

NPS-AM-15-124



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Persistent Platforms—The DDG 51 Case

30 September 2015

Ira Lewis, Associate Professor of Logistics

Graduate School of Business & Public Policy

Naval Postgraduate School

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Prepared for the Naval Postgraduate School, Monterey, CA 93943.



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The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Abstract

In the U.S. Navy, the DDG 51 (Arleigh Burke) class of guided-missile destroyer, which first entered service in 1991, remains in production with over 70 vessels delivered. This report explores some of the key reasons for the success of this ship. The upcoming Flight III of the class, which begins procurement in fiscal year 2016, faces the challenging integration of the Air and Missile Defense Radar, which adds ballistic missile defense capability to the vessel. We conclude that the DDG 51 class features the expandability (growth margin) and open systems characteristic of a “persistent platform” that continues in production and service for a greater period of time than would have originally been contemplated.

Keywords: DDG 51 Destroyer, Open Systems, Growth Margin



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Disclaimer: The views represented in this report are those of the author and do not reflect the official policy position of the Navy, the Department of Defense, or the federal government.



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Executive Summary

The idea behind this research originated with the Acquisition Research Program list of potential sponsored research topics for fiscal year (FY) 2015, which asked, “How do we acquire systems with performance margins and configuration flexibility to support 30 or 40 years of unknown threats?” One of the best examples of what could be called “persistent platforms” that have encountered success is the DDG 51 Arleigh Burke destroyer, a class that entered service in 1991. The DDG 51 is a multi-mission, guided-missile ship with an emphasis on air defense. The success of this class, which now includes more than 70 vessels (including the first Flight III vessel that will be procured beginning in FY2016), has been attributed to the ship’s “growth margin,” which is the capacity for successfully receiving new or additional equipment that is larger, heavier, or more power-intensive than in the original configuration.

The incorporation of evolving technologies into the DDG 51, culminating in a successful critical design review of Flight III’s Air and Missile Defense Radar in April 2015, makes it reasonable to characterize the DDG 51 as a persistent platform. Another contributing factor is the incorporation of major systems from the DDG 1000 and LHD 6/7 vessels into Flight III, reducing acquisition risk and lowering costs. On balance, the DDG 51 represents a good example of an open system as contemplated in Department of Defense (DOD) guidance: Minimized duplication for technology development investments, and shared life-cycle costs among several major shipbuilding programs.

Critics have pointed out that Flight III lacks an Analysis of Alternatives and is proceeding on the basis of an Engineering Change Proposal rather than a new requirements and contracting process. Yet the Navy’s strategy does allow for the benefits of multi-year procurement, and with production of ships split evenly between two yards using the Profit Related to Offers concept, there is stability accompanied by reasonable incentives in the industrial base—something observers of the shipbuilding industry have often expressed a desire for. With the cancellation of the CG(X) and truncation of the DDG 1000–class at three ships, the Navy will be relying on the DDG 51s for years to come to meet a wide variety of maritime requirements.



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Persistent Platforms—The DDG 51 Case

Introduction

The idea behind this paper originated with the Acquisition Research Program list of potential sponsored research topics for fiscal year (FY) 2015:

T14-031	How do we acquire systems with performance margins and configuration flexibility appropriate to support 30 or 40 years of unknown threats? What engineering standards and design protocols must be changed to accommodate non-point solution design solutions? In short how do we NOT end up with another AAV/EFV, F-22, B-2, or other really cool, really expensive, but broadly useless system? How did we get the B-52, the LPD 4 class and the CVN 68 class, all VERY useful and almost timeless systems that have served as first line platforms for their entire service lives and, actually beyond?
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The above statement makes a legitimate point. While programs can be troubled and subject to endless delays (like the Marine Corps' Expeditionary Fighting Vehicle) or built in much smaller quantities than anticipated (e.g., F-22, B-2), these "boutique" systems can't be fairly characterized as "broadly useless." The systems portrayed as successful in the above statement share a number of qualities, including long service lives, multiple changes in mission, the ability to integrate new technologies into the prime platform, and a sufficient number of end items to generate economies of scale. The "failures," like the F-22, often procured in smaller quantities than intended, do successfully perform the relatively narrow missions they were designed for.

