KNOW WHEN TO HOLD 'EM, KNOW WHEN TO FOLD 'EM: A NEW TRANSFORMATION PLAN FOR THE NAVY'S SURFACE BATTLE LINE

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This report is an expansion of a Center for Strategic and Budgetary Assessments Backgrounder entitled *Know When to Hold 'Em: Modernizing the Navy's Surface Battle Line*, dated September 20, 2006. It provides a broader, historical-based analysis of the Navy's current plans to modernize and recapitalize its fleet of guided-missile cruisers, guided-missile destroyers, and general-purpose destroyers, and proposes a different transformation approach than the one now being pursued.

I would like to acknowledge some of the many people who helped me in this effort. Several experts from Lockheed Martin either arranged for, or provided me with, briefings about the Aegis anti-air warfare combat system, the Mk-41 Vertical Launch System, Aegis ballistic missile defense capabilities, and Aegis Open Architecture. Among those who helped the most were: Paul Lemmo, Craig Quigley, Robby Harris, Ric Rushton, Bob Richie, Mac Grant, and Geoffrey Moss. I also received quite a bit of help and information from experts from General Dynamics. Karl Hasslinger arranged for me to take a tour of Bath Iron Works, and he accompanied me on the trip. A former member of the Office of Net Assessment, Office of the Secretary of Defense, Karl constantly challenged my assumptions and conclusions, thereby helping me to better frame my arguments. While in Maine, Dugan Shipway, Tom Bowler, Mike Hammes, Bob Sprigg, and Andrew Bond were all gracious hosts, and answered my many questions about the yard, the improvements being made to the yard's shipbuilding processes, and the DDG Modernization Program (Bath Iron Works is the planning yard for the program). They also mounted a spirited defense of the DDG-1000, the first new 21st century combatant. Dennis Stokowski, from General Dynamics' Advanced Information Systems, was also instrumental in helping me to understand the technical aspects of open architecture.

None of these fine people contributed to the final conclusions of this report, except to the degree that they answered my specific questions about existing or planned programs or capabilities. Indeed, I would guess that few, if any, would agree with my recommendation to stop building the DDG-1000 after two ships and to pursue instead a different transformation pathway for the Navy's surface battle line. These conclusions were my own, as are any mistakes found in the report.

Executive Summary

When hearing the term "ships-of-the-line"—warships that take their place in a navy's line of battle—most think of old two- or three-deck sailing ships carrying large cannon batteries, or perhaps steam-powered, armored battleships. Since entering the age of jet aircraft, guided missiles, and nuclear-powered submarines, however, the US Navy's "surface battle line" consists of *battle force capable* (BFC) surface combatants—large, multi-mission and focused-mission warships designed first to operate as part of a fast Carrier Strike Group. These include guided-missile cruisers (CGs), guided-missile destroyers (DDGs), and general-purpose destroyers (DDs). Battle force capable combatants are separate and distinct from legacy *protection of shipping* combatants (now known as frigates and guided missile frigates) and newer littoral combat ships, both of which are smaller, and less capable, focused-mission warships.

Today, the Navy's fleet of BFC combatants consists of 22 *Ticonderoga*-class CGs and 50 *Arleigh Burke*-class guided-missile destroyers. If not the finest warships of their types in the world, they are among the very best. All 72 vessels are equipped with the superb SPY-1 phased array radar and Aegis anti-air warfare combat system, which together are often described as comprising "the most advanced anti-air system in existence, land-based or naval." Their main batteries consist of the Mk-41 Vertical Launch System (VLS), a flexible, modular guided missile system consisting of groups of *missile cells* nestled in the hull, each capable of storing and launching the following types of *battle force missiles*: land-attack cruise missiles; ballistic missile interceptors; surface-to-air missiles; anti-submarine rockets; or, with proper modifications, any other type of guided missile that can physically fit inside the 25-inch by 25-inch cell. Alternatively, a single cell can be configured to carry four smaller short-range surface-to-air missiles in a so-called "quad-pack" arrangement. The Mk-41's modular weapons flexibility allows the Navy to tailor the battle line's missile load to account for the most likely threats, and allows it to meet emerging threats with newly-designed missiles rather than brand new ships.

An additional 12 *Burke* DDGs are either authorized or under construction. When the last of these ships is commissioned in 2011, the Navy's surface battle line will consist of 84 state-of-the-art Aegis/VLS combatants, with 84 common air defense radars and a distributed main battery consisting of no less than 8,468 VLS cells—an aggregate missile capacity greater than that found on all of the major warships in the world's next 17 largest navies. The battle line's secondary battery will be equally impressive: 106 5-inch naval guns; up to 672 *Harpoon* anti-ship cruise missiles or its land attack variant; 168 *Phalanx* close-in weapons systems for terminal missile and anti-boat defense; and 504 ready-to-fire anti-submarine homing torpedoes (with more in onboard magazines). The force will also be able to hangar up to 112 MH-60R *Seahawk* helicopters. No other line of battle in the world will be come close to matching the firepower and multi-mission capabilities associated with this impressive assemblage of ships.

