide funding for the procurement of an additional DDG-51 (for a total procurement of four DDG-51s rather than three) in FY2019;
- continued cost growth in the DDG-1000 program;
- the Navy's intended shift in mission orientation for the DDG-1000s;
- cost, schedule, and technical risk in the Flight III DDG-51 effort; 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 FY2019 budget requests funding for the procurement of three DDG-51s. Decisions that Congress makes concerning destroyer procurement could substantially affect Navy capabilities and funding requirements, and the U.S. shipbuilding industrial base.

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 Ronald O'Rourke.[1]

Background

Navy's Force of Large Surface Combatants (LSCs)

LSC Definition

Decades ago, the Navy's cruisers were considerably larger and more capable than its destroyers. In the years after World War II, however, the Navy's cruiser designs in general became smaller while its destroyer designs in general became larger. As a result, since the 1980s there has been substantial overlap in size and capability of Navy cruisers and destroyers. (The Navy's new Zumwalt [DDG-1000] class destroyers, in fact, are considerably larger than the Navy's cruisers.) In part for this reason, the Navy now refers to its cruisers and destroyers collectively as *large surface combatants (LSCs)*, and distinguishes these ships from the Navy's *small surface combatants (SSCs)*, the term the Navy now uses to refer collectively to its frigates, Littoral Combat Ships (LCSs), mine warfare ships, and patrol craft. The Navy's annual 30-year shipbuilding plan, for example, groups the Navy's surface combatants into LSCs and SSCs.[2]

LSC Force-Level Goal

In December 2016, the Navy released a goal to achieve and maintain a Navy of 355 ships, including 104 LSCs. The 104-ship LSC force-level goal represented an increase of 16 ships over the 88-ship LSC force-level goal that was included in the Navy's previous plan for achieving and maintaining a 308-ship fleet. The 16 additional LSCs included in the 355-ship force-level goal account for about a third of the 47 ships that were added to the 308-ship force-level goal to create the 355-ship force-level goal.[3]

LSC Force at End of FY2017

At the end of FY2017, the Navy's force of LSCs totaled 87 ships, including

[1] See also CRS Report R43838, *A Shift in the International Security Environment: Potential Implications for Defense—Issues for Congress*, by Ronald O'Rourke, and CRS Report R44891, *U.S. Role in the World: Background and Issues for Congress*, by Ronald O'Rourke and Michael Moodie.

[2] The Navy sometimes also uses the term *Cru-Des* (an abbreviation of cruiser-destroyer, pronounced "crew-dez") to refer collectively to its cruisers and destroyers.

[3] For more on the current 355-ship force-level goal and the previous 308-ship force-level goal, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O'Rourke.

- 22 Ticonderoga (CG-47) class cruisers;[4]
- 64 Arleigh Burke (DDG-51) class destroyers; and
- 1 Zumwalt (DDG-1000) class destroyer.

Additional Procurement for Achieving LSC Force-Level Goal

Additional Procurement Needed to Achieve 104-Ship Force

The Navy's FY2017 30-year (FY2017-FY2046) shipbuilding plan, which was intended to support the Navy's previous 308-ship force-level goal (and within that, the 88-ship goal for LSCs), included the procurement of 66 LSCs. The Navy projected that under the FY2017 30-year plan, the Navy would have maintained a force of 86 or more LSCs throughout most of the 30-year period before declining to 80 ships over the final five years of the plan.

CRS estimated in 2017 that 23 LSCs would need to be added to the FY2017 30-year shipbuilding plan (making for a total procurement during the 30-year period of 89 LSCs rather than 66) to achieve a force of 104 LSCs (as called for in the Navy's 355-ship force-level goal) and maintain the LSC force at that level through the end of the 30-year period (i.e., through FY2046)—unless the Navy reactivates retired cruisers and/or extends the service lives of currently active cruisers and destroyers, in which case the needed number of additional LSCs might be something less than 23.

The Congressional Budget Office (CBO) similarly estimated in 2017 that 24 or 25 LSCs would need to be added to the FY2017 30-year shipbuilding plan (making for a total procurement during the 30-year period of 90 or 91 LSCs) to achieve a force of 104 LSCs and maintain the force not only through the end of the 30-year period (i.e., through FY2047), but for another 10 years beyond that (i.e., through FY2057)—unless the Navy reactivates retired cruisers and/or extends the service lives of currently active cruisers and destroyers, in which case the needed number of additional LSCs might be something less than 24 or 25.[5]

Additional Procurement Included in FY2019 30-year Shipbuilding Plan

The Navy's FY2019 30-year (FY2019-FY2048) shipbuilding plan, which is intended to support the Navy's 355-ship force-level goal, includes the procurement of 76 LSCs—10 more than the 66 that were included in the Navy's FY2017 30-year shipbuilding plan, and 13 to 15 less than the 89 to 91 LSCs that CRS and CBO estimated in 2017 would needed to achieve and maintain a 104-ship LSC force on a sustained basis, unless the Navy reactivates retired cruisers and/or extends the service lives of currently active cruisers and destroyers (see previous section). The Navy's FY2019 budget submission also proposes service life extensions for six CG-47 class cruisers.

Consistent with the CRS and CBO estimates from 2017, the Navy projected that the FY2019 30-year shipbuilding plan would not maintain a 104-ship LSC force during most of the 30-year period. More specifically, the Navy projects that under the FY2019 30-year plan, the LSC force would grow to a peak of 104 ships in FY2024, then decline to a minimum of 88 ships in FY2035,

[4] 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.

[5] See CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O'Rourke.

grow to a secondary peak of 96 ships in FY2040 and FY2041, and then drop to a total of 91 or 92 ships in the final years of the plan.[6]

Service Life Extension to 45 Years Announced April 12, 2018

At an April 12, 2018, hearing on the Navy's 355-ship force-level goal before the Seapower and Projection Forces subcommittee of the House Armed Services Committee, Navy officials announced that the Navy has decided to extend the service lives of all DDG-51 destroyers to 45 years. Navy officials testified that this action would permit the Navy to achieve a total of 355 ships by the 2030s, although the resulting mix of ships would not match the mix called for in the Navy's 355-ship force-level goal—there would be more than the required number of LSCs, and fewer than the required numbers of other types of ships. When asked by the subcommittee chairman, Representative Rob Wittman, about the Navy's plans for modernizing its older DDG-51s, Vice Admiral William Merz, Deputy Chief of Naval Operations for Warfare Systems, replied in part:

> Yes, sir, Mr. Chairman. And thanks for that question, because it really does tee up a little bit larger conversation on how we're approaching the DDG-51 class.
>
> So as promised, and as stated in the shipbuilding plan, you know, we saw a path to accelerate this 355 achievement as quickly to the 2030s. And recently, NAVSEA [the Naval Sea Systems Command—the Navy's command for ship procurement and modernization] completed the analysis of that class, so we will, in fact, be extending the entire class out to 45 years.

A bit later in his exchange with Wittman, Merz stated:

> So how does this affect the [achievement of the] 355-ship number? It does—as we stated in the shipbuilding plan—the [total of] 355 [ships] will now be arriving in the mid-'30s [2030s]. And that's only with the DDG[-51] extensions. That does not include [the impact of] candidate options for [procuring] three [rather than two] SSNs per year or any other service life extensions in and around the time period.
>
> Typically the individual hull life extensions will only help you smooth the [ship retirement] ramp. They don't really affect the overall number [of ships] in the end on when you achieve it. But a class-wide extension does, and that's what you're seeing.
>
> So with the extension of that [DDG-51] class, with the modernization efforts with that class, we don't get the correct mix [of ships] in the 2030s, but it's not a bad mix. If you have to have an [sic: some] extra ships, destroyers are good ones to have. And then we'll work with Congress on how we manage that [ship] inventory, because we don't want them [ships with extended service lives] to come at the expense of the new construction [ships], especially the overall driver of [achieving] the correct mix, which is the SSN [force-level goal of 66 boats]. So we'll have to manage that very, very quickly.
>
> And right now, under the current plan, that's [i.e., achieving the 66-boat SSN force-level goal is] still [projected to be] at the 2048 timeline, but like I said, we have done—that [projected 2048 attainment date] does not include [the procurement of] any extra [attack] submarines [in] any particular years. And of course, the CVN plan [i.e., the goal for

[6] For the Navy's year-by-year projection of the number of LSCs under the FY2019 30-year shipbuilding plan, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O'Rourke.

> achieving a 12-carrier force] also is one of the lengthier ones [i.e., projected force-level goal attainment timelines].[7]

DDG-51 Program

Overview

The DDG-51 program was initiated in the late 1970s.[8] 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.

Figure 1. DDG-51 Class Destroyer

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

DDG-51s, like the Navy's 22 Ticonderoga (CG-47) class cruisers, 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.[9]

[7] Source: CQ transcript of hearing.

[8] 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. For an early discussion of the DDG-51 program, see Alva M. Bowen and Ronald O'Rourke, "DDG-51 and the Future Surface Navy," *U.S. Naval Institute Proceedings*, May 1985: 176-189.

