United States Government Accountability Office

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Report to the Ranking Member, Subcommittee on Defense, Committee on Appropriations, House of Representatives

January 2012

ARLEIGH BURKE DESTROYERS

Additional Analysis and Oversight Required to Support the Navy's Future Surface Combatant Plans

GAO

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GAO-12-113

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Highlights

Highlights of GAO-12-113, a report to the Ranking Member, Subcommittee on Defense, Committee on Appropriations, House of Representatives

Why GAO Did This Study

After nearly a decade and almost $10 billion in development on Zumwalt class destroyers, the Navy changed its acquisition approach from procuring Zumwalts to restarting production of Arleigh Burke class destroyers (DDG 51) and building a new version, known as Flight III. As requested, GAO reviewed the Navy's plans for DDG 51 and missile defense capabilities by (1) evaluating how the Navy determined the most appropriate platform to meet surface combatant requirements; (2) identifying and analyzing differences in design, cost, and schedule of the restart ships compared with previous ships; and (3) assessing the feasibility of Navy plans for maturing and integrating new technologies and capabilities. GAO analyzed Navy and contractor documentation and interviewed Navy, contractor, and other officials.

What GAO Recommends

GAO is making several recommendations to the Secretary of Defense, including requiring the Navy to conduct thorough analyses of alternatives for its future surface combatant program and conduct realistic operational testing of the integrated missile defense capability of the DDG 51's upgrade, ensuring that the Navy does not include the lead Flight III ship in a multiyear procurement request, and raising the level of oversight for this program. DOD agreed with the recommendations to varying degrees, but generally did not offer specific actions to address them. GAO believes all recommendations remain valid and has included matters for congressional consideration to ensure the soundness of the Navy's business case.

View GAO-12-113. For more information, contact Belva Martin at (202) 512-4841 or MartinB@gao.gov.

What GAO Found

The Navy relied on its 2009 Radar/Hull Study as the basis to select DDG 51 over DDG 1000 to carry the Air and Missile Defense Radar (AMDR) as its preferred future surface combatant—a decision that may result in a procurement of up to 43 destroyers and cost up to $80 billion over the next several decades. The Radar/Hull Study may not provide a sufficient analytical basis for a decision of this magnitude. Specifically, the Radar/Hull Study:

- focuses on the capability of the radars it evaluated, but does not fully evaluate the capabilities of different shipboard combat systems and ship options under consideration,
- does not include a thorough trade-off analysis that would compare the relative costs and benefits of different solutions under consideration or provide robust insight into all cost alternatives, and
- assumes a significantly reduced threat environment from other Navy analyses, which allowed radar performance to seem more effective than it may actually be against more sophisticated threats.

The Navy's planned production schedules of the restart DDG 51 ships are comparable with past performance and officials told us that hull and mechanical systems changes are modest, but these ships will cost more than previous DDG 51s. A major upgrade to the ship's combat system software also brings several challenges that could affect the restart ships, due in part to a key component of this upgrade that has already faced delays. Further delays could postpone delivery to the shipyard for the first restart ship, and could also jeopardize the Navy's plan to install and test the upgrade on an older DDG 51 prior to installation on the restart ships. This first installation would serve to mitigate risk, and if it does not occur on time the Navy will be identifying, analyzing, and resolving any combat system problems on the first restart ship. Further, the Navy does not plan to fully test new capabilities until after certifying the upgrade as combat-ready, and has not planned for realistic operational testing necessary to fully demonstrate its integrated cruise and ballistic missile defense performance.

The Navy faces significant technical risks with its new Flight III DDG 51 ships, and the current level of oversight may not be sufficient given these risks. The Navy is pursuing a reasonable risk mitigation approach to AMDR development, but it will be technically challenging. According to Navy analysis, selecting the DDG 51 hullform to carry AMDR requires significant redesign and reduces the ability of these ships to accommodate future systems. This decision also limits the radar size to one that will be at best marginally effective and incapable of meeting the Navy's desired capabilities. The Navy may have underestimated the cost of Flight III, and its plan to include the lead ship in a multiyear procurement contract given the limited knowledge about the configuration and the design of the ship creates potential cost risk. Finally, the current level of oversight may not be commensurate with a program of this size, cost, and risk and could result in less information being available to decision makers.

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Abbreviations

ACB	Advanced Capability Build
AOA	Analysis of Alternatives
AMDR	Air and Missile Defense Radar
BMD	Ballistic Missile Defense
DOD	Department of Defense
IAMD	Integrated Air and Missile Defense
MAMDJF	Maritime Air and Missile Defense of Joint Forces
SLA	Service Life Allowance
SPY	Maritime surveillance radar
TSCE	Total Ship Computing Environment

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Accountability * Integrity * Reliability
United States Government Accountability Office
Washington, DC 20548

January 24, 2012

The Honorable Norm Dicks
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Dear Mr. Dicks:

After nearly a decade and almost $10 billion in development of the Zumwalt class destroyer (DDG 1000), the Navy—citing in part advances in ballistic and anti-ship missiles and proliferation of this technology—changed its acquisition approach for surface combatants from procuring DDG 1000 to restarting production of the Arleigh Burke class destroyers (DDG 51). Navy officials believe that DDG 51—carrying the Aegis combat system[1]—has a proven ballistic missile defense capability that makes it the preferred option over other ships to fill a gap in the Navy's abilities to provide simultaneous defense against ballistic and cruise missiles (known as Integrated Air and Missile Defense, or IAMD), and that modifying DDG 1000 would be too costly and bear too much risk. Concurrently, the Navy also cancelled its planned new air warfare-focused cruiser program, known as CG(X). Ultimately the Navy is procuring current versions of DDG 51 ships and plans to begin building a new version of the class (known as Flight III[2]) that is to be modified to carry the advanced Air and Missile Defense Radar (AMDR) to meet the identified threats. Pursuing this strategy could require an investment of up to approximately $80 billion for up to 43 destroyers, with DDG 51s providing IAMD capability for potentially up to the next 60 years. In this context, you asked us to review the Navy's plans for DDG 51 and missile defense capabilities. In particular, we: (1) evaluated how the Navy determined the most appropriate platform to meet current and future surface combatant requirements; (2) identified and analyzed differences in design, cost, and

[1] A combat system is a naval defense architecture that uses computers to integrate sensors (such as a radar) with shipboard weapon systems and can recommend weapons to the sailor through a command and control function.

[2] There are three previous DDG 51 Flights: Flight I, Flight II, and Flight IIA. The differentiation of the various flights generally indicates upgrades that bring different capabilities and equipment to the ships of that flight.

schedule of the restart DDG 51 ships compared with previous ships, and risks associated with the restart; and (3) assessed the feasibility of Navy plans for maturing and integrating new technologies and capabilities into the Flight III ships.

To conduct our work, we analyzed Navy technical studies related to Flight III; documentation related to Flight III, CG(X), and AMDR; and Department of Defense (DOD) and Navy threat assessments. We analyzed AMDR performance specifications and contractor performance data related to ongoing Aegis combat system upgrades, as well as cost estimates for Flight III. We also met with Missile Defense Agency (MDA), Navy, and other DOD officials, as well as shipyard representatives from Bath Iron Works in Bath, Maine and Ingalls Shipbuilding in Pascagoula, Mississippi, and radar contractor representatives from Lockheed Martin, Northrop Grumman, and Raytheon. We are also providing you with a classified annex containing supplemental information. This annex is available upon request to those with the appropriate clearance and a validated need to know. For more information on our scope and methodology, see appendix I.

We conducted this performance audit from January 2011 to January 2012 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives, and that the data we obtained and analyzed are sufficiently reliable for the purposes of our assessment.

Background

In the mid-2000s, the Navy was developing the DDG 1000 Zumwalt class destroyer—a new multimission land-attack ship—and laying the analytical framework to support a new air warfare cruiser acquisition program known as CG(X). The Navy planned to end DDG 51 production with the delivery of DDG 112 in 2011 (which would have completed the 62-ship program), and concentrate instead on DDG 1000—initially intended to be a class of up to 32 ships—and building up to 19 CG(X). However, at a July 31, 2008, hearing before the House Armed Services Committee, Seapower and Expeditionary Forces Subcommittee, the Navy stated that it faces a growing proliferation of ballistic missiles and antiship cruise missiles, requiring greater integrated air and missile defense capability and that the naval land attack capability provided by DDG 1000 had been obviated by improved precision munitions and targeting. Navy officials added that DDG 1000 had performance deficiencies compared to DDG 51, most notably in the areas of ballistic missile defense (BMD), area air defense, and some types of antisubmarine warfare.[3] Most importantly, the Navy stated that at that time DDG 1000 could not carry the Standard Missile (SM) 2, SM-3, or SM-6 and was incapable of conducting BMD, though officials have since told us that DDG 1000 is now capable of carrying the SM-2 missile, and that the Mk 57 Vertical Launching System is expected to be capable of carrying any of the standard missiles.[4] The Navy stated that DDG 51 was a proven ship with a proven combat system, and that the Navy intended on restarting production of DDG 51 to defend against substantial ballistic missile proliferation as a bridge to the deployment of CG(X). The Navy focused on building additional DDG ships, but did not discuss AMDR during this hearing. Following this hearing, the Navy began to initiate plans to truncate the DDG 1000 program and made preparations to restart the DDG 51 program.

The DOD Joint Requirements Oversight Council had previously identified simultaneous defense against ballistic missiles and antiship cruise missiles as a capability gap and in 2006 validated that IAMD was an operational requirement not sufficiently addressed by other platforms. At the same time the Navy adopted BMD as a core Navy mission that it would perform in concert with MDA. In September 2009, the Joint Requirements Oversight Council also updated and revalidated IAMD requirements. In order to determine the appropriate type of ship and radar that would best address identified IAMD capability gaps, the Navy conducted an Analysis of Alternatives (AOA) known as the Maritime Air

[3] DDG 1000 is optimized for littoral antisubmarine warfare, and the Navy testified that the DDG 51 is superior in the deep ocean. However, in a May 11, 2009 letter to the Chairman of the Senate Armed Services Committee, Subcommittee on Seapower, the Chief of Naval Operations stated that in some conditions the DDG 1000 could be expected to perform as well as or better than DDG 51s in antisubmarine warfare activities, and that at a campaign level the performance of both ships could be assumed as the same.

[4] Officials stated that DDG 1000 requires a modification to the combat system in order for the radar and combat system to communicate with the missiles.

and Missile Defense of Joint Forces (MAMDJF).[5] An AOA is an analytical comparison of the operational effectiveness, suitability, and life-cycle cost of alternative potential solutions to address valid capability needs. According to DOD acquisition guidance, an AOA examines potential material solutions with the goal of identifying the most promising option and is required to support a program's initiation of the technology development phase at Milestone A.[6] We have previously reported on the importance of a robust AOA as a key element in ensuring a program has a sound, executable business case prior to program initiation.[7] Our work has found that programs that conduct a limited AOA tended to experience poorer outcomes—including cost growth.[8]

In 2007, as a result of conclusions identified in the MAMDJF AOA, the Navy determined that it needed a very large radar carried on a larger, newly designed surface combatant to counter the most stressing ballistic and cruise missile threats. Consequently, the MAMDJF AOA served as the AOA for both the CG(X) program and for a new, dual-band radar development effort called AMDR. The Navy initiated development of CG(X) and AMDR—a large radar designed to be scalable, meaning that it could be increased in physical size to allow it to provide increased capability to meet future threats.

[5] MAMDJF AOA considered a wide range of ship variants, including a new cruiser concept, a new radar ship concept, modified and upgraded DDG 1000 variants, a modified DDG 51 variant with a 40' hull extension (known as a plug), and a modified LPD 17 amphibious transport dock ship variant. IAMD is the simultaneous defense against both ballistic missile threat and air warfare threats such as hostile aircraft and cruise missiles. Some CG 47s and DDG 51s can perform air warfare and BMD, the Oliver Hazard Perry class frigates (FFG 7) can only conduct short range anti-air warfare and no ballistic missile defense.

[6] Defense Acquisition Guidebook, section 3.3. The Weapons System Acquisition Reform Act of 2009 established a requirement for the development of study guidance for an AOA that requires, at a minimum, full consideration of possible trade-offs among cost, schedule, and performance objectives for each alternative considered, and an assessment of whether or not the joint military requirement can be met in a manner that is consistent with the cost and schedule objectives recommended by the Joint Requirements Oversight Council. Pub. L. No. 111-23, § 201(d).

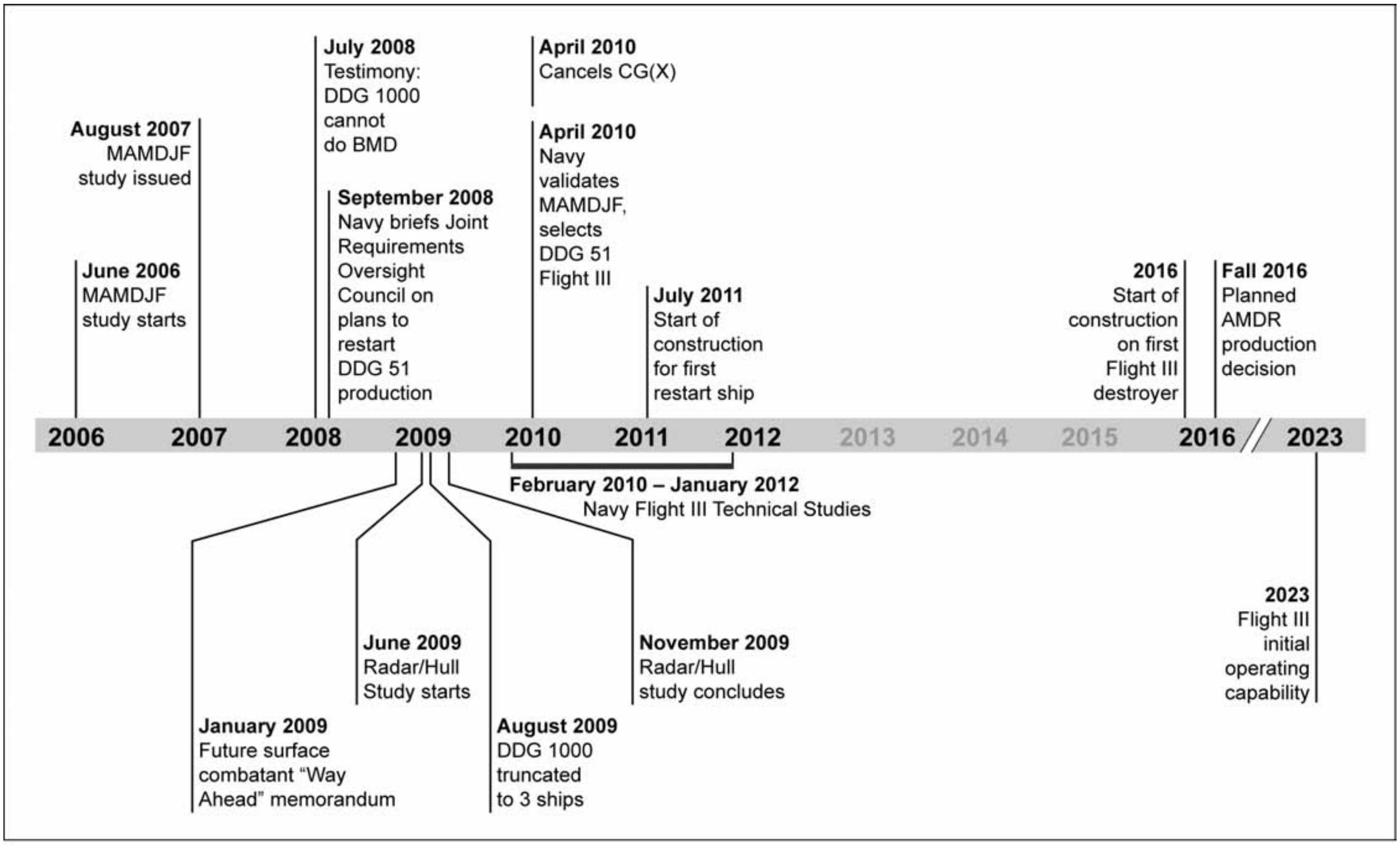
[7] *GAO, Many Analyses of Alternatives Have Not Provided a Robust Assessment of Weapon System Options*, GAO-09-665 (Washington, D.C.: Sept. 24, 2009).

[8] GAO-09-665.

In January 2009, in response to the Navy's planned changes to its surface combatant program, the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics released a memorandum stating that the Navy's plan to buy additional DDG 51 Flight IIA ships would be followed by a procurement of either DDG 1000- or DDG 51-based destroyers. The memorandum stated that this procurement would be referred to as the "Future Surface Combatant" until the appropriate hullform to carry AMDR was selected, and required that a study be conducted to identify this hullform.