The Navy is now in the early stages of a general transition to a next-generation battle line. The first step in the transition began in Fiscal Year 2007 with the authorization of the first two of seven planned *Zumwalt*-class DDG-1000s—very large multi-mission BFC combatants with an advanced stealth design, a new anti-air warfare combat system, a new integrated electric power and propulsion system, and a host of other technological advances. These seven ships are to be followed by 19 CG(X)s, multi-mission guided-missile cruisers (supposedly with the same hull as the DDG-1000) optimized for fleet air and missile defense. These 26 ships will be followed, in turn, by an entirely new DDG(X), which will replace the 62 *Burke*-class DDGs soon to be in service. Depending on the final building rate of the DDG(X)s (two or three per year), the last of the DDG(X)s will be commissioned sometime between 2046 and 2056. Assuming a 35-year service life, the last Aegis/VLS combatant, DDG-112, will leave the fleet in 2046.

This approach represents at least the third transformation plan for the Navy's future surface battle line developed in the last ten years:

- During the 1997 Quadrennial Defense Review (QDR), the Navy planned to do away with small combatants entirely, opting instead for 116 large BFC combatants, divided into a "high-end" group composed of 84 legacy multi-mission guided-missile cruisers and destroyers (27 *Ticonderoga* CGs and 57 *Burke* DDGs) and a "low-end" group composed of 32 new *focused-mission* DD-21 land-attack destroyers. This represented a 72/28 "high-low" capability split among US Navy surface combatants.

- With the DD-21's costs steadily climbing, after the 2001 QDR the Navy reclassified the ship as a *multi-mission* destroyer (DD(X)). The planned new 375-ship Global Concept of Operations Navy included a battle line consisting of 88 Aegis/VLS ships and 24 DD(X)s. These 112 multi-mission ships would be augmented by 56 small, focused-mission Littoral Combat Ships (LCSs). The combined 168-ship surface combatant fleet had a 67/33 "high-low" surface combatant capability split.

- With the DD(X)'s costs still escalating, the Navy reclassified the ship yet again, this time as a *multi-mission* guided-missile destroyer (DDG-1000). However, the high cost of the ship required the Navy to dramatically reduce its planned production run. The recently announced 313-ship Navy includes a surface combatant fleet of 143 ships, split between a multi-mission battle line of seven DDG-1000s, 19 CG(X)s, and 62 DDGs or follow-on DDG(X)s, augmented by 55 of the new small, multi-purpose, focused-mission LCSs. This new plan now shoots for a 61/39 "high-low" capability split.

If nothing else, the tortured lineage of the DD-21/DD(X)/DDG-1000 clearly demonstrates the declining usefulness of classic ship designators such as "destroyer," "guided-missile destroyer," and "guided-missile cruiser." Such terms are now essentially decoupled from ship size and displacement. They are used instead to separate ships in terms of the overall capabilities of their combat systems. By using both size and capabilities to classify ships, however, one sheds light on the Navy's most recent transformation plan. With apologies to the Navy's current ship titles, under current plans the future surface battle line will have three distinct tiers. The top tier will consist of 26 large and expensive multi-mission "CG-21s" (21^{st} century "cruisers) based on the "DDG-1000" hull: seven will carry two 155mm (6-inch) advance gun systems (on ships now known as the DDG-1000) and 19 will replace one or both gun systems with additional missile cells filled with new long-range SAMs and anti-tactical ballistic missile interceptors (on ships now known as CG(X)). The middle tier will be defined by 62 multi-mission *Arleigh Burke* DDGs or futuristic DDG(X)s. Finally, the bottom tier will consist of 55 focused-mission LCSs.

Regardless of the ship's ultimate designation, the evolution of the DD-21/DD(X)/DDG-1000 also helps to illuminate how the Navy's early failure to balance the ship's requirements with cost considerations has forced it to make repeated adjustments to its future surface combatant plans. Even now, after the DDG-1000's full load displacement has been reduced by around 4,000 tons (to 14,500 tons), as a result of design and requirement assumptions made over a decade ago, the ship remains very expensive—and considerably more expensive than originally expected. The original DoN cost projections for the fifth DD(X) were between $1.06 and $1.23 billion in FY 2007 dollars. In 2004, the DoN estimates for the fifth ship in the class jumped to $1.4 billion; in 2005, they jumped again to $2.1 billion. The Navy now projects that the first DDG-1000 will come in at $3.3 billion. However, the Cost Analysis Improvement Group (CAIG) within the Office of the Secretary of Defense (OSD) pegs the cost of the first ship at $4.1 billion, while the Congressional Budget Office (CBO) estimates a first-ship price of $4.7 billion.[1] Based on a *seven* ship production run—down from the 32 ships called for in the 1997 QDR fleet and the 24 ships called for in the 375-ship Global ConOps Navy—the Navy believes the average cost per ship will be $2.7 billion; the CBO projects the average cost of seven ships to be $3.7 billion.

