

CRS Report for Congress

Navy DDG-1000 Destroyer Program: Background, Oversight Issues, and Options for Congress

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Ronald O'Rourke
Specialist in National Defense
Foreign Affairs, Defense, and Trade Division



Prepared for Members and
Committees of Congress

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Summary

The Navy is procuring a new kind of destroyer called the DDG-1000 (formerly the DD(X)). Navy plans call for procuring 7 DDG-1000s between FY2007 and FY2013. The first two DDG-1000s were procured in FY2007 and are being split-funded (i.e., incrementally funded) across FY2007 and FY2008. The Navy estimates the combined procurement cost of the first two DDG-1000s at \$6,370 million. The two ships received \$1,010 million in FY2005 and FY2006 advance procurement funding, and \$2,557 million in FY2007 procurement funding. The Navy's FY2008 budget requests the two ships' remaining \$2,802 million in procurement funding. The Navy's FY2008 budget also requests \$151 million in advance procurement funding for the third DDG-1000, whose procurement cost the Navy estimates at \$2,563 million, and \$503 million in research and development funding for the DDG-1000 program.

The DDG-1000 program raises several potential oversight issues for Congress, including the accuracy of Navy cost estimates for the program, technical risk and system integration, the acquisition strategy for the third and subsequent ships in the program, the shared-production arrangement for the program, and the program's potential implications for the shipbuilding industrial base. Potential options for Congress for the DDG-1000 program include supporting the Navy's proposed plans, using a block-buy arrangement for procuring several DDG-1000s, and curtailing procurement of DDG-1000s.

FY2008 Defense Authorization Bill (H.R. 1585/S. 1547). The **House Armed Services Committee**, in its report (H.Rept. 110-146 of May 11, 2007) on H.R. 1585, recommended approving the Navy's request for FY2008 procurement funding for the DDG-1000 program and increasing the Navy's FY2008 request for research and development funding for the program by \$9 million. The **Senate Armed Services Committee**, in its report (S.Rept. 110-77 of June 5, 2007) on S. 1547, recommended approving the Navy's request for FY2008 procurement funding for the program and increasing the Navy's FY2008 request for research and development funding for the program by \$15 million.

FY2008 Defense Appropriations Bill (H.R. 3222). The **House Appropriations Committee**, in its report (H.Rept. 110-279 of July 30, 2007) on H.R. 3222, recommended reducing the Navy's FY2008 procurement funding request for the DDG-1000 program by \$30 million and increasing the Navy's FY2008 request for research and development funding for the program by \$8 million. The **Senate Appropriations Committee**, in its report (S.Rept. 110-155 of September 14, 2007) on H.R. 3222, recommended increasing the Navy's FY2008 procurement funding request for the DDG-1000 program by \$4.8 million and increasing the Navy's FY2008 request for research and development funding for the program by \$16 million.

This report will be updated as events warrant.

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Introduction

The Navy is procuring a new kind of destroyer called the DDG-1000 (formerly the DD(X)). Navy plans call for procuring 7 DDG-1000s between FY2007 and FY2013. The first two DDG-1000s were procured in FY2007 and are being split-funded (i.e., incrementally funded) across FY2007 and FY2008. The Navy estimates the combined procurement cost of the first two DDG-1000s at \$6,370 million. The two ships received \$1,010 million in FY2005 and FY2006 advance procurement funding, and \$2,557 million in FY2007 procurement funding. The Navy's FY2008 budget requests the two ships' remaining \$2,802 million in procurement funding. The Navy's FY2008 budget also requests \$151 million in advance procurement funding for the third DDG-1000, whose procurement cost the Navy estimates at \$2,563 million, and \$503 million in research and development funding for the program.

The issue for Congress is whether to approve, modify, or reject the Navy's proposals for the DDG-1000 program. Decisions that Congress makes on procurement of surface combatants will significantly affect future Navy capabilities, Navy funding requirements, and the U.S. defense industrial base.

This report previously covered both the DDG-1000 destroyer program and the CG(X) cruiser program. The CG(X) program is now covered in CRS Report RL34179, *Navy CG(X) Cruiser Program: Background, Oversight Issues, and Options for Congress*, by Ronald O'Rourke.

Background

DDG-1000 Program

Origin of Program. 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:¹

¹ The DD-21 program was part of a Navy surface combatant acquisition effort begun in the
(continued...)

- **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,² 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.³

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.⁴

Planned Surface Combatant Force Structure. The Navy in coming years wants to achieve and maintain a fleet of 313 ships, including 88 cruisers and destroyers and 55 LCSs.⁵ The 88 cruisers and destroyers are to include 7 DDG-1000s, 19 CG(X) cruisers, and 62 older Arleigh Burke (DDG-51) class Aegis destroyers.⁶

¹ (...continued)

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).

² For more on the CG(X) program, see CRS Report RL34179, *Navy CG(X) Cruiser Program: Background, Oversight Issues, and Options for Congress*, by Ronald O’Rourke.

³ For more on the LCS program, see CRS Report RL33741, *Navy Littoral Combat Ship (LCS) Program: Oversight Issues and Options for Congress*, by Ronald O’Rourke.

⁴ For more on Navy ship names, see CRS Report RS22478, *Navy Ship Names: Background For Congress*, by Ronald O’Rourke.

⁵ For more on the proposed 313-ship fleet, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O’Rourke.

⁶ The Navy’s 62 DDG-51s were procured between FY1985 and FY2005. The first entered service in 1991. By the end of FY2006, 49 had entered service and the remaining 13 were in various stages of construction, with the final ships scheduled to be delivered in 2010 or 2011. The Navy plans to give DDG-51s a mid-life modernization and operate them to age 35. (See CRS Report RS22595, *Navy Aegis Cruiser and Destroyer Modernization: Background and Issues for Congress*, by Ronald O’Rourke.) The DDG-51s, which displace about 9,200 tons, are equipped with the Aegis combat system and are therefore referred to

(continued...)

Planned DDG-1000 Procurement Through FY2013. Table 1 shows planned procurement of DDG-1000s in the FY2008-FY2013 Future Years Defense Plan (FYDP). As shown in the table, the Navy plans to procure all 7 DDG-1000s by the end of the FYDP. The Navy originally envisaged procuring a total of 16 to 24 DDG-1000s. Navy officials subsequently testified in February and March 2005 that they had a requirement for 8 to 12. The Navy's 313-ship plan, announced in February 2006, reduced the planned total to 7.

Table 1. Planned DDG-1000 Procurement

| | FY07 | FY08 | FY09 | FY10 | FY11 | FY12 | FY13 |
|-----------------|----------------|----------------|------|------|------|------|------|
| DDG-1000 | 2 ^a | 0 ^a | 1 | 1 | 1 | 1 | 1 |

Source: FY2008-FY2013 Future Years Defense Plan (FYDP).

a. Two DDG-1000s procured in FY2007 using split funding across FY2007 and FY2008.

Ship Missions and Design Features. The DDG-1000 program is essentially a restructured continuation of the earlier DD-21 program, and the DDG-1000 will resemble the DD-21 in terms of mission orientation and ship design: The DDG-1000 is to be a multimission ship with an emphasis on land-attack operations, reflecting a Navy desire to replace the large-caliber naval gunfire support capability that the Navy lost in 1990-1992, when it removed its four reactivated Iowa-class battleships from service.

The DDG-1000 is to have a reduced-size crew (compared to the Navy's current destroyers and cruisers) of about 142 sailors so as to permit reduced operating and support (O&S) costs. The ship is to incorporate a significant number of new technologies, including a wave-piercing, tumblehome hull design for reduced detectability, a superstructure made partly of large sections of composite materials rather than steel or aluminum, an integrated electric-drive propulsion system, a total-ship computing system for moving information about the ship, automation technologies for the reduced-sized crew, a dual-band radar, a new kind of vertical launch system (VLS) for storing and firing missiles, and two copies of a 155mm gun called the Advanced Gun System (AGS).

With a full load displacement of 14,564 tons, the DDG-1000 design is roughly 50% 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.

Program Funding. Table 2 shows DDG-1000 funding through FY2013. As can be seen in the table, the Navy requested \$503 million in FY2008 research and development funding for the DDG-1000 program. This \$503 million is included within \$621 million that the Navy requested in FY2008 for a line item (i.e., program element) in the Navy's research and development account called "SC-21 Total Ship System Engineering" (PE0604300N, the 100th line item in the account). This line

⁶ (...continued)
as Aegis destroyers.

item includes research and development funding for both the DDG-1000 and CG(X) programs. The other \$118 million requested in this line item is for the CG(X) program.⁷

Table 2. DDG-1000 Program Funding, FY2002-FY2013
(millions of then-year dollars, rounded to nearest million)

| | FY 02 | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | FY 08 | FY 09 | FY 10 | FY 11 | FY 12 | FY 13 | Total thru FY13 |
|--------------------------------------------------------------------------|------------|------------|-------------|-------------|----------------|-------------|------------------|-------------|-------------|-------------|-------------|-------------|-----------------|
| Research, Development, Test and Evaluation, Navy (RDTEEN) account | | | | | | | | | | | | | |
| DDG-1000 ^a | 490 | 895 | 1002 | 1120 | 1041 | 788 | 503 | 426 | 500 | 555 | 320 | 174 | 7814 |
| Shipbuilding and Conversion, Navy (SCN) account | | | | | | | | | | | | | |
| DDG-1000 | 0 | 0 | 0 | 220 | 285 | 1285 | 1401 | 0 | 0 | 0 | 0 | 0 | 3191 |
| -Construction | 0 | 0 | 0 | 0 | 8 | 825 | 1401 | 0 | 0 | 0 | 0 | 0 | 2234 |
| -DD/NRE ^d | 0 | 0 | 0 | 220 | 277 | 460 | 0 | 0 | 0 | 0 | 0 | 0 | 957 |
| DDG-1001 | 0 | 0 | 0 | 84 | 421 | 1272 | 1401 | 0 | 0 | 0 | 0 | 0 | 3179 |
| -Construction | 0 | 0 | 0 | 0 | 8 ^b | 839 | 1401 | 0 | 0 | 0 | 0 | 0 | 2248 |
| -DD/NRE ^c | 0 | 0 | 0 | 84 | 413 | 433 | 0 | 0 | 0 | 0 | 0 | 0 | 930 |
| DDG-1002 | 0 | 0 | 0 | 0 | 0 | 0 | 151 | 2412 | 0 | 0 | 0 | 0 | 2563 |
| -Construction | 0 | 0 | 0 | 0 | 0 | 0 | 151 ^d | 2338 | 0 | 0 | 0 | 0 | 2489 |
| -Plans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 74 | 0 | 0 | 0 | 0 | 74 |
| DDG-1003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51 | 2450 | 0 | 0 | 0 | 2501 |
| DDG-1004 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51 | 2215 | 0 | 0 | 2266 |
| DDG-1005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 2320 | 0 | 2370 |
| DDG-1006 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 2065 | 2115 |
| Subtotal SCN | 0 | 0 | 0 | 304 | 706 | 2557 | 2954 | 2463 | 2501 | 2265 | 2370 | 2065 | 18185 |
| TOTAL | 490 | 895 | 1002 | 1424 | 1747 | 3345 | 3457 | 2889 | 3001 | 2820 | 2690 | 2239 | 25999 |

Source: Navy office of Legislative Affairs, March 28, 2007. Figures may not add due to rounding.