To meet this requirement, in 2009 the Navy conducted a limited study referred to as the Radar/Hull Study. In the Radar/Hull Study, the Navy examined only the two existing destroyer designs—DDG 51 and DDG 1000—with several different radar concepts to determine which pairing would best address the IAMD capability gap and would be more affordable than CG(X), which Navy officials told us was estimated to cost upwards of $6 billion per ship. A senior review panel—known as a "red team"—also independently assessed the study, its analyses, and alternatives considered and provided a separate report on its findings. Following the conclusion of the Radar/Hull Study, the Navy validated the MAMDJF AOA's findings that a very large radar carried on a larger, newly designed surface combatant was necessary to counter the most stressing threats, but decided, based on the analysis of the Radar/Hull Study, that the preferred solution to meet the IAMD capability gap would be pairing a smaller AMDR with the familiar DDG 51 hullform and the Aegis combat system—which would be referred to as DDG 51 Flight III. The Navy at the same time also cancelled the CG(X) program, largely as a result of cost considerations. The timing of this analysis and key decision making was compressed, as reflected in figure 1.

Figure 1: Timeline of Key Events in Future Surface Combatant Selection Process



Source: GAO analysis.

The Navy now plans to build 9 DDG 51s in an upgraded Flight IIA configuration. Construction of the first restart ship (DDG 113) began at Ingalls Shipbuilding in July 2011, approximately 4 years after construction started on the last DDG 51 at that yard. Though the restart program refers to all 9 restart ships, we focus on DDG 113-115 because these are the first restart ships built at both yards—Ingalls Shipbuilding and Bath Iron Works, the only two shipyards that currently build destroyers—and because contracts for these three ships were recently awarded (DDG 113 in June 2011; DDG 114, 115, and an option for DDG 116 in September 2011). After the first 9 ships, the Navy will then transition to building 22 DDG 51s in the new Flight III configuration including AMDR, starting with construction of the lead Flight III ship (DDG 123) in fiscal year 2016, with an initial operating capability planned for 2023. The Navy is currently reviewing technical considerations and options for Flight III as part of an ongoing flight upgrade study that was initiated in February 2010. The Navy also has a notional Flight IV DDG 51 in its long-range shipbuilding plans.

The Navy's Study May Not Provide a Sufficient Basis for a Sound, Long-Term Acquisition Program

The Radar/Hull Study may not provide a sufficient analytical basis given the magnitude of the Navy's acquisition decision, including up to 43 destroyers (22 of which will be in the Flight III configuration and 21 in a later Flight IV configuration, and both may require significant ship redesign), a new radar, and major combat system upgrades. The cost of 22 Flight III ships is estimated to range from $58 to $64 billion (in constant 2012 dollars), including research and development and procurement. This study played a central role in determining future Navy surface combatant acquisitions by contributing to a selection of the Navy's preferred radar, combat system and ship solutions, making it, in essence, an AOA. Namely, the Radar/Hull Study provided analysis of the capability of multiple ship and radar alternatives against a revised IAMD capabilities gap, informing the selection of DDG 51 with AMDR as its preferred ship and radar combination. However, it does not provide an adequate evaluation of combat system and ship characteristics, and does not include key elements that are expected in an AOA that would help support a sound, long-term acquisition program decision.

The Navy Viewed Radar Capability as Primary Evaluative Criteria, Not Combat System and Ship Characteristics

Navy officials who were involved in the Radar/Hull Study told us that the capability of the technology concepts they evaluated was considered a major priority, and that the goal was identifying the most capable solution to meet the IAMD threat in the near-term that was also cost-effective. Within this context, the study team analyzed the capability of the radar variants considered. The Navy determined that a dual-band radar (S- and X-Band radars working together as an integrated unit) was required to effectively perform IAMD. As a result, the study team focused on assessing several different combinations of S- and X-Band radars, as show in table 1.

Table 1: Overview of Radar Options Considered in Radar Hull Study

Radar component	Component name	Component description
S-Band	AMDR-S	Developmental radar design; 12- or 14-foot array size considered.
	Volume Search Radar+ (VSR+)	Updated, more powerful version of the VSR developed for DDG 1000; 12- or 14-foot array size considered.
X-Band	SPY-3	Current X-Band radar for DDG 1000, consists of 3 array faces.
	SPQ-9B	Rotating X-Band radar currently on CG 47, LPD 17, and other ship classes.

Source: GAO analysis of Radar/Hull Study.

The maximum radar size studied in the Radar/Hull Study was a 14-foot radar, since this was determined to be the largest size of radar that the DDG 51 hull could carry and the largest radar that DDG 1000 could carry without substantial deckhouse modifications. These radars were evaluated first against each other, and then combinations of radars were evaluated and compared with the capability of the current S-Band SPY-1D(V) radar installed on recent DDG 51 ships. All provided enhanced power over and above that of SPY-1D(V); this difference was quantified as a "SPY+" (in decibels) equating to the increase in target tracking range for a fixed amount of resources over the SPY-1D(V) radar. SPY+15 has a 32 times better signal to noise factor—or intensity of the returning radar signal echoing off a target over the intensity of background noise—than a SPY-1D(V) radar. Radars with additional average power and larger antennas have enhanced sensitivity, and thus better performance in advanced threat environments. The Navy found that the SPY+15 S-Band radars performed better than the SPY+11 S-Band radars, and the Radar/Hull Study's independent red team described the capability of SPY+15 as marginally adequate. The Navy also found that the AMDR-S performed IAMD better than the VSR+. For the X-Band, the Radar/Hull Study identified that SPY-3 performed better than SPQ-9B.

Limited Evaluation of Combat System Architectures Capability

Although the Navy considered capability as a driving factor in its decision making, the Radar/Hull Study did not include a thorough comparative analysis of the capabilities of the two combat system architectures—Aegis on DDG 51 and the Total Ship Computing Environment (TSCE) on DDG 1000—into which the radars would need to be integrated.[9] Other

[9] According to the Navy, the combat system consists not only of the combat system architecture (such as Aegis or TSCE), but it also includes the ship's weapon systems, such as missiles and launchers, and ship sensors. When we discuss combat system options, we are referring only to the combat system architecture.

than assessing the BMD capability that Aegis currently possesses and the absence of BMD capability in TSCE, the Navy evaluated Aegis and TSCE by focusing on the amount of new software code that it estimated would be required to integrate the radars and to effectively perform IAMD and the costs and risks involved in this development. Such analysis is important because selection of a combat system essentially determines the ship choice, and the combat system is the interface between the radar and the ship's weapons. Since TSCE does not currently have an inherent BMD capability, the Navy identified several ways to add this capability using Aegis software and hardware. Similarly, changes were assessed to Aegis to provide it enhanced IAMD capability and the ability to leverage a dual-band radar. Table 2 depicts the combat system modifications that were considered.

Table 2: Combat System Architecture Modifications Considered

Combat system architecture	Goal	Modification considered[a]	Navy evaluation
Aegis	Integrate S-Band radar with SPY-3; enhance IAMD functionality.	TSCE components related to radar operation added into Aegis.	Preferred solution.
	Integrate S-Band radar with SPQ-9B; enhance IAMD functionality.		SPQ-9B considered inferior radar.
TSCE	Add BMD functionality to TSCE.	TSCE command and control component replaced with the Aegis component.	Complicated modification requiring significant software development.
		TSCE architecture stays largely intact, select components replaced with Aegis components.	Higher risk.

Source: GAO analysis of Radar/Hull Study.

[a] Each combat system architecture modification was further subdivided into VSR+ and AMDR-S radar options.

Though TSCE was intended to be the combat system architecture for CG(X) and thus would have been modified to perform BMD, the Radar/Hull Study states that developing a BMD capability "from scratch" for TSCE was not considered viable enough by the study team to warrant further analysis, particularly because of the investment already made in the Aegis program. The Navy concluded that developing IAMD software and hardware specifically for TSCE would be more expensive and present higher risk.[10] Ultimately, the Navy determined that Aegis was its preferred combat system option. Navy officials stated that Aegis had proven some BMD capability and was widely used across the fleet, and that the Navy wanted to leverage the investments it had made over the years in this combat system, especially in its current development of a version that provides a new, limited IAMD capability.

While the Navy's stated goal for the Radar/Hull Study was to identify the most capable solutions with an additional goal of affordability, the Navy selected Aegis based largely on its assessment of existing BMD capability, development costs and risk, and not on an analysis of other elements of combat system capability. Specifically, beyond the fact that Aegis already has a level of proven BMD capability and TSCE does not, other characteristics of the two combat systems that can contribute to overall performance were not evaluated.[11] Table 3 summarizes some examples of combat system characteristics that could have been evaluated; more characteristics may exist. Since this analysis was not conducted, any impact of these capabilities on IAMD or other missions or how each system compares with each other is unknown.

[10] Raytheon—the lead contractor for TSCE—submitted an unsolicited proposal to develop BMD capability within TSCE while the Radar/Hull Study was under way, but Navy officials told us that this proposal was rejected because it was deemed incomplete, and the Navy was unable to determine if it was realistic. Navy officials also told us that the TSCE contract contains language prohibiting BMD development work within TSCE.

[11] For additional discussion on combat system capabilities, see Classified Annex A which will be made available upon request to those with the appropriate clearance and a validated need to know.

Table 3: Examples of Combat System Characteristics That Could Have Been Evaluated in the Radar/Hull Study

Characteristic	Description
Computer processing ability	Ability of the computer system to process data; metrics may include the throughput of data that the system can manage and the speed at which it can complete work (e.g.: time to solution).
Cyber warfare capability	Offensive and defensive electronic and information operations may be a key component of future Navy missions. A combat system that enables the ship to defend against electronic attacks and possibly conduct electronic attacks of its own could contribute to enhanced capability and performance.
Reliability	A measure of how long the system can operate without incurring failures that may require corrective maintenance actions.
Information assurance capability	Measures that protect and defend information and information systems by ensuring their availability, integrity, authentication, confidentiality, and nonrepudiation. This includes providing for restoration of information systems by incorporating protection, detection, and reaction capabilities. A combat system with robust information assurance capabilities would be less vulnerable to interference in the ship's electronic network (e.g., viruses, hacking) than other systems.
Usability	A human-system interface measure of the extent to which a system can be used to achieve specified goals with effectiveness, efficiency, and satisfaction.
Proprietary versus open architecture combat systems	Level of proprietary software code, which dictates whether or not combat system development efforts can be openly competed. Competing combat system upgrades could lead to reduced costs.
Scalability	The ability of a system to handle an increased workload, either without adding or by adding additional resources.

Source: GAO analysis.

Note: Because the characteristics noted above were not included in the Navy's analysis, the implications of assessing or not assessing them is unknown.

While considering the resident BMD capabilities of Aegis and comparing software development costs and risks are essential to making a decision, without a thorough combat system assessment, the Navy cannot be sure how other combat system characteristics can contribute to overall performance.

Capability of Ships Not Evaluated Beyond Ability to Carry AMDR

Because Aegis is carried by DDG 51 and not DDG 1000 ships, selection of Aegis as the preferred combat system essentially determined the preferred hull form. The Radar/Hull Study did not include any significant analysis of the ships themselves beyond comparing the costs to modify the ships to carry the new radar configurations and to procure variants of both types. Several characteristics associated with the ships (such as displacement or available power and cooling) were identified in the study.

The ships were evaluated on their ability to meet Navy needs and the impact of these ship characteristics on costs. However, there was no documented comparison or discussion of the benefits or drawbacks associated with any additional capabilities that either ship may bring. Navy officials told us that these characteristics were not weighted or evaluated against one another. Other ship variables that directly relate to ship capability and performance—such as damage tolerance and stealth features that were explicitly designed into DDG 1000—were not discussed in the Radar/Hull Study, even though they were discussed in the MAMDJF AOA. The MAMDJF AOA notes that a stealthy ship is harder for enemy forces to detect and target, thus making it more likely that a stealthy ship would be available to execute its BMD mission. However, senior Navy officials told us that the Radar/Hull Study did not consider the impact of stealth on performance because the study assumed that stealth would not have a significant impact on performance in IAMD scenarios. Navy officials added that any additional benefits provided by DDG 1000 stealth features were not worth the high costs, and that adding larger radars to DDG 1000 would reduce its stealth. However, no modeling or simulation results or analysis were presented to support this conclusion. Table 4 depicts ship characteristics that were evaluated in the MAMDJF AOA that could have been evaluated in the Radar/Hull Study.

Table 4: Ship Characteristics That Could Have Been Evaluated in the Radar/Hull Study

Characteristics	Description
Damage survivability	Ability of ship to sustain damage. Navy standards establish a minimum, but some ships may exceed these standards.
Ship signatures	Ship emissions (e.g.: radar cross section, acoustic and magnetic signatures) which when reduced can enable stealthy operations.
Time on station	Ability of ship to remain in position without needing to refuel.
Range	Maximum distance a ship can travel on a full tank of fuel.
Surge-to-objective	Required number of replenishments required to transit ship to a specified objective.

Source: GAO analysis of Radar/Hull Study and MAMDJF AOA.

Note: Because the characteristics noted above were not included in the Navy's analysis, the implications of assessing or not assessing them is unknown.

These characteristics influence performance, and each ship option has strengths and weaknesses that could have been compared to help provide a reasonable basis for selecting a ship. For example, DDG 1000 has enhanced damage survivability and reduced ship signatures, while DDG 51 is capable of longer time-on-station and endurance.[12]

Radar/Hull Study Did Not Include a Robust Trade-off Analysis to Inform a Sound Decision

The Radar/Hull Study did not include a robust trade-off analysis for the variants studied to support the Navy's DDG 51 selection decision, which is currently planned to result in an acquisition of 22 modified Flight III DDG 51s and a further 21 modified DDG 51s known as Flight IV. DOD acquisition guidance indicates that a discussion of trade-offs between the attributes of each variant being considered is important in an AOA to support the rationale and cost-effectiveness of acquisition programs. A trade-off analysis usually entails evaluating the impact on cost of increasing the capability desired, essentially answering the question of how much more will it cost to get a greater degree of capability. A trade-off analysis allows decision makers to determine which combination of variables provides the optimal solution for a cost they are willing to pay. For the Radar/Hull Study, the Navy examined 16 different combinations of ship, radar, and combat system options based around DDG 51 and DDG 1000. These variants are depicted in figure 2.

[12] For a more detailed explanation of ship signature issues, see Classified Annex A which will be made available upon request to those with the appropriate clearance and a validated need to know.

Figure 2: Variants Considered in Radar/Hull Study

		DDG 51 variants								DDG 1000 variants							
Variant		1	2	3	4	4	6	7	8	9	10	11	12	13	14	15	16
S-Band array size		12’	12’	14’	14’	12’	12’	14’	14’	12’	12’	14’	14’	12’	12’	14’	14’
Radar suite	S	VSR+				AMDR-S				VSR+				AMDR-S			
	X	SPY 3	SPQ 9B	SPY 3	SPQ 9B	SPY 3	SPQ 9B	SPY 3	SPQ 9B	SPY-3							
Number of missiles		96								80	96	80	96	80	96	80	96
Combat system option																	

Aegis modified with select radar-related TSCE components

TSCE command and control replaced with Aegis command and control

TSCE select elements replaced with Aegis elements

Unspecified TSCE variant

Source: GAO analysis of Radar/Hull Study data.

The Radar/Hull Study documents full cost data for only 4 of the 16 ship variants; 8 ship variants have no cost data, and 4 others do not have ship procurement and operations and support costs. Instead, the Radar/Hull Study provided full cost data for only the most expensive and least expensive DDG 51 and DDG 1000 variants (high and low), and operations and support costs for these four variants. Higher costs were largely driven by the combat system selected. For example, the high DDG 1000 variant included a 14-foot AMDR coupled with a SPY-3 radar, and the more expensive combat system solution, which comprised replacing the central core of DDG 1000's TSCE combat system with the core of the Aegis combat system. The high DDG 51 variant included a 14-foot AMDR coupled with a SPY-3 radar and the Aegis combat system. The low DDG 1000 variant coupled a 12-foot VSR+ with the SPY-3 radar and a less expensive combat system solution involving replacing only portions of TSCE with portions of Aegis. The low DDG 51 included VSR+ coupled with the SPQ-9B radar and the Aegis combat system. In both the DDG 1000 high and low cases, the combat system solutions would be equally capable; the difference was in the level of effort and costs required to implement the changes. Since only a high and low version of DDG 1000s were priced out, the study did not include a DDG 1000 variant with AMDR and the less complicated TSCE combat system upgrade that may be a less expensive—but equally capable—option. Because this variant was not included in the study, cost data were not provided. This study also presented a brief analysis of operations and support costs; the Navy concluded that it found only negligible differences between the operations and support costs for the DDG 51 and DDG 1000 variants. Previous DDG 1000 cost estimates had indicated 28 percent lower long-term costs than DDG 51. While both ships had increases in these costs, the Navy determined in the Radar/Hull Study that adding additional crew to DDG 1000 to perform BMD-related tasks and increased fuel costs were more significant for that ship, and made the costs essentially equal between the two ships. The costs of the 4 variants that the Radar/Hull Study priced are shown in table 5.