No matter whose estimates turn out to be right in the long run, the ship's steady cost growth helps to explain the sharp turns in the long and winding road that defines the Navy's post-Cold War plans for its future surface combatant fleet. Indeed, even if the Navy's optimistic ship cost estimates prove to be true, it seems certain that the seven DDG-1000s and 19 CG(X)s will continue to have inevitable, disproportionate impacts on plans for the future surface battle line and the larger 313-ship battle fleet. One impact among many discussed in the body of this report is readily seen in the planned split between the fleet's "high-end" multi-mission combatants and "low-end" focused-mission ships. The planned percentage split for current 143-ship surface combatant fleet is now 61/39, a rather significant reduction from the 70/30 mix long pursued by naval planners. In other words, because of the unexpectedly high costs for future multi-mission ships, lower-cost, focused-mission ships will necessarily comprise a greater proportion of the future fleet.

Given the unwelcome impact that the DDG-1000 has had and will continue to have on the Navy's post-Cold War transformation plans, even the staunchest proponents of the ship have to question whether pursuing the ship continues to make sense. The arguments to go forward still have a definite appeal: the ship will mark a major advance in US surface combatant capability, especially in terms of stealth; the Navy needs to step toward improved automation to reduce the size of future ship crews and operating costs; the move to an integrated power system will result in quieter, more survivable ships and open the way toward exotic new weapon systems such as electromagnetic rail guns; building the ships will help to recover the Navy's considerable sunk research and development costs and help maintain the US national shipbuilding industrial base. Indeed, in a bow to the Navy's *Requirements School*—officers who believe ships should be built to requirements regardless of their cost impact—it is impossible to resist their claim that the

[1] O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," pp. 15-20

DDG-1000s (and, presumably, the follow-on CG(X)s) will be among the most survivable and powerful surface combatants ever built.

However, these arguments and claims are not as relevant as they appear to be. The Navy is in the midst of a grand transformation from a fighting organization that focuses first and foremost on the number of ships in its *Total Ship Battle Force* (TSBF) to one that focuses on the aggregate capabilities found in its *Total Force Battle Network* (TFBN). In this new construct, the individual power of any single ship is subordinate to the combined power of the TFBN. When shifting to this new "FORCEnet" construct, one thus has to ask a simple question: do the disproportionate costs and impacts associated with the Navy's plans for its future surface battle line unduly threaten the Navy's broader goal of building an affordable, balanced, and effective TFBN? This report concludes that the answer to this question is likely to be "yes." The question that immediately follows is: What should the Navy do about it?

In contemplating this important question, a gaming analogy might help. With apologies to naval purists, the US Navy finds itself in the very early stages of a high-stakes post-Cold War naval transformation game, patterned after Texas Hold 'Em. The objective of this game is to emerge with the largest stack of naval capability "chips," made up of a combination of fiscal resources, platforms, and battle fleet capabilities. In other words, the Navy seeks a future battle force more capable than any other naval competitor at the table. Its current stack of "chips" is quite high, including among them 22 *Ticonderoga*-class CGs, 62 programmed *Arleigh Burke* DDGs, 30 frigates, and 26 mine warfare ships. The Navy recently "bet" its 56 legacy frigates and mine warfare ships in order to "win" 55 new LCSs in return—a trade that it hopes will add to the size of the fleet's capabilities "stack." Now, the Navy has just been dealt two DDG-1000s in the FY 2007 budget and it is considering going "all in," risking all of its remaining "chips" with the hope that the DDG-1000 (and the follow-on CG(X)) will add significantly to the Navy's overall capabilities "chip stack."

Is this a smart move? Is now really a good time for the Navy to push "all in" on a highly capable, but perhaps ruinously expensive, surface combatant? As any poker player will tell you, in games of chance, every decision—even those made with an apparently dominating hand—entails some risk. Given the high stakes involved, should the Navy risk both its plans for the future surface battle line and the larger battle fleet so early in the post-Cold War transformation game on the apparent strength of one ship, or "hand"?

This report concludes the answer to this question is "no." Based on the major changes to the strategic, operational, and tactical assumptions that drove the design history of the DD-21/DD(X)/DDG-1000, and upon review of all the arguments for and against the new ship, it is easy to conclude that Navy's next best move is to walk away from its previous "bets" on the DDG-1000 and CG(X) and wait for a better "hand." "Folding" on the new ships will in no way threaten the Navy's current position as the number one player at the naval transformation table. In fact, by doing so, the Navy will have a rare opportunity to change its current game strategy and actually improve its long-term prospects for retaining the naval capabilities "chip lead."

In line with this thinking, then, the Navy should do five things:

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

- ***Second, "hold" the Aegis/VLS fleet: design a comprehensive, Aegis/VLS Battle Network Reliability and Maintenance (BNRAM) program, with the goal of producing the maximum number of interchangeable, Interim Large Battle Network Combatants. (I-LBNCs).*** The Navy's ultimate goal is to shift to a new *Large Battle Network Combatant*, or LBNC—a far better description of future Total Force Battle Network BFC combatants than the multi-mission guided-missile "cruisers" and "destroyers" or general-purpose "destroyers" associated with today's legacy Total Ship Battle Force. Until they can be designed, betting an additional $10-15 billion on five or six additional DDG-1000s would appear to provide far less of a TFBN payoff than making a similar sized or even smaller bet on a well-thought-out and executed BNRAM program to convert the 84 programmed Aegis/VLS warships into more powerful I-LBNCs. This conversion program would be patterned after earlier modernization and conversion efforts, like the Fleet Reliability and Maintenance (FRAM) program, which converted many of the large legacy fleet of World War II destroyers into effective Cold War ASW escorts. The BNRAM program would include a thorough mid-life upgrade to the ships' hull, machinery and electrical (HM&E) systems; an equally thorough combat systems upgrade to allow the ships to counter emerging threats; and a battle network upgrade to allow the ships to operate as part of a coherent naval battle network. Consistent with battle network precepts, the intent of the battle network upgrade would be to bring as many ships as possible to a common I-LBNC combat system baseline. The BNRAM program would also aim to lower substantially costs necessary to operate the legacy Aegis/VLS fleet, in order to save money in the near term and to offset to some degree the added costs necessary to keep older ships in service over the longer term. A key part of this effort centers on reducing the crew size needed to operate, maintain, and fight the ships. Importantly, because this effort can justifiably be seen as converting legacy Aegis/VLS ships into more capable I-LBNCs, these four components of the BNRAM program should be funded out of the more stable Ship Construction Navy (SCN) account rather than the more volatile operations and maintenance (O&M) account, used to pay for operations associated with the ongoing "Global War on Terror."

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

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

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

No plan is perfect, and this one is no exception. Indeed, rather than viewing the above recommendations as prescription, they should be viewed as a point-of-departure to guide efforts to develop a new transformation approach for the Navy's future battle line. This new approach is wholly consistent with the Navy's broader transition from a Total Ship Battle Force to a Total Force Battle Network. Moreover, it results in a more formidable near-term surface battle line; ensures the viability of both the design and industrial base for large, complex surface combatants; maximizes near-term operations and support savings; provides a smoother, more easily manageable transition to the next generation of Large Battle Network Combatants; and better positions the Navy to respond to any future maritime challenge. Better yet, it is less fiscally risky than the current plan, with ample built-in flexibility to adjust to unexpected changes in the threat and in future shipbuilding budgets.

Regardless of whether or not the Navy and Congress agrees with this approach and "folds" the DDG-1000 and CG(X), however, the requirement to design and execute a comprehensive

Aegis/VLS Battle Network Reliability and Maintenance program remains. These ships represent a $100 billion taxpayer investment. Moreover, keeping them in service for 35 years is absolutely critical if the Navy has any chance of building to, and maintaining, a 313-ship TFBN fleet. Said another way, making sure the Navy can count on over 2000 years of future fleet ship life for the Aegis/VLS fleet is far more important to the Navy's immediate future than building seven DDG-1000s which promise only 245 years of future fleet ship life.

The FY 2008 budget will be the first complete new budget since the Chief of Naval Operation's announcement that fleet personnel and O&M dollars are to be maintained at current levels and that research and development (R&D) money must be reduced to build a TFBN fleet of 313 ships. As discussed in this report, the former ensures that *any* fleet-wide sustainment program for the Aegis/VLS ships will be difficult to execute, while the latter may make it hard for the ships to keep up with pacing threats over the next two decades. It is therefore important that Congress be an early and interested observer when the Navy's FY 2008 budget is presented, and that it asks penetrating questions about the full extent of Navy's plans to modernize and sustain its Aegis/VLS fleet.

Among the most critical questions to be asked are:

- What are the Navy's plans for a balanced Aegis/VLS modernization and sustainment program? Do plans for their fleet-wide HM&E upgrades guarantee all 84 Aegis/VLS combatants will remain in service for a full 35 years? If not, what needs to be done to assure this?

- What are the most likely operational threats to naval battle forces over the next 25-35 years? Are the Navy's plans for Aegis/VLS combat system upgrades consistent with the evolution of likely future threats? Does the Navy have a robust R&D line to make sure the Aegis/VLS fleet can meet these projected threats?

- Are planned battle network upgrades sufficient to allow all 84 Aegis/VLS ships to seamlessly operate in improved future naval battle networks? If not, why not?

- Are planned crew reduction efforts taking full advantage of all technological options? If not, why not?

- What HM&E, combat system, and battle network upgrades are being cut to stay within established O&M caps? What will the effect of these cuts be on fleet combat capability?

- Should Aegis/VLS modernization programs be funded out of SCN accounts instead of O&M accounts?

- Are studies for possible expanded SLEPs for these ships adequately funded? What desirable HM&E, combat system, and battle network upgrades are not being pursued due to lack of funds? How would these upgrades improve fleet combat capability? How much would these additional improvements cost?

Getting the answers to these questions will help ensure the US Navy doesn't inadvertently "fold" a winning hand. The 84 Aegis/VLS ships soon to be in commissioned service will represent perhaps the most powerful surface battle line in naval history. With the proper planning, they will only get better. However, as this report suggest, keeping the ships combat effective for a full 35 years of commissioned service, as is now planned, is by no means a sure bet. Scrimping on any of the five components of a Battle Network Reliability of Maintenance program—a thorough mid-life upgrade to the ships' HM&E systems; an equally thorough combat systems upgrade; a battle network upgrade to make sure the ships can operate in future naval battle networks; additional crew reduction efforts; and a sustained follow-on maintenance regime—will sink the Navy's plans for both its future surface battle line as well as its larger plans for TFBN fleet of 313 ships.