- DDG-1000 portion of SC-21 Total Ship System Engineering (PE0604300N). Figures do not include \$1,111.4 million in RDT&E funding provided for DD-21/DD(X) program in FY1995-FY2001. Figures also do not include funding for Congressional adds in PE 0604300N. Additional funding required after FY2013.
- Funding for procurement of long lead time materials (forgings) for AGS.
- Detail design and non-recurring engineering costs for the class, including NRE costs for mission systems.
- Funding for procurement of long lead time materials for AGS, external communications, and land-based testing.

As can also be seen in the table, when about \$1.1 billion in pre-FY2002 DD-21/DD(X) research and development costs are included, the Navy estimates the total acquisition (i.e., development plus procurement) cost of the seven-ship DDG-1000 program through FY2013 at about \$27.1 billion in then-year dollars, or an average of about \$3.87 billion per ship. Several major technologies developed for the DDG-

⁷ As discussed in a previous footnote, SC-21 means surface combatant for the 21st Century and refers to the Navy's pre-November 2001 SC-21 program to develop a destroyer called the DD-21 (now called the DDG-1000) and an eventual cruiser called the CG-21 (now called CG(X)).

1000 are to be used on the CG(X) cruiser and other future Navy ships, so at least some portion of the DDG-1000 program's research and development costs might be viewed as not truly specific to the DDG-1000 program. As can be seen in the table, when the DDG-1000 program's research and development costs are excluded, the Navy estimates the total procurement cost of the DDG-1000 program through FY2013 at about \$18.2 billion in then-year dollars, or an average of about \$2.6 billion per ship.

Navy Contracting and Management. Since September 30, 2005, the Navy has managed the DDG-1000 program through a series of separate contracts with major DDG-1000 contractors, including Northrop Grumman Ship Systems (NGSS), General Dynamics Bath Iron Works (GD/BIW), Raytheon, and BAE Systems (the maker of the AGS). Under this arrangement, the Navy is acting as the overall system integrator for the program.

Earlier Proposal for Winner-Take-All Acquisition Strategy. 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 NGSS, 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 NGSS 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 NGSS and GD/BIW to build all DDG-1000s. On April 20, 2005, the USD AT&L issued a decision memorandum stating in part that "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 expressed opposition to Navy's proposal for a winner-take-all competition. Congress included a provision (Section 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 NGSS 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.

Milestone B Approval. On November 23, 2005, Kenneth Krieg, 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, Krieg 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 currently plans to procure).

Shared Production Arrangement. NGSS and GD/BIW have agreed on a shared-production arrangement for building DDG-1000s. Under this arrangement, certain parts of each ship will be built by NGSS, certain other parts of each ship will be built by GD/BIW, and the remaining parts of each ship would be built by the yard that does final-assembly work on that ship. The arrangement can be viewed as somewhat analogous to the joint-production arrangement for Virginia-class submarines that was proposed by industry and the Navy, and then approved by Congress in Section 121 of the FY1998 defense authorization act (H.R. 1119/P.L. 105-85 of November 18, 1997).⁸

NGSS will be the final-assembly yard for one of the two lead DDG-1000s, and GD/BIW will be the final-assembly yard for the other. The difference in the two ships' construction schedules (about six months) is driven in large part by the production capacities of vendors making certain components for the ships — some of these vendors can make only one ship-set worth of components at a time. The government provides these components to the shipyards as government-furnished equipment (GFE).

Construction Sequence for Two Lead Ships. Until July 2007, it was expected that NGSS 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 July 17 and 18, 2007, it was reported that the Navy was considering the option of instead assigning the first ship to GD/BIW and the second to NGSS. The potential switch in construction sequence reportedly was being considered by the Navy in part because the Navy believed it could provide some additional help in maintaining GD/BIW's work force as its DDG-51-related construction work winds down, and because it could also provide some additional time for NGSS to recover from Katrina-related damage.⁹ On September 10, 2007, it was reported that the Navy on July 27 had issued a request for proposal (RFP) to NGSS and GD/BIW seeking "updated pricing to reflect a proposed re-sequencing of government furnished equipment."¹⁰ On September 25, 2007, the Navy announced that it had decided to build the first DDG-1000 at GD/BIW, and the second at NGSS.¹¹

⁸ For more on the Virginia-class joint-production arrangement, see CRS Report RL32418, *Navy Attack Submarine Force-Level Goal and Procurement Rate: Background and Issues for Congress*, by Ronald O'Rourke.

⁹ Christopher P. Cavas, "First DDG 1000 Could Shift To Bath," *Defense News*, July 17, 2007; Geoff Fein, "Navy Exploring Workload Options For DDG-1000," *Defense Daily*, July 18, 2007.

¹⁰ Chris Johnson, "Navy Seeks Information On Possible Schedule Change For DDG-1000," *Inside the Navy*, September 10, 2007.

¹¹ Geoff Fein, "Bath Iron Works To Take Delivery of First Set of DDG-1000 Equipment," *Defense Daily*, September 26, 2007; Christopher P. Cavas, "Bath To Build First DDG 1000," *DefenseNews.com*, October 1, 2007; and Chris Johnson, "Navy Changes Equipment

(continued...)

Procurement Cost Cap. Section 123 of the FY2006 defense authorization act (H.R. 1815/P.L. 109-163 of January 6, 2006), limits the procurement cost of the fifth DDG-1000 to \$2.3 billion, plus adjustments for inflation and other factors.

Surface Combatant Industrial Base

All cruisers, destroyers, and frigates procured since FY1985 have been built at two shipyards — General Dynamics' Bath Iron Works (GD/BIW) in Bath, ME, and the Ingalls shipyard in Pascagoula, MS, that forms part of Northrop Grumman Ship Systems (NGSS).¹² 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 Ingalls' ship-construction work. Navy surface combatants are overhauled, repaired, and modernized at GD/BIW, NGSS, other private-sector U.S. shipyards, and government-operated naval shipyards (NSYs).

Lockheed Martin and Raytheon are generally considered the two leading Navy surface ship radar makers and combat system integrators. Boeing is another system integrator and maker of Navy surface ship weapons and equipment.

The surface combatant industrial and technological base also includes hundreds of additional firms that supply materials and components. The financial health of the 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.

Oversight Issues for Congress

Accuracy of Navy Cost Estimate

Although the Navy substantially increased its estimates of DDG-1000 procurement costs between 2004 and 2005, some observers believe the Navy is still underestimating these costs.

October 2007 Report on CAIG Estimate. On October 1, 2007, it was reported that the Cost Analysis Improvement Group (CAIG), a cost-estimating office within the Office of the Secretary of Defense, had recently estimated that the first two DDG-1000s would together cost about \$7.2 billion to procure, or about 13% more than the Navy's combined estimate for the two ships.¹³

¹¹ (...continued)

Delivery For First Two DDG-1000 Destroyers," *Inside the Navy*, October 1, 2007.

¹² NGSS also includes the Avondale shipyard near New Orleans and a third facility at Gulfport, MS..

¹³ "Sticker Price," *Defense Daily*, October 1, 2007. See also Christopher P. Cavas, "DDG 1000 Contract Talks Hit Rough Seas," *DefenseNews.com*, October 15, 2007, which refers to "a recent non-Navy estimate" of \$7.2 billion for the two ships.

CBO July 2007 Estimate. The Congressional Budget Office (CBO) believes that the Navy is significantly underestimating DDG-1000 procurement costs. CBO believes the first two DDG-1000s will each cost about 60% more than the Navy estimates, that the other five ships in the program would each cost about 75% more than the Navy estimates, and that the complete seven-ship class consequently would cost about 70% more than the Navy estimates. CBO testified in July 2007 that:

The [Navy's FY]2008 budget suggests that the Navy expects the first two ships to cost \$3.0 billion each and the following five to cost an average of \$2.0 billion apiece — meaning that the entire class would have an average cost of \$2.3 billion per ship. CBO, by contrast, estimates that the first two DDG-1000s would cost \$4.8 billion apiece and the next five would cost an average of \$3.5 billion each. The average per-ship cost of the class would be \$3.9 billion....

The Navy's estimate for the two lead ships of the DDG-1000 class is equivalent to about \$230 million (in 2008 dollars) per thousand tons of lightship displacement (the weight of the ship without its fuel, payload, or crew). That figure is smaller than the cost of the lead DDG-51 class destroyer or the lead Ticonderoga class cruiser.... CBO's estimate for the first two DDG-1000s — which equals \$380 million per thousand tons — is based on the cost of the lead DDG-51, adjusted for differences in the size of the two types of ships.

The Navy has argued that comparing the new DDG-1000 with the DDG-51 may not be valid because the older destroyer had various problems in the early stages of construction that increased its cost. In particular, the design of the ship was disrupted and delayed because a new design tool being used at the time was incomplete and not well understood. The design tool had to be abandoned and the design restarted using more-traditional methods. In comparison, the design process for the DDG-1000 is going far more smoothly, and the Navy expects to have the design largely settled when construction begins. In addition, the Navy says, the DDG-51 was a smaller, more densely built ship and thus, on a ton-for-ton basis, was more difficult to construct than the DDG-1000 class will be.

In CBO's view, however, several factors offset those arguments. First, as Navy officials often state, lead ships are generally very difficult to build and typically encounter many problems during construction. The problems with the first few littoral combat ships and with the lead ship of the LPD-17 class of amphibious transport docks — both of which are much less complex technologically than the DDG-1000 — illustrate those difficulties. A survey of lead-ship programs shows that although many experience problems in design or construction, those problems vary from program to program. In other words, the lead DDG-1000 may not face the same difficulties as the lead DDG-51, but it will have problems of its own that will increase costs and delay construction.

Second, the DDG-1000 program is incorporating 10 new technologies into the class that are not found on the current generation of destroyers. Those technologies include an electric drive and a distributed-power system, a tumblehome hull (which slopes inward above the waterline to make the ship less visible to radar), the Advanced Gun System, and new radars, as well as composite materials and stealth coatings for the deckhouse. In the past, the Navy has typically introduced just three or four new technologies in a new class of surface combatants.

Finally, a comparison of the Navy's cost estimates for two more DDG-51s and for the seventh DDG-1000 (to be purchased in 2013) illustrates the risk for cost growth in the new destroyer program. The Navy has stated that if the Congress authorized and bought two additional DDG-51s in 2008 — which would be the 63rd and 64th ships of their class — those destroyers would cost a total of \$3.0 billion to \$3.1 billion, or \$1.5 billion to \$1.6 billion apiece (in 2008 dollars). At the same time, the Navy's 2008 budget submission to the Congress estimates the cost of building the seventh DDG-1000 in 2013 at about \$2.1 billion (in 2013 dollars). Deflated to 2008 dollars (using the inflation index for shipbuilding that the Navy provided to CBO), that estimate equals about \$1.6 billion — or the same as for an additional DDG-51, which would have the benefit of substantial efficiencies and lessons learned from the 62 models built previously. The lightship displacement of the DDG-1000 is about 5,000 tons greater than that of the DDG-51s under construction today. In effect, the Navy's estimates imply that those 5,000 extra tons, as well as the 10 new technologies to be incorporated into the DDG-1000 class, will be free.¹⁴

The Navy and CBO have been engaged in an extended conversation about potential procurement costs for the DDG-1000 and other Navy ships. CBO testified in July 2007 that in developing its cost estimates,

CBO looks at the relationship between cost and weight (specifically, the cost per thousand tons of lightship displacement) of analogous past or present ships to estimate the prices of future naval vessels. That method assumes, broadly speaking, that what has happened in the past will be repeated in the future. CBO takes into account changes or productivity improvements in shipbuilding practices and procedures; but such changes are frequently offset by, for example, cost increases for labor and materials, unexpected production problems, increased requirements, or new technologies.