One of the best examples of what could be called "persistent platforms" that have encountered success is the DDG 51 Arleigh Burke guided-missile destroyer, a class that entered service in 1991. The destroyer's production run "has outlasted every other battleship, cruiser, destroyer and frigate in U.S. Navy history" (Sharp, 2009). The DDG 51 is a multi-mission destroyer with an emphasis on air defense. The success of the Arleigh Burke class, which now includes more than 70 vessels, has been attributed to the ship's "growth margin," which is the capacity for successfully receiving new or additional equipment that is larger, heavier, or more power-intensive than in the original configuration (O'Rourke, 2015a). For example, some future vessels will feature a hybrid electric drive (Scott, 2015). Additionally, modular vertical launch systems featuring the Standard Missile Three have been installed on DDG 51s (Doerry, 2012). The relatively high volume of vessels and the allocation of ships to two builders while maintaining competition (as discussed



below) are also indicators of successful shipbuilding practices (Government Accountability Office [GAO], 2009).

This paper uses the “snowball” technique of data gathering. Starting with visits to the websites of DOD organizations, manufacturers, think tanks and Congress, as well as the commercial databases available through the Naval Postgraduate School library, information is collected until redundancy begins to occur, at which point data collection ends and the analysis phase begins (Biernacki and Waldorf, 1981).

This paper begins by reviewing the background of the DDG 51 class of vessels. Second, we discuss the development of the upcoming Flight III of the vessels. The next section covers the integration challenges associated with the new Air and Missile Defense Radar aboard that series of ships. We conclude by discussing the characteristics of the DDG 51 as a persistent platform.

The Open Systems Approach

While the concept of “growth margin” is very useful for the physical capacity for renewal of a prime system, the “open systems” or “modular open systems” concepts promote an incremental or evolutionary view of the acquisition process, with each increment providing an increased level of capability. Open systems architecture enables design for affordable change, employs evolutionary acquisition and spiral development, and uses an integrated roadmap for system design and development (DOD, 2014; GAO, 2014c). Department of Defense Instruction (DODI) 5000.02, *Operation of the Defense Acquisition System* (OUSD[AT&L], 2015, January 7), requires the program manager to apply “open system approaches in product designs where feasible and cost effective” (enclosure 3, sec. 14).

Open system approaches form part of an overall Intellectual Property (IP) strategy according to DODI 5000.02, Enclosure 2, Section 7b. Program needs for IP deliverables and associated license rights are considered necessary for “competitive and affordable acquisition and sustainment over the entire life cycle” (OUSD[AT&L], 2015, January 7, enclosure 2, sec. 7b). Beyond the requirements internal to the DOD, contracts should also be structured to encourage vendors to provide open systems, and contractors must describe how they will meet modular open system requirements (Rendon, 2006; DOD, 2013, p. 5).

The following business practices are recommended by the DOD (2013) to support open systems programs:

- Seek data deliverables and rights in technical data and computer software sufficient for competition throughout the life cycle as an objective;



- Continuous competition throughout the life cycle;
- Increased capability to the warfighter on a faster development timeline;
- Reduced life cycle costs;
- Shared risks with other programs;
- Minimized duplication for technology development investments, shared life cycle costs; and
- Collaboration through peer reviews. (p. ix)

In addition to the above, an “open business model” is recommended, as such an approach “requires doing business transparently to leverage the collaborative innovation of numerous participants across the enterprise permitting shared risk, maximize asset reuse and reduce total ownership costs“ (DOD, 2013, p. 139). Reuse of assets allows unique development efforts to serve several purposes, including uses that were unknown or unintended at the time of fielding of the original system. Open systems architecture is therefore a means for stimulating innovation.

A shift toward persistent platforms like the DDG 51 needs to be carried out in parallel to a move toward open systems. As stated recently in an Air Force policy document,

To the extent that our current policies and regulations can be modified to change the paradigm from large, complex programs rife with crippling interdependencies to programs with simple, severable components, open architectures, and more distributed participation, we will enact those changes. (Department of the Air Force [DAF], 2014)

However, requirements discipline remains critical. As the GAO has found, shipbuilding should include (1) demonstrating balance among program requirements, technology demands, and cost considerations by preliminary design review, and (2) retiring technical risk and closing any remaining gaps in design requirements before a contract for detail design is awarded (GAO, 2009).