In the words of a famous Kenny Rogers song, the Navy has "got to know when to hold 'em, know when to fold 'em." Cancelling further DDG-1000s beyond the two now authorized, and instead planning, budgeting, and executing a balanced Aegis/VLS BNRAM program supported by a sustained follow-on maintenance regime; starting a clean-sheet design for the next 21st century LBNC; and building additional *Burke* DDGs until the new LBNC is ready for production is an affordable, executable, and effective transformation strategy which will help to ensure continued US naval superiority for the foreseeable future.

I. THE LONG AND WINDING ROAD: RETRACING THE DEVELOPMENT OF POST-COLD WAR PLANS FOR THE NAVY'S FUTURE SURFACE BATTLE LINE

A RAPID FALL FROM GRACE

In November 1989, the Berlin Wall—the jarring physical reminder of the "Iron Curtain" that had separated free from occupied Europe since 1961—was torn down by joyous Germans. Although it would take another two years for the Soviet Union to collapse, the demolition of the Berlin Wall marked the symbolic end of the ideologically-driven Cold War between the United States and its allies and the communist Soviet empire.

In the mid-1970s, US Navy leaders began warning that the United States had lost any measure of naval superiority over the Soviet Union.[2] This warning helped to spark a naval expansion and modernization program that extended through most of the 1980s. The ultimate goal of this effort was to build a 600-ship battle force, including 100 nuclear-powered attack submarines; 15 deployable aircraft carriers; four re-commissioned World War II battleships armed with anti-ship cruise missiles and land-attack cruise missiles; 100 guided-missile cruisers and destroyers; 37 general-purpose destroyers; and 101 frigates to escort convoys, amphibious task forces, and underway replenishment groups.[3] By 1989, the Navy was within eight ships of its overall goal, with a *Total Ship Battle Force* (TSBF) of 592 ships.[4] With the unexpected implosion of the Soviet Union and the subsequent dismantlement of its powerful navy, the US battle fleet was easily the most powerful in the world, if not in all of naval history.

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[2] For example, Admiral Elmo Zumwalt, Chief of Naval Operations from 1970-74, asserted that, "In the case of surface ships, our deterioration in numbers and in quality was such that they, together with the aircraft carriers and the submarines, gave us by 1971 or '72 only [a] 35 [percent] probability of victory (over the Soviet Navy)." See Elmo R. Zumwalt, Jr., "The Most Dangerous World is One Where the Soviets Have It and We Do Not," an interview with John M. Whitley, found online at http://www.ucf.ics.uci.edu/~zencin/peace2/interviews/zumwalt.html.

[3] Norman Polmar, *Ships and Aircraft of the US Fleet*, 13th edition (Annapolis, MD: US Institute Press, 1987), pp. 5-7; 104-110; 160.

[4] The current counting rules for the TSBF were established in the early 1980s by then-Secretary of the Navy John Lehman, who was leading the Department of the Navy (DoN) during an intense open-ocean competition with the Soviet Navy, and before the signing of the Goldwater-Nichols Act. At the time, Secretary Lehman decided that the only ships that would "count" toward the TSBF were ships that contributed *immediate* combat capability *to the Navy*. As a result, the Navy operates far more ships than those indicated in the TSBF count. For example, sealift ships are not included in the count; neither are smaller Patrol Coastal ships (PCs) or some mine warfare ships found in the Naval Reserve. The current official inventory of US naval ships in the TSBF can be found online at the Naval Vessel Register, at http://www.nvr.navy.mil. Historical ship counts, such as the 592 ships cited here, can be found at the Department of the Navy, Naval Historical Center, "US Navy Active Ship Force Levels, 1886-present," found online at http://www.history.navy.mil/branches/org9-4c.htm.

Faced with this unexpected circumstance, a logical question was: whither the 600-ship Cold War Navy? The passage of the 1986 Goldwater-Nichols Act, with its pointed emphasis on unified action of the US armed forces and joint operations, helped to prevent the worst of the ferocious inter-Service rivalry seen after the end of World War II. As a result, the naval officers who helped fight and "win" the Cold War did not have to answer as many questions about the future relevance of naval power as did the naval officers who helped fight and win the Second World War. Nevertheless, there were still numerous opinions about how the Navy should transform its battle force to account for the radical change in the new strategic environment. Some believed that the day of the large deck aircraft carrier had passed, arguing instead for large mobile offshore bases that would support joint task forces. Others noted that the diminished ASW threat meant that the attack submarine fleet and frigate forces could be greatly reduced without any increase in risk. Others argued for smaller, less capable surface combatants optimized for forward presence and patrolling operations.