In testimony before the Congress, some Navy officials have characterized CBO's methodology as "worst-case analysis" or an "extremely conservative" estimating technique that seeks to include all possible sources of cost risk. Despite its purported conservatism, however, that method would have understated the actual costs of the littoral combat ship [LCS], the LPD-17 amphibious warfare ship, and the CVN-76 and CVN-77 aircraft carriers, and it would have closely approximated the cost of the lead Virginia class attack submarine.¹⁵

GAO July 2007 Testimony. Although the Navy publicly stands by its DDG-1000 cost estimates, the Government Accountability Office (GAO) testified in July 2007 that the Navy has assigned a confidence level of about 45% to its own estimates, meaning that the Navy itself believes there is about a 55% chance that DDG-1000s will exceed the Navy's estimates. GAO testified that:

¹⁴ Statement of J. Michael Gilmore, Assistant Director for National Security, and Eric J. Labs, Senior Analyst, [on] The Navy's 2008 Shipbuilding Plan and Key Ship Programs, before the Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, U.S. House of Representatives, July 24, 2007, pp. 14-16.

¹⁵ Ibid, p. 22.

One way to improve the cost-estimating process is to present a confidence level for each estimate, based on risk and uncertainty analyses. By conducting an uncertainty analysis that measures the probability of cost growth, the Navy can identify a level of confidence for its estimates and determine whether program costs are realistically achievable. Navy cost analysts told us that they used quantitative risk analyses to test the validity of cost estimates of CVN 78 and DDG 1000. We believe that the Navy and the Department of Defense (DOD) should take this a step further — requiring a high confidence level threshold when making program commitments and budget requests. The Defense Acquisition Performance Assessment Panel recommended an 80 percent confidence level, meaning that a program has an 80 percent chance of achieving its estimated costs. Whether this is the right level warrants thoughtful discussion, but it is worth noting that analyses for CVN 78 and DDG 1000 were well below an 80 percent confidence level (in the case of DDG 1000 at around 45 percent) — increasing the likelihood that costs will grow above budget.¹⁶

October 2007 Report on Contract Talks. On October 15, 2007, it was reported that

Negotiators for the U.S. Navy and Northrop Grumman reportedly are at odds in nailing down details of the initial DDG 1000 Zumwalt-class advanced destroyers....

Several sources said a sticking point is the “man/day rate,” a complex estimate of the time workers need to perform specific tasks. The Navy reportedly considers Northrop’s estimates “way too high,” according to one source, who added the two sides are “far apart” in price.

Negotiations also are under way with General Dynamics, although they have not progressed as far as the talks with Northrop.¹⁷

Technical Risk and System Integration

Over the past few years, GAO has reported on the technical risks involved in developing the several significant new technologies that are to be incorporated into the DDG-1000. The Navy over the years has worked to retire these risks. GAO testified in July 2007 that:

The DDG 1000 development has been framed by challenging multi-mission requirements, resultant numerous technologies and a tight construction schedule driven by industrial base needs. In the DDG 1000 program, the Navy estimates that approximately 75 percent of detail design will be completed prior to the start of lead ship construction in July 2008. Successfully meeting this target, however, depends on maturing 12 technologies as planned. Currently, three of these

¹⁶ Government Accountability Office, *Defense Acquisitions[:] Realistic Business Cases Needed to Execute Navy Shipbuilding Programs*, Statement of Paul L. Francis, Director, Acquisition and Sourcing Management Team, Testimony Before the Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, House of Representatives, July 24, 2007 (GAO-07-943T), pp. 17-18.

¹⁷ Christopher P. Cavas, “DDG 1000 Contract Talks Hit Rough Seas,” *DefenseNews.com*, October 15, 2007.

technologies are fully mature. Two DDG 1000 technologies — the volume search radar and total ship computing environment — have only completed component-level demonstrations and subsequently remain at lower levels of maturity. Schedule constraints have also forced the Navy to modify its test plans for the integrated power system and external communication systems.

The volume search radar, one of two radars in the dual band radar system, will not have demonstrated the power output needed to meet requirements even after integrated land-based testing of the prototype radar system is completed in 2009. Production of the radars, however, is scheduled to begin in 2008, introducing additional risk if problems are discovered during testing. According to Navy officials, in the event the volume search radar experiences delay in testing, it will not be integrated as part of the dual band radar into the DDG 1000 deckhouse units that will be delivered to the shipbuilders. Instead, the Navy will have to task the shipbuilder with installing the volume search radar into the deckhouse, which program officials report will require more labor hours than currently allocated. The DDG 1000 program's experience with the dual band radar has added significance as the same radar will be used on CVN 78.

In the case of the DDG 1000 total ship computing environment, the Navy is developing hardware infrastructure and writing and releasing six blocks of software code. Although development of the first three software blocks progressed in line with cost and schedule estimates, the Navy has been forced to defer some of the functionalities planned in software release four to software blocks five and six due to changes in availability of key subsystems developed external to the program, introduction of non development items, and changes in program integration and test needs. The Navy now plans to fully mature the integrated system following ship construction start — an approach that increases program exposure to cost and schedule risk in production.

The DDG 1000 program also faces challenges completing testing for its integrated power system and external communications systems. Currently, shipbuilder-required equipment delivery dates for these systems do not permit time for system-level land-based integration testing prior to delivery. As a result, the Navy has requested funds in fiscal year 2008 for the third shipset of this equipment so that testing can be completed without interrupting the planned construction schedules of the first two ships. However, in the event problems are discovered, DDG 1000 construction plans and costs could be at risk.¹⁸

As individual DDG-1000 technologies mature, technical risk in the DDG-1000 program will shift more to the follow-on task of system integration — of getting all ship's technologies to work together smoothly in a single platform. In past defense acquisition programs, system integration has often proven to be at least as challenging as the task of developing individual new technologies.

As mentioned in the Background Section, the Navy since September 30, 2005, has been acting as the system integrator for the DDG-1000 program. Problems in the

¹⁸ Government Accountability Office, *Defense Acquisitions[:] Realistic Business Cases Needed to Execute Navy Shipbuilding Programs*, Statement of Paul L. Francis, Director, Acquisition and Sourcing Management Team, Testimony Before the Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, House of Representatives, July 24, 2007 (GAO-07-943T), pp. 12-13.

execution of the Coast Guard Deepwater program¹⁹ and the Littoral Combat Ship (LCS) program led to a reexamination in Congress in 2007 of the concept of the private-sector lead system integrator (LSI), and to a desire among some Members to shift certain acquisition functions, including system design and integration, from the private sector, to where they had migrated starting in the 1990s, back to the federal government. The Navy's decision in 2005 to begin acting as the system integrator for the DDG-1000 program will make the program an early test of DOD's ability to once again perform the system-integration function following the downsizing of DOD's technical and acquisition workforce that occurred when acquisition functions were earlier transferred to the private sector. The DDG-1000 program, in addition to being an early test of DOD's abilities in this area, may represent a fairly challenging test, given the number of significant new technologies that are to be integrated into the ship. Potential oversight questions for Congress include the following:

- Does the Navy retain sufficient in-house acquisition and technical expertise to perform the system-integration functions that the Navy is to perform under its DDG-1000 contracting strategy?
- Does the Navy's contracting strategy for the DDG-1000 program have any implications for how other defense acquisition programs should be pursued?

Acquisition Strategy for Third and Subsequent Ships

The Navy's intended acquisition strategy for the third and subsequent DDG-1000s is unclear. The issue has potentially significant implications for the shared-production arrangement and the industrial-base effects of the DDG-1000 program (see discussions below).

Shared Production Arrangement

As mentioned in the Background section, NGSS and GD/BIW have agreed on a shared-production arrangement for building DDG-1000s. Under this arrangement, certain parts of each ship will be built by NGSS, certain other parts of each ship will be built by GD/BIW, and the remaining parts of each ship would be built by the yard that does final-assembly work on that ship.

It is possible that the Navy might wish to have the two yards compete for the role of final-assembly yard for the third and subsequent ships in the class. Such a competition could be done on a one-time basis for all the ships in question, or serially, for each ship. One potential question for Congress is whether competing the role of final-assembly yard for the third and subsequent ships, particularly if done on a one-time basis, would be consistent with the intent of Section 1019 of the Emergency Supplemental Appropriations Act for 2005 (H.R. 1268/P.L. 109-13 of

¹⁹ For additional discussion of the Deepwater program, see CRS Report RL33753, *Coast Guard Deepwater Program: Background, Oversight Issues, and Options for Congress*, by Ronald O'Rourke.

May 11, 2005) and Section 125 of the FY2006 defense authorization act (H.R. 1815/P.L. 109-163 of January 6, 2006). As discussed in the Background section, both of these provisions prohibit the Navy from using a winner-take-all acquisition strategy for the DDG-1000 program. The provisions require the participation of a second shipyard in the program, but they do not specify the share of the program that is to go to the second yard.

Industrial Base

The Navy's 30-year shipbuilding plan calls for procuring an average of about 1.5 DDG-1000s/CG(X)s over the next 17 years. The light-ship displacement of the DDG-1000 (about 12,435 tons) is about 79% greater than that of the DDG-51 Flight IIA design (about 6,950 tons). If shipyard construction work for these two ship classes is roughly proportional to their light-ship displacements, and if the CG(X) is about the same size as the DDG-1000, then procuring an average of 1.5 DDG-1000s/CG(X)s per year might provide an amount of shipyard work equivalent to procuring about 2.7 DDG-51s per year. Splitting this work evenly between GD/BIW and the Ingalls shipyard that forms parts of NGSS might thus provide each yard with the work equivalent of about 1.35 DDG-51s per year.

Supporters of these two yards argued in the 1990s that a total of 3 DDG-51s per year (i.e., an average of 1.5 DDG-51s per year for each yard), in conjunction with other work being performed at the two yards (particularly Ingalls), was the minimum rate needed to maintain the financial health of the two yards.²⁰ Navy officials in subsequent years questioned whether this figure remained valid. Building the equivalent of about 2.7 DDG-51s per year equates to about 90% of this rate.

If affordability considerations limit DDG-1000/CG(X) procurement to one ship per year in FY2011 and subsequent years, the workload for the cruiser-destroyer industrial base in those years would be reduced substantially from levels that would be achieved under the Navy's 30-year plan. Procuring one DDG-1000/CG(X) per year might provide an amount of shipyard work equivalent to procuring about 1.8 DDG-51s per year, and splitting this work evenly between GD/BIW and Ingalls might provide each yard with the work equivalent of about 0.9 DDG-51s per year, which would be equivalent to 60% of the rate cited in the 1990s by supporters of the two shipyards as the minimum needed to maintain the financial health of the two yards.

If the Navy at some point holds a competition between the two yards for the right to be the final assembly yard for all remaining DDG-1000s, the yard that loses could experience a significant reduction in workloads, revenues, and employment levels.

²⁰ See, for example, CRS Report 94-343, *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, by Ronald O'Rourke (out of print, available from author).