For reuse to be possible, “strategic use of data rights” is needed to moderate the monopolistic power of the vendor throughout the life cycle, which can result in “vendor lock” (DOD, 2013, pp. vii–ix, pp. 167–176). Vendor lock gives the vendor what can become monopolistic powers, freeing the vendor to establish noncompetitive prices and become a sole source for a product or service. The DOD has “little leverage to control costs and manage performance in a vendor lock scenario” (GAO, 2014b; GAO, 2014c). As further explained by the GAO:

The most difficult challenge is overcoming a general cultural preference within the services for acquiring proprietary systems that



puts life-cycle decisions in the hands of the contractors that developed and produced those systems. Those contractors, therefore, benefit from maintaining the status quo with respect to long-term weapon system sustainment. (GAO, 2014c)

However, the effects of vendor lock can be mitigated through, among other practices, exploring common product lines for commonality and shared technology, rather than developing new products that correspond to individual program requirements (Wydler, 2014). Such an approach should result in modular systems and subsystems that can be openly competed.

An example of the use of an open architecture approach is the Navy's procurement of the Ground Control Segment (GCS) for its Unmanned Aerial Vehicles (UAVs). The GCS is a common baseline for all Navy UAV programs, with users selecting mission applications from an "app store." Within the GCS environment, all interfaces are known to all vendors, allowing a modular approach that promotes competition. A working group with representatives of more than 200 organizations defined both the interfaces and systems architecture (Lundquist, 2013).

The emphasis on reducing life-cycle costs is particularly notable. Successful, long-lived systems may have lived through the "death spiral" of decreasing quantities and increasing unit cost during their initial development and production. However, at later stages, such as following Full Operational Capability, ongoing modifications to persistent platforms may be significantly less expensive than the development of new products. The Navy's approach to the DDG 51 class has been described as follows:

Prior to Flight III, the program has produced three flights (I, II and IIA). Flights II and IIA included important modifications for changing mission requirements and technology updates, thus demonstrating the substantial capacity and flexibility of the base DDG 51 hull form. Flight II introduced enhanced capability in Combat Systems and Electronic Warfare. Flight IIA constituted a more significant change to the ship by incorporation of an organic dual hangar/dual helicopter aviation facility, extended transom, zonal electrical power distribution, enhanced missile capacity, and reconfigured primary radar arrays. The combined scope and means for integrating the changes for Flight III is similar to the approach used in the Flight IIA upgrade. (...)

The previous ship system changes were successfully executed by ECPs [Engineering Change Proposals] introduced via the existing systems engineering processes on both Flight II and IIA in support of the ongoing construction program. This methodology takes advantage of Navy and prime contractor experience with the proven processes while offering effective and efficient introduction of the desired



configuration changes. It also provides the more affordable and effective approach toward producing this enhanced ship capability in lieu of starting a new ship design to incorporate the same capabilities into a new production line for ship construction. (ASN[RDA], 2015)

Another relevant example is the development of the F/A-18 E/F Super Hornet into the EA-18G Growler. It would have cost far more to develop a new aircraft solely to meet the electronic attack mission. It is interesting that the Royal Australian Air Force has ordered that 12 of its acquisition of 24 Super Hornets be wired for potential conversion to Growlers, should the need arise (Fulghum, 2011). The success of the Super Hornet has been aptly described as follows:

Although the E/F version continues the basic name and design concept of the original F/A-18, it was significantly redesigned. While originally maintaining 90% avionics and software commonality with the F/A-18C/D model, its airframe is 25% larger, and features radar, avionics, and weapons upgrades and more powerful engines. Its weapons and fuel stores capacity have been significantly increased, and it can be utilized as an aerial refueling tanker. The newer models also provide frontal stealth qualities. The enhanced capabilities of the F/A-18E/F are a possible explanation for the Navy's decision not to seek to develop a direct replacement for the F-14 Tomcat. The multiple mission suites of the Hornet and Super Hornet may have allowed the retirement of a sizeable number of specialized Navy aircraft which had been fulfilling its combat aircraft roles with an associated reduction in logistics complexity. (Franck, Lewis, & Udis, 2011)

A final note on the F/A-18 E/F is from the perspective of industrial policy. Only Lockheed Martin and Boeing remain as U.S. manufacturers of fighter aircraft. If production of the Super Hornet ends without a replacement aircraft, then Lockheed Martin will have a monopoly. There are some practical reasons to keep the Super Hornet in production, such as the fact that it can act as a tactical refueling aircraft for other F/A-18s, a capability the F-35 does not have. The Navy has a replacement program for the Super Hornets known as the F/A-XX, but that acquisition is far off. The future of Boeing's vast St. Louis plant, which currently produces the F-15 in small quantities for export customers as well as the F/A-18 E/F, depends in great part on whether the DOD wishes there to be one or two providers of combat aircraft. As we discuss shortly, industrial base considerations play a more pronounced role in shipbuilding policy than is the case for aircraft manufacturing.