[9] 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 (continued...)

The first DDG-51 was procured in FY1985 and entered service in 1991. A total of 79 have been procured through FY2018, including 62 in FY1985-FY2005 and 17 in FY2010-FY2018.[10] (During the period FY2006-FY2009, the Navy procured three Zumwalt [DDG-1000] class destroyers [see discussion below] rather than DDG-51s.) With a total of 79 ships funded through FY2018, the DDG-51 program is, in terms of number of hulls, one of the largest Navy shipbuilding programs since World War II. As noted earlier, as of the end of FY2017, a total of 64 DDG-51s were in service.

Design Changes

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.
- In FY1994, the Navy shifted DDG-51 procurement to the Flight IIA DDG-51 design, which incorporated a significant design change that included, among other things, the addition of a helicopter hangar. A total of 47 Flight IIA DDG-51s (i.e., DDG-79 through DDG-124, plus DDG-127)[11] were procured through FY2016.
- In FY2017, the Navy shifted DDG-51 procurement to the Flight III DDG-51 design, which incorporates a new and more capable radar called the Air and Missile Defense Radar (AMDR) or SPY-6 radar and associated changes to the ship's electrical power and cooling systems. DDG-51s procured in FY2017 and subsequent years (i.e., DDGs 125 and higher, except for DDG-127 noted above) are to be Flight III DDG-51s.

Multiyear Procurement (MYP)

As part of its action on the Navy's FY2018 budget, Congress granted the Navy authority to use a multiyear procurement (MYP) contract for the 13 DDG-51s planned for procurement in FY2018-FY2022. This is the fourth MYP contract for the DDG-51 program—previous DDG-51 MYP contracts covered DDG-51s procured in FY2013-FY2017, FY2002-FY2005, and FY1998-FY2001.

Additional DDG-51s in FY2019 Five-Year Plan

The Navy's FY2018 five-year (FY2018-FY2022) shipbuilding plan included a total of 10 DDG-51s at a rate of two per year. The Navy's FY2019 five-year (FY2019-FY2023) shipbuilding plan includes a total of 14 DDG-51s—3 DDG-51s per year, except for 2 in FY2020. The Navy says that the 14 DDG-51s included in the FY2019 five-year shipbuilding plan are 4 more than the 10 DDG-51s that were included in the period FY2019-FY2023 under the Navy's FY2018 budget submission. (The FY2023 column was not visible to Congress in the Navy's FY2018 budget submission.) The 4 additional DDG-51s in the period FY2019-FY2023 account for more than

(...continued)

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 Ronald O'Rourke.

[10] The 17 DDG-51s procured in FY2010-FY2018 include one in FY2010, two in FY2011, one in FY2012, three in FY2013, one in FY2014, two in FY2015, three in FY2016, two in FY2017, and two in FY2018.

[11] The hull-number discontinuity regarding DDG-127 is an administrative consequence of the ship having been funded as a Congressional addition to the Navy's proposed FY2016 shipbuilding request.

one-third of the 11 ships that the Navy says were added to the FY2019 five-year shipbuilding plan compared to the period FY2019-FY2023 under the Navy's FY2018 budget submission.

Shipbuilders, Combat System Lead, and Radar Makers

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. Lockheed is the lead contractor for the Aegis system installed on all DDG-51s. The SPY-1 radar—the primary radar for the Aegis system on Flight I/II and Flight IIA DDG-51s—is made by Lockheed. The AMDR—the primary radar for the Aegis system on Flight III DDG-51s—is made by Raytheon.

Modernization of Existing DDG-51s

The Navy is modernizing its existing DDG-51s (and its CG-47s) so as to maintain their mission and cost-effectiveness out to the end of their projected service lives.[12]

Service Life Extension to 45 Years

As noted earlier, at an April 12, 2018, hearing on the Navy's 355-ship force-level goal before the Seapower and Projection Forces subcommittee of the House Armed Services Committee, the Navy announced that it wants to extend the service lives of all DDG-51s to 45 years—an increase of 5 or 10 years over previous plans to operate DDG-51s to age 35 or 40. Doing this, the Navy said, would permit the Navy to accelerate from the 2050s to the 2030s the attainment of a fleet with 355 ships, although the 355-ship fleet of the 2030s would have more destroyers and fewer ships of other kinds (including attack submarines and aircraft carriers) than called for in the 355-ship force-level goal. At the hearing, the following exchange occurred:

> REPRESENTATIVE WITTMAN, CHAIRMAN (continuing):
>
> To you, Vice Admiral Merz, in looking at the existing destroyer fleet and looking at the modernization plans, it does appear as there's a significant gap in modernizing Flight I [DDG-51] destroyers and Flight II [DDG-51] destroyers. And there's significant gaps there.
>
> And it seems like a lot of those ships are not going to make it to their expected service life, because we're essentially frontloading much of the modernization on later generation Flight IIs and Flight IIAs. And I understand that with upgrading radars and baseline nine improvements through the Aegis programs.
>
> But I wanted to get your perspective on, how do we take advantage of those existing ships to get the full service life expectations out of those ships, especially with a lot of the technology that's there today? Mr. Norcross and I had an opportunity to travel to the Aegis operational center there, where they're bringing in some of the new radars to test up in Morristown, New Jersey, as well as Lockheed, and we've had conversations with Raytheon. There's a lot of technology out there that seems to me that could be put into these Flight I destroyers and Flight II destroyers that would give us capability that extends well into the years, gets us more quickly to the 355-ship number, and really modernizes these systems as the Navy envisions this multi-ship platform, increased lethality into the future battle space. So give me your perspective on how the Navy envisions that going in the future.

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

VICE ADMIRAL WILLIAM MERZ, DEPUTY CHIEF OF NAVAL OPERATIONS FOR WARFARE SYSTEMS:

Yes, sir, Mr. Chairman. And thanks for that question, because it really does tee up a little bit larger conversation on how we're approaching the DDG-51 class.

So as promised, and as stated in the shipbuilding plan, you know, we saw a path to accelerate this 355 achievement [i.e., achievement of a fleet of 355 ships] as quickly to the 2030s. And recently, NAVSEA [the Naval Sea Systems Command] completed the analysis of that [DDG-51] class, so we will, in fact, be extending the entire class out to [a service life of] 45 years. And this gets directly to your question, OK, now what? What are we going to do with the ships along the way?

So there's a couple types of service life extensions. There's the [extension of selected] individual hull platforms [within a class], [which is] a little bit laborious, ship by ship, [because you] got to figure out how to do it, when to do it, and kind of cram it into the plan...

WITTMAN:

Now, that part of it, let me just jump in real quick. So that part of the plan is the--which [is] what the Navy terms HM&E, hull, mechanical, electrical, and the upgrades there, aside from ship systems upgrades?

MERZ:

It's typically both [i.e., modernization includes both the ship's HM&E systems and its combat system].

WITTMAN:

OK.

MERZ:

We have to look at the whole envelope of the ship. And that's how we go through that lens of, can we, should we [do the modernization], the opportunity cost [of doing the modernization] versus buying new [ships], and it's a pretty structured approach. The much more productive and helpful extension [i.e., the other type of service life extension, as opposed to extensions of selected individual ships within a class] is when we extend [the service life of] the entire class and do the terrific [analytical] work of the NAVSEA engineers. We've come through that [analysis]—I'd say pretty quickly. Unfortunately, it was not completed in time for the [submission of the] current [FY2019] shipbuilding plan, but it will certainly be reflected in subsequent plans.

So with that, now we know the life expectancy of the entire [DDG-51] class and then we can roll in the right maintenance and modernizations much more efficiently, much more affordably for the entire duration of the class.

The good news is, there's no destroyers left behind under the old [modernization] plan. Every destroyer will be modernized. And there's two—we talk in terms of baselines [i.e., DDG-51 combat system configurations]. There's three fundamental baselines the entire class will end up with. You'll either be [baseline] 5.4, [baseline] 9, or [baseline] 10. All of them provide a ballistic missile defense capability, which is fundamentally the requirement we have to have.