Options for Congress

Potential options for Congress for the DDG-1000 program, some of which could be combined, include the following:

- approve the seven-ship DDG-1000 program as proposed by the Navy;
- use a block-buy contract for DDG-1000s procured during the five-year period FY2007-FY2011 or the five-year period FY2009-FY2013;
- establish terms and conditions for the acquisition strategy to be used for the third and subsequent ships in the program;
- as an annual affordability measure, limit DDG-1000/CG(X) procurement to a combined total of no more than one ship per year;
- as total-program affordability measure, limit DDG-1000/CG(X) procurement to a combined total of 12 ships (one for each of 12 planned carrier strike groups (CSGs));²¹
- procure no more than two DDG-1000s for use as technology demonstrators for future surface combatants (and also as operational warships), and supplement the industrial base with other work;
- to help accelerate CG(X) procurement, procure three CG(X)s in FY2011, FY2012, and FY2013 in lieu of the fifth, sixth, and seventh DDG-1000s, and possibly also procure two CG(X)s in FY2009 and FY2010 in lieu of the third and fourth DDG-1000s; and
- start design work now on a lower-cost naval gunfire support ship and/or a lower-cost cruiser-destroyer, and start procuring these ships, rather than additional DDG-1000s or CG(X)s, when these new designs are ready for procurement.

Supporters of the **second option** could argue that it could reduce the total cost of the DDG-1000s procured by a few percent. Opponents could argue that it would reduce DOD's flexibility for making adjustments in the shipbuilding plan, and similarly tie the hands of future Congresses — something that Congress traditionally tries to avoid in decisions on discretionary spending — by creating a commitment to procure a certain number of DDG-1000s through FY2011 or FY2013.

The **fourth option** might be considered as a response to limits on Navy resources and desires for funding other Navy programs. This option would release DDG-1000/CG(X) procurement funding programmed for FY2011 and future years

²¹ Carrier strike group (CSG) is the Navy's term for what used to be called carrier battle group (CVBG).

for application to other Navy programs. It would also increase DDG-1000/CG(X) unit procurement costs due to reduced economies of scale in production.

The **fifth option**, like the third option, might be considered as a response to limits on Navy resources and desires for funding other Navy programs. It could provide 12 DDG-1000s and CG(X)s for the fleet, while permitting procurement to shift to a follow-on design (such as the DDG(X), the Navy's planned replacement for the DDG-51s) sooner than under the Navy's current plan. This option would deprive the fleet of the capabilities that would have been provided by the 14 other DDG-1000s and CG(X)s currently planned for procurement. It would also increase average DDG-1000/CG(X) unit acquisition costs due to reduced amortization of up-front DDG-1000/CG(X) development and design costs and the elimination ships that would have been further down the DDG-1000/CG(X) production learning curve.

The **sixth option** might be consistent with a view that the DDG-1000 is not affordable or not cost effective. This option could release DDG-1000 procurement funding for application to other Navy programs. It would deprive the fleet of five ships' worth of DDG-1000 capabilities, including the naval gunfire support capabilities to be provided by the 10 AGSs on those five ships. This option could also have implications for the shipbuilding industrial base, particularly if the industrial base receives a smaller amount of other work in lieu of additional DDG-1000s.

The **seventh option** would accelerate the introduction of CG(X) air defense and ballistic missile defense capabilities into the fleet, should that be viewed as desirable for countering emerging anti-ship cruise missile or ballistic missile threats. This option would also deprive the fleet, in the nearer term at least, of three to five ships' worth of DDG-1000 capabilities, including the naval gunfire support capabilities to be provided by the AGSs on the three to five ships. Additional DDG-1000s (or other ships equipped with AGSs) could be procured at a later point. Procuring two CG(X)s in lieu of two DDG-1000s in FY2009 and FY2010 could require stretching out the construction schedule for those two ships, which could increase their cost.²²

The **eighth option** could reduce the average unit procurement cost of planned cruisers and destroyers, permitting a larger number of cruisers and destroyers to be procured for a given amount of funding. It would also reduce the average unit

²² Under current Navy plans, the first CG(X) is to be procured in FY2011, and key CG(X) technologies, including the CG(X) radar, are being developed on a schedule to support a lead CG(X) procured in FY2011. The fifth, sixth, and seventh DDG-1000s are currently planned for procurement in FY2011, FY2012, and FY2013, respectively, which is not earlier than currently planned year of procurement for the lead CG(X). The third and fourth DDG-1000s, however, are currently planned for procurement in FY2009 and FY2010. Procuring two CG(X) in lieu of two DDG-1000s in FY2009 and FY2010 could require stretching the construction schedule for these two ships by one or two years to provide additional time for the CG(X) radar or other CG(X) technologies to become ready for installation on the ships. Other things held equal, a longer ship construction schedule often translates into a higher ship construction cost due to factors such as sub-optimal construction sequencing and added absorption of shipyard fixed overhead costs.

capability of the future cruisers and destroyers. For additional discussion of potential lower-cost ships, see **Appendix B**.

FY2008 Legislative Activity

FY2008 Defense Authorization Bill (H.R. 1585/S. 1547)

House. The House Armed Services Committee, in its report (H.Rept. 110-146 of May 11, 2007) on the FY2008 defense authorization bill (H.R. 1585), recommended approving the Navy's request for FY2008 procurement funding for the DDG-1000 program and increasing the Navy's FY2008 request for research and development funding for the program by \$9 million for work on permanent magnet motor technology. The report states:

The budget request contained \$503.4 million in PE [program element] 64300N for DDG 1000 total ships systems engineering, but contained no funds for continued development of the permanent magnet motor. The committee understands that the permanent magnet motor technology will save weight and increase fuel efficiency in the next generation of surface combatants, including the DDG 1000. The committee recommends an increase of \$9.0 million in PE 64300N to complete design of the motor and motor control electronics. (Page 187)

Senate. The Senate Armed Services Committee, in its report (S.Rept. 110-77 of June 5, 2007) on the FY2008 defense authorization bill (S. 1547), recommended approving the Navy's request for FY2008 procurement funding for the DDG-1000 program and increasing the Navy's FY2008 request for research and development funding for the program by \$15 million, of which \$9 million would be for work on a permanent magnet motor system and \$6 million would be for work on wireless encryption technology for use on Navy ships. The report states:

Permanent magnet motor

The budget request included \$621.5 million in PE 64300N for [DDG-1000] destroyer total ship systems engineering. The budget request included no funding for completing the development and testing of the permanent magnet motor (PMM).

Present Navy and Marine Corps electric propulsion and power generation systems are several times larger and heavier than mechanical drive equivalents, limited by very heavy generation equipment and propulsion motors. The PMM was developed to resolve this. Congress provided funding in fiscal year 2006 which the Navy and the contractor team used to complete factory testing, ship the PMM engineering development model to the Navy's land based test site, and begin testing.

Because of the promise of this technology for future ship applications, the committee recommends an increase of \$9.0 million to incorporate changes resulting from land based testing, repackage PMM design to reflect evolving DDG-1000 requirements, and perform shock analysis.

Wireless encryption technology

The budget request included \$621.5 million in PE 64300N for [DDG-1000] destroyer total ship systems engineering, but included no funding to develop wireless encryption technology. With the reduced manning planned on the DDG-1000 and other vessels, the Navy will have to place greater reliance on automation and having the crews stay connected to the ships' computing environment. Absent better wireless encryption technology, the goal of being connected to all information systems will be problematic for very sensitive information. The committee recommends an increase of \$6.0 million to develop better wireless encryption technology for use aboard Navy vessels. (Pages 203-204)

FY2008 Defense Appropriations Bill (H.R. 3222)

House. The House Appropriations Committee, in its report (H.Rept. 110-279 of July 30, 2007) on the FY2008 defense appropriations bill (**H.R. 3222**), recommended reducing the Navy's FY2008 procurement funding request for the DDG-1000 program by \$30 million and increasing the Navy's FY2008 request for research and development funding for the program by \$8 million for work on a "Floating Area Network (FAN) Littoral Sensor Grid" (\$5 million), "SmartLink Planar Scanner Antenna Modernization" (\$2 million), and "Smart Integrated Data Environment" (\$1 million). The changes to the research and development funding request are shown on page 338 of the committee's report. The report states:

DDG-1000 ADVANCE PROCUREMENT

The DDG-1000 Guided Missile Destroyer is being designed as a multi-mission surface combatant that is envisioned to be the centerpiece of the future Navy fleet. The request includes funding in the amount of \$150,886,000 for advance procurement for the fiscal year 2009 ship for the purchase of the Integrated Power System and Communication Suite. Although this equipment is certainly necessary for the construction of the fiscal year 2009 ship, it is being requested in fiscal year 2008 for testing to mitigate the risk for the first two ships in an effort to maintain the Navy's acquisition schedule. The Department of Defense's own Financial Management Regulation (FMR) states that "Long lead-time procurements shall be for components, parts, and material whose lead times are greater than the life of the appropriation". In this case, lead times are well within the life of the appropriation and the items are being requested strictly as a risk mitigation effort. The Committee believes this to be an improper use of advance procurement funding due to lead times of the requested equipment. However, since the Committee is already skeptical of the amount of funding budgeted for the DDG-1000 lead ships based on the Navy's track record of advance procurement in the DDG-1000 program in an effort to minimize further perturbations to the DDG-1000 schedule. The Navy is encouraged to review the FMR regarding the proper use of advance procurement funding for future requests.

DDG — 1000

The request includes funding for the procurement of hardware for the new dual band radar for installation on the first two ships of the class. Although these installations represent the lead installations for this system, the hardware is

priced at more than \$35,000,000 per shipset for the comparable system being installed on board the CVN-78. In an effort to reduce this mismatch, the DDG-1000 dual band radar funding is reduced by \$15,000,000 per shipset for the first two ships for a total of \$30,000,000. (Pages 229-230)

Senate. The **Senate Appropriations Committee**, in its report (S.Rept. 110-155 of September 14, 2007) on H.R. 3222, recommended increasing the Navy's FY2008 procurement funding request for the DDG-1000 program by \$4.8 million and increasing the Navy's FY2008 request for research and development funding for the program by \$16 million. The \$4.8-million increase in procurement funding is for Advanced Gun System (AGS) pallets. (Page 132) The \$16-million increase in research and development funding is for work on a permanent magnet motor (\$9 million), an advanced wireless encryption module (\$3 million), and bio/nano MEMS (micro-electro mechanical systems) for defense applications (\$4 million). (Page 227)

Appendix A. Earlier DDG-1000 Program Oversight Issues

Program Affordability and Cost Effectiveness

Procurement Cost Affordability. At the end of a July 19, 2005, hearing on the DDG-1000 program before the Projection Forces Subcommittee of the House Armed Services Committee, DOD and Navy witnesses were asked to provide the subcommittee with their own individual views on the procurement cost figures at which the lead DDG-1000 and a follow-on DDG-1000 (defined as the fifth ship) would become unaffordable. At the beginning of part two of the hearing, which was held on July 20, the chairman of the subcommittee, Representative Roscoe Bartlett, stated that the figures provided by the witnesses ranged from \$4 billion to \$4.5 billion for the lead ship and \$2.5 billion to \$2.9 billion for the fifth ship. CBO's cost estimates for the DDG-1000 program are higher than these figures.