Our brief discussion of a number of weapon systems has emphasized the benefits of continuing production of existing platforms that are flexible enough to meet the challenges of changing requirements and evolving technologies. We now turn to a review of the features of the DDG 51 vessels.



DDG 51 Class: Background

The DDG 51 (Arleigh Burke) class of multi-mission destroyer is unique because of the size of the class, with 72 ships having been procured from FY1985 through FY2015. The DDG 51 class shares the Aegis defense system with the Ticonderoga (CG 47) class of cruiser, and both types of vessels are often referred to generically as “Aegis ships.” The original main role of the Arleigh Burke class was air defense and mid-ocean operations, but the destroyers are now being outfitted for ballistic missile defense operations (O’Rourke, 2015c; McCullough, 2013).

The first 28 DDG 51s (DDG 51–DDG 78) are referred to as Flights I/II. DDG 79–123 are part of Flight IIA, which notably includes a hangar for two embarked Light Airborne Multi-Purpose System MK-III SH-60R helicopters omitted in Flight I/II ships (O’Rourke, 2015a; Program Executive Officer Ships, 2015). Current plans are to build at least 22 Flight III vessels (Director, Operational Test and Evaluation, 2015). Additionally, in-service vessels of the DDG 51 class are undergoing a DDG Modernization Program that will provide mid-life upgrades (Program Executive Officer Ships, 2015).

No DDG 51s were procured during FY2006–FY2009 (O’Rourke, 2015c). Credit for the restart of production of the Arleigh Burke class in 2011 must be attributed in part to the significant development problems encountered with the Zumwalt-class (DDG 1000) destroyer. Only three of these vessels are under construction, with further production of DDG 51s in effect replacing the troubled Zumwalts. The DDG 1000s were designed with a number of revolutionary features, including a stealthy tumbledown hull and electric-drive propulsion. Of the 10 transformational technologies incorporated in the DDG 1000, four were found to be immature at Milestone B. The decision to terminate the DDG 1000 program and restart the DDG 51 has been described as follows:

The FY 2011 budget decision to truncate the DDG-1000 program at three ships and restart DDG-51 production was largely due to a change in the perceived threat and mission priority by Navy senior leadership. Priority was placed on ballistic missile defense rather than the original DDG-1000 precision and volume fire support mission.

The radar hull study recommended the DDG-51 hull form with a new advanced missile defense radar (AMDR) as more effective in the ballistic missile defense mission than DDG-1000. DDG-51 with AMDR was also assessed to have less cost risk. (Blickstein et al., 2011)

The Navy has also cancelled its CG(X) cruiser development program, with the DDG 51 intended as a bridge in capability, particularly in air and ballistic missile defense, to the eventual acquisition of new cruisers (Bliss, 2010; GAO, 2012; Hagerty, Stevens, & Wolfe, 2008). It could be suggested that the difficulties



encountered by the DDG 1000 and CG(X) have proven to be advantageous for continued production of the DDG 51.

Traditional Navy policy has been to keep surface combatants such as destroyers and cruisers in service for 25 years. However, current projections show that the Navy intends to maintain the DDG 51 Flights IIA and III in service for 40 years. The Congressional Budget Office (CBO) viewed this plan with skepticism, pointing out that it might not be cost-effective or technically feasible to maintain and refit these complex vessels for such a long period of time (*Analysis of the Navy's*, 2013; CBO, 2013).