So whether that [combination of baselines] carries these [ships] through the [newly adopted 45-year] life of the ship, with the extension, we have time to work through that on what it will take [i.e., whether additional combat system modernization will eventually be needed], and the threat [i.e., adversary capabilities] will get a big vote in how we do that. So how does this affect the 355-ship number? It does—as we stated in the shipbuilding plan—the 355 [ship total] will now be arriving in the mid-[20]'30s. And

> that's only with the DDG[-51] extensions. That does not include [the potential effect of] candidate options for [procuring] three SSNs [attack submarines] per year or any other [potential additional] service life extensions [for other types of ships] in and around the time period.
>
> Typically the individual hull life extensions will only help you smooth the [retirement] ramp [i.e., the decline in the number of ships in a class as the ships reach the end of their service lives and begin to retire]. They don't really affect the overall number [of ships] in the end on when you achieve it [a force-level goal]. But a class-wide extension does, and that's what you're seeing.
>
> So with the extension of that [DDG-51] class, with the modernization efforts with that class, we don't get the correct mix [of 355 ships] in the 2030s, but it's not a bad mix. If you have to have an [sic: some] extra ships [within the mix], destroyers are good ones to have. And then we'll work with Congress on how we manage that inventory, because we don't want them [the life-extended ships] to come at the expense of the new construction [ships], especially the overall driver of [achieving] the correct mix, which is [attaining the 66-boat force-level goal for] the SSN [category]. So we'll have to manage that very, very quickly.
>
> And right now, under the current plan, that's [i.e., achieving the SSN force-level goal] still at the 2048 timeline, but like I said, we have done—that does not include [the procurement of] any extra submarines [in] any particular years. And of course, [attaining] the CVN [i.e., aircraft carrier] plan [i.e., the 12-ship force-level goal for aircraft carriers] also is one of the lengthier ones [i.e., time lines].[13]

Older CRS reports provide additional historical and background information on the DDG-51 program.[14]

DDG-1000 Program

Overview

The DDG-1000 program was initiated in the early 1990s.[15] The DDG-1000 (**Figure 2**) is a multi-mission destroyer with an originally intended emphasis on naval surface fire support (NSFS) and operations in littoral (i.e., near-shore) waters. (NSFS is the use of naval guns to provide fire support for friendly forces operating ashore.) The DDG-1000 was originally 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,[16] to improve the Navy's general capabilities for operating in defended littoral waters, and to introduce several new technologies

[13] Source: CQ transcript of hearing.

[14] 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).

[15] 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.

[16] 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.

that would be available for use on future Navy ships. The DDG-1000 was also intended to serve as the basis for a planned cruiser called CG(X) that was subsequently canceled.[17]

Figure 2. DDG-1000 Class Destroyer

Source: U.S. Navy photo 151207-N-ZZ999-435, posted December 8, 2015, with a caption that reads in part: "The future USS Zumwalt (DDG 1000) is underway for the first time conducting at-sea tests and trials in the Atlantic Ocean Dec. 7, 2015."

The DDG-1000 is to have a reduced-size crew of 175 sailors (147 to operate the ship, plus a 28-person aviation detachment), 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 system[18] and automation technologies enabling its reduced-sized crew.

With an estimated full load displacement of 15,612 tons, the DDG-1000 design is roughly 64% larger than the Navy's current 9,500-ton Aegis cruisers and destroyers, and larger than any Navy 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 FY2019 budget submission estimates their combined procurement cost at $9,242.3 million. The third DDG-1000 was procured in FY2009 and split-funded in FY2009-FY2010; the Navy's FY2019 budget submission estimates its procurement cost at $3,789.9 million.

[17] For more on the CG(X) program, see CRS Report RL34179, *Navy CG(X) Cruiser Program: Background for Congress*, by Ronald O'Rourke.

[18] 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 first DDG-1000 was commissioned into service on October 15, 2016, although its delivery date was revised in the Navy's FY2018 budget submission to May 2018, and revised further in the Navy's FY2019 budget submission to December 2018, creating an unusual situation in which a ship was commissioned into service more than two years prior to its delivery date. The delivery dates for the second and third ships were revised in the Navy's FY2018 budget submission to May 2020 and December 2021, respectively, and were revised further in the Navy's FY2019 budget submission to September 2020 and September 2022, respectively.[19]

Shipbuilders and Combat System Prime Contractor

GD/BIW is the builder for all three DDG-1000s, 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).

Reduction in Procurement to Three Ships

Navy plans for many years called for ending DDG-51 procurement in FY2005, to be followed by procurement of up to 32 DDG-1000s and some number of CG(X)s. In subsequent years, the planned total number of DDG-1000s was reduced to 16 to 24, then to 7, and finally to 3.

At the end of July 2008, in a major reversal of its destroyer procurement plans, the Navy announced that it wanted to end procurement of DDG-1000s and resume procurement of DDG-51s. In explaining this reversal, which came after two DDG-1000s had been procured, the Navy stated that it had reevaluated the future operating environment and determined that its destroyer procurement now needed to emphasize three missions: open-ocean antisubmarine warfare (ASW), countering anti-ship cruise missiles (ASCMs), and countering ballistic missiles. Although the DDG-1000 could perform the first two of these missions and could be modified to perform the third, the Navy concluded that the DDG-51 design could perform these three missions adequately and would be less expensive to procure than the DDG-1000 design.

The Navy's proposal to stop procuring DDG-1000s and resume procuring DDG-51s was presented in the Navy's proposed FY2010 budget, which was submitted to Congress in 2009. Congress, in acting on the Navy's FY2010 budget, approved the idea of ending DDG-1000 procurement and restarting DDG-51 procurement, and procured a third DDG-1000 as the final ship in the class.

In retrospect, the Navy's 2008 reversal in its destroyer procurement plans can be viewed as an early indication of the ending of the post-Cold War era (during which the Navy focused its planning on operating in littoral waters against the land- and sea-based forces of countries such as Iran and North Korea) and the shift in the international security environment to a new situation featuring renewed great power competition (during which the Navy is now focusing its planning

[19] The revised delivery dates for the three ships reflect Section 121 of the FY2017 National Defense Authorization Act (S. 2943/P.L. 114-328 of December 23, 2016), a provision that establishes standards for determining vessel delivery dates and which also required the Secretary of the Navy to certify that the delivery dates for certain ships, including the three DDG-1000s, had been adjusted in accordance with the provision. The Navy's original plan for the DDG-1000 program was to install certain elements of each DDG-1000's combat system after delivering the ship and commissioning it into service. Section 121 of P.L. 114-328 in effect requires the Navy to defer the delivery date of a DDG-1000 until those elements of the combat system are installed. By the time P.L. 114-328 was enacted, DDG-1000, per the Navy's original plan, had already been commissioned into service without those elements of its combat system.

more on being able to operate in mid-ocean waters against capable naval forces from near-peer competitors such as China and Russia).[20]

Change in Mission Orientation

As noted earlier, the DDG-1000 is a multi-mission destroyer with an originally intended emphasis on naval surface fire support (NSFS) and operations in littoral (i.e., near-shore) waters. Consistent with that mission orientation, the ship was designed with two new-design 155mm guns called Advanced Gun Systems (AGSs). The AGSs were to fire a new 155mm, gun-launched, rocket-assisted guided projectile called the Long-Range Land-Attack Projectile (LRLAP, pronounced LUR-lap). DDG-1000s are designed carry 600 LRLAP rounds (300 for each gun), and to have additional LRLAP rounds brought aboard the ship while the guns are firing, which would create what Navy officials called an "infinite magazine." In November 2016, however, it was reported that the Navy had decided to stop procuring LRLAP projectiles because the projected unit cost of each projectile had risen to at least $800,000.[21] The Navy began exploring options for procuring a less expensive (and less capable) replacement munition for the AGSs.

The Navy to date has not announced a replacement munition for the AGSs.[22] In the meantime, it was reported in December 2017 that, due to shifts in the international security environment and resulting shifts in Navy mission needs, the mission orientation of the DDG-1000s will be shifted from an emphasis on NSFS to an emphasis surface strike, meaning the use of missiles to attack surface ships and perhaps also land targets.[23]

Under this new plan, the mix of missiles carried in the 80 vertical launch system (VLS) tubes of each DDG-1000 may now feature a stronger emphasis on anti-ship and land-attack cruise missiles missiles. The two AGSs on each DDG-1000 will, for the time being at least, remain for the most part dormant, pending a final decision on whether to procure a replacement munition for the AGSs (which would require modifying the AGSs and their below-deck munition-handling equipment, since both were designed specifically for LRLAP), or instead pursue another option, such as removing the AGSs and their below-deck equipment and replacing them with additional VLS tubes.

A February 15, 2018, press report states the following:

> The Navy has a new vision for what its enormous high-tech destroyers will do: Killing enemy warships at extended ranges.
>
> The Navy is asking Congress to fund a conversion of its 600-foot stealth destroyers from primarily a land attack ship to an anti-surface, offensive strike platform, according to budget documents released Feb. 12.

[20] For additional discussion, see CRS Report R43838, *A Shift in the International Security Environment: Potential Implications for Defense—Issues for Congress*, by Ronald O'Rourke, and CRS Report RL33153, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, by Ronald O'Rourke.

[21] Christopher P. Cavas, "New Warship's Big Guns Have No Bullets," *Defense News*, November 6, 2016; Sam LaGrone, "Navy Planning on Not Buying More LRLAP Rounds for Zumwalt Class," *USNI News*, November 7, 2016; Ben Guarino, "The Navy Called USS Zumwalt A Warship Batman Would Drive. But at $800,000 Per Round, Its Ammo Is Too Pricey to Fire," *Washington Post*, November 8, 2016.

[22] See Sam LaGrone, "No New Round Planned For Zumwalt Destroyer Gun System; Navy Monitoring Industry," *USNI News*, January 11, 2018; Richard Abott, "Navy Still Has No Plans For DDG-1000 Gun Ammo," *Defense Daily*, January 12, 2018: 1-2.