Table 5: Lead Ship Cost Estimates, Radar/Hull Study

(Dollars in millions)

DDG 51 variants				DDG 1000 variants			
Low VSR+/SPQ-9B		High AMDR-S/SPY-3		Low VSR+/SPY-3		High AMDR-S/SPY-3	
Operations and support[a]	Procurement[b]	Operations and support	Procurement	Operations and support	Procurement	Operations and support	Procurement
$65.3	$2,310	$65.3	$2,946	$66.5	$3,203	$67.8	$3,367

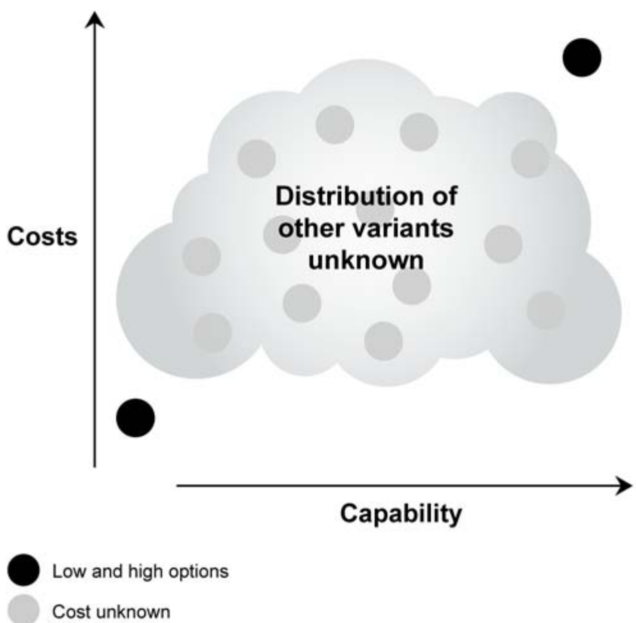
Source: Radar/Hull Study.

[a] Operations and support costs are provided in fiscal year 2010 dollars in millions/per ship/per year

[b] The low options of both ships are priced in fiscal year 2015 dollars, while the high options are priced in fiscal year 2016 dollars.

Navy officials agreed that they could have developed cost estimates for all 16 of the variants, but stated that there was a time constraint for the study that prohibited further analysis, and that they believed that pricing the high and low options was enough to bound the overall costs for each ship class. Without complete cost data for all variants, the Navy could not conduct a thorough trade-off analysis of the variants that fell between the high and low extremes because the costs of these variants are unknown. DOD acquisition guidance highlights the importance of conducting a trade-off analysis. Conducting a trade-off analysis with costs for all the variants would have established the breakpoints between choices, and identified potential situations where a cheaper, slightly less capable ship or a more expensive but much more capable ship might be a reasonable choice. Figure 3 is a notional depiction of the limitations of missing cost data when conducting a trade-off analysis with only high and low data points.

Figure 3: Notional Depiction of a Limited Trade-off Analysis



Source: GAO analysis based on DOD acquisition guidance.

Further, the Navy also did not prioritize what aspects of the radar, combat system, and ship it valued more than others, which could also be used to inform a trade-off analysis. For example, if performance is valued more than cost, choosing a ship variant that has 10 percent more performance than another variant but with a 20 percent increase in cost might be in the Navy's best interest. Alternatively, if cost was weighted more than performance, the Navy might choose the cheaper and slightly less capable ship as it would be able to get a 20 percent reduction in cost with only a 10 percent reduction in performance. Similarly, the study did not discuss the Navy's preferences with regard to ship characteristics and the impact that differences in these characteristics might have on a trade-off analysis. For example, Navy officials told us that electrical power was a major concern for future destroyers, but the considerable difference in available power between DDG 51 and DDG 1000 (approximately 8,700 kilowatts for DDG 51 after the addition of a supplemental generator compared to 78,000 kilowatts for DDG 1000 with no additional generators required) was not compared in a trade-off analysis. Finally, the Navy did not assess potential impacts of ship selection on future fleet composition. The MAMDJF AOA found that more capability can be obtained by fewer, more capable ships (meaning those with larger radars) than a greater number of less capable ships (meaning those with smaller radars). This could change the acquisition approach and would result in different program costs as a result if it is found that fewer, more capable ships are more cost-effective than many, less capable ships.

Navy officials told us that some of these trade offs were not done in the Radar/Hull Study because they were already studied in the MAMDJF AOA. However, that study, using a different threat environment and ship concepts, eliminated the DDG 51 variant from further consideration as a single ship solution; it also eliminated the DDG 1000 option without a radar larger than the 14-foot design that was considered in the Radar/Hull Study. Consequently, its analysis is not directly comparable or interchangeable with the Radar/Hull Study. When comparing the raw ship data from the Radar/Hull Study, we found that the two ships offer different features worth evaluating. For example, all DDG 1000 variants offer more excess cooling and service life allowance, meaning the ability of the ship to accommodate new technologies over the life of the ship without major, costly overhauls than DDG 51 variants, while DDG 51 variants offer greater endurance and lower procurement costs. Table 6 depicts a simplified presentation of this comparison.

Table 6: Comparison of Selected Ship Characteristics from the Radar/Hull Study

(Dollars in millions)

Variants	Procurement cost[a]	Excess power	Excess cooling	Service life allowance[b]	Full load displacement	Number of missile cells
High DDG 51	$2,946	1,174 kW after addition of a generator	284 tons	4.4 percent 0.52 feet	9,865 long tons	96
High DDG 1000	$3,367	968 kW no additional generator required	461 tons	10.0 percent 1.0 feet	15,300 long tons	96

Source: GAO analysis of Radar/Hull Study.

[a] Procurement costs only (fiscal year 2016 dollars, in millions)

[b] Navy weight and center of gravity allowances to enable future changes to the ships, such as adding equipment and reasonable growth during the ship's service life without unacceptable impacts on the ship. Ten percent of weight and 1.0 foot of center of gravity are the Navy requirements for surface combatants.

As this table shows, these two ships offer different characteristics. Both were deemed capable of carrying AMDR, but without conducting a trade-off analysis of these characteristics, the Navy did not consider their relative merit and the significance, if any, of any differences between the two. Senior Navy officials told us that it is now conducting these types of trade-off analyses; however, these analyses are focused only on assessing various DDG 51 configurations, and were not done to help inform the ship selection decision. A preliminary finding of these new analyses is that the cost of Flight III is estimated to range from $58 billion to $64 billion (in constant 2012 dollars), including research and development and procurement.

Radar/Hull Study Assumed a Significantly Reduced Threat Than Other Studies

The Radar/Hull Study assumed a significantly reduced threat environment compared to the earlier MAMDJF AOA and other Navy studies. How the threat is characterized is important because against a reduced threat environment, a less capable radar than what was identified as necessary in the MAMDJF AOA was described by the Radar/Hull Study as marginally adequate. Both the Radar/Hull Study and MAMDJF AOA analyzed the performance of radars in several different classified tactical situations that presented threats of varying levels of complexity. The most stressing situations involved a number of different air and missile threats and a complex timing of events.[13] In the MAMDJF AOA, these tactical situations involved many different types of simultaneous threats and larger radars, and were developed in consultation with the Office of Naval Intelligence—the agency tasked to provide validated threat intelligence to support Navy and joint, Navy-led acquisition programs—as well as MDA. Conversely, the subsequent Radar/Hull Study assumed a significantly reduced threat environment and smaller radar solutions than did the MAMDJF AOA. This study modeled radar performance based on a very limited air and missile threat which are both quantitatively and qualitatively less stressing than the threat environment established in the MAMDJF AOA, in other Navy and DOD threat analyses, and in system guideline documents for AMDR. Also, the Office of Naval Intelligence was

[13] For a more detailed description of the threat environments, see Classified Annex B which will be made available upon request to those with the appropriate clearance and a validated need to know.

not actively engaged in the Radar/Hull Study.[14] The system guideline documents for AMDR that were generated at approximately the same time as the Radar/Hull Study also included significantly more taxing tactical situations than the Radar/Hull Study, and in some cases they are even more stressing than those found in the MAMDJF AOA. The Office of Naval Intelligence also provided input to these AMDR system guidelines.

The Navy believes that some of the differences in the threat environment result from the different timeframes for the Radar/Hull Study and the MAMDJF AOA; the MAMDJF AOA states that it is based on a 2024 through 2030 timeframe while the Radar/Hull Study states that it is based on a 2015 through 2020 timeframe. However, Navy officials also told us that the IAMD threats are actually emerging more rapidly than they had assumed in the MAMDJF AOA, which could mean that some of the MAMDJF AOA threats may be present earlier. The Navy does not document why the Radar/Hull Study based its analysis on a reduced threat environment compared to the MAMDJF AOA, since both studies are attempting to identify solutions to the same capabilities gap and set of requirements. Navy officials later told us that the assumption in the Radar/Hull Study was that no single Navy ship would likely have to deal with all the threats in the battlespace, compared to the threat environment in the MAMDJF AOA where more of a single-ship solution was considered. However, other Navy studies developed in a similar timeframe to the Radar/Hull Study describe a larger number of threats than the Radar/Hull Study. Further, while the Navy’s assumption may account for some of the quantitative differences between the Radar/Hull Study and all the other Navy studies we analyzed, it should have no bearing on the qualitative difference in the composition of the threat, since this is a variable that is independent of Navy concepts of operations and is a variable over which the Navy has no influence.

[14] Navy officials stated that the Office of Naval Intelligence provided information to the Radar/Hull Study team in two briefings on ballistic and cruise missile threats. However, in a written statement the Office of Naval Intelligence stated that they did not participate in the development or review of the Radar/Hull Study.

Restart Ships are Costlier than Recent DDG 51s and Face a Challenging Combat System Upgrade

According to the Navy and shipbuilders, the changes to the restarted DDG 51's hull and mechanical systems appear less substantial than previous modifications to earlier DDG 51s. However, due in part to a break in production, an initially noncompetitive environment, and other factors, the restart ships are budgeted to cost more than previous DDG 51 Flight IIA ships. While the shipbuilders' planned production schedules are generally in line with past shipyard performance, the delivery schedule for the first restart ship (DDG 113) may be challenging because of a significant upgrade in the Aegis combat system, where major software development efforts are under way and a critical component has faced delays. Although the Navy plans to install and test this upgrade on an older DDG 51 (DDG 53) prior to installation on DDG 113, delays in these efforts could pose risks to a timely delivery in support of DDG 113 and ability to mitigate risk. If this occurs, the Navy may need additional time to identify, analyze, and work to resolve problems with the combat system—adding pressure to the schedule for DDG 113. Even if current testing goes as planned, the Navy has not planned for realistic operational testing necessary to ensure that the Aegis upgrades are capable of performing IAMD against multiple ballistic and cruise missile targets.

The Navy Believes Proposed Hull and Mechanical Changes Are Less Substantial Than Previous Modifications

While the restart ships will have some changes to the ship's design and physical structure, Navy officials told us that they are less substantial than prior modifications, despite changes to a large number of design drawings. The Navy has been building DDG 51s since the late 1980s, and over time the ship design has been modified, including additions such as helicopter hangars, additional missiles, and significant combat system upgrades. As shown in table 7, a large number of design drawing changes are required for the DDG 51 restart program, similar to those implemented as part of previous major upgrades, such as the upgrade from Flight II to Flight IIA (DDGs 79 and higher). While these design changes may not be complex, they affect numerous areas of the ship.

Table 7: Selected Major DDG 51 Changes and Corresponding Design Changes

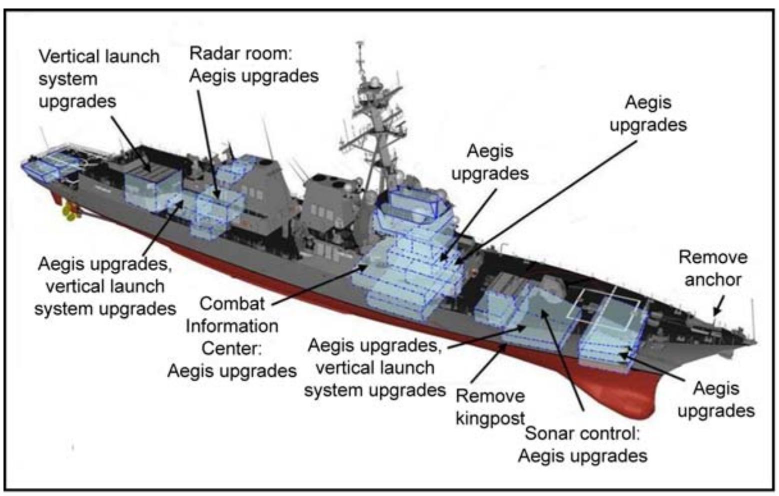
Hull number	Number of drawing changes	Description of changes
DDG 79	2705	Addition of dual helicopter hangars and moving radar arrays, and replacement of crane used to move missiles with additional missiles.
DDG 85	659	Physical dimensions of the ship unchanged, major Aegis combat system upgrade.
DDG 103	1898	Physical dimensions of the ship unchanged, major Aegis upgrade.
DDG 113	1175[a]	Physical dimensions of the ship unchanged, major Aegis upgrade, modest hull and mechanical changes (e.g. anchor deletion)

Source: GAO analysis of Navy data.

[a] Design work for DDG 113 is still underway, so this number is estimated.

According to shipyard officials, most design drawings for the restart ships will have applicability from previous hulls and will not require re-design, but the Navy told us that they currently expect 1175 drawings will be changed, and the design work is still underway. As figure 4 shows, some of the changes will affect the topside of the ship, and include removing some redundant or unneeded equipment from the ship (e.g. the forward kingpost and port anchor) while internal changes largely pertain to upgrading the Aegis combat system with new computer displays and computer cabinets.

Figure 4: Proposed Design Changes for Restart Ships



Source: GAO analysis of Navy data.

Restart Ships Cost More Than Previous DDG 51 Flight IIA Ships

The Navy has budgeted approximately $17.5 billion for the 10 Flight IIA restart ships.[15] The first three restart ships, beginning with DDG 113, cost 45 percent more than recently delivered DDG 51s.[16] DDG 113 through DDG 115 are currently budgeted to cost a total of $5.8 billion, which is approximately $1.8 billion higher than the last three DDG 51s built.[17] Unlike the previous 24 ships, the restart ships are not part of multiyear ship procurements, which can be more cost-efficient due to economies of scale. The Navy partially attributes the increase in procurement costs to a 4-year gap in production. Construction of the last DDG 51s began in late 2007 and production on DDG 113 began in July 2011. The shipbuilders and the Navy anticipate that additional labor hours will be required to build DDG 113-115 due in part to a loss of experienced workers who will have been laid off or otherwise left the shipyard during the production gap. This attrition—along with changes in equipment and processes associated with the shutdown of the production line—contributes to a loss of learning whereby a less experienced and less efficient workforce requires more time to complete tasks with additional hours spent on rework. While the Navy in part attributes the higher ship costs to the need for additional labor hours to build the ships, it does not associate increases with significant changes in the supplier base. In general, the Navy found the supplier base for ship equipment was primarily intact, with most of the DDG 51 suppliers still in production, which allowed the Navy to get the equipment it needed at prices it considered reasonable.[18] In cases where the suppliers were no longer available, the Navy recompeted some key equipment contracts in order to maximize value and to compensate for some modest changes in its supplier base.

The Navy's initial noncompetitive acquisition strategy also contributed to a higher budgeted cost for the first three restart ships. In response to the truncation of the DDG 1000 program, the Navy and the two shipyards had

[15] In then-year dollars.

[16] The Navy calculates this difference to be 27 percent based on future anticipated budget savings and differences in inflation indices.

[17] In constant fiscal year 2012 dollars. Cost includes the procurement of the ship, including ship construction, design, change orders and government-furnished equipment. Research and development (R&D) costs are not included.