In a unique arrangement, construction of the class is split between General Dynamics' Bath Iron Works (Bath, ME) and Huntington Ingalls Industries' Ingalls Shipbuilding (Pascagoula, MS). The Navy allocates hulls equally to both yards, and the yard that submits a bid lower than what had been assigned by the Navy receives a higher profit margin. This approach, termed Profit Related to Offers bidding (a variant of Fixed Price Incentive [Firm Target]), has been described as competition for profit rather than for quantity and is considered a successful means of dealing with the challenge of maintaining competition in the face of small procurement quantities (*Case Studies*, 2014; GAO, 2012; Kendall, 2015; OUSD[AT&L], 2014, September 19), and has won a David Packard Excellence in Acquisition Award (Freedberg, 2012). As emphasized by the GAO (2009),

Moving to fixed-price contracting is an important element in changing the paradigm for shipbuilding programs—fixed-price contracting can only be used if risk is appropriately retired by the time a contract for construction is agreed on and a clear understanding of the effort needed to deliver the ship exists.

Further stability is offered by the DOD's funding strategy, which proposes buying two DDG 51s annually for FY2015 through FY2019 (Pentagon Budget, 2014). This approach should assist both builders in recruitment and retention of skilled workers (GAO, 2009; Arena, Blickstein, Younossi, & Grammich, 2006, pp. 61–62). It has been pointed out that industrial base considerations play an explicit role when developing a ship program's acquisition strategy (Drezner, Arena, McKernan, Murphy, & Riposo, 2011, p. 39).

Flight III Development

The development of the most recent version of the ship, known as Flight III, has been a challenge for the Navy, yet confirms the presence of the “growth margin” discussed previously. The Navy plans to begin procurement of 33 Flight III ships in FY2016, with the first vessel, DDG 124, expected to achieve initial operating



capability in 2023 (Scott, 2015). Similarly, it has been observed that modifying the DDG-51

over time has used up some of the design's growth margin. The Flight III DDG-51 would in some respects have less of a growth margin than what the Navy would aim to include in a new destroyer design of about the same size. (O'Rourke, 2014)

The current development challenges have been described as follows:

DDG 51 Flight III ships are expected to feature new electric plants, new air-conditioning plants, and the AMDR. According to the Navy, the new electric plants are based on a design used on DDG 1000 and modification will be required for integration with DDG 51. The DDG 1000 electrical system has faced delays in completing testing. Detail design work for Flight III will begin at the end of fiscal year 2014, according to the Navy. Adding AMDR to DDG 51 will result in a significant redesign of the ship and the Navy expects that Flight III will result in changes to more than 25 percent of Flight IIA drawings, although the Navy believes many of these will be minor alterations. The Navy will need AMDR's design assumptions, such as its size, shape, weight, and power and cooling requirements in order to accurately redesign the ship. However, the Navy only recently awarded a contract for AMDR system development and the AMDR program is at least 6 months behind schedule. Based on its current schedule, the Navy plans to begin detail design work for Flight III at the end of fiscal year 2014—before AMDR has demonstrated full maturity—adding risk and uncertainty to the DDG 51 program. (GAO, 2014a).

It should be noted, however, that the AMDR successfully completed its Critical Design Review in April 2015, including “a thorough review of all design information to ensure the system will meet required specifications within cost and schedule constraints” (Department of the Navy [DON], 2015) Among the benefits of the AMDR, other than its contribution to missile defense, will be a significant reduction in maintenance, allowing crews to spend more time actually operating the radar (Taylor, 2014). The AMDR is the largest new system on the ship, which otherwise uses existing systems from Flight IIA and some adopted in other classes of vessel:

According to Capt [Mark] Vandroff [DDG 51 Shipbuilding Program Manager], development risk has been kept in check by the widespread re-use of existing machinery and systems. “When I needed electrical power, my friends in PMS 320 [NAVSEA's Electric Ship Office], they said ‘Yes, we've got a generator for you. We'll get you a power conversion module. They're already out there, you don't have to invent something new.’”



“That reduces our R&D [research and development] cost. You take a look at my budget, you will see that we are really tightening our purse strings for so much procurement. That’s always been our philosophy on Flight III. We’ve got one new thing we are inventing [AMDR]; everything else is what’s out there.”