[23] Megan Eckstein, "New Requirements for DDG-1000 Focus on Surface Strike," *USNI News*, December 4, 2017. See also Richard Abott, "Navy Will Focus Zumwalt On Offensive Surface Strike," *Defense Daily*, December 5, 2017.

> The service's 2019 budget request includes a request for $89.7 million to transform its Zumwalt-class destroyers by integrating Raytheon's long-range SM-6 missile, which can dual hat as both an anti-air and anti-surface missile, as well as its Maritime Strike variant of the Tomahawk missile.
>
> Converting DDG-1000 into a hunter-killer is a win for the surface warfare community's years-long drive to beef up the force's offensive capabilities. It also answers the bell for U.S. Pacific Command, which has been pushing for the Navy to add longer range weapons to offset the increasing threat from Chinese long-range missile technology....
>
> The decision to switch the requirements from a land-attack platform to an anti-surface platform came in November following a review of the requirements, according to the documents.
>
> "After a comprehensive review of Zumwalt class requirements, Navy decided in November 2017 to refocus the primary mission of the Zumwalt Class Destroyers from Land Attack to Offensive Surface Strike," the documents read. "The funding requested in [FY19] will facilitate this change in mission and add lethal, offensive fires against targets afloat and ashore."[24]

Increase in Estimated Procurement Cost

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 $4,055.1 million, or 45.1%, 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

Budget submission	Estimated combined procurement cost (millions of dollars)	Change from prior year's budget submission	Cumulative change from FY2009 budget submission
FY09	8,977.1	—	—
FY10	9,372.5	+395.4 (+4.4%)	+395.4 (+4.4%)
FY11	9,993.3	+620.8 (+6.6%)	+1,016.2 (+11.3%)
FY12	11,308.8	+1,315.5 (+13.2%)	+2,331.7 (+26.0%)
FY13	11,470.1	+161.3 (+1.4%)	+2,493.0 (+27.8%)
FY14	11,618.4	+148.3 (+1.3%)	+2,641.3 (+29.4%)
FY15	12,069.4	+451.0 (+3.9%)	+3,092.3 (+34.4%)
FY16	12,288.7	+219.3 (+1.8%)	+3,311.6 (+36.9%)
FY17	12,738.2	+449.5 (+3.7%)	+3,761.1 (+41.9%)
FY18	12,882.0	+143.8 (+1.1%)	+3,904.0 (+43.5%)
FY19	13,032.2	+150.2 (+1.2%)	+4,055.1 (+45.1%)

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

[24] David B. Larter, "The Navy's Stealth Destroyers to Get New Weapons and a New Mission: Killing Ships," *Defense News*, February 15, 2018. Material in brackets as in original.

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 in the program 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 the 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**), 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 implemented this directive in a year-by-year fashion with each budget submission from FY2010 through FY2015, 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.[25]

The Navy states that the cost growth shown in the FY2019 budget submission (about $150 million from the figure in the FY2018 budget submission) is not due to any problem with shipyard construction performance, but instead reflects costs for design changes resulting from both learning from the construction of the first ship and the shift in the ships' mission orientation from an emphasis on NSFS to an emphasis on surface strike.[26]

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

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 and cutters for the Coast Guard.) Navy surface combatants are overhauled, repaired, and modernized at GD/BIW, HII/Ingalls, and other U.S. shipyards.

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.

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

[26] Source: Navy briefing on FY2019 budget submission for DDG-1000 program for CRS and CBO, March 16, 2018.

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. Several Navy-operated laboratories and other facilities support the Aegis system and other aspects of the DDG-51 and DDG-1000 programs.

FY2019 Funding Request

The Navy estimates the combined procurement cost of the three DDG-51s requested for procurement in FY2019 at $5,292.7 million, or an average of $1,764.2 million each. The ships are to receive $39.4 million in prior-year (FY2018) Economic Order Quantity (EOQ) advance procurement (AP) funding (i.e., funding for up-front batch orders of components of DDG-51s to be procured under the FY2018-FY2022 MYP contract). The Navy's proposed FY2019 budget requests the following:

- the remaining $5,253.3 million in procurement funding needed to complete the estimated procurement cost for the three DDG-51s requested for FY2019;
- $391.9 million in additional EOQ AP funding for DDG-51s to be procured under the FY2018-FY2022 MYP contract;
- $54.0 million in cost-to-complete procurement funding to cover cost increases on DDG-51s procured in prior fiscal years; and
- $271.0 million in procurement funding to cover cost increases on Zumwalt (DDG-1000) class destroyers.

Issues for Congress for FY2019

FY2019 Funding Request

One issue for Congress for FY2019 is whether to approve, reject, or modify the Navy's FY2019 funding requests for the DDG-51 and DDG-1000 programs. In considering this issue, Congress may consider, among other things, whether the Navy has accurately priced the work it is proposing to fund for FY2019.

Funding an Additional DDG-51 in FY2019

Another issue for Congress for FY2019 is whether to provide funding for the procurement of an additional DDG-51 (for a total procurement of four DDG-51s in FY2019 rather than three). Supporters could argue that a fourth ship could help make a start toward procuring the 13 to 15 additional DDG-51s that CRS and CBO estimate would need to be added to the Navy's FY2019 30-year shipbuilding plan to achieve and maintain the Navy's 104-ship large surface combatant force-level goal. (See "Additional Procurement for Achieving LSC Force-Level Goal.") Skeptics or opponents could argue that in a situation of finite defense funding, procuring an additional DDG-51 could reduce funding for other Navy or Department of Defense (DOD) programs, or that there are other, higher-priority Navy or DOD programs to which the funding needed to procure an additional DDG-51 could be applied.

Cost Growth in DDG-1000 Program

Another oversight issue for Congress for FY2019, as in previous years, is the continued cost growth in the DDG-1000 program shown in **Table 1**. Potential oversight questions for Congress include the following: Does the Navy expect the cost growth to continue past FY2019? What is the Navy doing to end this cost growth?

Change in DDG-1000 Mission Orientation

Another potential oversight issue for Congress for FY2019 concerns the Navy's plan to shift the mission orientation of the DDG-1000s from an emphasis on NSFS to an emphasis surface strike. Potential oversight questions for Congress include the following:

- What is the Navy's analytical basis for shifting the ships' mission orientation?
- What are the potential costs of implementing this shift? How much of these costs are in the Navy's FY2019 budget submission?
- How cost-effective will it be to operate and support DDG-1000s as ships with an emphasis on surface strike?
- When does the Navy plan to decide on whether to procure a replacement munition for the ships' AGSs, or instead pursue another option, such as removing the AGSs and their below-deck equipment and installing additional VLS tubes? What would be the cost of the latter option, and how many additional VLS tubes could be installed?
- If the ships will operate with their AGSs for the most part dormant, to what degree will that reduce the return on investment (ROI) involved in developing, procuring, operating, and sporting the DDG-1000s?

Cost, Technical, and Schedule Risk in Flight III DDG-51 Effort

Another oversight issue for Congress for FY2019, as in previous years, concerns cost, technical, and schedule risk for the Flight III DDG-51.

April 2018 GAO Report

An April 2018 Government Accountability Office (GAO) report assessing selected DOD acquisition programs stated the following in its assessment of the Flight III DDG-51:

> **Current Status**
>
> The Navy continues to undertake Flight III detail design activities, which have included extensive changes to the ship's hull, mechanical, and electrical systems to incorporate the SPY-6 radar and restore weight and stability safety margins within the ship. Both Flight III shipbuilders completed zone design activities—three-dimensional modeling of the individual areas within the ship—by December 2017, before the start of lead ship construction. All four of Flight III's critical technologies are mature and undergoing testing. To help reduce technical risk, the Navy plans to field all but one of the critical technologies—the SPY-6 radar—on other ship classes before integration with Flight III.
>
> A draft Test and Evaluation Master Plan for Flight III is under review within DOD. The Director, Operational Test and Evaluation (DOT&E) and the Navy are deliberating whether Flight III initial operational test and evaluation will include the use of a self-defense test ship equipped with the Aegis combat system and SPY-6 radar. The Navy currently does not plan to provide funding for this modified self-defense test ship,

contending there are other means to validate performance. However, DOT&E reports that it will not be able to fully determine Flight III's defensive capabilities without it.

In June and September 2017, the Navy modified existing Flight IIA multiyear procurement contracts—contracts that allow the Navy to procure multiple years' worth of ships on a single contract action—to include construction of the first two Flight III ships, with the Flight III configuration upgrades incorporated. Huntington Ingalls plans to begin construction of DDG 125 in May 2018; Bath Iron Works will begin DDG 126 in April 2019. For later Flight III ships, Congress has authorized the Navy to enter into multiyear procurement contracts for up to 15 additional ships.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. Navy officials noted the DDG 51 program has successfully delivered 65 ships since program inception in 1985 and made awards for 77 ships to date. They said that Flight III design efforts are stable and on track, with planned completion prior to Flight III construction.[27]

Regarding the AMDR specifically, the report stated the following:

Technology Maturity

The program assessed AMDR's four critical technologies as mature. Although the program has continued to further demonstrate the AN/SPY-6(V)1 system's performance and capabilities, as indicated by our attainment of production knowledge section, we believe that the program cannot demonstrate the full maturity of critical technologies until they are tested in their realistic, at-sea environment.