[18] Some suppliers were keeping their production lines open due to the Aegis modernization program, a backlog of orders, or the fact that suppliers were producing and selling equipment to foreign navies such as Australia.

agreed to allocate the construction of DDG 1000s and the first three DDG 51s (DDG 113-115) between Bath Iron Works and Ingalls Shipbuilding to ensure workload stability between the shipyards.[19] The parties agreed, subject to negotiation of fair and reasonable prices and other conditions, that Bath Iron Works would be responsible for all of the remaining DDG 1000 design and construction work and construction of DDG 115, while Ingalls Shipbuilding would construct DDG 113 and DDG 114.[20] After these first three ships, the Navy intended to competitively award contracts for future surface combatants. The Navy assumed that it would pay a premium for the first three ships because a lack of competition between the two shipyards would drive up costs. Indeed, Navy officials noted that a noncompetitive environment, along with disagreements on the impact of the production gap, were among the reasons that initial bids from the shipbuilders were unreasonably high and in excess of Navy budget estimates.

In an effort to generate more competitive pricing, the Navy changed its acquisition strategy in May 2011 to “competitively allocate” DDG 114 and 115. This strategy change allowed the Navy to award contracts to each shipbuilder using a Profit Related to Offers strategy, whereby the shipbuilder that submitted the lowest cost bid for its allocated ship would receive a higher target profit percentage, and the shipbuilder that submitted the lower bid for DDG 116 would be awarded an option for construction of that ship. The Navy believed that through its new strategy it would be able to reduce the costs for DDG 114 and DDG 115, noting its successful use on 30 previous DDG 51 ships since 1996. Additionally, the strategy allowed the Navy to award both DDG 114 and DDG 115 to one shipbuilder in the event that it failed to arrive at a fair and reasonable price with each shipbuilder on its allocated ship. After prolonged negotiations with the shipyards and over a year delay from when the Navy planned to award the DDG 113 contract, the Navy awarded a contract to Ingalls Shipbuilding for DDG 113 in June 2011 and DDG 114 in September 2011, and awarded a contract to Bath Iron Works for DDG 115 in September 2011, with an option to build DDG 116.

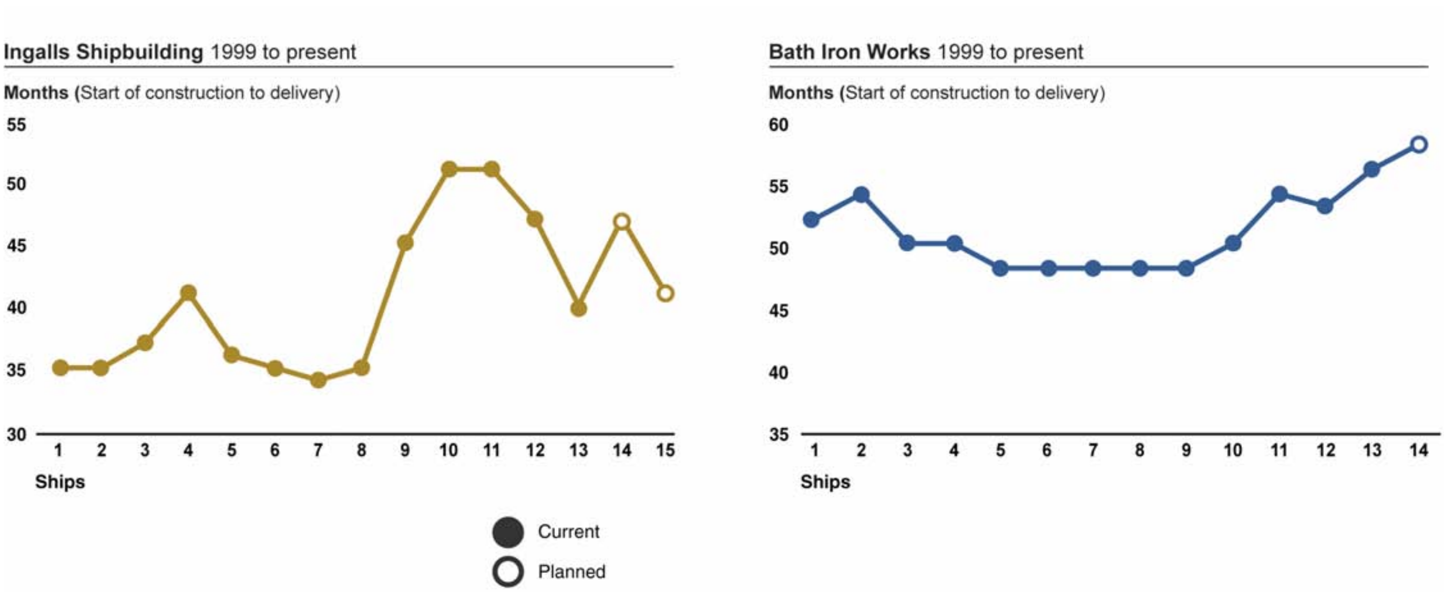
[19] Prior to the truncation Bath Iron Works was responsible for building the majority of DDG 1000, while Ingalls Shipbuilding was responsible for the majority of DDG 1001. The shipbuilders shared in designing the ship. The Navy had planned to compete DDG 1002 and the remaining four ships.

[20] Ingalls Shipbuilding would also continue to build the composite deckhouse and hanger for all three DDG 1000 ships.

Restart Production Schedules Appear in-Line with Past Shipyard Performance

The Navy expects DDG 113 to be built in 47 months (from the start of construction to delivery), DDG 114 in 41 months, and DDG 115 in 58 months. As show in figure 5, Ingalls Shipbuilding—which is building the two first ships —averages 41 months to build a DDG 51, though in recent years has required more time due in part to after-effects of Hurricane Katrina. Bath Iron Works typically requires an average of closer to 54 months. Navy officials told us that this longer 58 month schedule planned for DDG 115 is due to the shipyard beginning construction earlier than planned in part to maintain stability in the shipyard labor force, while maintaining the delivery date.

Figure 5: Historic DDG 51 Construction Durations



Source: GAO analysis of Navy and shipyard data.

The schedules, while in line with past performance, are contingent on achieving an optimum build sequence, meaning the most efficient schedule for constructing a ship, including building the ship from the bottom up and installing ship systems before bulkheads have been built and when spaces are still easily accessible. Shipbuilders generate specific dates for when systems need to arrive at the shipyard in order to take advantage of these efficiencies. According to shipyard officials, approximately 10 percent to 12 percent of the suppliers for the restart ships will be new vendors. Some key pieces of equipment—like the main reduction gear, the machinery control system, and the engine controllers

—will now be government-furnished equipment, meaning that the Navy will be responsible for ensuring an on-time delivery to the shipyard, not the shipbuilder.[21] For the main reduction gear, the Navy is now contracting with a company that bought the gear production line from the past supplier, and while this supplier builds reduction gears for San Antonio class ships, it does not have experience building DDG 51 main reduction gears. An on-time delivery of this key component is particularly important to the schedule because it is installed early in the lower sections of the ship. A delay in a main reduction gear could result in a suboptimal build sequence as the shipbuilder has to restructure work to leave that space open until the gear arrives. The Defense Contract Management Agency reports production of the first gear ship set is progressing well, and that Navy officials are tracking the schedule closely.

Combat System Upgrade Has Faced Delays, and Key Testing Is Undefined

A major change for the restart ships is a significant upgrade to the Aegis combat system currently under way. This upgrade, known as Advanced Capability Build 12 (ACB 12), will be retrofitted on some of the current fleet of DDG 51s (starting with DDG 53); following DDG 53, the upgrade will also be installed on the restart ships (starting with DDG 113). The retrofit on DDG 53 will provide the Navy with a risk mitigation opportunity, since any challenges or problems can be identified and resolved prior to installation on DDG 113. The Navy believes this is the most complex Aegis upgrade ever undertaken and will enable the combat system to perform limited IAMD for the first time. This upgrade will also move the Navy towards a more open architecture combat system, meaning that there will be a reduction of proprietary software code and hardware so that more elements can be competitively acquired in the future. To date, Lockheed Martin maintains intellectual property rights over some Aegis components. ACB 12 requires both software and hardware changes, and consists of three related development efforts: (1) development of a multimission signal processor (MMSP), (2) changes to the ballistic missile suite (BMD 5.0), and (3) changes to the Aegis combat system core. While the Navy manages the development of MMSP and ACB 12, MDA manages the development of BMD 5.0. Table 8 describes each of the three efforts.

[21] Main reduction gears function like a transmission and reduce the high-speed rotations from the engines to a lower speed that can be used to turn the ship's propellers.

Table 8: ACB 12 Components

Element	Description
MMSP	Radar signal processor that enables IAMD by simultaneously processing radar inputs from ballistic and cruise missile targets. This component is the essential enabler for providing initial IAMD capability.
BMD 5.0	Upgraded set of algorithms and software integrated for the first time into the combat system. Development managed by MDA.
Aegis Modernization	Overall combat system upgrade in addition to MMSP and BMD 5.0, including new workstations and display screens.

Source: GAO analysis of Navy and contractor data.

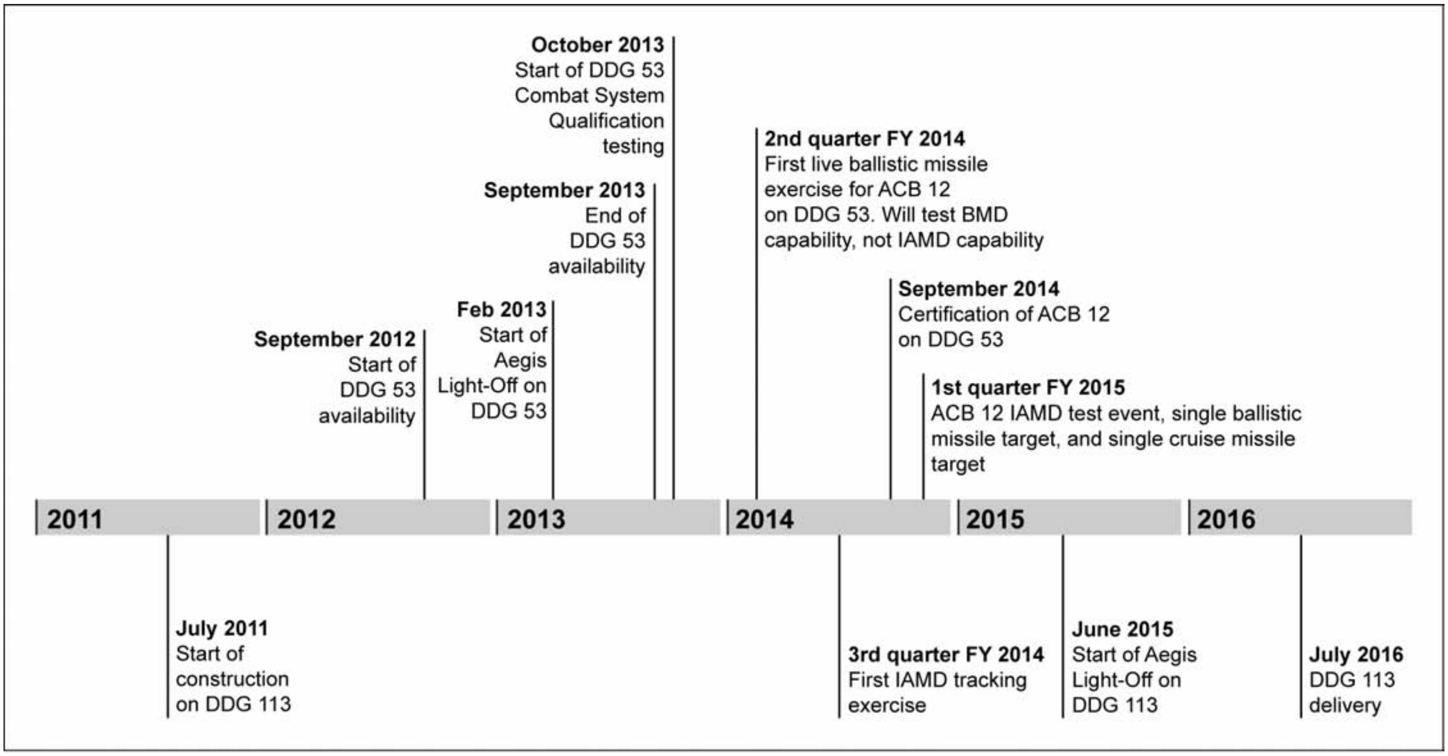
Delays in Aegis Combat System Development May Compromise Installation and Testing Schedule, Shifting Risk to DDG 113

While the Navy has made significant progress in developing the components of ACB 12, MMSP is proving more difficult than estimated and is currently 4 months behind schedule, with $10 million in cost growth realized and an additional $5 million projected. A substantial amount of software integration and testing remains before MMSP can demonstrate full capability and is ready for installation on DDG 53—and later DDG 113. While all of the software has been developed, only 28 percent of the eight software increments have been integrated and tested. The integration phase is typically the most challenging in software development, often requiring more time and specialized facilities and equipment to test software and fix defects. According to the Navy, the contractor underestimated the time and effort required to develop and integrate the MMSP software. In December 2010, MMSP was unable to demonstrate planned functionality for a radar test event due to integration difficulties, and MMSP more recently experienced software problems during radar integration which resulted in schedule delays. In response, the contractor implemented a recovery plan, which included scheduling additional tests and replanning the remaining work to improve system stability. However, the recovery plan compresses the time allocated for integrating MMSP with the rest of the combat system from 10 months to 6 months.

In order to meet schedule goals and mitigate software development risk in the nearterm, the contractor also moved some development of MMSP capability to future builds. However, this adds pressure to future development efforts and increases the probability of defects and integration challenges being realized late in the program. The contractor already anticipates a 126 percent increase in the number of software defects that it will have to correct over the next year, indicating the significant level of effort and resources required for the remaining development. According to the program office, the high level of defects projected is due to the complexities of integrating and testing with Aegis. Each defect takes time to identify and correct, so a high level of defects could result in significant additional work and potentially further delays if the contractor cannot resolve the defects as planned. The Navy believes the schedule risk associated with this increase is understood and anticipates no further schedule impacts. However, the Defense Contract Management Agency, which is monitoring the combat system development for the Navy, has characterized the MMSP schedule as high risk.

As shown in figure 6 below, the Navy will not test ACB 12's IAMD capabilities with combined live ballistic and cruise missile tests until after it certifies the combat system. Certification is an assessment of the readiness and safety of ACB 12 for operational use including the ability to perform Aegis ship missions. The Navy and MDA plan to determine future opportunities for additional testing to prove the system. The Navy plans to leverage a first quarter fiscal year 2015 test that MDA does not actually characterize as an IAMD test to demonstrate IAMD capabilities.

Figure 6: Timeline of Aegis Upgrade Installation and Testing Events



Source: GAO analysis.

The Navy initially planned to test the combat system's IAMD tracking capability during a BMD test event to occur by third quarter fiscal year 2013. The test—tracking and simulated engagement of BMD and air warfare targets—would have provided confidence prior to certification of ACB 12 that the software worked as intended. However, this event was removed from the test schedule The Navy now plans to test tracking and simulated IAMD engagement capability during a BMD test event in third quarter 2014. According to the Navy, this is the earliest opportunity for sea-based testing of the ACB 12 upgrade installed on DDG 53. This event will help demonstrate functionality and confidence in the system, but only allows five months between the test and certification of the system to resolve any problems that may be identified during testing. The Navy and MDA plan on conducting a live ballistic missile exercise in second quarter fiscal year 2014, this will only test the combat system's BMD capability, not IAMD. Consequently, the Navy will certify that the combat system is mission ready without validating with live ballistic and cruise missile targets that it can perform the IAMD mission. The first

IAMD test with live targets is not scheduled until first quarter fiscal year 2015.

Delays in MMSP could also lead to concurrence between final software integration and the start of ACB 12 installation on DDG 53. Although the Navy has stated that the contractor is currently on schedule, if the contractor is unable to resolve defects according to plan, Aegis Light-Off (when the combat system is fully powered on for the first time) on DDG 53 could slip or the test period could move closer to the start of installation on DDG 113, which could limit risk mitigation opportunities. Contractor officials told us that they plan to deliver the combat system hardware to the shipyard for installation on DDG 113 in May 2013. While the Navy believes the current schedule allows time for the Navy and contractor to remedy any defects or problems found with ACB 12 before it is scheduled to be installed on DDG 113, we have previously reported that concurrent development contributes to schedule slips and strains resources required to develop, integrate, test, and rework defects, which could encroach into this buffer.[22]

Additionally, if DDG 53 is not available when currently planned to begin its upgrade, this process could also be delayed. DDG 53's upgrade schedule already slipped from May 2012 to September 2012, and any significant shifts could mean further schedule compression, or if it slipped past the start of installation on DDG 113 this new-construction ship could become the ACB 12 test bed, which would increase risk.