“So I take the DDG 1000 generators, I take the LHD 6/7 electrical distribution system, I marry them up and I give the ship more power. I need to convert that power to 1000 V DC, do I take a power conversion module now under contract with DRS. We’re going with something we understand.” (Scott, 2015)

As just stated, Flight III will use the generator (and power conversion module) from the DDG 1000, and the 4160 VAC Electric Plant from the LHD 6/7 class (ASN [RDA], 2015). Sharing the risk of systems from other programs and reusing existing systems were described as being among the characteristics of an open system approach. The reuse of systems from other classes of vessels is also an effective means of dealing with the “vendor lock” and IP challenges discussed previously (Wydler, 2014). In constant FY2013/2014 dollars, the cost of each Flight III vessel has been estimated by the DDG 51 program manager at \$1.7 billion for a total fleet of 22 destroyers with two ships procured annually. In comparison, Flight IIA vessels cost an average of \$1.5 billion each (Jean, 2014).

The potential lack of sufficient growth margin in the DDG 51 Flight III, combined with the small number of DDG 1000s to be built, may raise questions as to the long-term capabilities of the combatant fleet. For example, electric drive, a feature of the DDG 1000s but absent from the DDG 51 class, is intended in part to provide sufficient power for future weapons such as lasers and the AMDR. One suggestion has been to lengthen the hull of the ships to permit future insertion of technologies such as electric drive and more advanced versions of the AMDR (Fabey, 2012; O’Rourke, 2015a; GAO, 2012; DON, 2014). It should be noted that the DDG 51 does not represent a full replacement of the projected capabilities of the three-ship DDG 1000 class and the cancelled CG(X):

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



for substantially reducing ship crew size or for otherwise reducing ship O&S [operations & support] costs substantially below that of Flight IIA DDG-51s. (O'Rourke, 2015a)

However, the Navy still plans to include electric drive in at least some of the Flight III ships, although space constraints are currently a concern. There are also plans to retrofit 36 Flight IIA destroyers with hybrid electric drive (Mazumdar, 2012), with a trial on one vessel described as follows:

The fuel savings offered by a hybrid electric drive have prompted consideration of back-fitting a CODLOG [combined diesel electric or gas] option to the USN's most numerous class, the Arleigh Burke destroyers. Changing the propulsion configuration of a warship post-build potentially raises a large number of engineering challenges which, if costly, would negate the savings to be derived from reduced fuel usage. A pilot installation of a 1.9 MW electric motor attached to an existing lay shaft of the DDG 51 gearbox was trialled in USS *Truxtun* in 2012 [Flight IIA], and is scheduled for a much wider roll-out from 2017. Electrical power is drawn from the main electrical distribution system, which in the DDG 51 is provided by up to three 2.5 MW gas turbine-powered generators. The configuration only provides electric drive to the port shaft, a compromise driven by cost versus benefit. (Scott, 2015)

The GAO has also pointed out that adding a hybrid electric drive to the ship in Flight III "would require additional design changes to accommodate the new motors and supporting equipment" (GAO, 2012). Electric drive will be particularly important should the Navy proceed with plans to install laser weapons on the Flight III vessels (O'Rourke, 2015b).

A GAO review of plans for the DDG 51 noted that the Navy's Radar/Hull Study of 2009, which recommended the integration of the AMDR onboard Flight III vessels, "does not provide an adequate evaluation of combat system and ship characteristics, and does not include key elements that are expected in an AOA [analysis of alternatives] that would help support a sound, long term acquisition program decision" (GAO, 2012) These elements include computer processing ability, cyber warfare capability, reliability, information assurance capability, usability, proprietary versus open architecture combat systems, and scalability (GAO, 2012) .

A related concern is that the Navy is considering a scaled-down (12-foot) version of the AMDR for Flight III; however, this smaller radar may not be able to meet the Navy's Integrated Air and Missile Defense (IAMD) requirements. This challenge brings into question the entire strategy of using the DDG 51 as a means to bring ballistic missile defense to Aegis vessels (Fabey, 2011). The Navy is, however, considering an as-yet unproven concept of networking IAMD capabilities, which may



reduce the requirements for the AMDR carried onboard each vessel. The dilemma was summarized as follows:

Analysts and contractors say it's starting to appear that the Flight IIIs will be heavily modified to accommodate the AMDR. But the Navy's top shipbuilder executive warns against that course. "Sometimes we get caught up in the glamour of the high technology," [Huntington Ingalls Industries CEO Mike] Petters says. "The radars get bounced around. They get changed. Their missions get changed... The challenge is if you let the radars drive the ships, you might not get any ships built." (Fabey, 2011)

It should be noted, as mentioned in the next section, that the AMDR will now be 14 feet in width, so concerns about a scaled-down radar were premature (ASN[RDA], 2015).