As part of radar development, the contractor built a full-scale, single-face radar array, which the Navy has used extensively for developmental testing. This production-representative array is undergoing live ballistic missile defense and anti-air and anti-surface warfare testing through mid-2018 at the Navy's Pacific Missile Range Facility. In April 2019, the Navy plans to integrate the array and an initial version of the Aegis combat system—which integrates ship sensors and weapon systems to engage threats—planned for DDG 51 Flight III at a land-based test site to support further testing. However, the Navy will not test the full integrated radar and Aegis combat system until both are installed on the lead ship, sometime in 2022.

In spring 2017, AMDR completed software development to support core AN/SPY-6(V)1 capabilities prior to entering production. Remaining software development includes software updates—occurring through 2020—that are intended to enhance radar defense capabilities and integrate the radar with the combat system.

Design Stability and Production Readiness

AMDR entered low-rate initial production for three AN/SPY-6(V)1 radars in May 2017—4 months ahead of schedule—with core system hardware and software complete, a stable design, and production capabilities that meet DOD guidelines, but which fall short of industry best practices. Program officials stated AMDR also realized an overall reduction in procurement cost from the original independent cost estimate due to a better understanding of ownership, production, and material costs realized during development.

The AMDR program office plans to procure more than two-thirds of the total radars prior to operational testing completion. The Navy deliberately planned for AMDR to begin

[27] Government Accountability Office, *Weapon Systems Annual Assessment[:] Knowledge Gaps Pose Risks to Sustaining Recent Positive Trends*, GAO-18-360SP, April 2018, p. 114.

production prior to the start of Aegis upgrade software development, a prerequisite for operational testing, to allow time for key radar technologies to mature and for the design to stabilize, minimizing the risk of beginning combat system development with insufficient radar knowledge. However, the concurrency between AMDR's schedule for Aegis combat system integration, land- and sea-based testing, and production dictates that the Navy will need to address any deficiencies yet to be identified for radar integration with the Aegis upgrade after production is underway or complete for many of the radars. Any retrofitting needed to address these deficiencies could increase costs.

Other Program Issues

AMDR entered production without an approved Test and Evaluation Master Plan. DOD's Director, Operational Test and Evaluation (DOT&E) has expressed concern for several years that the Navy's proposed test approach cannot provide for realistic operational conditions without including the use of an unmanned self-defense test ship equipped with AN/SPY-6(V)1 and Aegis. In 2016, the Deputy Secretary of Defense directed the Navy to include funding for such a test ship in its budget planning. However, in December 2017, program officials stated that the Navy does not plan to request funds for the test ship. Instead, the Navy expects to complete initial operational test and evaluation for DDG 51 Flight III, AN/SPY-6(V)1, and Aegis upgrade through a segmented test approach that includes land-based tests, tests on a manned Flight III ship, and models and simulation. DOT&E reaffirmed to us in late 2017 that for initial operational test and evaluation, the only way to adequately demonstrate the required self-defense capability for Flight III is to test AN/SPY-6(V)1 and Aegis aboard an unmanned test ship.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office also stated that AMDR is executing on schedule, within budget, and remains on schedule for delivery to the DDG 51 Flight III program. It also said that the current developmental test phase, which began at Pacific Missile Range Facility in August 2016, included live testing to demonstrate surface warfare and integrated air and missile defense capabilities. According to the program office, the combat systems integration test event completed in May 2017 led to lessons learned for both the radar and combat system that will enable improvements in interfaces. The program office also said that modeling indicates the ability to support the needs of the Aegis operational requirements for Flight III.

Additionally, the program office reiterated its position that the required self-defense capability for Flight lll can be demonstrated without the use of a AN/SPY-6(V)1 and Aegis equipped unmanned test ship through a combination of land- and sea-based testing on the first Flight III ship and simulation of previous test data.[28]

January 2018 DOT&E Report

A January 2018 report from DOD's Director of Operational Test and Evaluation (DOT&E)—DOT&E's annual report for FY2017—stated the following regarding the Flight III DDG-51:

Assessment

• Absent an AMDR- and Aegis-equipped SDTS [self-defense test ship], the Navy's operational test programs for the AMDR, Aegis Combat System, ESSM [Evolved Seasparrow Missile] Block 2, and DDG 51 Flight III destroyer programs will not be

[28] Government Accountability Office, *Weapon Systems Annual Assessment[:] Knowledge Gaps Pose Risks to Sustaining Recent Positive Trends*, GAO-18-360SP, April 2018, p. 81.

adequate to fully assess their capabilities, in particular those associated with self-defense. They would also not be 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 ASCM [anti-ship cruise missile] threats. The CDD also includes an AMDR minimum track range requirement as part of the IAMD Key Performance Parameter.

- The DDG 51 Flight III destroyer has a survivability Key Performance Parameter 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.

- 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 engagements will take place. The November 2013 mishap on USS Chancellorsville (CG 62) involving an ASCM surrogate target resulted in even more stringent safety constraints.

- In addition to stand-off ranges, 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 preclude manned ship testing of five of the seven self-defense ASCM scenarios included in the Navy-approved requirements document for the Aegis Modernization Advanced Capability Build 20 Combat System upgrade and will severely limit the operational realism of the two scenarios that can be flown against a manned ship. Safety restrictions also 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 on the SDTS 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 Navy should do the same 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 an 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 Navy intends to conduct phases of the ESSM Block 2 IOT&E [initial operational test and evaluation] 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 few test data available concerning ESSM's performance 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 a different radar suite supports.

• The cost of building and operating an Aegis SDTS is estimated to be about $350 Million, compared to the estimated $14 Billion cost of the AMDR development/procurement and the estimated $45 Billion cost of the additional 22 or more DDG 51 Flight III ships that are planned for acquisition. Additionally, the cost of the ships that the DDG 51 Flight III destroyer is expected to protect is approximately $450 Billion in new ship construction over the next 30 years. Failure to adequately test the self-defense capability of DDG 51 Flight III destroyers means their survivability and that of a significant number other of ships the DDG-51 Flight III destroyers are intended to defend will be unknown. It is essential that the Navy program now fund the tests, targets, and Aegis Combat System equipment needed to conduct realistic self-defense testing using an AMDR- and Aegis-equipped SDTS.

• The modifications planned for DDG 51 Flight III are substantial enough to justify an assessment of ship survivability. To assess the effects of those modifications on ship survivability, the DDG 51 Flight III LFT&E strategy should include at least component shock qualification tests, a Total Ship Survivability Trial, a shock trial, and a plan to validate simulation tools used in the survivability assessment. The Navy has not yet developed an LFT&E Strategy for the program.

Recommendations

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

1. Program for and fully 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 (TEMPs) to include a phase of IOT&E using an SDTS equipped with the AMDR and DDG 51 Flight III Combat System.

3. Modify the AMDR, ESSM Block 2, and DDG 51 Flight III TEMPs 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 [Deputy Secretary of Defense] 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.

5. Provide DOT&E the DDG 51 Flight III LFT&E Strategy for review and approval in coordination with the TEMP.

6. Comply with the DEPSECDEF direction to work with DOT&E to develop an integrated test strategy for the DDG 51 Flight III, AMDR, Aegis Modernization, and ESSM Block 2 programs, and document that strategy into draft TEMPs for those programs to be provided to DOT&E.

• FY17 Recommendation.

1. The Navy should program funds in the Future Years Defense Plan to complete all activities and procurement required to conduct adequate operational testing in FY24 of the DDG 51 Flight III, AMDR, and ESSM Block 2's self-defense capabilities on an Aegis-equipped SDTS.[29]

The report also stated the following:

Equipping a Self-Defense Test Ship for Aegis Combat System, Air and Missile Defense Radar, and Evolved Seasparrow Missile Block 2 Operational Testing

The close-in ship self-defense battlespace is complex and presents a number of challenges. For example, this environment requires:

• Weapon scheduling with very little time for engagement

• The combat system and its sensors to deal with debris fields generated by successful engagements of individual ASCMs within a multi-ASCM raid

• Rapid multi-salvo kill assessments for multiple targets

• Transitions between Evolved Seasparrow Missile (ESSM) guidance modes

• Conducting ballistic missile defense and area air-defense missions (i.e., integrated air and missile defense) while simultaneously conducting ship self-defense

• Contending with stream raids of multiple ASCMs attacking along the same bearing, in which directors illuminate multiple targets (especially true for maneuvering threats)

• Designating targets for destruction by the Close-In Weapons System (CIWS)

Multiple hard-kill weapon systems operate close-in, including the Standard Missile 2, the ESSM, and the CIWS. Soft-kill systems such as the Nulka MK 53 decoy launching system also operate close-in. The short timelines required to conduct successful ship self-defense place great stress on combat system logic, combat system element synchronization, combat system integration, and end-to-end performance.