Navy Has Not Fully Planned for Realistic Operational Testing of Aegis IAMD Capabilities

At present, DOD weapons testers and Navy and MDA officials are unsure to what extent the new IAMD capabilities of Aegis will be fully operationally tested and evaluated. Operational testing involves the employment of a new system in a realistic operational environment to determine the operational effectiveness and suitability of the system. This testing is required to: (1) determine if performance thresholds are met, (2) assess impacts to combat operations, and (3) provide additional information on the system's operational capability. Since the ACB 12 upgrade of Aegis is central to the combat capabilities of the ship, Navy weapons testers believe that Aegis should have a rigorous operational

[22] GAO, Defense Acquisitions: Significant Challenges Ahead in Developing and Demonstrating Future Combat System's Network and Software, GAO-08-409, (Washington, D.C.: Mar. 7, 2008) and Joint Strike Fighter: Restructuring Places Program on Firmer Footing, but Progress Still Lags, GAO-11-325 (Washington, D.C.: Apr. 7, 2011).

testing program—similar in scope to what was done for the first DDG 51s—in order to validate that the combat system still functions in all areas. According to DOD officials, there should be a high level of coordination between the Navy and MDA with regard to testing the IAMD capability of ACB 12. However, creation of robust test plans for IAMD is complicated because of the division of responsibility between MDA and the Navy. While IAMD consists of both defense against cruise missile and aircraft threats and BMD, MDA is responsible for funding and testing BMD functionality while the Navy is responsible for funding and testing everything else. [23]

Since Navy assessments include the possibility of IAMD engagements with multiple-missile threats, DOD weapons testers agree that a robust, operationally relevant test of IAMD capabilities should include a test with multiple, simultaneous BMD and air warfare targets. However, neither the Navy nor MDA has such a test in their current plans, nor, according to MDA officials, has such a test ever occurred.[24] The IAMD test event in first quarter fiscal year 2015 will only test the combat system's capability against a single ballistic missile and cruise missile target—not multiple targets. According to MDA officials, the focus of MDA testing is to validate BMD performance, not IAMD performance. MDA officials have stated that MDA test assets are very expensive, and the agency does not know how the Navy intends to validate the performance of IAMD capabilities, though they have stated that they will try to support the Navy as best they can, and that they are currently assisting the Navy in developing strategies to test and characterize IAMD performance. The Navy's proposed test plan includes acquiring three Aegis BMD targets to be fired and tracked with simulated cruise missile threats, which will allow the Navy to simulate ACB 12 performance in an IAMD environment. Though cost and other constraints may limit the practicality of live test events, DOD weapons testers told us that though Aegis testing and performance evaluation can

[23] Because MDA has not yet formally entered the defense acquisition cycle, it has not followed the procedures under DOD Instruction 5000.02, *Operation of the Defense Acquisition System*, and does not generate a Test and Evaluation Master Plan like the Navy which is subject to Director, Operational Test and Evaluation review and approval. MDA does prepare an Integrated Master Test Plan.

[24] According to MDA officials, the Aegis combat system first demonstrated the potential to be used for IAMD during a flight test on April 26, 2007, when Aegis engaged a BMD target and a target simulating a high-performance aircraft, but this test did not use the ACB 12 version of Aegis.

be done via modeling and simulation, the Navy still needs sufficient data from flight tests conducted in an operationally relevant environment in order to validate the simulation models with actual performance data. Similarly, MDA told us that model validation requires making comparisons between previous flight test results and the results of the models. Without actual operational tests, the Navy's IAMD models will lack vital real-world data needed to validate how accurately they model the performance of Aegis.

Flight III Cost and Technical Risks Pose Challenges for Oversight

The Navy plans to procure the first of 22 Flight III DDG 51s in 2016 with the new AMDR and plans to achieve Flight III initial operational capability in 2023. Other than AMDR, the Navy has not identified any other technologies for inclusion on Flight III or decided on the size of AMDR. Although the analysis supporting Flight III discusses a 14-foot AMDR, senior Navy officials recently told us that a 12-foot AMDR may also be under consideration. While the Navy is pursuing a thoughtful approach to AMDR development, it faces several significant technical challenges that may be difficult to overcome within the Navy's current schedule. The red team assessment of an ongoing Navy Flight III technical study found that the introduction of AMDR on DDG 51 leads to significant risks in the ship's design and a reduced future capacity and could result in design and construction delays and cost growth on the lead ship. Further, the Navy's choice of DDG 51 as the platform for AMDR limits the overall size of the radar to one that will be unable to meet the Navy's desired (objective) IAMD capabilities. If the Navy selects a 12-foot AMDR—which may reduce the impacts on the ship and design—it may not be able to meet the requirements for AMDR as currently stated in the Navy's draft capabilities document.[25] Given the level of complexity and the preliminary Navy cost estimates, the Navy has likely underestimated the cost of Flight III. However, since the DDG 51 program is no longer in the DOD milestone review process, decision makers currently cannot take advantage of knowledge gained through a thorough review of the program typically provided at a milestone. Further, since the Navy is responsible for acquisition oversight of the program, there is no

[25] While the capabilities document has been approved by the Navy, it has not been formally reviewed by the Office of the Secretary of Defense and is subject to change. Since AMDR has not yet reached its milestone decision, according to DOD officials, AMDR requirements could still change.

requirement for a DOD-level assessment before making further investments in the program.

The Navy Is Pursuing a Thoughtful Approach to AMDR, but Success Is Contingent on a Number of Technological Advancements

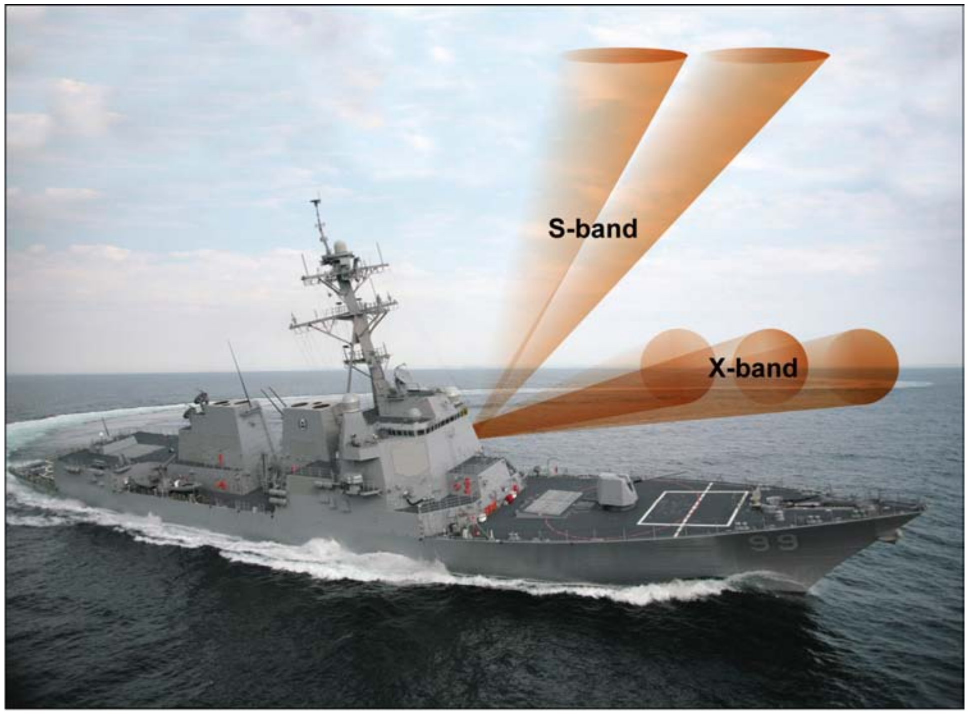
AMDR represents a new type of radar for the Navy, which the Navy believes will bring a significantly higher degree of capability than is currently available to the fleet. AMDR is to enable a higher degree of IAMD than is possible with the current legacy radars. Further, the Navy believes that through the use of active electronically scanned array radars, AMDR will be able to “look” more places at one time, thus allowing it to identify more targets with better detection sensitivity.[26] It will also allow the radar to view these targets with better resolution. AMDR is conceived to consist of three separate parts:

- AMDR-S: a 4 faced S-Band radar providing volume search for air and ballistic missile defense;
- AMDR-X: a 3 faced, 4-foot by 6-foot X-Band radar providing horizon search (as well as other tasks such as periscope and floating mine detection); and
- Radar suite controller: interface to integrate the two radars and interface with the combat system.

Figure 7 depicts a notional employment of AMDR’s two radar bands. Three contractors are under contract to mature and demonstrate the critical AMDR-S radar technology required; the acquisition of the AMDR-X portion is still in the preliminary stage, and the Navy plans to award a contract for it in fiscal year 2012.

[26] Radar sensitivity is a measure of how well the radar can detect an object at a distance. A more sensitive radar can detect smaller objects at a range farther from the radar given a fixed resource consumption. It is a function of radar power and radar aperture (size).

Figure 7: Notional DDG 51 Flight III with AMDR



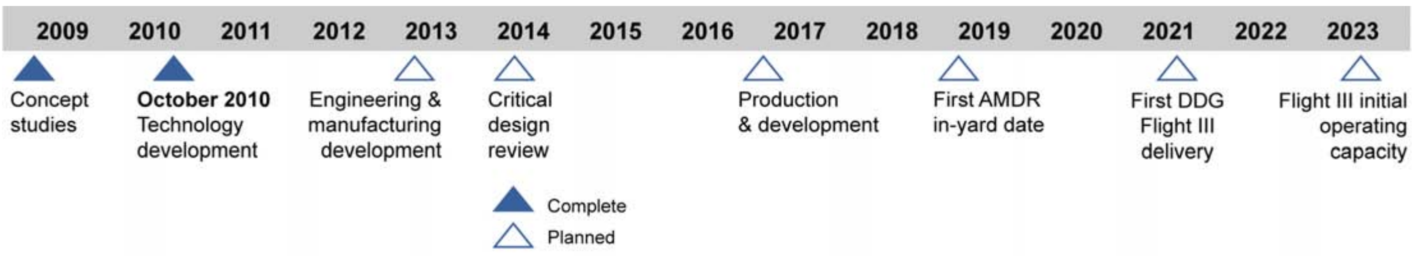
Source: GAO representation of Navy data.

The Navy recognized the risks inherent in the AMDR-S program early on, and implemented a risk mitigation approach to help develop and mature specific radar technologies that it has identified as being particularly difficult. Additionally, the Navy used an initial AMDR-S concept development phase to gain early contractor involvement in developing different concepts and earlier awareness of potential problems. In September 2010, the Navy awarded three fixed-priced incentive contracts to three contractors for a 2-year technology development phase. All three contractors are developing competing concepts with a goal of maturing and demonstrating S-Band and radar suite controller technology prototypes. In particular, the contractors are required to demonstrate performance and functionality of radar algorithms in a prototype one-fifth the size of the final AMDR-S.

The Navy has estimated that AMDR will cost $2.2 billion for research and development activities and $13.2 billion to procure at most 24 radars. At the end of the 2-year phase, the Navy will hold a competition leading to award of an engineering and manufacturing contract to one contractor.

As shown in figure 8, AMDR is first scheduled to be delivered to a shipyard in fiscal year 2019 in support of DDG 123—the lead ship of Flight III.

Figure 8: AMDR Schedule



Source: GAO analysis of Navy data.

AMDR-S relies on several cutting-edge technologies. Three of the most significant of these pertain to digital beamforming, the transmit/receive modules, and the radar/combat system interface. Table 9 highlights these technologies and key challenges.

Table 9: AMDR Technologies and Key Technical Challenges

Technology	Description	Key technical challenges
Digital beamforming	• Advanced software algorithms digitize the radar signal, enabling simultaneous generation and processing of multiple beams, increasing radar resources available for multiple missions.[a] This allows beams to be modified to help eliminate interference or clutter in an electromagnetic interference environment.	• Without this technology, requirements may have to be reduced and radar may be less efficient in littoral or dense electromagnetic interference environments. • This technology has never been demonstrated to the size and architecture planned for AMDR.
Transmit/ receive modules	• Individual units that emit the radar signal from the radar. • AMDR transmit/receive modules must generate significantly more radio frequency power over modules in the DDG 1000's Volume Search Radar, and 10 percent more efficiency to enable AMDR's required capabilities.[b]	• To achieve this increased level, the contractors may use Gallium Nitride-based semiconductors, which may provide higher power and efficiency than current material. This material is relatively new and long-term reliability is unknown. It has never been used in a radar of this scale. • Inability to use Gallium Nitride may require use of current materials, and thus additional ship power and cooling. Alternatively, performance requirements may be set lower with a spiral development plan to achieve the objective power levels at a later date. • Past radar programs (Volume Search Radar and the Cobra Judy Replacement radar) have needed more time to test and mature transmit/receive modules than estimated, causing cost and schedule growth.[c]
Combat system integration	• Aegis Combat System requires modification in order to accommodate and exploit AMDR's additional capability and mission sets (e.g. periscope detection).	• Software integration and testing is a lengthy effort and is typically the most challenging phase of software development, requiring specialized skills and integration test lines. • The Navy has yet to fully identify what interfaces will be impacted or to develop estimates of the level of effort that will be required. A Navy/industry combat system integration working group was established but has had a limited role to date. Integration will likely be challenging because multiple technology developers and two program offices will have to work closely together. • Lack of test and evaluation assets early in process could result in shipboard integration issues.

Source: GAO analysis of Navy data.

[a] Radar resources are a percentage that radar arrays are required to be dedicated to a particular task. For instance, if a searching task takes a total of 1 second and is repeated every 4 seconds, that task would consume 25 percent of radar resources.

[b] Radar efficiency means that it can operate at higher levels of power with less demand for electricity and less heat generation that requires cooling.

[c] The Cobra Judy Replacement program is a ship that carries a powerful dual band radar suite that is used for ballistic missile treaty verification and to provide data collection of ballistic missiles in flight. The ship consists of an X and S-band radar with a common radar controller.

Though the Navy has been pursuing risk mitigation efforts related to some key AMDR technologies, realizing AMDR will require overcoming several significant technical challenges. For example, though the Navy worked with the United Kingdom on a radar development program to demonstrate large radar digital beamforming, including limited live target testing, the technical challenges facing the development of AMDR have not been fully mitigated by these efforts. The joint radar development program used a digital beamforming architecture different than what is intended for AMDR, and the demonstrator was much smaller than what is envisioned for AMDR-S. Further, the Navy's previous effort also did not demonstrate against BMD targets, which are the most stressful for the radar resources. The Navy told us that the contractors have been successful in their AMDR development efforts to date, and that power and cooling requirements may be less than initially estimated. However, substantial work remains, and failure to achieve any of these technologies may result in AMDR being less effective than envisioned. AMDR development is scheduled for 10 years, compared with 9 years for the DDG 1000's VSR.[27]

Integration with the Aegis combat system may also prove challenging: Aegis currently receives data from only a single band SPY-1D(V) radar, and adding AMDR will require modifying Aegis to receive these data, to accommodate some new capabilities, and to integrate Aegis with the radar suite controller. The Navy has deferred this integration, as it recently decided to eliminate AMDR integration work from its upcoming Aegis upgrade (ACB 16) contract, although Navy officials pointed out that this work could be started later under a separate contract. If the Navy does not fund AMDR integration work in ACB 16, this work may not be under way until the following ACB upgrade, which could be completed in 2020 at the earliest if the Navy remains on the same 4 year upgrade schedule. With an initial operating capability for Flight III planned for 2023, this could leave little margin for addressing any problems in enabling AMDR to communicate with the combat system.

[27] This included development and land-based testing for VSR.

Physical Constraints Will Result in a Complicated Flight III Design and Construction Process and May Increase Ship Costs

DDG 51 is already the densest surface combatant class; density refers to the extent to which ships have equipment, piping, and other hardware tightly packed within the ship spaces.[28] According to a 2005 DOD-sponsored shipbuilding study, the DDG 51 design is about 50 percent more dense and complex than modern international destroyers. High-density ships have spaces that are more difficult to access; this results in added work for the shipbuilder since there is less available space to work efficiently. As a legacy design, the ship's physical dimensions are already fixed, and it will be challenging for the Navy to incorporate AMDRs' arrays and supporting equipment into this already dense hullform. Some deckhouse redesign will be necessary to add the additional radar arrays: a current DDG 51 only carries four SPY radar arrays, while Flight III is envisioned to carry four AMDR-S arrays plus three additional AMDR-X band arrays. The deckhouse will need to be redesigned to ensure that these arrays remain flush with the deckhouse structure. Adding a 14-foot AMDR to DDG 51 will also require significant additional power generating and cooling equipment to power and cool the radar. Navy data show that as a result of adding AMDR the ships will require 66 percent more power and 81 percent more cooling capacity than current DDG 51s. If the Navy elects to use a smaller AMDR for Flight III these impacts may be reduced, but the ship would also have a significant reduction in radar performance.