Integration Challenges

The ship is already packed with equipment, with the DDG 51 being described as the "surface combatant class" (GAO, 2012). In a moment of pique, the CBO referred to a potential DDG 51 Flight IV as the DDG(X), stating that the CBO "considers it unlikely that the Navy would or could use the DDG-51 design for the next-generation destroyer" (*An analysis of the Navy's fiscal year 2014 shipbuilding plan*, 2013). However, the point is now moot, as Flight IV was cancelled in 2014 in order to fund replacement of the Ohio-class ballistic missile submarine (LaGrone, 2014). One observer described the Flight III challenge as follows:

Once this ship is built—mostly by performing superhuman feats of engineering on an already crowded ship—there will be a limited margin (power, weight, cooling, displacement) for future upgrade. What the Navy buys is essentially what it will have for the life of the ship, with modest upgrades available through computer program refreshes and the like, but not the kind of upgrades available (theoretically) in a more modular design in which power, cooling, radars, and weapons, etc. are treated as commodities that can be swapped out when increased capability (payloads) is available. (McGrath, 2013)

In a similar vein, the GAO has assessed that the Navy's acquisition approach to Flight III is not commensurate with risks, both financial and technical. For example, multi-year procurement is being used despite the high level of uncertainty associated with a challenging ship redesign:

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 [the last Flight IIA ship] 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. (GAO, 2012)

Despite the Navy's optimism, there is reason for some concern regarding acquisition plans for up to 43 DDG 51 vessels. Flights I through IIA were highly successful during both acquisition and operation. However, attempts to retrofit the vessel with the AMDR, increased power and cooling requirements, and a high density of equipment are driving a significant increase in the risk of this "proven" Aegis destroyer. The AMDR requires five times more power and 10 times more cooling capacity than the SPY-1D(V) radar being replaced (LaGrone, 2012). A recent discussion, however, showed that the Navy is aware of the risk and is managing accordingly:

Three mantras characterise the Flight III design and development effort: minimum change, minimum risk, and maximum re-use.

"We know what we need to do," said Capt [Mark] Vandroff [DDG 51 Shipbuilding Program Manager]. "We need to get a SPY +15 dB radar onto a DDG 51 hull and deliver it to the fleet. Every other one of those requirements after that, some of them might be nice but we might say, 'I'm not taking that stuff today. I'm going to do something else. I'm going to keep the risk low.' So the only technology that's getting on [Flight III] is something that's already ripe and ready right now." (Scott, 2015)

With the DDG 1000 class reduced to a boutique fleet of three vessels and the cancellation of the CG(X) program, the burden of IAMD rests squarely on the DDG 51. A key finding of the Radar/Hull study was that the DDG 51 design represented better value for money than the DDG 1000 for delivering IAMD capability (Scott, 2015). The GAO (2012) has recommended a "robust operational test program" for Flight III, despite Navy reticence. While there remains no formal AOA for Flight III, the DOD position is that documents such as the Radar/Hull study, when assembled, constitute an equivalent body of knowledge (GAO, 2012). The GAO has commented on the maturity and testing of the AMDR as follows:

All four of AMDR's critical technologies—digital-beam-forming; transmit-receive modules; software; and digital receivers/exciter—are approaching full maturity, and program officials state that AMDR is on pace to meet DDG 51 Flight III's schedule requirements. In 2015, the contractor is expected to complete an engineering development model consisting of a single full-sized 14 foot radar array—as opposed to the final four array configuration planned for installation on DDG 51 Flight III—and begin testing in the contractor's indoor facilities. Following the



critical design review, scheduled for April 2015, the program plans to install the array in the Navy's land-based radar test facility in Hawaii for further testing in a more representative environment. However, the Navy has no plans to test AMDR in a realistic (at-sea) environment prior to installation on the lead DDG 51 Flight III ship. Though the Navy is taking some risk reduction measures, there are only 15 months planned to install and test the AMDR prototype prior to making a production decision. Delays may cause compounding effects on testing of upgrades to the Aegis combat system since the Navy plans to use the AMDR engineering development model in combat system integration and testing. (GAO, 2015)

Furthermore, concerns have been raised about the lack of a self-defense test ship in Flight III's operational test and evaluation program, as well as the absence of the at-sea testing plan with the AMDR, the testing plan having been specifically mandated by the Deputy Secretary of Defense in a March 6, 2014, memorandum (Director, Operational Test and Evaluation, 2015). The requirement for an at-sea testing plan is echoed by the GAO's (2009) recommendations on shipbuilding practice, which state that "critical technologies be developed into representative prototypes and successfully demonstrated in a relevant environment."