Total Life-Cycle Cost Affordability. The Navy argues that, in terms of total life-cycle cost (i.e., procurement plus lifetime O&S cost), the DDG-1000 is more affordable than might appear from looking only at procurement cost, because the ship will have lower lifetime O&S costs than existing Navy cruisers and destroyers. The Navy has estimated that over a 35-year life cycle, a DDG-1000 would cost an average of about \$12 million or \$13 million less per year to operate and support than a DDG-51. Over a 35-year life, this would equate to a savings of \$420 million to \$455 million in O&S costs relative to a DDG-51. On this basis, the Navy has argued that a force of 10 DDG-51s would have a total 35-year O&S cost of \$4.2 billion to \$4.5 billion less than that of a force of 10 DDG-51s.

Skeptics could argue that reducing a ship's future O&S costs, though desirable, does not make that ship any more affordable to procure in the budget that funds its procurement. Skeptics could also argue that, in terms of total life-cycle cost, the DDG-1000 is not as affordable as the Navy argues, for the following reasons:

- The Navy's estimated 35-year O&S savings of \$420 million to \$450 million only partially offsets difference between the DDG-1000's higher procurement cost and the procurement cost of a DDG-51 when DDG-51s are procured at a rate of two per year.
- Office of Management and Budget (OMB) Circular A-94²³ and standard business procedures call for future funding flows to be calculated on a present-value basis so as to capture the investment value of money over time. When calculated on this basis, the single-ship 35-year savings figure is reduced by about 46%, to \$226 million to \$242 million, and the 10-ship 35-year savings figure of \$4.5 billion

²³ U.S. Office of Management and Budget, *Circular A-94, Guidelines And Discount Rates For Benefit-Cost Analysis of Federal Programs*, available at [<http://www.whitehouse.gov/omb/circulars/a094/a094.pdf>].

(assuming procurement of one ship per year) is reduced by about 53%, to about \$2.1 billion.²⁴

- The above calculations accept the Navy's estimate that a DDG-1000 would, on a 35-year basis, have an annual O&S cost \$12 million to \$13 million less than that of a DDG-51. CBO has questioned the accuracy of the Navy's estimate of relative DDG-1000 and DDG-51 O&S costs, and has estimated that the difference might range from zero to \$10 million per year.

Table 3 compares follow-ship DDG-51 and DDG-1000 total procurement and life-cycle O&S costs using the above figures, which date to 2005. The table uses constant FY2007 dollars, which results in some adjustments to the above figures. As can be seen in the table, on a present-value basis, the combined procurement and 35-year life-cycle O&S cost of the follow-on DDG-1000 is 16% greater than that of the DDG-51 using the Navy's estimates, or 91% to 101% greater using CBO's estimates.

Cost Effectiveness. The Navy argues that the DDG-1000 would be cost effective because the higher procurement cost of the DDG-1000 compared to previous Navy surface combatants would be more than offset by the DDG-1000's numerous and significant improved capabilities.²⁵ Skeptics could argue that these

²⁴ CRS calculations using the 3.1% real discount rate set forth in **Appendix B** (Revised January 2005) for discounting constant-dollar flows of 30 years or more.

²⁵ The Navy states that, compared to the DDG-51, these capability improvements include, among other things:

- three-fold improvement in capability against anti-ship cruise missiles, including significantly better radar performance in situations involving near-land radar clutter;
- a 10-fold improvement in overall battle force defense capability, in part because of a 5-fold improvement in networking bandwidth capacity;
- 15% more capability to defend against group attacks by enemy surface craft (i.e., "swarm boats");
- a 50-fold improvement (i.e., reduction) in radar cross-section, which dramatically enhances survivability and reduces by half the total number of missiles that need to be fired in an intercept engagement;
- a 10-fold increase in operating area against mines in shallow-water regions;
- 3 times as much naval surface fire support capability, including an ability to answer 90% of Marine Corps calls for fire within 5 minutes, permitting the ship to meet stated Marine Corps firepower requirements — a capability otherwise unavailable in the surface fleet — giving the ship a capability roughly equivalent to one-half of an artillery battalion, and permitting a 65% reduction in Marine Corps artillery;
- a ship design that allows underway replenishment of gun shells, creating the equivalent of an almost-infinite ammunition magazine and permitting nearly continuous fire support;
- about 10 times as much electrical capacity available for ship equipment, giving the ship an ability to support future electromagnetic rail guns and high-energy laser weapons; and
- features such as an automated fire-suppression system, peripheral vertical launch system, and integrated fight-through-damage power system that significantly increase ship survivability.

(continued...)

capability improvements, though significant, are not worth the ship's cost, particularly if that cost is closer to CBO's estimates than to the Navy's estimates, and that if the DDG-1000's most-needed contribution to fleet capabilities is the naval surface fire support capability provided by the ship's two AGSs, then the DDG-1000 represents a very expensive way to add this capability to the fleet.

Table 3. Follow-ship DDG-51 and DDG-1000 Costs
(using 2005 cost estimates, expressed in millions of constant FY2007 dollars)

| | Constant FY2007 dollars | | | Present-value calculation | | |
|-----------------------------------------------------------------------------------------|-------------------------|----------------------------|-------|---------------------------|----------------------------|-------|
| | Procurement cost | 35-year lifecycle O&S cost | Total | Procurement cost | 35-year lifecycle O&S cost | Total |
| Navy Estimate | | | | | | |
| Follow-on DDG-51 | 1,393 | 2,115 | 3,508 | 1,393 | 1,133 | 2,526 |
| Follow-on DDG-1000 | 2,058 | 1,627 | 3,685 | 2,058 | 871 | 2,929 |
| DDG-1000 less DDG | 665 | (488) | 177 | 665 | (262) | 403 |
| DDG-1000 as % DDG-51 | 148% | 77% | 105% | 148% | 77% | 116% |
| CBO Estimate (with \$10-million annual DDG-1000 O&S cost savings vs. DDG-51) | | | | | | |
| Follow-on DDG-51 | 1,393 | 1,120 | 2,513 | 1,393 | 600 | 1,993 |
| Follow-on DDG-1000 | 3,400 | 770 | 4,170 | 3,400 | 412 | 3,812 |
| DDG-1000 less DDG | 2,007 | (350) | 1,657 | 2,007 | (188) | 1,819 |
| DDG-1000 as % DDG-51 | 244% | 69% | 166% | 244% | 69% | 191% |
| CBO Estimate (with zero annual DDG-1000 O&S cost savings vs. DDG-51) | | | | | | |
| Follow-on DDG-51 | 1,393 | 1,120 | 2,513 | 1,393 | 600 | 1,993 |
| Follow-on DDG-1000 | 3,400 | 1,120 | 4,520 | 3,400 | 600 | 4,000 |
| DDG-1000 less DDG | 2,007 | 0 | 2,007 | 2,007 | 0 | 2,007 |
| DDG-1000 as % DDG-51 | 244% | 100% | 180% | 244% | 100% | 201% |

Source: CRS calculations based on 2005 Navy and CBO DDG-1000 and DDG-51 cost data and a 3.1% real discount rate, as specified in Appendix B to OMB Circular A-94 for discounting constant-dollar flows of 30 years or more. DDG-51 procurement cost is an average unit cost based on a two-per-year procurement. (For a three-per-year procurement rate, the average unit procurement cost would be \$1,251 million.)

²⁵ (...continued)

(Source: Points taken from Statement of Admiral Vern Clark, U.S. Navy, Chief of Naval Operations, Before The House Armed Services Committee Projection Forces Subcommittee, July 19th, 2005, and Statement of The Honorable John J. Young, Jr., Assistant Secretary of the Navy (Research, Development and Acquisition), and RADM Charles S. Hamilton, II, Program Executive Officer For Ships, Before the Projection Forces Subcommittee of the House Armed Services Committee on DD(X) Shipbuilding Program, July 19, 2005.)

Mission Requirements

The DDG-1000's size and procurement cost appear to have been driven not by any one technology or payload element, but rather by the ship's total collection of payload elements, which reflect requirements to perform various missions. These payload elements include, among other things:

- more gunfire capability than any cruiser the Navy has built since World War II;
- a vertical launch system (VLS) whose weapon storage volume and weapon weight capacity are between that of the DDG-51 and Aegis cruiser designs;²⁶
- an area-defense anti-air warfare (AAW) capability that in some respects is greater than that of the DDG-51;²⁷
- sonars and other antisubmarine warfare (ASW) systems that are roughly equivalent to that of the DDG-51;²⁸
- command facilities for a flag-level officer and his command staff — a feature that previously has been installed on cruisers but not destroyers;
- a large helicopter flight deck and a hangar and maintenance facilities for two helicopters or one helicopter and three UAVs;
- additional berthing, equipment-stowage space, and mission-planning space for a platoon of 20 special operations forces (SOF) personnel; and

²⁶ Although the DDG-1000 has 80 VLS cells, compared to 96 on the DDG-51 and 122 on the Aegis cruiser, the DDG-1000's VLS cells are larger. The Mk 41 VLS cells on DDG-51s and Aegis cruisers can fire a missile up to 21 inches in diameter, 21 feet in length, and about 3,000 pounds in weight. The Advanced VLS (AVLS) cells on the DDG-1000 can fire a missile up to 24 inches in diameter, 22 feet in length, and about 4,000 pounds in weight.

²⁷ The Navy states that radars on the DDG-1000 and DDG-51 are roughly equivalent in terms of dB gain (sensitivity) and target resolution, that the firm track range of the DDG-1000's dual-band radar — the range at which it can maintain firm tracks on targets — is 25% greater for most target types than the firm track range of the DDG-51's SPY-1 radar, that the DDG-1000's radar has much more capability for resisting enemy electronic countermeasures and for detecting targets amidst littoral clutter, that the DDG-1000's AAW combat system would be able to maintain 10 times as many tracks as the DDG-51's Aegis system, and that the two ships can support roughly equal numbers of simultaneous AAW engagements. Given the features of the DDG-1000's AAW system, plus its much-greater C4I/networking bandwidth, the Navy has stated that replacing a DDG-51 with a DDG-1000 in a carrier strike group would increase the strike group's AAW capability by about 20%.

²⁸ The Navy states that due to differences in their sonar designs, the DDG-1000 would have more littoral-water ASW capability, while the DDG-51 would have more blue-water ASW capability.

- facilities for embarking and operating two 11-meter boats and four rubber raiding craft (as opposed to two 7-meter boats on the DDG-51).

The payload elements of the DDG-1000 design reflect an Operational Requirements Document (ORD) for the DDG-1000 that was approved by the Joint Staff of DOD in February 2004. Key performance parameters included in this document include having two AGSs that can each fire 10 rounds per minute, for a total of 20 rounds per minute.²⁹ DOD states that

During the restructuring of the DD-21 program into the DD(X) program, the Navy re-evaluated each DD-21 Key Performance Parameter (KPP) to determine the potential for minimizing the size of the ship and ultimately the cost. The Navy made many adjustments and the resulting DD(X) KPPs represent the Navy's minimum requirements. No other known alternative meets all of the DD(X) KPPs and provide the sustained, precision, long-range naval surface fire support that the United States Marine Corps requires.³⁰

Skeptics could argue that, notwithstanding the February 2004 DDG-1000 ORD, at least some requirements for the DDG-1000 are not clear. A November 2006 GAO report states:

In December 2005, more than a decade after the Navy and Marine Corps began to formulate requirements, agreement was reached on the capabilities needed for naval surface fire support. However, quantifiable measures are still lacking for volume of fire — the delivery of a large quantity of munitions simultaneously or over a period of time to suppress or destroy a target. Until further quantifiable requirements are set for volume of fire, it is difficult to assess whether additional investment is necessary or the form it should take.³¹

Skeptics could argue that with estimated DDG-1000 procurement costs now much higher than they were in February 2004, and in light of the effect that increased cost appears to have had in reducing planned DDG-1000 procurement, the February 2004 ORD might not reflect a sufficiently up-to-date consideration of how increasing DDG-1000 capability (and therefore cost) might reduce DDG-1000 numbers and therefore reduce the collective capability of the total DDG-1000 force. In light of the reduction in planned DDG-1000 procurement, skeptics could argue, certain capabilities that might have been viewed as desirable in February 2004 might now be viewed as less desirable because of their role in increasing DDG-1000 unit cost and thereby reducing planned DDG-1000 procurement.