The addition of AMDR and the supporting power and cooling equipment will significantly impact the design of Flight III. For example, additional large cooling units—each approximately 8 feet by 6 feet—required to facilitate heat transfer between the radar coolant and the ship's chilled water system will have to be fit into the design. Similarly, a new electrical architecture may be required to power AMDR, which would result in changes to many electrical and machinery control systems and the addition of a fourth large generator. The red team assessment of the Navy's ongoing Flight III technical study found that modifying DDG 51 to accommodate these changes will be challenging with serious design complexity. Since Flight III design work is just in the concept phases, it is currently unknown how the additional cooling and power generating units added to support AMDR will be arranged, or any impact they will have on ship spaces and habitability. For example, the Navy is currently considering five possible cooling unit configurations. Of these, one cannot

[28] Measured in terms of pounds of weight per cubic foot (lbs/cf), the DDG 51 class has an outfit density of close to 8 lbs/cf, which is more than the DDG 1000 and FFG 7 classes, which are approximately 7 lbs/cf, and the CG 47 class, which is approximately 7.5 lbs/cf.

be arranged within the existing spaces, another will be very difficult to arrange, and three of these options will require significant changes to the arrangements of the chilled water systems. Similarly, all of the options the Navy is considering for possible power generation options will require rearrangement and some impact on other spaces, including encroachment on storage and equipment rooms. Navy officials told us that hybrid electric drive is being researched for Flight III, and the Navy has awarded a number of contracts to study concepts.[29] The Navy told us that this technology has the ability to generate an additional 1 megawatt of electricity, and thus could potentially obviate the need for an additional generator to support AMDR. However, adding hybrid electric drive would require additional design changes to accommodate the new motors and supporting equipment.

Not only can density complicate design of the ship as equipment needs to be rearranged to fit in new items, but Navy data also show that construction of dense vessels tends to be more costly than construction of vessels with more open space. For example, submarine designs are more complicated to arrange and the vessels are more complicated and costly to build than many surface ships. DDG 1000 was designed in part to have reduced density, which could help lower construction costs. According to a 2005 independent study of U.S. naval shipbuilding, any incremental increase in the complexity of an already complex vessel results in a disproportionate increase in work for the shipbuilder, and concluded that cost, technical and schedule risk, and the probability of cost and schedule overrun all increase with vessel density and complexity.[30] Therefore, further adding to the density of DDG 51 to incorporate AMDR is likely to result in higher construction costs and longer construction schedules than on Flight IIA ships.

The addition of equipment to Flight III adds weight to the ship, and adding the large, heavy AMDR arrays to the deckhouse will also change the ship's center of gravity—defined as the height of the ship's vertical center of gravity as measured from the bottom of the keel, including keel

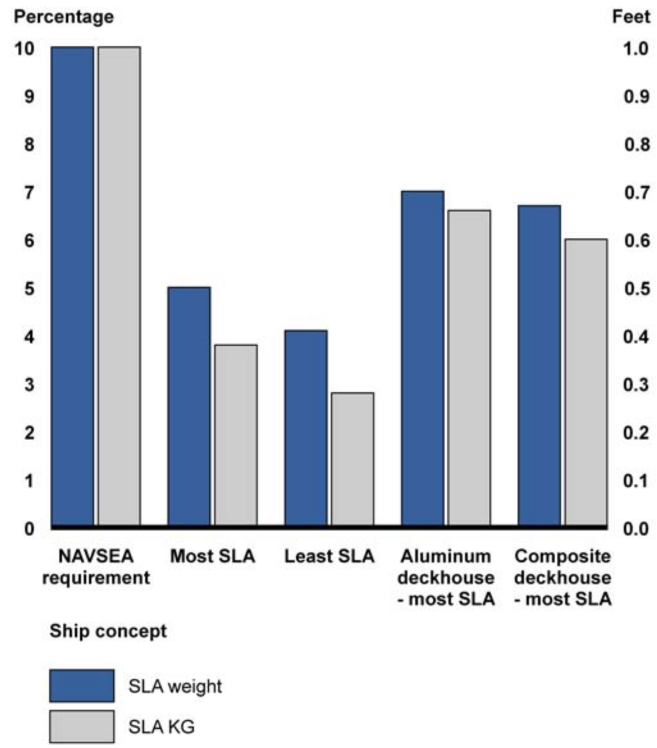
[29] Hybrid electric drive uses an electric motor integrated through the main reduction gear to reduce the use of the ship's primary gas turbines to provide both propulsion (which in turn can reduce fuel consumption) and additional electrical power. This equipment may also be backfit on prior ships.

[30] *First Marine International Findings for the Global Shipbuilding Industrial Base Benchmarking Study*, First Marine International (London: August 2005).

thickness. Weight and center of gravity are closely monitored in ship design due to the impact they can have on ship safety and performance. The Navy has required service life allowances (SLA) for weight and center of gravity for ships to allow for future changes to the ships, such as adding equipment and reasonable growth during the ship's service life—based on historical data—without unacceptable compromises to hull strength, reserve buoyancy, and stability (e.g., tolerance against capsizing). Adding new systems or equipment may require mitigating action such as removing weight (e.g., equipment, combat systems) from the ship to provide enough available weight allowance to add desired new systems or equipment. A reduced center of gravity may require mitigation such as adding additional weight in the bottom of the ship to act as ballast, though this could also reduce the available weight allowance. These changes all require redesign which can increase costs, and this design work and related costs can potentially recur over the life of the ship.

The Navy is considering a range of design options to deal with adding AMDR and its supporting power and cooling equipment. None of the DDG 51 variants under consideration as part of an ongoing Navy study meet Navy SLA requirements of 10 percent of weight and 1 foot of center of gravity for surface combatants. Figure 9 shows that several variants provide less than half of the required amounts.

Figure 9: SLA of Navy DDG 51 Flight III Concepts



Source: GAO analysis of Navy data.

[a]The "most SLA" variant has the highest percentage of weight margin and the second best KG margin.

The Navy has determined that only by completely changing the material of the entire fore and aft deckhouses and the helicopter hangars to aluminum or composite as well as expanding the overall dimensions of the hull (especially the width, or beam) can the full SLA be recovered for a Flight III with a 14-foot AMDR. Though a decision has not yet been made, at this time Navy officials do not believe that a composite or aluminum deckhouse will be used. The Navy also told us that removing combat capability from DDG 51 may be required in an effort to manage weight after adding AMDR, effectively reducing the multimission functionality of the class. Navy officials stated that SLA has not always been required, and that this allowance is included in designs to eventually be consumed. They pointed to other classes of ships that were designed with less than the required SLA margins and that have performed adequately. However, as shown in Table 10, our analysis of the data indicates that these ships have faced SLA-related issues.

Table 10: SLA Considerations with Select Ship Classes

Class	Description
CG 47 Ticonderoga	• Based on DD 963 Spruance class hullform. According to a naval architect on the Navy's technical study red team, adding Aegis compromised weight and center of gravity margins, requiring weight removal from the deckhouse to compensate. This weight removal in part contributed to cracking and buckling of deckhouses and superstructure. • CG 47-CG 51 had most significant SLA impacts. These hulls were retired with an average life of 20 years; structural modernization needed so remaining hulls can reach 35-year service life. • No CG 47's can accept an increase in weight or a rise of center of gravity due to reduced SLA; any new equipment will require weight and center of gravity adjustments.
FFG 7 Oliver Hazard Perry	• 21 of 49 have been retired early after an average lifespan of only 17 years.[a] • Reduced SLA means majority of remaining hulls cannot accept weight or center of gravity growth.

Source: GAO analysis of Navy data.

[a] Other factors that can contribute to early decommissioning are structural integrity of the hull, costs to upgrading the combat systems, condition of propulsion machinery, and cost to operate the vessel. The ships of the FFG 7 class are expected to operate for 30 years.

According to Navy data, delivery weight of DDG 51s has gotten considerably heavier over the course of building the class, with current 51s weighing approximately 700-900 long tons (a measure of ship displacement) more than the first DDG 51s. Further, while the current DDG 51s all can accept both an increase in weight or rise in the center of gravity, the ships are already below the required center of gravity allowances, though Navy officials told us that this could be corrected with ballasting if the Navy opted to fund the change. In commenting on the ongoing Navy study, the independent red team identified reduced SLA as a significant concern for Flight III, and noted that if the Navy does not create a larger hullform for Flight III, any future ship changes will be significantly constrained.

Flight III Will Not Achieve Navy Desired IAMD Capabilities with No Future Ship Planned in the Near-Term

Flight III with a 14-foot AMDR will not be powerful enough to meet the Navy's objective, or desired IAMD capabilities. The shipyards and the Navy have determined that 14-foot radar arrays are the largest that can be accommodated within the confines of the existing DDG 51 configuration. Adding a radar larger than 14 feet to DDG 51 is unlikely without major structural changes to the ship. AMDR is being specifically developed to be a scalable radar—meaning that it can be increased in size and power to provide enhanced capability against emerging threats.

According to AMDR contractors, the Navy had originally contracted for an investigation of a Variant 2 AMDR with a sensitivity of SPY+40, but this effort was cancelled. They added that the maximum feasible size of AMDR would be dictated by the ship and radar power and cooling demands, but that they had investigated versions as large as 36 feet. Leveraging AMDR's scalability will not be possible on DDG 51 without major changes, such as a new deckhouse or adding to the dimensions of the hullform itself by broadening the beam of the ship or adding a new section (called a plug) to the middle of the ship to add length. Navy officials have stated that adding a plug to DDG 51 is not currently a viable option due to the complexity, and that a new ship design is preferable to a plugged DDG 51.

The Navy has not yet determined the size of AMDR for Flight III, and two sizes are under consideration: a 14-foot AMDR with a sensitivity of SPY+15, and a 12-foot AMDR with a sensitivity of SPY+11. According to a draft AMDR Capability Development Document, the Navy has identified that an AMDR with SPY+15 will meet operational performance requirements against the threat environment illustrated in the Radar/Hull Study. This document also notes that a significantly larger SPY+30 AMDR is required to meet the Navy's desired capability (known as objective) against the threat environment illustrated in the MAMDJF AOA. The Navy could choose to change these requirements. The MAMDJF AOA eliminated the DDG 51-based SPY+15 solution from consideration in part due to the limited radar capability, and identified that a radar closer to SPY+30 power with a signal to noise ratio 1,000 times better than SPY+0 and an array size over 20 feet is required to address the most challenging threats.[31] If a 12-foot array is chosen, the Navy will be selecting a capability that is less than the "marginally adequate" capability offered by a SPY+15 radar as defined by the Radar/Hull Study red team assessment. According to Navy officials, only through adding additional square footage can the Navy effectively make large improvements in the

[31] Other reasons provided in the MAMDJF AOA for the elimination of the DDG 51 concept from consideration as a single ship concept include minimal opportunity for growth, limited service life, and constrained operational capabilities. For a discussion of the performance of SPY+15 and SPY+30 radars against the different threat environments, see Classified Annex C which will be made available upon request to those with the appropriate clearance and a validated need to know.

sensitivity of the radar;[32] the SPY+30 radar considered in the MAMDJF AOA could only be carried by a newly designed cruiser or a modified San Antonio class ship, and only a modified DDG 1000 and could carry the approximately SPY+25 radar. According to the draft AMDR Capability Development Document, the Navy's desired IAMD capability can only be accommodated on a larger, currently unspecified ship. As part of the MAMDJF AOA, the Navy identified that DDG 1000 can accommodate a SPY+25 radar. As part of a technical submission to the Navy, BIW—the lead designer for DDG 1000—also identified a possible design for a 21-foot radar on DDG 1000. The Navy did not include a variant with this size radar in the Radar/Hull Study.

Navy Plans to Leverage Off-board Sensors to Augment Radar Performance, but Concept Is Unproven

According to senior Navy officials, since the MAMDJF AOA was released the Navy has changed its concept on the numbers of Navy ships that will be operating in an IAMD environment. Rather than one or a small number of ships conducting IAMD alone and independently managing the most taxing threat environments without support, the Navy now envisions multiple ships that they can operate in concert with different ground and space-based sensor assets to provide cueing for AMDR when targets are in the battlespace. This cueing would mean that the shooter ship could be told by the off-board sensors where to look for a target, allowing for earlier detection and increased size of the area that can be covered. According to the Navy, this concept—referred to as sensor netting—can be used to augment the reduced radar capability afforded by a 12 or 14-foot AMDR as compared to the larger radars studied in the MAMDJF AOA. For example, the Navy cited the use of the Precision Tracking Space System program as an example of sensors that could be leveraged. However, this program (envisioned as a constellation of missile tracking satellites) is currently in the conceptual phase, and the independent Radar/Hull Study red team stated that the development timeline for this system is too long to consider being able to leverage this system for Flight III. Navy officials told us that another option would be to leverage the newly completed Cobra Judy Replacement radar ship and its very powerful dual-band radar to provide cueing for DDG 51s. This cueing could allow the DDG 51s to operate a smaller AMDR and still be effective. The Cobra Judy Replacement ship is comparatively cheaper than DDG 51s

[32] Navy officials explained that radar sensitivity scales as a cube of the size of the radar aperture. While improvements can also be made to the transmit/receive modules that emit the radar signal, Navy officials stated that this is a linear (not cubic) relationship and only adds marginal capability on the order of +1 or 2 dB.

(approximately $1.7 billion for the lead ship), and was commercially designed and built. However, it is not a combatant ship, which would limit its employment in a combat environment and make it difficult to deploy to multiple engagement locations.

Senior Navy officials told us that the concept of sensor netting is not yet well defined, and that additional analysis is required to determine what sensor capabilities currently exist or will be developed in the future, as well as how sensor netting might be conceptualized for Flight III.[33] Sensor netting requires not only deployment of the appropriate sensors and for these sensors to work alone, but they also need to be able to share usable data in real-time with Aegis in the precise manner required to support BMD engagements. Though sharing data among multiple sensors can provide greater capabilities than just using individual stand-alone sensors, officials told us that every sensor system has varying limitations on its accuracy, and as more sensors are networked together and sharing data, these accuracy limitations can compound. Further, though there have been recent successes in sharing data during BMD testing, DOD weapons testers responsible for overseeing BMD testing told us that there have also been issues with sending data between sensors. Although sensor technology will undoubtedly evolve in the future, how sensor netting will be leveraged by Flight III and integrated with Navy tactics to augment Aegis and the radar capability of Flight III is unknown.

No Navy Plans to Procure a More Capable Ship until Flight IV in 2032

The Navy has added a future DDG 51 flight (known as Flight IV) to its annual long-range shipbuilding plan submitted to Congress, with procurement of 21 ships to begin in 2032. According to the Navy, this Flight IV ship could be notionally based on the DDG 51 hullform, but it may be largely or entirely a clean sheet design. DOD officials stated that no decisions have been made with respect to the capabilities of this future platform, and that Executive Office of the President and DOD decisions may ultimately dictate further analysis on the capabilities needed for future surface combatants. If additional studies are completed and materiel solutions are recommended, DOD officials stated that an AOA may be warranted. Senior Navy officials told us that they do not know if Flight IV will carry a larger, more powerful radar or not or what the overall

[33] For more specifics on sensor netting, see Classified Annex C which will be made available upon request to those with the appropriate clearance and a validated need to know.

improvements in capabilities will be, even though AMDR is being built with the capability to be scaled up in size. In its recent annual long-range shipbuilding plan, the Navy currently estimates that its notional Flight IV ships will cost approximately $2.1 billion each—the same as the Flight III ships, which implies no expectations of changes to the hullform.[34] Navy officials told us that this amount was a placeholder.

Officials told us that a major consideration in the future will be electrical power. While Flight III will most likely not leverage technologies developed as part of the DDG 1000 program because of DDG 51's design constraints, Navy officials stated that Flight IV may carry some form of the integrated power system developed for DDG 1000. The Navy examined the use of the integrated power system for Flight III in the Flight Upgrade Study, but found that it was not currently viable due to current component technology. The constrained nature of Flight III will likely limit the ability of the Navy to add future weapon technologies to these ships—such as an electromagnetic rail gun or directed energy weapons as these technologies mature—unless the Navy wants to remove current weapon systems. For example, the ongoing Navy Flight Upgrade Study examined an option to add a small rail gun by removing the ship's main 5-inch gun and the forward 32-cell missile launcher system. It is unknown when these future technologies may be used.

Navy Acquisition Approach for Flight III Not Commensurate with Risks

Costs of the lead Flight III ship will likely exceed current budget estimates. Although the Navy has not yet determined the final configuration for the Flight III ships, regardless of the variant it selects, it will likely need additional funding to procure the lead ship above the level in its current shipbuilding budget. The Navy has estimated $2.6 billion in its fiscal year 2012 budget submission for the lead Flight III ship. However, this estimate may not reflect the significant design and construction challenges that the Navy will face in constructing the Flight III DDG 51s—and the lead ship in particular. In fact, the Navy's most current estimates for a range of notional Flight III options are between $400 million and $1 billion more than current budget estimates, depending on the configuration and equipment of the variant selected (see table 11 below).