In a similar vein, a Congressional Research Service report expressed skepticism that the Flight III design potentially precludes fitting the vessel with a high-power laser due to lack of sufficient electrical power or cooling capacity. Lasers were viewed as being essential to the Navy's ability to counter anti-ship cruise missiles or ballistic missiles in the future (O'Rourke, 2015a).

Additionally, the GAO has expressed concern that the Navy plans to use ECPs to the existing Flight IIA multiyear procurement contracts, rather than establish new contracts, to construct the first three Flight III ships (GAO, 2015). Focusing on the AMDR as the major new system aboard Flight III, Congress mandated that the Navy submit a report on the AMDR ECP before going ahead with the work. That report explained the Navy's strategy for Flight III development:

ECP development is a fundamental systems engineering approach; an approach currently implemented in the DDG 51 program that has been continuously updated and improved since the program's inception in the early 1980s and has resulted in the successful delivery of 62 DDG 51 Class destroyers. The last three ships of the FY13-17 MYP [Multi-Year Procurement] are designated as Flight III beginning with one of the FY16 ships. The Flight III is a modified repeat of the existing baseline and will be centered on the addition of an IAMD capability in the form of the AMDR-S [S-band radar], associated enhanced combat systems elements and requisite supporting HM&E [Hull, Mechanical, and Electrical] changes. These changes will be incorporated via discrete ECPs with the same proven processes and rigor that



produced successful Flight II and IIA upgrades to the class. (ASN [RDA], 2015)

The Navy's approach to Flight III balances the incremental need for ballistic missile defense (which led to the AMDR) with the demanding systems integration challenges of a complex vessel. The overall approach is somewhat conservative in the sense of limiting changes to those required by the AMDR itself or the supporting systems. In doing so, the goal is to continue the incremental approach that has characterized the successful development of the DDG 51 class.

Conclusion: A Persistent Platform?

With more than 70 vessels delivered or on order, the large size of the DDG 51 class of guided-missile destroyer leads to the reasonable finding that this ship has been successful. The technology insertion and myriad of changes made to the ship over its four flights (I, II, IIA, and III), while retaining the same hull and essentially the same turbine, are further confirmation of the endurance of the Arleigh Burke's fundamental design. Had funding not been cut to fund the Ohio-class submarine replacement, there might have been a Flight IV as well.

The successful incorporation of evolving technologies into the class, culminating in a successful critical design review of Flight III's AMDR in April 2015, makes it reasonable to characterize the DDG 51 as a persistent platform. Another supporting factor is the incorporation of major systems from the DDG 1000 and LHD 6/7 vessels into Flight III, reducing acquisition risk and lowering costs. The GAO's harsh January 2012 criticism of the planned insertion of the AMDR was perhaps justified; the watchdog agency's concerns were probably the key factors behind Congress mandating a report on the AMDR ECP, which was released in February 2015. On balance, the DDG 51 does represent a good example of an open system as contemplated in DOD guidance: minimized duplication for technology development investments, as well as shared life-cycle costs among several major shipbuilding programs.

Critics have pointed out that Flight III lacks an AOA and is proceeding on the basis of an ECP rather than a new requirements and contracting process. Yet the Navy's strategy does allow for the benefits of multi-year procurement, and with production of ships split evenly between two yards using the Profit Related to Offers concept, there is stability accompanied by reasonable incentives in the industrial base—something observers of the shipbuilding industry have often expressed a desire for.

The DDG 51 has become a persistent platform because it is adaptable and was built with sufficient growth margin to accommodate evolving operational needs such as ballistic missile defense. With the cancellation of the CG(X) and truncation



of the DDG 1000 class at three ships, the Navy will be relying on the DDG 51s for years to come to meet a wide variety of maritime requirements.



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