Navy range safety restrictions prohibit close-in testing on a manned ship because targets and debris from successful intercepts will pose an unacceptable risk to the ship and personnel at the ranges where these self-defense engagements take place. These restrictions were imposed following a February 1983 incident on USS Antrim (FFG 20), which was struck with a subsonic BQM-74 aerial target during a test of its self-defense weapon systems, killing a civilian instructor. The first unmanned, remotely controlled self-defense test ship (SDTS) – ex-USS Stoddard – was put into service that same year. A similar incident occurred in November 2013, when two sailors were injured when an aerial target struck USS Chancellorsville (CG 62) during a test of its combat system. The Chancellorsville incident underscores the inherent dangers of testing with manned ships in the close-in battlespace.

The investigation into the Chancellorsville incident caused the Navy to rethink how it will employ subsonic and supersonic aerial targets near manned ships. The Navy has always considered supersonic ASCM targets high risk to safety and will not permit flying them directly at a manned ship. The Navy has invested in a seagoing, unmanned, remotely-controlled test asset (the SDTS) and is using it to overcome these safety restrictions. The Navy is accrediting a high-fidelity M&S capability – utilizing data from the SDTS as well as data from manned ship testing – so that a full assessment of the self-

[29] Department of Defense, *Director, Operational Test and Evaluation, FY 2017 Annual Report*, January 2018, pp. 174-175.

defense capabilities of non-Aegis ships can be completely and affordably conducted. The Navy recognizes that the SDTS is integral to the test programs for certain weapons systems (the Ship Self-Defense System, Rolling Airframe Missile Block 2, and ESSM Block 1) and ship classes (LPD 17, LHA 6, Littoral Combat Ship, LSD 41/49, DDG 1000, and CVN 78). However, it has not made a similar investment in an SDTS equipped with an Aegis Combat System, Air and Missile Defense Radar (AMDR), and ESSM Block 2 for adequate operational testing of the DDG 51 Flight III destroyer self-defense capabilities. The current SDTS lacks appropriate sensors and other combat system elements to test these capabilities.

On September 10, 2014, DOT&E submitted a classified memorandum to USD(AT&L) with a review of the Design of Experiments study by the Navy Program Executive Office for Integrated Warfare Systems. The Navy study attempted to provide technical justification to show that an Aegis-equipped SDTS was not required to adequately assess the self-defense capability of the DDG 51 Flight III class destroyers. DOT&E found that the study presented a number of flawed justifications and failed to make a cogent argument for not using an Aegis-equipped SDTS for operational testing.

On December 10, 2014, the Deputy Secretary of Defense (DEPSECDEF) issued a memorandum directing the Director of Cost Assessment and Program Evaluation (CAPE) to identify viable at-sea operational testing options that meet DOT&E adequacy requirements and to recommend a course of action (with cost estimates, risks, and benefits) to satisfy testing of the AMDR, Aegis Combat System, and ESSM Block 2 in support of the DDG 51 Flight III destroyer program. The CAPE study evaluated four options to deliver an at-sea test platform adequate for self-defense operational testing. Each option required funding beginning in FY18 to support operational testing of these systems in FY22.

On February 10, 2016, the DEPSECDEF directed the Navy to adjust funds within existing resources to procure long lead items to begin procurement of an SDTS equipped with the Aegis Combat System and AMDR. He further directed the Navy to work with DOT&E to develop an integrated test strategy for the DDG 51 Flight III, AMDR, Aegis Modernization, and ESSM Block 2 programs. The DEPSECDEF required the Navy to document that strategy in draft TEMPs for those programs and submit them to DOT&E by July 29, 2016. The Navy has not complied with the direction to provide an integrated test strategy or TEMPs for those programs. Despite initially budgeting for long lead AMDR components, the Navy did not program funding in the Future Years Defense Plan to complete other activities and equipment required to modify the SDTS to support adequate operational testing of the self-defense capabilities of the DDG 51 Flight III, AMDR, and ESSM Block 2 in FY23 as planned. The Navy subsequently removed funding for the long-lead AMDR components.

On November 21, 2016, the DEPSECDEF directed the Navy to fully fund the Aegis SDTS and aerial targets required for testing the DDG 51 Flight III, AMDR, and ESSM Block 2 programs. The Navy initially complied with the direction but subsequently removed all funding for the Aegis SDTS and aerial targets.

On May 4, 2017, the DEPSECDEF directed the Navy to reinstate funding for the Aegis SDTS and associated test firings in compliance with the November 21, 2016, guidance. DOT&E continues to recommend equipping an SDTS with capabilities to support Aegis Combat System, AMDR, and ESSM Block 2 OT&E to test ship self-defense systems' performance in the final seconds of the close-in battle and to acquire sufficient data to validate ship self-defense performance M&S.[30]

[30] Department of Defense, *Director, Operational Test and Evaluation, FY 2017 Annual Report*, January 2018, pp. 328-329.

February 2017 CBO Report

A February 2017 Congressional Budget Office (CBO) report on the cost of the Navy's shipbuilding programs stated the following about the Flight III DDG-51:

> The Navy's strategy for meeting the combatant commanders' goal of improving ballistic missile defense capabilities so that in the future they 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 to create a Flight III configuration. That modification 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.
>
> With those improvements incorporated into the design of the Flight III and the 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 2016 dollars—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 to the ship's design to integrate the new radar.[31]

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

Another issue for Congress for FY2019, as in previous years, 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.

[31] Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2017 Shipbuilding Plan*, February 2017, pp. 28-29.

Legislative Activity for FY2019

Summary of Congressional Action on FY2019 Funding Request

Table 2 summarizes congressional action on the Navy's FY2019 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 FY2019 Funding Request

Millions of dollars, rounded to nearest tenth

		Authorization			Appropriation		
	Request	HASC	SASC	Conf.	HAC	SAC	Conf.
DDG-51 funding							
Procurement funding	5,253.3	4,941.3	5,225.8		5,187.8	5,171.8	
Economic Order Quantity (EOQ) advance procurement (AP) funding	391.9	391.9	641.9		391.9	641.9	
Cost to complete funding for DDG-51s procured in prior years	54.0	54.0	54.0		54.0	54.0	
DDG-1000 funding							
Procurement funding	271.1	271.1	0		271.0	271.0	
Cost to complete funding for DDG-1000s	0	0	271.0		0	0	

Source: Table prepared by CRS based on Navy's FY2019 budget submission, committee and conference reports, and explanatory statements on FY2019 National Defense Authorization Act and FY2019 DOD Appropriations Act.

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.

National Defense Authorization Act for Fiscal Year 2019/John S. McCain National Defense Authorization Act for Fiscal Year 2019 (H.R. 5515/S. 2987)

House

The House Armed Services Committee, in its report (H.Rept. 115-676 of May 15, 2018) on H.R. 5515, recommends the funding levels for the DDG-51 and DDG-1000 programs shown in the HASC column of **Table 2**. The recommended reduction of $312.0 million for DDG-51 procurement funding includes a reduction of $150.0 million for "DDG Flight III Multiyear Procurement Savings" and a reduction of $162.0 million for "Excessive Basic Construction Unit Cost Growth." (Page 344)

Section 131 of H.R. 5515 as reported by the committee states:

> SEC. 131. Limitation on use of funds for DDG–51 destroyers.
>
> None of the funds authorized to be appropriated or otherwise made available by this Act for fiscal year 2019 for Shipbuilding and Conversion, Navy, for DDG–51 class destroyers

> may be obligated or expended until the Secretary of the Navy submits to the congressional defense committees a report that includes—
>
> (1) a detailed description of the current degaussing standards;
>
> (2) a plan for incorporating such standards into the destroyer construction program; and
>
> (3) an assessment of the requirement to backfit such standards in service destroyers.