Although there were many opinions on the desired shape of the future Navy, they all shared one common assumption: the next battle force would be much smaller than the one needed to fight and win the Cold War. Just before the fall of the Berlin Wall, the mere thought of a smaller battle fleet had prompted a Secretary of the Navy to resign in protest. In February 1988, then-Secretary James Webb objected to a plan developed by the Office of the Secretary of Defense (OSD) to decommission several older frigates, which he interpreted as evidence that the administration was backing away from its stated commitment to maintain a 600-ship Navy. To make his point, he submitted his resignation, and promptly left office.[5] However, Secretary Webb's gesture barely made headlines, and the decommissioning of the frigates went forward as directed. As a result of these decommissionings, on September 30, 1987, the post-Vietnam War TSBF peaked at 594 ships. Exactly two years later, just before the tide of freedom swept through Eastern Europe, the number of ships in the battle force stood at 592.[6]

Secretary Webb's resignation was prompted, in part, because the post-Vietnam war defense build-up had peaked several years earlier and the Services were beginning to feel the pinch caused by decreased defense budgets. Concerns over persistent deficit spending had spurred Congress to make real decreases in overall defense spending in every fiscal year after Fiscal Year (FY) 1985.[7] However, with the demolition of the Berlin Wall, officials and officers inside the Department of the Navy (DoN)—as well as all of the other Services—instinctively knew the worst was yet to come. They understood that the end of the Cold War would trigger a broad national demobilization. The only uncertainty was over how deep the budget cuts and how steep the postwar drawdown would be.

The initial budget cuts were sobering enough. In real terms, yearly funding for national defense declined by about 16.9 percent between the last Reagan Administration defense budget (FY

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[5] See Secretary Webb's letter of resignation at http://www.reagan.utexas.edu/archives/speeches/1988/ 022388b.htm.

[6] "US Navy Active Ship Force Levels, 1886-present."

[7] See "Defense Budget," at http://www.dod.mil/execsec/adr95/budget_5.html.

1989) and the last Bush Administration budget (FY 1993).[8] While these cuts turned out to be the deepest of the post-Cold War period, they may have been even deeper if not for General Colin Powell, then-Chairman of the Joint Chiefs of Staff, and his efforts to identify a so-called *Base Force*. Like many US officers who helped to fight and win the Cold War, General Powell wanted to prevent a repeat of the wholesale post-World War II demobilization that had left the United States so weakened militarily. In line with this aim, the Base Force effort was concerned less with developing a new national security strategy and more with establishing a floor below which the post-Cold War military should not be allowed to fall.[9]

The ultimate Base Force Review called for a TSBF of 451 ships—a 25 percent reduction from the ultimate Cold War fleet requirement. In addition, Admiral Frank B. Kelso II, the first post-Cold War Chief of Naval Operations, had to agree not to develop any new ships during his tenure. Although Admiral Kelso was not particularly happy with either the size of the Base Force fleet or the prohibition against building any new ships, he decided to accept them both. He understood that the Navy's future force structure would be determined more by the size of the defense budget than by any articulation of fleet operating requirements. For this reason, he publicly welcomed the Base Force as an "anchor" against the tide of further fleet reductions. Privately, he believed the Navy would be lucky to maintain 451 ships in active commission.[10]

PLANNING UNDER CONDITIONS OF SCARCE RESOURCES AND UNCERTAINTY[11]

Despite Admiral Kelso's promise not to design any new ships during his tenure, to keep the US shipbuilding base warm he won agreement to continue producing the *Arleigh Burke* guided-missile destroyer.[12] As will be discussed, this decision was to have an important impact on the subsequent development of the post-Cold War surface combatant fleet. Equally important was Admiral Kelso's decision to conduct studies to identify the desired requirements for future warships. For example, the *21st Century Destroyer Technology Study,* initiated in 1992, aimed to identify the tactical and design requirements for a new 21st century surface combatant, to be

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[8] Steven Kosiak and Elizabeth Heeter, "Post-Cold War Defense Spending Cuts: A Bi-Partisan Decision," Center for Strategic and Budgetary Assessments, dated August 31, 2000, found online at http://www.csbaonline.org/4Publications/Archive/H.20000831.Post-Cold_War_Defe/H.20000831.Post-Cold_War_ Defe.htm.

[9] Although the Base Force review did anticipate the future regionalization of US defense problems, it was clearly focused first on establishing a postwar demobilization target. See Lorna S. Jaffe, *The Development of the Base Force, 1989-1992* (Washington, DC: Joint History Office, Office of the Chairman of the Joint Chiefs of Staff, July 1993), especially p. 40.

[10] Jaffe, *The Development of the Base Force 1989-1992,* p. 44.

[11] The next several sections are derived, in part, from Andrew F. Krepinevich and Robert O. Work, *A New Global Defense Posture for the Second Transoceanic/Joint Expeditionary Era* (Washington, DC: Center for Strategic and Budgetary Assessments, January 2007).

[12] The same did not hold true for attack submarines. The Navy decided to forego the ultimate Cold War SSN, the *Seawolf* class, in favor of a new submarine optimized for littoral undersea warfare. The eventual result was the *Virginia*-class SSN. However, while the submarine was being designed, the Navy stopped authorizing submarines for a period of six years.

ordered around 2005.[13] As were all studies initiated at the time, the *21st Century Destroyer Technology Study* was indelibly shaped by two strong opposing winds—those caused by the aforementioned cuts to the defense budgets, and those caused by high levels of strategic and technical uncertainty.