Some observers speculate that the Navy and DOD established requirements for the DDG-1000 without a full appreciation of how large and expensive a ship design

²⁹ Statement by The Honorable Kenneth J. Krieg, Under Secretary of Defense (Acquisition, Technology and Logistics), Before the Subcommittee on Projection Forces, House Armed Services Committee, United States House of Representatives, July, 19, 2005, p. 2.

³⁰ *Ibid*, pp. 6-7.

³¹ Government Accountability Office, *Defense Acquisitions[:] Challenges Remain in Developing Capabilities for Naval Surface Fire Support*, GAO-07-115, November 30, 2006.

the requirements would generate. Naval analyst Norman Friedman, the author of numerous books on U.S. warship designs, states in a 2004 book on U.S. destroyer designs that

In past [Navy ship design] practice, the naval policymakers in OpNav [the Office of the Chief of Naval Operations] would write a draft set of [ship] characteristics.... The Preliminary Design branch of BuShips [the Bureau of Ships] or NAVSEA [the Naval Sea Systems Command] would develop sketch designs to meet the requirements. Often the OpNav policymakers would find the results outrageous — for example, exorbitantly expensive. Such results would force them to decide just how important their various requests had been. Eventually Preliminary Design would produce something OpNav found acceptable, but that might not actually be built....

In contrast to past practice, no preliminary design [for the DDG-1000] was drawn up to test the cost of various requirements. Each requirement was justified in operational terms, (e.g., a level of stealth that would reduce detectability by some percentage); but those sponsoring the ship had no way of knowing the impact that a particular combination of such requirements would have. Normally NAVSEA would have created a series of sketch designs for exactly that purpose.³²

An August 2005 trade press article suggests that growth in DD-21/DDG-1000 requirements (and cost) over time may have been related to the disestablishment of a Navy ship-design board called the Ship Characteristics Improvement Board (SCIB) — an entity that Admiral Michael Mullen, who became the Chief of Naval Operations on July 22, 2005, reestablished under a new name:

Adm. Michael Mullen, the chief of naval operations, has directed the Navy to re-establish a high-level panel to closely monitor and control the requirements and configurations of new ships in a bid to rein in the skyrocketing cost of new vessel procurement.

Adm. Robert Willard, vice chief of naval operations, is leading the effort as part of a larger undertaking to draw up alternative options for the Navy's current shipbuilding program....

In essence, sources said, Mullen is looking to reconstitute the Ship Characteristics Improvement Board, which eventually became inactive in 2002. For more than 100 years, the Navy has maintained a high-level group of officials to advise service leaders on ship design and configuration. This group, established in 1900 as the General Board has gone through many name changes, including the Ship Characteristics and Improvement Board in the early 1980s and, until 2002, the Ship Characteristics and Improvement Panel.

Navy officials say that the panel's oversight began to wane in the late 1990s, just as the DD-21 program — originally envisioned as a \$750 million replacement for Spruance-class destroyers — took off, before becoming officially inactive in 2002. Requirements during this time were added to the new

³² Norman Friedman, *U.S. Destroyers, An Illustrated Design History, Revised Edition*. Annapolis, Naval Institute Press, 2004, pp. 437 and 447-448. Punctuation as in the original.

destroyer program, some of which raised eyebrows in the Navy, such as the need for a flag officer quarters. No other ship in that class has accommodations for an admiral. Still, the DDG-1000 has come to be regarded as a technology carrier for future surface ships and the price tag has ballooned to \$3 billion a copy.

Mullen's goal, spelled out in a July 25 memo to Willard and provided to *InsideDefense.com*, is to put in place a "process that adequately defines warship requirements and manages changes to those requirements (e.g. Ship Characteristics Improvement Board) in a disciplined manner, with cost and configuration control as the paramount considerations."...

A recent RAND study conducted at the request of Mullen's predecessor, retired Adm. Vern Clark, concluded that a key cause for climbing ship costs is the number of requirements tacked on to a program, according to a consultant familiar with the findings of the study, which has not been made public.

"So, what I think Mullen has in the back of his head is, 'I've got to get the requirements process for ships back under control or we're always going to end up, every time we talk about a new destroyer, with a \$3 billion ship,'" said a former senior Navy official.

This senior official, who was in a key Pentagon position as the DD-21 program commenced, said that without a panel overseeing the ship's configuration and true requirements the new destroyer program became weighed down with capabilities that carried a high price tag.

"In hindsight, we realized that we had put requirements on the ship that no one had really vetted for its cost impact on the ship. For example, it was to operate acoustically silent and risk free in minefields," said the official. "If the SCIB had existed, this probably would not have happened."³³

A March 2007 report from the Center for Strategic and Budgetary Assessments (CSBA) makes a similar point:

For nearly a century, the Navy's SCIB — a group of high-ranking DoN [Department of the Navy] officials — worked to balance desired warship warfighting requirements against their impact on a ship's final design and production costs. The primary reason why the Navy lost cost control over the DD-21/DD(X)/DDG-1000 was that just as the ship entered its design definition phase, the power of the Navy's SCIB was waning, replaced by a Joint requirements definition process with no fiscal checks and balances.³⁴

Some observers, such as Norman Friedman, have raised questions about the Navy's decision to use a tumblehome (i.e., inward-sloping) hull for the DDG-1000. A 2006 magazine article by Friedman, for example,

³³ Jason Sherman, "Mullen To Bring Back Panel To Control Ship Configuration, Cost," *Inside the Navy*, August 8, 2005.

³⁴ Robert Work, *Know When To Hold 'Em, Know When To Fold 'Em: Thinking About Navy Plans For The Future Surface Battle Line*, Washington, Center For Strategic and Budgetary Assessments, 2007. p. 6. (CSBA Backgrounder, March 7, 2007).

- raises questions about the implications of a tumblehome hull for the ship's ability to deal with underwater damage;³⁵
- asks whether the Navy knew at the outset of the DDG-1000 design process how much a decision to incorporate a tumblehome hull (and other survivability features) would increase the size of the ship; and
- questions whether the reduced visibility of the tumblehome hull to certain types of radars — the central reason for using a tumblehome hull — will be negated by its visibility to high-frequency (HF) surface wave radars that are now for sale on the international market.

The article, which refers to the DDG-1000 by the previous designation DD(X), states:

In the case of the DD(X), the overriding requirement [in determining the hull design] was to minimise radar cross section — stealth. Much of the hull design was dictated by the attempt to reflect radar pulses away from the radar emitting them, so that radar returns would be minimised. By now the main technique is well known: slope all flat surfaces and eliminate the corner reflector created by the juncture of the hull and water....

If the ship could be stabilized sufficiently [against rolling from side to side], then she would never (or almost never) present any vertical surfaces [to a radar]. In the case of DD(X), stabilization is apparently achieved using ballast tanks. Such tanks in turn demand internal volume deep in the ship. Overall, stealth demands that as much as possible of the overall volume of the ship be buried in her hull, where the shape of the ship can minimise radar returns. That is why, paradoxically, a carefully-designed stealthy ship will be considerably larger — for more internal volume — than a less stealthy and more conventional equivalent. In the case of DD(X), there were also demands for improved survivability. The demand for stealth implied that anti-ship missiles were the most important envisaged threat. They hit above water, so an important survivability feature would be to put as much of the ship's vitals as possible below water — which meant greater demands for underwater volume....

Once the tumblehome hull had been chosen, [the ship's designers] were apparently also constrained to slope the bow back [creating a surface-piercing or ram bow] instead of, as is usual, forward....

There were numerous reasons why [past] naval architects abandoned tumblehome hulls and ram bows. Tumblehome reduces a ship's ability to deal with underwater damage. When a conventional flared (outward-sloping) hull sinks deeper in the water, its waterplane area [the cross-section of the ship where it intersects the plane of the water] increases. It becomes somewhat more stable, and it takes more water to sink it deeper into the water. Because the waterplane area of a tumblehome ship *decreases* as it draws more water, such a ship is easier to sink deeper. Tumblehome also apparently makes a ship less stable, and hence less capable of resisting extreme weather conditions. The larger the ship, the

³⁵ Other observers have also expressed concerns about the stability of the DDG-1000's tumblehome hull in certain sea conditions. For a discussion, see Christopher P. Cavas, "Is New U.S. Destroyer Unstable?," *DefenseNews.com*, April 2, 2007.

more extreme the weather has to be to make that critical. Critics of DD(X) have concentrated on the danger; defenders have concentrated on how extreme the critical weather condition would be.

In the end, whether the DD(X) hull form is attractive depends on an evaluation of anti-radar stealth as a design driver. About a decade ago, the DD(X) design concept was sold on the basis of a lengthy (and, incidentally, unclassified) analysis, the gist of which was that a heavily-armed surface combatant could play a decisive role in a Korean scenario...

The key analytic point... was that it would be very important for the ship to come reasonably close to enemy shores unobserved. That in turn meant anti-radar stealth. However, it soon came to mean a particular kind of anti-radar performance, against centimetric-wave radars [radars with wavelengths on the order of centimeters] of the sort used by patrol aircraft (the ship would fire [its weapons] from beyond the usual horizons of shore-based radars). As it happens, anti-ship missiles use much the same kinds of radars as patrolling aircraft, so it could be argued that the same anti-radar techniques would be effective in the end-game in which missiles would approach the ship....

Without access to files of the time, it is impossible to say whether those approving the [DDG-1000] project realised that its stealth and survivability characteristics would produce a 14,000 to 17,000 ton destroyer. About the same time that DD(X) characteristics (requirements) were being approved, the decision was taken at [the] Defense Department (not Navy) level that there would be no internal feasibility design. In the past, the feasibility stage had the very useful role of showing those setting requirements what their implications would be. At the very least, the Navy's senior leadership would have been given warning that they would have to justify a drastic jump in destroyer size when they wanted to build DD(X). That jump might well have been considered justified, but on the other hand the leadership might also have asked whether a somewhat less dramatic approach would have been acceptable.

About a decade after the requirements were chosen, with DD(X) well advanced, the situation with regard to stealth may be changing. Shaping is relevant only at relatively short [radar] wavelengths. For about a quarter-century, there has been talk of HF surface wave radars, which operate at wavelengths of about 10 to 200 meters — i.e. at wavelengths the size of a ship. Canada currently operates this type of radar, made by Raytheon, for surveillance of the Grand Banks; another is being tested in the Caribbean. Australia has bought this kind of radar to fill gaps in over-the-horizon radar coverage. Turkey is buying such radars for sale for some years. In 2005 it was reported unofficially that China had bought [a] Russian HF surface wave radar the previous year.