H.Rept. 115-676 states:

> *Arleigh Burke-class destroyer radar backfit*
>
> The committee notes that Navy witnesses have provided testimony to the committee and indicated their recommendation to extend the service life of the Arleigh Burke-class destroyers for 45 years. Navy notes that expansion of the service life will allow Navy to reach the 355-ship Navy by 2036 or 2037. The committee supports retention of destroyers beyond their current service life but notes that such support is contingent on providing a comprehensive modernization plan for the entirety of the in-service destroyers. As part of this overall modernization of the destroyer fleet, the committee believes that it is essential the Navy develop a next generation maritime radar system for in service Arleigh Burke-class destroyers to address existing and emerging gaps in integrated air and missile defense. The committee understands that the Secretary of the Navy is still developing its strategy for how to pursue this capability. The committee further recognizes that the recent decision to perform a class wide service life extension program (SLEP) on all in service destroyers could have an impact on the timing of a radar backfit program. The committee believes that it would be premature to make any decisions regarding specific radars until the Secretary has completed a comprehensive threat and capabilities based assessment of what will be required for a new radar for in service destroyers. Therefore, the committee directs the Secretary of the Navy to brief the House Armed Services Committee on the details of their DDG–51 radar backfit strategy once an overall modernization strategy has been completed. (Page 18)

H.Rept. 115-676 also states:

> *SPY–6 inherent capabilities*
>
> The committee is aware that next generation AN/SPY–6(V) Air and Missile Defense Radars will soon be entering the fleet. As the SPY–6 family of radars begin to deploy and better protect our service members and allies, the committee is also aware that capabilities beyond those designed for nominal radar operations may exist. To provide the committee a better understanding of the full range of capabilities resident in SPY–6(V) radar modular assembly (RMA) based radars, the committee directs the Secretary of the Navy to provide a briefing to the House Armed Services Committee on a plan that will exploit the inherent capabilities of SPY–6(V) within 90 days from the enactment of this Act. (Page 19)

Senate

The Senate Armed Services Committee, in its report (S.Rept. 115-262 of June 5, 2018) on S. 2987, recommends the funding levels for the DDG-51 and DDG-1000 programs shown in the SASC column of **Table 2**. The recommended reduction of $27.5 million in DDG-51 procurement funding is for "Multiyear procurement contract savings," and the recommended increase of $250.0 million in DDG-51 advance procurement (AP) funding is for "Enable greater long lead material procurement." (Page 455) As shown in **Table 2**, S.Rept. 115-262 recommends transferring the $271.0 million requested for DDG-1000 procurement funding to the cost-to-complete (aka completion of prior year [PY] shipbuilding) line in the Navy's shipbuilding account.

Regarding the recommendations for DDG-51 program funding, S.Rept. 115-262 states:

> **Arleigh Burke-class destroyers**
>
> The budget request included $5.3 billion in line number 9 of [the] Shipbuilding and Conversion, Navy (SCN) [account], for Arleigh Burke-class destroyer procurement.
>
> The committee notes the budget request includes procurement of three Arleigh Burke-class destroyers, which is one additional destroyer in fiscal year 2019 as compared to last year's request. The committee further notes the unit costs of the fiscal year 2019 destroyers slightly increased. The committee believes a higher procurement rate should decrease unit costs.
>
> Therefore, the committee recommends a decrease of $27.5 million in line number 9 of [the] SCN [account].
>
> **Arleigh Burke-class destroyer advance procurement**
>
> The budget request included $391.9 million in line number 10 of [the] Shipbuilding and Conversion, Navy (SCN) [account], for Arleigh Burke-class destroyer advance procurement.
>
> The committee notes the Navy future years defense program includes procurement of two Arleigh Burke-class destroyers in fiscal year 2020, which would be procured using a multiyear procurement contract. The committee understands that advance procurement of long lead time material could reduce component costs and enable optimal ship construction intervals.
>
> Therefore, the committee recommends an increase of $250.0 million in line number 10 of [the] SCN [account]. (Pages 24-25)

Regarding the recommendation for DDG-1000 program funding, S.Rept. 115-262 states:

> **DDG–1000**
>
> The budget request included $271.0 million in line number 8 of [the] Shipbuilding and Conversion, Navy (SCN) [account], for procurement of the DDG–1000 program.
>
> The committee notes these funds are requested as subsequent year full funding. The committee is unaware of incremental funding authority for this program in fiscal year 2019.
>
> Therefore, the committee recommends a decrease of $271.0 million in line number 8 of [the] SCN [account] and transfer of these funds to line number 28 [of the SCN account] for completion of the prior year shipbuilding program.[32]

[32] S.Rept. 115-262 similarly states on page 27:

> **Completion of prior year shipbuilding programs**
>
> The budget request included $207.1 million in line number 28 of [the] Shipbuilding and Conversion, Navy (SCN) [account], for completion of prior year shipbuilding programs.
>
> The committee notes $271.0 million are requested in line number 8 [of the SCN account] as subsequent year full funding for the DDG–1000 program. The committee is unaware of incremental funding authority for this program in fiscal year 2019.
>
> The committee further notes the budget request in line number 28 funds completion of prior year shipbuilding programs, including cost overruns for seven Littoral Combat Ships, three Arleigh Burke-class destroyers, three Ship to Shore Connectors, CVN–78, and LHA–7.
>
> Therefore, the committee recommends an increase of $271.0 million in line number 28 of [the] SCN [account] and the transfer of these funds from line number 8.

CRS and CBO, in a prior-year briefing on the DDG-1000 program, asked the Navy briefers why the Navy places (continued...)

FY2019 DOD Appropriations Act (H.R. 6157/S. 3159)

House

The House Appropriations Committee, in its report (H.Rept. 115-769 of June 20, 2018) on H.R. 6157, recommends the funding levels for the DDG-51 and DDG-1000 programs shown in the HAC column of **Table 2**. The recommended reduction of $65.49 million in DDG-51 procurement funding is for "Basic construction excess growth" ($62.0 million) and "Electronics excess growth" ($3.49 million). (Page 161)

Senate

The Senate Appropriations Committee, in its report (S.Rept. 115-290 of June 28, 2018) on S. 3159, recommends the funding levels for the DDG-51 and DDG-1000 programs shown in the SAC column of **Table 2**. The recommended reduction of $81.5 million in DDG-51 procurement funding is for "Restoring acquisition accountability: Excess growth in multiyear procurement program," and the recommended increase of $250.0 million in DDG-51 advance procurement (AP) funding is for "Program increase: Advance procurement for an additional fiscal year 2020 ship." (Page 105)

Regarding research and development funding for the DDG-1000 program (funding that is not shown in **Table 2**), S.Rept. 115-290 states:

> *DDG 1000 Mission Change*.—The fiscal year 2019 President's request includes $40,852,000 in fiscal year 2019 and $396,194,000 over the next 5 years in research, development, test and evaluation for development efforts in support of new DDG 1000 mission requirements. The Committee notes that the requirements, schedules and revised Test and Evaluation Master Plan in support of the new DDG 1000 mission are not yet complete and therefore recommends a reduction of $21,000,000. (Page 177)

(...continued)

continued procurement funding for DDG-1000s on the DDG-1000 procurement funding line rather than the cost-to-complete funding line. The briefers replied that because the DDG-1000s were originally funded incrementally in FY2007-FY2008 (DDG-1000 and DDG-1001) and FY2009-FY2010 (DDG-1002), the Navy classifies additional funds needed to complete the ships as additional funding increments for the DDG-1000 procurement funding line, rather than as cost-to-complete funding. It can also be noted, however, that while Navy Ford (CVN-78) class aircraft carriers and LHA-6 class amphibious assault ships are incrementally funded, the Navy classifies additional funds needed to complete those ships as cost-to-complete funding.

Appendix. 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[33]

- **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.[34]

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.[35]

New Technologies

The DDG-1000 incorporates a significant number of new technologies, including a wave-piercing, tumblehome hull design for reduced detectability,[36] 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,[37] a total-ship computing system for moving information about the ship, automation technologies enabling its reduced-sized crew, a dual-band radar, a new kind

[33] 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).

[34] For more on the LCS program, see CRS Report RL33741, *Navy Littoral Combat Ship (LCS) Program: Background and Issues for Congress*, by Ronald O'Rourke.

[35] For more on Navy ship names, see CRS Report RS22478, *Navy Ship Names: Background for Congress*, by Ronald O'Rourke.

[36] 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.

[37] 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.

of vertical launch system (VLS) for storing and firing missiles, and two copies of a new 155mm gun called the Advanced Gun System (AGS).

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/Ingalls[38] 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 the 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 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.

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

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.[39]

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/Iingalls 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 security and that there are no alternatives to the program that will provide acceptable capability to meet the joint military requirement at less cost.[40]

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.[41] 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

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

[40] For more on the Nunn-McCurdy provision, see CRS Report R41293, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, by Moshe Schwartz and Charles V. O'Connor.

[41] 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.

acquisition unit cost (PAUC)—one of two measures used under the Nunn-McCurdy provision for measuring cost growth[42]—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.[43] 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 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.[44]

[42] 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.

[43] 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.

[44] 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.

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.[45] 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 the following: "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."[46]

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%, 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]."