The level of strategic uncertainty in the first years of the post-Cold War era was particularly high. Unlike during the Second World War, when US strategists began planning for the postwar world in late 1942, three years before the war ended, the abrupt Cold War victory caught most US defense strategists and military planners by surprise.[14] The psychological dislocation caused by their unexpected victory practically guaranteed there would be no major adjustments to existing US strategies and plans.[15] Indeed, immediately after the dismantling of the Berlin Wall, the Joint Chiefs of Staff still believed the Soviet Union would remain the most serious threat facing the United States in the 1990s.[16]

Even after it became clear the Soviet Union was truly finished, the 1990s were characterized by relatively tentative strategic adjustments. The first decade of the post-Cold War era presented a planning challenge similar to the one that faced US defense planners between 1945 and 1948, a period before the Soviet threat had fully manifested itself.[17] The full range of potential future national security threats was extremely broad; no single threat immediately rose above the others, and many competed for the attention of US strategists. Moreover, as will be discussed more fully later in the report, the tools of warfare were changing dramatically, particularly with regard to conventional guided weapons and sensor, information, and networking technologies. Given the inherent strategic and technological uncertainty of the time, it is therefore unsurprising that US defense strategists acted in the 1990s precisely as did planners in the immediate aftermath of World War II. That is, they tended to think about the future military posture first in terms of the previous strategic era. Said another way, US strategists naturally gravitated toward the familiar, comfortable assumptions of the past era than to the less familiar, less comfortable assumptions about the emerging one.

IMPACT OF THE GULF WAR

If anything, the natural tendency to revert to assumptions more attuned to past strategic eras was accentuated by the apparent lessons of the new era's first war—Operation *Desert Storm*, the combined operation to eject Iraqi forces from Kuwait, conducted between August 1990 and

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[13] Norman Friedman, *US Destroyers*, revised edition (Annapolis, MD: Naval Institute Press, 2004), p. 434.

[14] For a wonderful recapitulation of US planning for the post-World War II world, see Elliott V. Converse III, *Circling the Earth: United States Plans for a Postwar Overseas Military Base System, 1942-1948* (Maxwell AFB, AL: Air University Press, August 2005).

[15] The uncertainty that existed in the early years following the end of the Cold War is well captured in John Lewis Gaddis, "Toward the Post-Cold War World," *Foreign Affairs,* Spring 1991, pp. 102-122.

[16] Jaffe, *The Development of the Base Force 1989-1992*, p. 2.

[17] For the planning challenges during this period, see Converse III, *Circling the Earth: United States Plans for a Postwar Overseas Military Base System, 1942-1948.*

March 1991.[18] The first war in any new strategic era often has a major impact on how military officers initially perceive the most likely future threats and how best to transform the armed forces to address them. Sometimes these perceptions turn out to be accurate. For example, at the broadest level, the Korean War—the first "hot" war of the Cold War era—indicated that conventional wars were still likely to be fought in the atomic age, and that there would be a continuing utility for conventional air, naval, and ground forces. Sometimes, however, these perceptions turn out to be inaccurate. The Inchon landing in the Korean War seemed to indicate a continuing need for amphibious forcible entry forces in the new strategic era. In hindsight, though, Inchon turned out to be an anomaly; the remainder of the Cold War was marked by conditions of assured access, and, as a result, the demand for amphibious landing forces declined dramatically over time. Whether or not the perceptions formed after a strategic era's first war turn out to be accurate or inaccurate, however, they have a powerful influence on the initial judgments and choices made by military planners.

This proved to be especially true for Operation *Desert Storm,* which began less than a year after the fall of the Berlin Wall. The first Persian Gulf War helped to mark the abrupt transition from one strategic era to another in a way that few events could. Heavy Army armored units that had for decades been based in Germany to guard against the possibility of a Soviet attack through the Fulda Gap were transferred from their European garrisons to Saudi Arabia to participate in the war—an event unthinkable even two or three years earlier. More to the point, the war's execution and outcome provided US defense planners with a future force planning and sizing model with many comfortable links to the earlier Cold War era. As a result, Operation *Desert Storm* likely had an even greater impact on the initial direction of strategic thinking in the post-Cold War era than might otherwise have been reasonably expected.

The war's impact was made plain in the *Bottom-up Review* (BUR), conducted by the first Clinton administration in 1992-93. As its name implies, the BUR was ostensibly the first "clean-sheet" post-Cold War strategic/posture review since the identification of the Base Force. However, even though then-Secretary of Defense Les Aspin cautioned planners against re-fighting the last war, they proceeded to do just that. During the Cold War, US defense planners worried that war with the Soviet Union would break out in one of two ways—an attempted Soviet invasion of Central Europe or (beginning in the 1970s) the Persian Gulf. Wherever the war started, planners anticipated that combat operations would quickly spread to the other theater, as well as the Pacific. As a result, the US military fully expected to conduct major combat operations in *at least* two widely separated theaters, and most likely three. In the emerging strategic era, instead of preparing to fight a multi-theater war against the Soviet Union, the BUR required that the US military be prepared to fight two nearly-simultaneous "major regional contingencies" (MRCs) in separate theaters. Moreover, the BUR decreed that future adversaries would look remarkably like those of the recently defeated Iraqi armed forces, with large ground forces consisting of