[34] In constant fiscal year 2011 dollars.

Table 11: Differences in the Estimated Cost of the Lead DDG 51 Flight III Ship

2012 President's Budget	2009 Radar-Hull Study	2011 Flight Upgrade Study
$2.6 billion	$2.9 billion[a]	$3.0-3.6 billion[b]

Source: GAO analysis of Navy documentation.

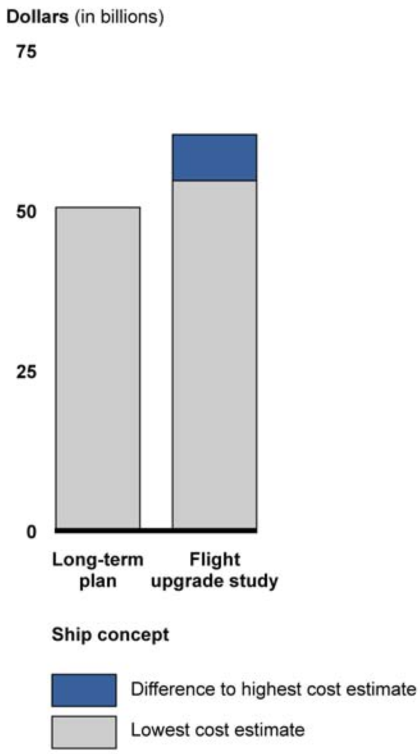
Note: Shipbuilding and Conversion, Navy (SCN) in then year dollars for the lead ship.

[a]Compared with an estimated $3.4 billion for the DDG 1000 alternative.

[b]Represents the range of options currently under review.

Further, across the entire flight of 22 ships, the Navy currently estimates Flight III research and development and procurement costs to range from $58.5 billion to $64.1 billion in constant 2012 dollars. However, the Navy estimated in its 2011 long-range shipbuilding plan to Congress that these same 22 ships would cost approximately $50.5 billion in constant 2012 dollars. As shown in figure 10 below, depending on the extent of changes to hullform, the Navy may need at least $4.2 billion to $11.4 billion more to procure DDG 51 Flight III ships.

Figure 10: Comparison of Procurement Costs for Flight III



Source: GAO analysis of Navy data.

Based on past experience, the Navy's estimates for future DDG 51s will likely increase further as it gains greater certainty over the composition of Flight III and beyond. At the beginning of a program, uncertainty about cost estimates is high. Our work has shown that over time, cost estimates become more certain as the program progresses—and generally increase as costs are better understood and program risks are realized.[35] Recent Navy shipbuilding programs, such as the Littoral Combat Ship program, initially estimated each ship to cost less than $220 million. This estimate has more than doubled as major elements of the ships' design and construction became better understood. In the case of Flight III, the Navy now estimates 3 to 4 additional crew members will be required per Flight III ship to support the IAMD mission and AMDR than it estimated in the

[35] GAO: *GAO Cost Estimating and Assessment Guide*, GAO-09-3SP (Washington D.C.: March 2009).

earlier Radar/Hull Study. Increases in the cost of Flight III would add further pressure to the Navy's long-range shipbuilding plan. Beginning in 2019, the Navy will face significant constraints on its shipbuilding account as it starts procuring new ballistic missile submarines to replace the current Ohio class. The Navy currently estimates that this program will cost approximately $80.6 billion in procurement alone, with production spanning over a decade.

The Navy Plans to Procure Lead Ship in Multiyear Procurement Despite Inherent Risks

Despite uncertainty in the costs of the DDG 123, the Flight III lead ship, the Navy currently plans to buy the ship as part of a multiyear procurement, including 8 DDG Flight IIA ships, and award the contract in fiscal year 2013. Multiyear contracting is a special contracting method to acquire known requirements for up to 5 years if, among other things, a product's design is stable and technical risk is not excessive. According to the Navy, from fiscal year 1998 through 2005, the Navy procured Flight IIA ships using multiyear contracts yielding significant savings estimated at over $1 billion. However, the Navy first demonstrated production confidence through building 10 Flight IIAs before using a multiyear procurement approach. While Flight III is not a new clean sheet design, the technical risks associated with AMDR and the challenging ship redesign as well as a new power and cooling architecture coupled with the challenges to construct such a dense ship, will make technical risk high. Further, technical studies about Flight III and the equipment it will carry are still underway, and key decisions about the ship have not yet been made. DDG 123 is not due to start construction until fiscal year 2016. If the Navy proceeds with this plan it would ultimately be awarding a multiyear contract including this ship next fiscal year, even though design work has not yet started and without sufficient knowledge about cost or any construction history on which to base its costs, while waiting until this work is done could result in a more realistic understanding of costs. Our prior work has shown that construction of lead ships is challenging, the risk of cost growth is high, and having sufficient construction knowledge is important before awarding shipbuilding contracts. [36]

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

Current Level of Program Oversight May Not Be Sufficient Given Potential Risks

Given the potential technology, design, and construction risks, and level of the investment, the current level of program oversight for DDG 51 Flight III may not be sufficient. The DDG 51 program has a long history and has already passed through all of the DOD acquisition milestone reviews (formerly Milestones 0 through IV, now Milestones A through C), and is now an Acquisition Category (ACAT) 1C program.[37] A program's acquisition category is based on its location in the acquisition process, dollar value, and Milestone Decision Authority special interest, and the acquisition category determines the program's decision authority. For an ACAT 1C program, the Assistant Secretary of the Navy (Research, Development, and Acquisition) is ultimately the Milestone Decision Authority. As the Milestone Decision Authority, the Assistant Secretary is designated as having the authority to approve entry of an acquisition program into the next phase of the acquisition process, and is accountable for cost, schedule, and performance reporting to higher authority, including congressional reporting. This differs from the higher-level ACAT 1D designation, where the Undersecretary of Defense for Acquisition, Technology and Logistics is the Milestone Decision Authority. The ACAT 1D designation provides a higher level of oversight to the program, and also provides enterprisewide visibility over acquisition program decisions.

Although it is a potentially $64 billion investment spanning decades, DDG 51 program office officials do not believe that the Flight III changes are significant enough to warrant a return to ACAT 1D oversight. According to officials, since the AMDR program—which they believe is the risky element of Flight III—is already an ACAT 1D on its own and is also progressing through the milestone process, the ship does not warrant ACAT 1D designation. Similarly, program officials have stated that they believe AMDR has sufficient oversight for Flight III and that it is unnecessary for the ship to repeat any milestones. However, significant re-design and changes to the hull and mechanical and electrical systems will be required for Flight III, which could bring potentially significant risks not being captured by AMDR oversight alone. For example, the addition

[37] According to DOD Instruction 5000.02, a program is designated as ACAT I if it is either a Major Defense Acquisition Program—defined as a program estimated by the Undersecretary of Defense for Acquisition, Technology and Logistics to require an eventual total expenditure for research, development, and test and evaluation of more than $365 million in fiscal year 2000 constant dollars or, for procurement, of more than $2.190 billion in fiscal year 2000 constant dollars—or if it is designated by the Milestone Decision Authority as a special interest program.

of AMDR requires a challenging ship redesign and software modifications to Aegis to integrate the new radar. Further, the program has historically switched from ACAT 1C to ACAT 1D during the transition from Flight I to Flight II which introduced new capabilities. Our analysis shows that Flight III meets DOD criteria for ACAT ID (see table 12 below).

Table 12: Flight III Program Compared with Factors to Determine ACAT ID Status

DOD Instruction 5000.02	Flight III Program
Technological complexity	Addition of AMDR and significant design changes to ship.
Large commitment of resources	At least $2.6 billion for lead ship, approximately $58-$64 billion for the entire Flight III class.
Critical to achievement of a capability/capabilities	Brings IAMD capability to the fleet.
Joint program	Shared development effort with the Missile Defense Agency.

Source: GAO analysis of DOD and Navy documentation.

Note: Other factors include congressional interest.

Officials from the Office of the Secretary of Defense have indicated support for designating the Flight III program an ACAT 1D program, though a final decision is not expected until 2012 at the earliest. It has also not been decided if the program will be required to return to a prior milestone, a decision also not expected until 2012 at the earliest. Typically, a milestone review gives decision makers an opportunity to evaluate important program documentation to help demonstrate that the program has the appropriate knowledge to proceed with development or production. In preparation for a milestone, programs submit documents for well over 10 information requirements, including an independent cost estimate, and technology readiness and affordability assessments. Though the Navy is working on a draft capabilities document for Flight III, without a milestone decision there may be no requirement to compel the Navy to develop this document. Further, without a milestone there will be no requirement for the Navy to seek an independent cost estimate from the office of Cost Assessment and Program Evaluation, typically submitted at a milestone review. According to Navy officials, they may consider developing a life-cycle cost estimate prior to requesting approval for the multiyear procurement approach. The DDG 51 program last conducted an independent cost estimate in 1993.

Conclusions

The Navy is in the early stages of a potential $80 billion investment in up to 43 DDG 51 destroyers to provide IAMD capability for potentially up to the next 60 years. Such investment decisions cannot be made without some degree of uncertainty; they will always involve risks—especially in the early stages of a program. Yet, a decision of this magnitude should proceed with a solid base of analysis—regarding the alternatives, cost, and technical risks—as well as a plan for oversight that provides sufficient leverage and flexibility to adapt to information as it emerges. These pieces are not sufficiently in place, at least with respect to Flight III and AMDR. To its credit, the Navy's goal was to move towards a lower-cost solution that could be rapidly fielded; however, there are a number of key shortfalls in the Navy's analysis in support of its decisions. As it stands, the Navy risks getting a solution that is not low cost, will not be fielded in the near-term, or meet its long-term goals. DDG 51 may ultimately be the right decision, but at this point, the Navy's analysis has not shown this to be the case. Specific issues include:

- The Navy's choices for Flight III will likely be unsuitable for the most stressful threat environments it expects to face.
- While the Navy potentially pursued a lower-cost ship solution, it did not assess the effect of this decision in terms of long-term fleet needs where more of these ships may be required to provide the same capability of a smaller number of more costly, but more capable, ships.
- Though the Navy hopes to leverage sensor netting to augment the capability of these ships, there is a shortage of analysis and testing with operational assets to demonstrate that this is a viable option.
- The Navy clearly states in recent AMDR documents that a new, as-of-yet undefined ship is required to meet its desired IAMD capability. However, it has not yet articulated its long-term plans for a new surface combatant that is sized to be able to carry a larger AMDR, and such a ship is not currently in the Navy's long-range shipbuilding plan.
- Without a robust operational test program that will demonstrate both DDG 51 with the modified Aegis combat system and the new AMDR, the Navy cannot be sure that the ships can perform the IAMD mission as well as planned.

In addition to these issues about the analysis underpinning the DDG 51 program, oversight of the program moving forward could be limited by two factors:

- If the milestone decision authority remains at its current level, needed scrutiny may not occur. While the proper milestone entry may be discretionary, it is clear that the cost and risk of Flight III and AMDR warrant additional oversight.
- If the Navy pursues a multiyear shipbuilding contract that includes the lead ship of Flight III, visibility over the risks inherent in lead ship construction could be obscured.

Recommendations for Executive Action

We recommend that the Secretary of Defense direct the Secretary of the Navy to take the following three actions:

1. Conduct a thorough AOA in accordance with DOD acquisition guidance for its future surface combatant program to include: (a) a range of representative threat environments developed in concert with the intelligence community; (b) results of its ongoing Flight III studies and full cost estimates in advance of awarding DDG 51 Flight III production contracts; (c) implications of the ability of the preferred ship to accommodate new technologies on future capabilities to determine the most suitable ship to carry AMDR and meet near-term IAMD requirements and provide a path to far-term capabilities; (d) implications on future fleet composition; and (e) an assessment of sensor netting—conducted in consultation with MDA and other cognizant DOD components—to determine the risks inherent in the sensor netting concept, potential current or planned programs that could be leveraged, and how sensor netting could realistically be integrated with the selected future surface combatant to assist in conducting BMD. This AOA should be briefed to the Joint Requirements Oversight Council.
2. Report to Congress in its annual long-range shipbuilding plan on its plans for a future, larger surface combatant, carrying a more capable version of AMDR and the costs and quantities of this ship.
3. In consultation with MDA and DOD and Navy weapons testers, define an operational testing approach for the Aegis ACB-12 upgrades that includes sufficient simultaneous live-fire testing needed to fully validate IAMD capabilities.

We also recommend that the Secretary of Defense take the following two actions:

1. Upgrade the oversight of the Navy's future surface combatant program to ACAT 1D status, and ensure that the appropriate milestone entry point is selected to provide cost baselines and assessments of design and technical risks and maturity.

2. Ensure that the planned DDG 51 multiyear procurement request does not include a Flight III ship.

Agency Comments and Our Evaluation

We provided a draft of this report to DOD for review and comment. DOD provided a written response which is reprinted in appendix II. DOD also submitted technical comments that were incorporated into the report as appropriate.

DOD concurred with our second recommendation that the Navy report to Congress in its annual long-range shipbuilding plan on its plans for a future larger surface combatant carrying a more capable version of AMDR. Given the assessments that the Navy is currently conducting on surface combatants, the Navy's next submission should include more specific information about its planned future surface combatant acquisitions. DOD also agreed with our third recommendation on live-fire testing of Aegis ACB-12 upgrades, stating that the Navy and the MDA—working under Office of the Secretary of Defense oversight—are committed to conducting adequate operational testing of ACB-12, but did not offer concrete steps they would take to address our concerns. Moving forward, DOD should demonstrate its commitment to fully validating IAMD capabilities by including robust simultaneous operational live-fire testing of multiple cruise and ballistic missile targets in its Aegis Test and Evaluation Master Plan that is signed by Director, Operational Test and Evaluation.

DOD did not agree with our first recommendation to conduct an AOA to support its future surface combatant selection decision, stating that its previous analyses—specifically the MAMDJF AOA and the Radar/Hull Study—comprise a body of work that satisfies the objectives of an AOA. However, DOD did not present any additional evidence to refute our findings. DOD did agree that an assessment of sensor netting needs to be performed. Our analysis shows that the Radar/Hull Study, which was the key determinant in the DDG 51 decision, was a departure from the MAMDJF AOA. These studies are neither complementary nor can they be aggregated. While both sought to determine the best solution to address identified integrated air and missile defense gaps, the Radar/Hull Study essentially answered a different question than the MAMDJF AOA. In essence, it was attempting to identify a cost-constrained, less robust solution, which makes analysis from one study not always appropriate to apply to the other. Specifically, the MAMDJF AOA considered a significantly more taxing threat environment than the Radar/Hull Study, requiring ships carrying very large radars to independently manage these threats. Alternatively, the Radar/Hull Study considered a much less taxing threat environment, allowing for ships carrying smaller radars but that would need to work together to be effective. Ultimately, the MAMDJF AOA eliminated DDG 51 from consideration as a single-ship solution. DOD also states that it is currently conducting additional studies on Flight III, but since these are solely focused on DDG 51, they do not provide any additional insight into the decision as to the appropriate ship that might be used to supplement the Navy's existing analysis. As we note in this report, the proposed program calls for an investment of up to approximately $80 billion for 43 destroyers, and likely more if the Navy chooses to pursue a Flight IV concept. Given the scope of the Navy's plans, a thorough AOA is essential to affirm that the decision made is the right one and a sound investment moving forward. This AOA should be briefed to Joint Requirements Oversight Council because of the magnitude of this potential acquisition and because of the joint service interest in IAMD that make it important to have an overarching body review the Navy's analysis and decisions. We believe that this recommendation remains valid.

DOD disagreed with our fourth recommendation to upgrade the acquisition category designation of the Navy's future surface combatant program to ACAT ID at this time, stating that a determination on the ACAT designation of DDG 51 Flight III will be made by the fourth quarter of fiscal year 2012, once sufficient information is available. If the results of the Navy's analysis continue to support a DDG 51 Flight III as the appropriate solution, our analysis shows that Flight III already meets criteria for ACAT ID status, and that this status provides an enhanced level of oversight appropriate for a program of this magnitude. This strategy is also in line with the past flight upgrades that were also conducted under ACAT ID status. We therefore believe this recommendation remains valid.