It seems almost certain that HF surface wave radar can defeat any kind of stealth shaping designed primarily to deal with shorter-wave[length] radars. Moreover, [HF surface wave] radars have an inherent maximum range (due to the way they operate) of about 180nm.... At long range [the radar's beam] is not nearly accurate enough to aim a missile. However, we can easily imagine a netted system which would use the long-range [HF surface wave] radar to define a small box within which the target ship would be. A missile with GPS [Global Positioning System] guidance could be flown to that box, ordered to search it....

If the argument given here is realistic, then the considerable sacrifices inherent in the DD(X) design no longer seem nearly as attractive. It can still be argued that a design like the DD(X) is attractive well out to sea, beyond the reach of coastal radars. In that case, however, there may be other signatures which can be exploited. For example, ships proceeding at any speed create massive wakes.... it is clear that the wake produces a radar return very visible from an airplane or, probably, from a space-based radar....

In the end, then, how much is stealth worth? As a way of avoiding detection altogether, probably less than imagined. That leaves the rather important end-game, the hope being that decoys of some sort greatly exceed actual ship radar cross-section. That is probably not a foolish hope, but it does not require the sort of treatment reflected in [the] DD(X).

Now, it may be that the United States typically faces countries which have not had the sense to buy anti-stealth radars (though we would hate to bet on that). In that case, DD(X) may well be effectively invisible to them. So will a lot of less thoroughly stealthy ships.³⁶

Potential oversight questions for Congress include the following:

- **SCIB and DDG-1000 requirements.** Are the DDG-1000's requirements partly a result of inadequate discipline, following the disestablishment of the SCIB, in the Navy's process for setting requirements for new ships? If the SCIB had remained in existence during the DD-21/DDG-1000 design process, which of the DDG-1000's current requirements would have been reduced or eliminated?
- **Tumblehome hull.** How much did the decision to use a tumblehome hull (and other survivability features) increase the size and cost of the DDG-1000? In the mid-1990s, when design work began on the ship now known as DDG-1000, how well did the Navy understand the relationship between using a tumblehome hull and ship size and cost? What effect does the tumblehome hull have on the DDG-1000's ability to deal with underwater damage? To what degree will HF surface wave radars negate the stealth characteristics of the DDG-1000 design?
- **AGSs.** Since the DDG-1000 is the only ship planned to carry AGSs, and since AGSs are viewed by the Marine Corps as necessary to meet Marine Corps requirements for naval surface fire support capability, should the AGSs be considered the most-critical payload element on the DDG-1000, and certain other payload elements, though desirable, be considered as possibly less critical by comparison?

³⁶ Norman Friedman, "The New Shape of Ships," *Naval Forces*, No. II, 2006: 56-58, 60, 62-63. Italics as in the original. Friedman makes somewhat similar comments in chapter 17 (pages 431-450) of *U.S. Destroyers, An Illustrated Design History, Revised Edition*, op cit.

- **Hangar.** In light of the 167 or more current or planned helicopter hangar spaces on other Navy surface combatants (2 spaces on each of 22 Aegis cruisers and the final 34 DDG-51s, and at least 1 space on each of 55 LCSs), and the relatively limited number of Navy helicopters available for filling those spaces, how critical is it for the DDG-1000 to have a hangar with spaces for two helicopters? Would it be acceptable for the DDG-1000 instead to have only a helicopter landing platform and an ability to refuel and rearm helicopters, like the first 28 DDG-51s?
- **VLS tubes.** In light of the 8,468 vertical launch system (VLS) missile tubes on the Navy's planned force of 84 VLS-equipped Aegis ships (22 cruisers with 122 tubes each, 28 earlier DDG-51s with 90 tubes each, and 34 later DDG-51s with 96 tubes each), the ability of VLS tubes to store and fire either one 21-inch diameter missile or four smaller-diameter Evolved Sea Sparrow Missiles (ESSMs), the ability in a networked force for a ship to control a missile fired by another ship, and the DDG-1000's key role in providing naval gunfire support with its two AGSs, how critical is it for the DDG-1000 to have 80 enlarged VLS tubes as opposed to a smaller number, such as 64, 48, or 32?
- **Command facilities.** In light of the flag-level command facilities on the 22 Aegis cruisers, as well as additional command facilities on aircraft carriers and planned amphibious assault ships, how critical is it for the DDG-1000 to have flag-level command facilities?
- **SOF support facilities.** In light of SOF support facilities on the Navy's planned force of four converted Trident submarines, or SSGNs (66 or more SOF personnel for each ship),³⁷ support facilities for smaller numbers of SOF on Navy attack submarines (SSNs), and the secondary SOF support role for the Navy's planned force of 55 LCSs, how critical is it for the DDG-1000 to have SOF support facilities?
- **AAW system.** In light of the Aegis area-defense AAW systems on the Navy's 84 Aegis cruisers and destroyers — which, though not as capable in some respects as the DDG-1000's AAW system in littoral operating environments, would still be quite capable, particularly when numbers of Aegis ships are taken into account — how critical is it for the DDG-1000 to have an area-defense-capable AAW system, as opposed to a more modest point-defense AAW system capable of defending only the DDG-1000 itself (which might be

³⁷ For more on the SSGN program, see CRS Report RS21007, *Navy Trident Submarine Conversion (SSGN) Program: Background and Issues for Congress*, by Ronald O'Rourke.

closer to the more modest AAW system that was originally envisaged for the DD-21, the precursor to the DDG-1000)?³⁸

³⁸ Earlier editions of this report also asked the following question:

Gun shell capacity. In light of the DDG-1000 design feature that allows underway replenishment of gun shells, creating the equivalent of an almost-infinite ammunition magazine and permitting nearly continuous fire support, how critical is it for the DDG-1000 to have a total gun shell capacity of 920 shells, as opposed to a smaller number, such as 600?

A December 2005 press stated that, as part of an effort to reduce the cost of the DDG-1000, the Navy had reduced the magazine capacity of the design from 920 shells to 600. (Christopher P. Cavas, "U.S. Ship Plan To Cost 20% More," *Defense News*, December 5, 2005: 1, 8.)

Appendix B. Potential Lower-Cost Ships

Lower-Cost Gunfire Support Ship

CBO and naval analyst Robert Work of the Center for Strategic and Budgetary Assessments (CSBA) have both suggested, as a lower-cost naval gunfire support ship, an AGS-equipped version of the basic hull design of the San Antonio (LPD-17) class amphibious landing ship. Such a ship might begin procurement in FY2009, following procurement of a final “regular” LPD-17 amphibious landing ship in FY2008. CBO estimates that an initial AGS-armed LPD-17 might cost about \$1.9 billion, including \$400 million detailed design and nonrecurring engineering costs, and that subsequent ships might cost about \$1.5 billion each.³⁹

Lower-Cost Cruiser-Destroyer

A new-design, lower-cost cruiser-destroyer might:

- start procurement as soon as FY2011, if design work were started right away;
- incorporate many of the same technologies now being developed for the DDG-1000 and CG(X);
- employ a modular, “plug-and-fight” approach to some of its weapon systems, like the LCS;
- be similar to the DDG-1000 and CG(X) in terms of using a reduced-size crew reduce annual operation and support costs;
- use a second-generation surface combatant integrated electric-drive propulsion system that is smaller and lighter than the first-generation system to be installed in the first DDG-1000s;⁴⁰
- carry a payload — a combination of sensors, weapon launchers, weapons, and aircraft — that is smaller than that of the DDG-1000 or CG(X), but still sizeable; and
- be built in one or two variants — an air- and missile-defense version to replace the CG(X), which would preserve CG(X) radar

³⁹ See Congressional Budget Office, *Options for the Navy’s Future Fleet*, May 2006, pp. 56-57 (Box 3-1).

⁴⁰ The integrated electric-drive system to be installed in the first DDG-1000s uses advanced induction motors. A second-generation system could use smaller and lighter motors and generators that employ permanent magnet or high-temperature superconducting technology. Both of these technologies are currently being developed. For more on these technologies, see CRS Report RL30622, *Electric-Drive Propulsion for U.S. Navy Ships: Background and Issues for Congress*, by Ronald O’Rourke. (July 31, 2000)

capabilities while reducing other payload elements, and possibly also a surface fire support version to supplement the DDG-1000, which would preserve the DDG-1000's two AGSs while reducing other payload elements.

Notional options for a lower-cost cruiser-destroyer include, but are not limited to, the following:

- a ship displacing about 9,000 tons — about the same size as the DDG-51; or
- a ship displacing about 11,000 tons — about 25% less than the DDG-1000's displacement of about 14,500 tons, about the same size as the nuclear-powered cruisers procured for the Navy in the 1960s and 1970s, and about 1,800 tons larger than the DDG-51.

Such a ship might be based on either the DDG-51 hull design, which is a conventional flared hull that slopes outward as it rises up from the waterline,⁴¹ or a new flared hull design, or a reduced-sized version of the DDG-1000's tumblehome (inwardly sloping) hull design.

The Navy in 2002 identified the following ship-design characteristics as items that, if varied, would lead to DDG-1000 concept designs of varying sizes, capabilities, and procurement costs:

- cruising range,
- maximum sustained speed,
- number of Advanced Gun Systems (AGSs) and AGS shells,
- hangar space for helicopters and UAVs,
- undersea warfare systems (i.e., sonars and mine countermeasures systems), and
- numbers and types of boats for special operations forces.

Using these variables, the Navy in 2002 developed notional DDG-1000 concept designs with estimated full load displacements ranging from 12,200 tons to about 16,900 tons. One of the concept designs, with an estimated full load displacement of about 12,700 tons, included 32 Advanced Vertical Launch System (AVLS) cells (rather than the DDG-1000's 80), two AGSs (like the DDG-1000), 600 AGS shells (like the DDG-1000), a maximum sustained speed a few knots lower than the DDG-1000's, and a helicopter flight deck smaller than the DDG-1000's. Another concept design, with an estimated full load displacement of about 12,200 tons, included 64 AVLS cells, 1 AGS, 450 AGS rounds, a maximum sustained speed a few knots lower than the DDG-1000's, and helicopter flight deck smaller than the DDG-1000's.

⁴¹ Using the DDG-51 hull in its current dimensions might produce a ship of about 9,000 tons; lengthening the DDG-51 hull with a mid-hull plug might produce a ship of about 11,000 tons.

The Navy in 2003 developed another set of notional DDG-1000 concept designs with estimated full load displacements ranging from 11,400 tons to 17,500 tons. One of the concept designs, with an estimated full load displacement of 13,400 tons, included 64 AVLS cells, 1 AGS, and 450 AGS rounds. Another concept design, with an estimated full load displacement of 11,400 tons, included 32 AVLS cells, 1 AGS, and 300 AGS rounds.

The 2002 and 2003 notional DDG-1000 concept designs with displacements of less than 14,000 tons appear to have preserved other DDG-1000 features, such as the wave-piercing, tumblehome hull, the integrated electric drive system (though with reduced total power in at least some cases), the total ship computing environment, the autonomic fire-suppression system and other features permitting a reduced-sized crew, the DDG-1000 radar suite, the hull and towed-array sonars, medium-caliber guns for use against surface targets, and a helicopter hangar (though not necessarily as large a hangar as on the DDG-1000).