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

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

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.[47]

Technical Risk and Test and Evaluation Issues

April 2018 GAO Report

An April 2018 GAO report assessing selected major DOD weapon acquisition programs stated the following of the DDG-1000 program:

> **Technology Maturity and Design Stability**
>
> Several DDG 1000 critical technologies continue to approach maturity, although the program reports it has released 100 percent of its basic and functional design work, which the program office considers a stable design. As the program continues to mature each technology into a final form, fit, and function, the program may need to revise its basic and functional design to accommodate necessary changes, which could compromise the program's design stability.
>
> To date the Navy has fully matured 5 of 12 critical technologies with plans to demonstrate most of the remaining technologies during post-delivery availability and combat systems activation. In November 2016, program officials reported that the Navy canceled its planned acquisition of the long-range land-attack projectile—a critical technology—due to the munition's high cost per round. DDG 1000 destroyers planned to rely on these munitions for precision fires and offensive operations. The Navy evaluated 5 other munition options but none could meet DDG 1000's requirements. Consequently, the Navy has decided not to pursue a replacement munition, guided or unguided, in the near term—effectively rendering the gun systems useless for combat operations in the foreseeable future.
>
> The planned date for completion of software development for the class has slipped to September 2018, a 9-month slip since last year, due to delays in starting combat system activation trials. These trials will mark the first time that DDG 1000's total ship computing environment, including software, is integrated with system-representative hardware.
>
> The DDG 1000 design was not stable at lead ship fabrication start in 2009—an approach inconsistent with best practices—although the Navy and its shipbuilders reported otherwise at the time. Ongoing development and shipboard testing of technologies have resulted in design changes that have led to significant schedule delays and cost increases.
>
> **Production Readiness**
>
> The HM&E systems for all three ships of the class have been delivered or are approaching completion. Delivery of the lead ship's HM&E was 18 months behind schedule due in part to challenges completing electrical work associated with the lead ship's power system, a critical technology which provides energy to DDG 1000's propulsion and combat systems simultaneously.
>
> When the lead ship's HM&E was delivered in May 2016, the Navy identified over 320 serious deficiencies that could impact ship operation or safety. Program officials noted the lead ship will not complete final contract trials, foregoing an opportunity to identify

[47] Christopher J. Castelli, "Pentagon Approves Key Milestone For Multibillion-Dollar Destroyer," *Inside the Navy*, November 22, 2010.

and mitigate technical and design deficiencies prior to completing construction of the remaining two ships. As of October 2017, the two remaining ships in the class were 97 and 67 percent complete, with HM&E delivery expected in March 2018 and March 2020, respectively.

Other Program Issues

The Chief of Naval Operations (CNO) recently approved a change in DDG 1000's primary focus from land attack to offensive surface strike. Following a decision to cancel procurement of the long-range land attack projectile, the Navy developed seven courses of action that include, among other things, outlining new missions and associated modifications for the ship. Upon completing these efforts, the Navy, in a January 2018 decision memorandum, changed the ship's mission and, among other things, tasked the program office with examining the cost and schedule implications of removing the gun systems and replacing them with additional launch cells, in addition to providing a summary of requirements to restart DDG 1000 production beyond the three current ships. The DDG 1000's current baseline does not yet reflect the changes resulting from the CNO's decision. Any changes to the baseline may further delay the program's schedule. Since last year, delays in the start of combat system activation and integrating new capability have resulted in an additional 1-year delay to the lead ship's initial operational capability date. Mission change notwithstanding, DDG 1000 will not be ready to deploy until 2021—5 years after the Navy accepted delivery of the HM&E systems.

Program Office Comments

We provided a draft of this assessment to the program office for review and comment. The program office provided technical comments, which we incorporated where appropriate. The program office stated that, as the lead ship in the Zumwalt class, DDG 1000 has experienced technical and producibility challenges not uncommon to first-of-class ships. It also stated that lessons learned from the lead ship are being applied to follow-on ships, as evidenced by reductions in DDG 1001 and DDG 1002 production labor hours. DDG 1001 completed acceptance trials in February 2018, and according to the program, demonstrated a sharp reduction in deficiencies as compared to the lead ship. The program anticipates preliminary acceptance of DDG 1001 in March 2018 followed by combat system activation in the ship's San Diego homeport later this year. Additionally, the program stated that DDG 1002 construction is 74 percent complete. The program said that in November 2017, after a review of mission requirements, Navy leadership refocused the primary mission of the Zumwalt class on lethal, offensive fires against targets afloat and ashore. The program stated that the Navy's fiscal year 2019 budget request supports this change.[48]

December 2016 DOT&E Report

The January 2018 report from DOD's Director of Operational Test and Evaluation (DOT&E)—DOT&E's annual report for FY2017[49]—mentions the DDG-1000 program several times in passing in sections focused on other Navy programs, but does not contain a section focused on the DDG-1000 program itself.

The December 2016 report from DOD's Director of Operational Test and Evaluation (DOT&E)—DOT&E's annual report for FY2016—did contain a section focused on the DDG-1000 program, which stated the following:

[48] Government Accountability Office, *Weapon Systems Annual Assessment[:] Knowledge Gaps Pose Risks to Sustaining Recent Positive Trends*, GAO-18-360SP, April 2018, p. 87.

[49] Department of Defense, *Director, Operational Test and Evaluation, FY 2017 Annual Report*, January 2018, 356 pp.

Assessment

• The threat torpedo surrogates currently available for operational assessment of the Zumwalt-class destroyer have significant limitations in their representation of threat torpedoes. The proposed development of a GTT [general threat torpedo] addresses many of the DOT&E concerns; however, the GTT's capability to support realistic operational testing is dependent upon future Navy decisions to procure sufficient quantity of GTTs.

• All three ships of the Zumwalt class share significant new designs, including the unique wave-piercing tumblehome hull form, as well as the new Integrated Power System, Total Ship Computing Environment (software, equipment, and infrastructure), Integrated Undersea Warfare System, Peripheral Vertical Launching System, the AGS, and the associated automated magazines. These systems and equipment have not been subjected to shock testing on previous ship classes. Moreover, the significant automation and relatively small crew may limit the sailors' ability to conduct repairs needed to enable recovery from shock-induced damage.

• Additional AN/SPY-3 radar development and testing at the Wallops Island test facility has significantly compressed the schedule for self-defense testing of the Zumwalt-class destroyer and the Gerald R. Ford-class nuclear aircraft carrier on SDTS [self-defense test ship]. The completion of this live-fire testing, and the subsequent use of the Probability of Raid Annihilation test bed, is essential to be able to evaluate the self-defense and survivability of the Zumwalt-class destroyer. The Navy must identify how the required ship self-defense testing will be completed prior to deployment of a Zumwalt-class destroyer. This may mean delaying the AN/SPY-3 radar installation on DDG 1002.

• The Navy has requested funding in FY18/19 to execute a reduced scope component shock qualification program, and is going through the process to identify the equipment/systems and shock grade to which these will be qualified.

- Indications are that the number of components undergoing shock qualification will be a reduced set, which will introduce risk for the shock trial. Additionally, by reducing the number of components undergoing shock qualification, the assessment of the vulnerability and recoverability capability of the ship at design levels for underwater threats will be limited. The Navy had indicated in prior years that the component shock testing would be funded and conducted prior to installation of any equipment on the first ship, which is the normal, common-sense approach. However, the Navy diverted that funding to other uses; so, the component shock testing was not done and cannot now be done in the normal sequence.

- Despite these limitations, the shock trials currently scheduled for FY20 must be performed at the traditional severity levels for a surface combatant. These trials will now be the sole source of comprehensive data on the survivability of mission-critical ship systems to shock, and are therefore critical to the success in combat of the ship and her crew.

• The Program Office and the Navy Technical Community encountered problems when attempting to upgrade the survivability M&S [modeling and simulation] tools, which led them to an off-ramp decision to perform the DDG 1000 vulnerability analysis using the existing M&S tools and methods with known shortfalls. The Navy could benefit largely from existing improvements in specific M&S modules by troubleshooting the upgraded M&S modules in a stand-alone mode before integrating them into the over-arching survivability M&S tool that has demonstrated module interface and integration issues. The Navy should also develop a long-term investment strategy to improve the confidence and fidelity levels of its vulnerability and recoverability M&S tools.

• If the Zumwalt-class destroyers are not outfitted with LRLAP because of the high cost of the projectiles, the ships will have no capability to conduct Joint Surface Fire Support missions until replacement projectiles are acquired and the AGS is modified to fire the

new projectiles. Thus, Zumwalt-class destroyers' land attack capability will be limited to TLAMs.

• The currently approved version of the TEMP [test and evaluation master plan] does not address significant changes to the Zumwalt-class destroyer baseline, test strategies and delays in the production schedule. The TEMP revision in Navy routing is required to support operational test.

Recommendations

• Status of Previous Recommendations. The Navy should address the following open recommendations from FY15 and earlier:

1. Fund and schedule component shock qualification to support the Zumwalt-class destroyers' requirement to maintain all mission essential functions when exposed to underwater explosion shock loading.

2. Develop and conduct an accreditation plan to assess the acceptability of the Probability of Raid Annihilation test bed to support operational testing of the ship's air defense effectiveness.

• FY16 Recommendations. The Navy should:

1. Complete the revision to the TEMP that accounts for Zumwalt-class destroyer baseline changes and system delivery schedule.

2. Acquire a sufficient quantity of GTTs, when developed, to support testing and fully characterize Zumwalt-class destroyer capability to defeat threat torpedoes during FOT&E.

3. Develop and implement a strategy to address the current limitations with damage predictions in the underwater and air explosion vulnerability assessment tools.

4. Update DOT&E on the details of the component shock qualification program.

5. Develop and implement a strategy to complete self-defense testing of the Zumwalt-class destroyer on the SDTS.[50]

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[50] Department of Defense, *Director, Operational Test and Evaluation, FY 2016 Annual Report*, December 2016, pp. 228-229.