Regarding our fifth recommendation that DOD not include a Flight III ship in its planned DDG 51 multiyear procurement request, DOD partially concurred, stating that it is following the statutory requirements for multiyear procurement authority. DOD commented that it will select an acquisition approach that provides flexibility and minimizes the cost and technical risk across all DDG 51 class ships. DOD expects to make a determination on including or excluding Flight III ships within the certification of the planned multiyear procurement that is due to Congress by March 1, 2012. While the Secretary can certify that due to exceptional circumstances, proceeding with a multiyear contract is in the "best interest" of DOD, notwithstanding the fact that one or more of the conditions of the required statutory certification are not met, requesting a multiyear procurement in March 2012 that includes the lead Flight III ship carries significant risk. DOD will be committing to a cost with no actual construction performance data on which to base its estimates and a ship concept and design that are not finalized. While DOD argued that it has in the past included DDG 51's that were receiving major upgrades in multiyear procurements, as this report shows, planned changes for Flight III could far exceed those completed in past DDG 51 upgrades. We therefore believe that, in view of the current uncertainty and risk, our recommendation remains valid to exclude a Flight III ship from the upcoming multiyear procurement request.

Matters for Congressional Consideration

In view of the Navy's disagreement with a number of our recommendations, we are elevating these issues to the attention of Congress. In the coming years, the Navy will ask Congress to approve funding requests for DDG 51 Flight III ships and beyond. Without a solid basis of analysis, we believe Congress will not have assurance that the Navy is pursuing an appropriate strategy with regard to its future surface combatants, including the appropriate level of oversight given its significant cost. To help ensure that the department makes a sound investment moving forward, Congress should consider directing the Secretary of Defense to:

1. require the Navy to submit a thorough, well-documented AOA for the its future surface combatant program that follows both DOD acquisition guidance and the elements outlined in our first recommendation prior to issuing solicitations for any detail design and construction contracts of DDG 51 Flight III ships;

2. elevate the ACAT status of the DDG 51 Flight III to an ACAT ID level if the decision is made to continue pursuing the program; and

3. include the lead DDG 51 Flight III ship in a multi-year procurement request only when the Navy has adequate knowledge about ship design, cost, and risk.

We are sending copies of this report to the Secretary of Defense. We are also sending copies to the appropriate congressional committees. In addition, the report is available at no charge on GAO's website at http://www.gao.gov.

If you or your staff has any questions about this report, please contact Belva Martin at (202) 512-4841 or martinb@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

Sincerely yours,

Belva M. Martin
Director, Acquisition and Sourcing Management

Appendix I: Objectives, Scope, and Methodology

The overall objectives of this review were to assess (1) the Navy's determination of the most appropriate platform to meet current and future surface combatant requirements; (2) the differences in cost, schedule, and design of the restart DDG 51 destroyers compared with previous ships, and the risks associated with the restart; and (3) the feasibility of the Navy's plans for maturing and integrating new technologies into the future DDG 51 ships.

To assess how the Navy determined the most appropriate platform to meet current and future surface combatant requirements, we analyzed the Navy's Radar/Hull Study, which was the main tool the Navy used for assessing the radar and ship options and reviewed the accompanying "red team" assessment. We compared this study with other Navy studies related to ballistic missile defense (BMD) and integrated air and missile defense (IAMD), including the Navy's Maritime Air and Missile Defense of Joint Forces (MAMDJF) analysis of alternatives, the Navy BMD "Knee in the Curve Study," a Navy Cruiser and Destroyer analysis study, and Office of Naval Intelligence threat assessment studies. We also reviewed the Operational Requirements Document for the DDG 1000 and the draft Capability Definition Document for the Air and Missile Defense Radar (AMDR). We also obtained and reviewed internal Navy briefing slides used to present the findings of the Radar/Hull Study to Navy decision makers. To assess the steps taken by the Navy in making this decision, we reviewed relevant Department of Defense (DOD) policy and guidance documents addressing, among other things, acquisition program initiation including DOD Instruction 5000.02 and the Weapon Systems Acquisition Reform Act of 2009. We compared the Radar/Hull Study with DOD analysis of alternatives guidance found in the Defense Acquisition Guidebook, DOD Instruction 5000.02, and a July 2008 Air Force Analysis of Alternatives handbook. We also analyzed key contractor data submissions related to the ship variants and the radar concepts that were provided to the Navy to support its decision. We met with officials from the Radar/Hull Study team, the Applied Physics Laboratory at Johns Hopkins University who were technical consultants on the study, the DDG 51 and DDG 1000 program offices, representatives from the Office of the Chief of Naval Operations Surface Warfare Division, officials from the Program Executive Office for Ships (PEO Ships), the Program Executive Office for Integrated Warfare Systems (PEO IWS) program offices responsible for the Aegis combat system and for AMDR, and contractor officials from Raytheon, Lockheed Martin, and Northrop Grumman. We met with officials from the Office of Naval Intelligence to discuss the threat environment, and we met with officials from the Joint Integrated Air and Missile Defense Organization to discuss the recent Joint Capabilities Mix study which established required numbers of Navy BMD capable ships. We also met with an official from the Joint Staff to discuss the role of the Joint Requirements Oversight Council in the DDG 1000 truncation and DDG 51 restart decisions.

To assess the differences in cost between the restart DDG 51 ships and previous DDG 51 ships, we examined the Navy budget for DDG 51 restart ships and compared it with the budget for prior ships. We also spoke with the DDG 51 program office and Navy cost estimating officials, and discussed their methodology for estimating the impact of the production gap on prices, and spoke to officials from Bath Iron Works in Bath, Maine and Ingalls Shipbuilding in Pascagoula, Mississippi—the shipyards responsible for building DDG 51 destroyers—and the officials from the Navy's Supervisor of Shipbuilding at both sites about the impact of the gap on cost estimates. We also spoke to shipyard officials at both sites about their readiness to begin construction. We analyzed the Navy's revised acquisition strategy for hulls DDG 114 through DDG 116. To assess differences in production schedules we compared the Navy's projected schedules for the Flight IIA restarts with the actual schedule performance on previous Flight IIA ships. We also spoke with Navy and shipyard officials at both shipyards. To assess the design changes for the restart ships, we compared the estimated number of design drawing changes and engineering change proposals for Flight IIA restart ships with those for previous Flight IIA ships. We examined Navy and contractor-provided analyses pertaining to the Aegis upgrade (ACB 12) with specific focus on the source lines of code (SLOC), and compared SLOC estimates with SLOC actual numbers. We also reviewed software defect rates and development schedules related to the ACB 12 upgrade, and we analyzed the ACB-12 development and test schedules, risk matrices, and results from relevant test events that might impact ACB 12 availability for installation on DDG 113. We analyzed Defense Contract Management Agency (DCMA) reports on ACB 12 development, and spoke to relevant DCMA officials. We also reviewed Navy, Missile Defense Agency (MDA), and Director, Operational Test and Evaluation (DOT&E) proposed operational test schedules and plans to assess integration efforts to verify IAMD capability, and interviewed relevant Lockheed Martin, MDA, DOT&E, and DOD Development Test and Evaluation officials.

To address the feasibility of the Navy's plans for maturing new technologies intended for DDG 51 Flight III ships, we analyzed key Navy documentation including the DDG 51 Flight Upgrade Study (Phase I) and the accompanying "red team" assessment, contractor AMDR concept development documents, and AMDR Top Level Radar Performance documents. We compared the development of AMDR and its development schedule with previous Navy radar development programs (e.g. Cobra Judy Replacement radar, Dual Band Radar) to determine the feasibility of the technology and the development schedule. We also discussed development, testing, and in-yard date schedules with the Navy. We met with each of the three AMDR contractors: Raytheon, Lockheed Martin, and Northrop Grumman. To determine the feasibility of integrating AMDR and other technologies into Flight III, we compared the Navy's Flight III concepts with Navy service life allowance guidelines, and spoke with officials from both shipyards and a former Navy ship designer. To assess the feasibility of the Navy's acquisition strategy for Flight III we analyzed relevant DOD acquisition guidance including DOD Instruction 5000.02, and spoke with officials from the Office of the Secretary of Defense for Acquisition, Technology, and Logistics. We also used GAO's Cost Estimating and Assessment Guide. We are providing you with a classified annex containing supplemental information.

We conducted this performance audit from January 2011 through January 2012 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives, and that the data we obtained and analyzed are sufficiently reliable for the purposes of our assessment.

Appendix II: Comments from the Department Of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION, TECHNOLOGY AND LOGISTICS

JAN - 6 2012

Ms. Belva M. Martin
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street NW
Washington, DC 20548

Dear Ms. Martin:

This is the Department of Defense (DoD) response to the GAO draft report, GAO-12-113, "ARLEIGH BURKE DESTROYERS: Additional Analysis and Oversight Required to Support Navy's Future Surface Combatant Plans," dated November 22, 2011 (GAO Code 120948). The Department's comments on the five specific recommendations are enclosed.

The DoD concurs with recommendations 2 and 3. The DoD partially concurs with recommendations 1, 4, and 5. In response to recommendation 2, the DoD agrees to include in long range shipbuilding plans any future, larger surface combatant, carrying a more capable version of the Air and Missile Defense Radar, including the costs and quantities, if such capability is determined necessary and affordable. With regard to recommendation 3, the DoD will conduct adequate operational testing of the Aegis Advanced Capability Build 12 upgrades. The partial concur on recommendation 1 relates to Department concerns about conducting another analysis of alternatives on future surface combatants, following extensive studies that have already met the objectives of the GAO recommendations. The partial concur on recommendation 4 relates to the DoD's concerns on the timing and need for designating the DDG 51 Flight III program as acquisition category ID. The Department agrees to review the program scope and make a determination on oversight level when appropriate. The partial concur on recommendation 5 relates to the DoD's concern about potentially excluding DDG 51 Flight III ships from the planned multi-year procurement. The Department will review the costs and risks of including Flight III ships and make its determination prior to submitting the certification report to Congress.

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

Sincerely,

David G. Ahern
Deputy Assistant Secretary of Defense
Strategic and Tactical Systems

Enclosure:
As stated

GAO DRAFT REPORT DATED NOVEMBER 22, 2011
GAO-12-113 (GAO CODE 120948)

"ARLEIGH BURKE DESTROYERS: ADDITIONAL ANALYSIS AND OVERSIGHT REQUIRED TO SUPPORT NAVY'S FUTURE SURFACE COMBATANT PLANS"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: GAO recommends that the Secretary of Defense direct the Secretary of the Navy to conduct a thorough AoA in accordance with DOD acquisition guidance for its future surface combatant program to include: (1) a range of representative threat environments developed in concert with the intelligence community, (2) results of its ongoing Flight III studies and full cost estimates in advance of awarding DDG 51 Flight III production contracts, (3) implications of the ability of the preferred ship to accommodate new technologies on future capabilities to determine the most suitable ship to carry AMDR and meet near-term IAMD requirements and provide a path to far-term capabilities, (4) implications on future fleet composition, and (5) an assessment of sensor netting conducted in consultation with MDA and other cognizant DOD components-to determine the risks inherent in the sensor netting concept, potential current or planned programs that could be leveraged, and how sensor netting could realistically be integrated with the selected future surface combatant to assist in conducting BMD. This AoA should be briefed to the Joint Requirements Oversight Council.

DoD RESPONSE: Partially concur. The Department of Defense (DoD) disagrees with the GAO recommendation to conduct another Analysis of Alternatives (AoA) relative to the way ahead for DDG 51 Flight III. The DoD previously conducted detailed analyses covering items one through four of the five items identified in the GAO recommendation. The DoD conducted a thorough analysis of alternatives for future integrated air and missile defense ship systems under phase 1 of the Maritime Air and Missile Defense of Joint Forces AoA, which reported out in August 2007. That AoA, combined with the Navy's Hull and Radar Study completed in 2009, analyzed a broad range of representative threat environments developed in concert with the intelligence community and assessed the ability of alternative ship types to accommodate new technologies and to provide a path to far term capabilities. From those analyses, the DoD concluded that the most cost effective way ahead is to continue production of DDG 51 class ships and to insert Air and Missile Defense Radar (AMDR) capabilities in a Flight III variant, thus stabilizing the future fleet composition on a DDG 51-based surface combatant rather than a DDG 1000-based surface combatant. The Navy is currently conducting additional studies on Flight III and OSD Cost Assessment and Program Evaluation will provide an assessment of the cost estimates in advance of awarding production contracts for the Flight III ships. The DoD also disagrees that the GAO-recommended AoA should be

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briefed to the Joint Requirements Oversight Council (JROC). The JROC previously reviewed the Navy's future surface combatant plan and had no objections. The DoD agrees that sensor netting might be a key capability for the future; however, sensor netting has not been determined to be a requirement for any future surface combatant including DDG 51 Flight III. The DoD agrees that an assessment of sensor netting involving all cognizant DoD components to determine the risks inherent in the sensor netting concept, potential current or planned programs that could be leveraged, and how sensor netting could realistically be integrated with both future surface combatants and other military assets to assist in conducting Ballistic Missile Defense needs to be performed. For reference purposes this recommendation will be identified as item GAO-12-113-01.

RECOMMENDATION 2: GAO recommends that the Secretary of Defense direct the Secretary of the Navy to report to Congress in its annual long range shipbuilding plan on its plans for a future, larger surface combatant, carrying a more capable version of AMDR and the costs and quantities of this ship.

DoD RESPONSE: Concur, although additional direction to the Navy is not required. Section 231 of title 10, United States Code, requires the submission of a periodic report to Congress on the long range plan for the construction of naval vessels. The Navy will continue to assess future threats and ship affordability, modify its shipbuilding plan, and make future periodic reports as required by section 231. The Navy will include in long range shipbuilding plans any future, larger surface combatant, carrying a more capable version of AMDR, including the costs and quantities, if such capability is determined necessary and affordable. For reference purposes this recommendation will be identified as item GAO-12-113-02.

RECOMMENDATION 3: GAO recommends that the Secretary of Defense direct the Secretary of the Navy to, in consultation with MDA and DoD and Navy weapons testers, define an operational testing approach for the Aegis ACB-12 upgrades that includes sufficient simultaneous live-fire testing needed to fully validate IAMD capabilities.

DoD RESPONSE: Concur. The Navy and the Missile Defense Agency, working under OSD oversight for both developmental and operational test and evaluation, are committed to conducting adequate operational testing of the Aegis Advanced Capability Build-12 not limited to Integrated Air and Missile Defense capabilities. The Navy's Commander Operational Test and Evaluation Forces (COTF) has and will continue its early involvement in land-based and at-sea testing via developmental testing assists and through the COTF Detachment Naval Surface Warfare Center Dahlgren Division to provide early insight into system performance. For reference purposes this recommendation will be identified as item GAO-12-113-03.

RECOMMENDATION 4: GAO recommends that the Secretary of Defense upgrade the oversight of the Navy's future surface combatant program to ACAT ID status, and ensure that the appropriate Milestone entry point is selected to provide cost baselines and assessments of design and technical risks and maturity.

Page 2 of 3

DoD RESPONSE: Partially concur. The DoD does not agree to upgrade oversight of the Navy's future surface combatant program to Acquisition Category (ACAT) ID status at this time. The Defense Acquisition Executive (DAE) will review the DDG 51 Flight III program and make a determination on the ACAT designation at the appropriate time. If the DAE determines that his oversight is needed, then the program will be designated ACAT ID. The DoD plans to make the determination on ACAT designation for the Flight III program once sufficient information on the scope and cost of the modifications to the Flight IIa design are fully characterized, by the fourth quarter of FY 2012. Once the ACAT decision is made, the designated Milestone Decision Authority will select the appropriate milestone entry point and require an Acquisition Program Baseline along with assessments of design and technical risks and maturity to support entering the acquisition system at the selected point. For reference purposes this recommendation will be identified as item GAO-12-113-04.

RECOMMENDATION 5: GAO recommends that the Secretary of Defense ensure that the planned DDG 51 multi-year procurement request does not include a Flight III ship.

DoD RESPONSE: Partially concur. The DoD is following the certification requirements of section 2306b of title 10, United States Code, regarding requests for multi-year procurement authority. The DoD will make its determination on including or excluding Flight III ships within the certification of the planned multi-year procurement that is due to Congress by March 1, 2012. The DoD will select an acquisition approach that provides flexibility and minimizes the risk, both cost and technical, to successful procurement across all DDG 51 Class ships. It should be noted that the Navy successfully introduced major upgrades to the DDG 51 Class within the two previous DDG 51 Class multi-year procurements. For reference purposes this recommendation will be identified as item GAO-12-113-05.

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Appendix III: GAO Contacts and Staff Acknowledgments

GAO Contact

Belva Martin, 202-512-4841 or martinb@gao.gov.

Acknowledgments

In addition to the contact above, Diana Moldafsky, Assistant Director; Jennifer Echard; Laura Greifner; Kristine Hassinger; Jeremy Hawk; Ioan Ifrim; C. James Madar; G. Michael Mikota; Karen Richey; W. Kendall Roberts; Roxanna Sun; and Alyssa Weir made key contributions to this report.

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