Reducing payload features a bit more than under the smallest of the 2002 and 2003 notional concept designs might lead to a design with a displacement of about 9,000 to 11,000 tons. The Navy has viewed designs of less than 14,000 tons as unsatisfactory because of their reduced individual capabilities. It is not clear, however, to what degree the Navy's assessment of such designs also takes into account the difference that size (and thus unit procurement cost) can have on the total number of ships that might be procured within available resources, and consequently on future cruiser-destroyer force levels. Total cruiser-destroyer force capability is dependent on both cruiser-destroyer unit capability and the total number of cruisers and destroyers.

Notional Procurement Profiles With Lower-Cost Ships

Table 4 and **Table 5** show notional procurement profiles incorporating the ships described above. In **Table 4**, an AGS-equipped version of the basic LPD-17 hull design is procured to supplement the Navy's DDG-1000s, and an air- and missile-defense version of the smaller cruiser-destroyer is procured starting in FY2011 in lieu of the CG(X). In **Table 5**, a smaller cruiser-destroyer in two versions — an AGS-equipped version to supplement the Navy's DDG-1000s, and air- and missile-defense version in lieu of the CG(X) — is procured starting in FY2011.

**Table 4. Alternative With LPD (AGS)
and Smaller Cruiser-Destroyer**
(annual quantities procured, FY2007-FY2021)

| | 07 | 08 | 09 | 10 | 11 | 12 | 13-21 | Total |
|------------------------|----------------|----------------|----|----|----|----|--------|-------|
| DDG-1000 | 2 ^a | 0 ^a | 1 | 1 | | | | 4 |
| LPD (AGS) ^b | | | 1 | 1 | 1 | 2 | | 5 |
| SCD ^c | | | | | 1 | | 2/year | 19 |

Source: Prepared by CRS.

- a. Each of the two ships to be procured in FY2007 is to be split-funded across FY2007 and FY2008.
- b. Basic LPD-17 hull equipped with 2 Advanced Gun Systems (AGSs).
- c. Air- and missile-defense version of smaller cruiser-destroyer (SCD), in lieu of CG(X).

Table 5. Alternative With Smaller Cruiser-Destroyer
(annual quantities procured, FY2007-FY2022)

| | 07 | 08 | 09 | 10 | 11 | 12 | 13-22 | Total |
|------------------|----------------|----------------|----|----|----|----|--------|-----------------|
| DDG-1000 | 2 ^a | 0 ^a | 1 | 1 | | 1 | | 5 |
| SCD ^b | | | | | 1 | | 2/year | 21 ^b |

Source: Prepared by CRS.

- a. Each of the two ships to be procured in FY2007 is to be split-funded across FY2007 and FY2008.
 b. Includes 2 AGS-equipped versions of smaller cruiser-destroyer (SCD), for a total (along with 5 DDG-1000s) of 7 AGS-equipped ships, and 19 air- and missile-defense versions, in lieu of CG(X).

CSBA Report Recommendations

A March 2007 report from the Center for Strategic and Budgetary Assessments (CSBA) on the Navy's surface combatant force discusses existing and future Navy surface combatants and makes the following recommendations (emphasis as in the original):

— **First, “fold” the CG-21 hand: cancel all planned new CG-21s [i.e., DDG-1000s and CG(X)s] beyond the two DDG-1000s already authorized.**⁴² A variation of this plan would be to build just one ship. By building two (or one) operational test beds/technology demonstrators, the Navy can recoup most of the previous “bets” made on the CG-21s. Having one or two test ships would allow further testing and refinement of the SPY-3 multifunction radar, which is to be installed on future aircraft carriers regardless of what happens with the DDG-1000, and perhaps on other ships. Over time, the ships could be modified to test other future surface combatant combat systems such as underwater combat systems or electronic warfare systems. Regardless of configuration, the ships would provide the battle fleet with a test article for new integrated power system components as well as electrically-powered weapons. In this role, the less capable advanced induction motor to be installed on the first two DDG-1000s ships will be as effective as the permanent magnet motor — the Navy's desired electric motor. The ships' larger VLS cells would allow the Navy to test larger diameter guided missiles. In fleet exercises, the ships would help to identify the true operational payoffs of ship stealth within the context of distributed naval battle networks. Finally, these large ships with small crews would help the Navy to refine the maintenance concepts for future optimally manned fleet combatants (i.e., warships with reduced crews).

— **Second, “hold” the Aegis/VLS fleet: design a comprehensive, Aegis/VLS Battle Network Reliability and Maintenance (BNRAM) program, with the goal of producing the maximum number of interchangeable, Interim Large Battle Network Combatants. (I-LBNCs).** The Navy's ultimate goal is to shift to a new Large Battle Network Combatant, or LBNC — a far better description of future Total Force Battle Network [TFBN] ships-of-the-line than the multimission guided-missile “cruisers” and “destroyers” or general-purpose “destroyers” associated with today's legacy Total Ship Battle Force. Until they can be designed, betting an additional \$10-15 billion on five or six additional

⁴² The CSBA report uses the term CG-21s to refer collectively to DDG-1000s and CG(X)s.

DDG-1000s would appear to provide far less of a TFBN payoff than making a similar sized or even smaller bet on a well-thought-out and executed BNRAM program to convert the 84 programmed Aegis/VLS warships into more powerful I-LBNCs. This conversion program would be patterned after earlier modernization and conversion efforts, like the Fleet Reliability and Maintenance (FRAM) program, which converted many of the large legacy fleet of World War II destroyers into effective Cold War ASW escorts. The BNRAM would include a thorough mid-life upgrade to the ships' hull, machinery and electrical (HM&E) systems; a combat systems upgrade to allow the ships to counter emerging threats; and a battle network upgrade to allow the ships to operate as part of a coherent naval battle network. Consistent with battle network precepts, the intent of the BNRAM would be to bring as many ships as possible to a common I-LBNC combat system baseline. The BNRAM would also aim to lower substantially the operations and maintenance costs (O&M) costs necessary to operate the legacy Aegis/VLS fleet, in order to save money in the near term, and to offset to some degree the added costs necessary to keep older ships in service over the longer term. A key part of this effort centers on reducing the crew size needed to operate, maintain, and fight the ships. Importantly, because this effort can justifiably be seen as converting legacy Aegis/VLS ships into more capable I-LBNCs, the BNRAM should be funded out of more stable Ship Construction Navy (SCN) funds rather than the more volatile O&M accounts.

— **Third, immediately kick-start a clean-sheet competition to develop and design a family of next-generation Large Battle Network Combatants, with close oversight by the newly reconstituted Ship Characteristics Improvement Board (SCIB).** For nearly a century, the Navy's SCIB — a group of high-ranking DoN [Department of the Navy] officials — worked to balance desired warship warfighting requirements against their impact on a ship's final design and production costs. The primary reason why the Navy lost cost control over the DD-21/DD(X)/DDG-1000 was that just as the ship entered its design definition phase, the power of the Navy's SCIB was waning, replaced by a Joint requirements definition process with no fiscal checks and balances. One of the first things Admiral Mike Mullen, the current Chief of Naval Operations, did upon assuming his office was to reconstitute the Navy's SCIB. With a chance to start from a clean sheet of paper, naval design architects could leverage an additional decade of experience in the post-Cold War era to design an entirely new family of next-generation LBNCs, under the close oversight of the newly reconstituted SCIB. These new warships would have a common gas turbine or perhaps even a nuclear power plant that supplies enormous shipboard electrical generating capacity; common electric propulsion motors; common integrated power systems that distribute electric power to the ships' electric motors, combat systems, and weapons, as needed; and advanced automation to enable them to operate with relatively small crews. Their single common hulls, or network frames, should be large and easily produced, based on the best ideas of naval engineers, with an affordable degree of stealth. The network frames would be able to accept a range of open architecture battle network mission modules consisting of sensors and onboard and offboard weapons designed explicitly to support a battle network rapid capability improvement strategy. The cost-constrained goal for the combination of network frames and network mission modules would be to build new LBNCs at a rate of five every two years, allowing the complete transition from 84 Aegis/VLS I-LBNCs to 88 next-generation LBNCs in 35 years. The ships would be built under a profits-related-to-offer arrangement. While each of the two remaining surface combatant shipyards could count on building one LBNC per year, they would compete for an extra ship every other year. The yard with the lowest bid would

be able to claim higher profit margins on the two LBNCs it would build until the next bi-annual competition. In this way, in addition to the natural cost savings due to learning curve efficiencies, the Navy would be able to spark continuous competition between the two building yards.

— **Starting in FY 2008, build a minimum of seven additional [Arleigh] Burke-class DDGs [i.e., DDG-51s] to help sustain the industrial base until the new LBNC is ready for production.** In effect, building one modified Burke each year between FYs 2008 and 2014 would replace the seven DDG-1000s in the current plan. For reasons that are detailed in the forthcoming report, the first four modified Burkes would be configured with the same Area Air Defense Command Capability System (AADCCS) found on the Ticonderoga-class CGs. In addition, all seven ships would serve as active test beds for DDG improvements identified as possible candidates for further BNRAM backfits, or to test next-generation LBNC technologies. As such, the ships would serve much the same purpose as both the Forrest Sherman-class destroyers — which helped to bridge the shipbuilding gap between World War II combatants and Cold War combatants designed to battle jets, missiles, and high-speed submarines — and modified legacy combatants like the USS Gyatt, DDG-1, which helped to illuminate the way forward toward a new generation of BFC combatants. Provided all went as planned, Congress would authorize two of the next-generation LBNCs in FY 2015, split funded as in the current arrangement for the DDG-1000, giving each of the two remaining surface combatant construction yards one ship. The general fleet-wide transition from Aegis/VLS I-LBNCs to the new LBNC design would then begin in FY 2017, with three ships authorized after a bidding competition. Of course, if the design was not ready for production, additional Burkes could be built until it was.

— **Task each of the planning yards for CG and DDG modernization to design and implement a comprehensive follow-on maintenance regime to ensure all Aegis/VLS combatants are able to serve out the remainder of their 35-year service lives effectively.** The Navy's plan counts on every one of the 84 programmed Aegis/VLS combatants of completing 35 years of commissioned service. Yet, since the end of World War II, few surface combatants remain in commission beyond 25-30 years of service — even after receiving mid-life upgrades. Unless the BNRAM program includes a sustained maintenance regime beyond its mid-life HM&E, combat systems, and battle network upgrades and crew reduction measures, it is unlikely the ships will see their 35th year. The building shipyards might be the logical organizations to implement this new maintenance regime on the Navy's behalf. By establishing financial incentives that provide the yards with bonuses for every year a ship stays in service beyond 25 years, the Navy will maximize the probability that the ships will remain in service. As part of their efforts, the yards and the Navy should also solicit ideas for further ship improvements from vendors, and complete the trade studies for an expanded service life extension program (SLEP) of the existing ships, with a goal of extending their expected service lives to 40 years. This would provide a hedge should design work on the next-generation LBNC be delayed for any reason, or if a future maritime challenge spurs the need to rapidly expand the number of large combatants beyond the 88 included in the 313-ship Navy.⁴³

⁴³ Robert Work, *Know When To Hold 'Em, Know When To Fold 'Em: Thinking About Navy* (continued...)

⁴³ (...continued)

Plans For The Future Surface Battle Line, Washington, Center For Strategic and Budgetary Assessments, 2007. pp. 5-8. (CSBA Backgrounder, March 7, 2007).