[18] The build-up to actual combat operations, which occurred from August 1990 to January 1991, was named Operation *Desert Shield.* For the sake of clarity, when used in this report, the term *Desert Storm* is used to describe the entire war, from build-up to repdeployment.

numerous tanks, infantry fighting vehicles, artillery pieces backed up by modest air and naval forces.[19]

In essence, then, when considering the most likely future national security challenges, the BUR used Operation *Desert Storm* to justify a simple regionalization of the Cold War military problem of forward defense along the inner-German border and the demilitarized zone that separated North and South Korea. The only wrinkle in the "new" defense thinking was that the two near-simultaneous MRCs would be "'short notice' scenario(s) *in which only a modest number of U.S. forces are in a region at the outset of hostilities*" (emphasis added).[20]

Certainly, the US armed forces would confront more than just major regional contingencies. Among other things, they would assist US nonproliferation efforts by deterring the use of weapons of mass destruction (WMD, e.g., nuclear, chemical, and biological weapons) against the United States and its allies, and developing the capabilities to destroy WMD production facilities. They would also participate in international peacekeeping operations; protect fledgling democracies from subversion and external threats; and use military-to-military contacts to help foster democratic values in other countries.[21] Without doubt, however, the primary focus of defense planning—and the driving postwar force sizing and shaping construct—would be the requirement to fight and win two nearly-simultaneous major campaigns against much smaller and less capable regional versions of the Soviet armed forces.

A "Defining Battle"

To fully appreciate the full impact that Operation *Desert Storm* had on US strategic thinking, not to mention the Navy's subsequent plans for its surface combatant fleet, one must also understand its powerful impact on US thinking about the operational and tactical levels of war. Military revolutions—periods during which existing methods of waging war are made subordinate to new ones—are often triggered by a "defining battle" during which the superiority of new methods and operations are made clear.[22] In hindsight, it seems apparent that Operation *Desert Storm* was the defining battle for a new guided weapons warfare regime, which supplanted the unguided weapons warfare regime, particularly in the conduct of conventional, force-on-force campaigns.[23]

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[19] Secretary of Defense Les Aspin, *Report on the Bottom-Up Review* (Washington, DC: Office of the Secretary of Defense, October 1993), found online at http://www.fas.org/man/docs/bur/index.html.

[20] Aspin, *Report on the Bottom Up Review.*

[21] Aspin, *Report on the Bottom-Up Review.*

[22] I would like to thank my colleague, Michael G. Vickers, for pointing out the significance of "defining battles" in revolutionary war theory, a subject of his PhD dissertation at the John Hopkins School of Advanced International Studies.

[23] Much of my thinking on the Guided Weapons Warfare Regime has been shaped by discussions with Barry D. Watts, and especially from reading his *Six Decades of Guided Weapons: An Assessment of Progress and Prospects* (Washington, DC: Center for Strategic and Budgetary Assessments). I used the manuscript dated July 22, 2004, for this report. Interactions with Watts as he refined this first draft have given me a deep appreciation for his work in this area.

Guided weapons are projectiles, rockets, bombs, missiles, torpedoes or other weapons or munitions that actively correct their flight path, trajectory, or course after being released, fired, or launched, in order to reach a specific aim point. They come in two general types. The first type are weapons that "home" on a target by sensing and guiding toward radar returns generated by a remote fire control radar; the target's own active radar emissions; energy reflected off the target by a laser illuminator; the target's acoustic or infrared signature; imaging infrared or electro-optical images of the target; or other means. The second type use inertial guidance, space-based positioning information, digital scene matching, or a combination thereof to glide or fly to a specific set of geospatial coordinates on, over, under, or in the vicinity of a designated target. Regardless of type, however, their common ability to actively correct their flight path or trajectory transformed weapons and munitions that mostly missed into weapons and munitions that mostly hit—at least close enough to have the desired effect against a chosen target—up to the weapon's maximum range.[24]

Prior to the advent of guided weapons, the accuracy of purely ballistic or unguided munitions decreased as the range to target increased. Even assuming no aiming or target location error, range probable error for some high velocity ballistic rounds was measured in thousands of yards at their maximum engagement ranges. Meanwhile, a ten-milliradian aiming error in azimuth against a target located 1,000 feet away would cause a miss distance of some ten feet, left or right; at a range of 10,000 feet, the miss distance for an identical aiming error would grow to 100 feet. As a result, even in combat engagements between well-equipped and well-trained forces, most unguided munitions missed their targets, particularly those fired over beyond-visual ranges.[25]

Combat operations in the unguided weapons warfare regime were thus characterized by massed formations of both troops and platforms and prodigious expenditures of ammunition. Ground offensives were preceded by enormous artillery barrages that sometimes lasted days. Hitting attacking aircraft from the ground required intense aerial barrages, even when using radar-controlled gunfire and proximity fuzes. Hitting a ground target from the air required the massing of large numbers of planes which together could drop enough ordnance to saturate a geographical area, incidentally destroying the intended target. Hitting a violently maneuvering aircraft with unguided machine gun or cannon rounds from another maneuvering aircraft was more of an art than a science, as indicated by the Pareto distribution of kills made by air combat pilots. In naval warfare, effectively firing high-velocity guns on one moving ship at another moving ship, dropping unguided depth charges on high-speed submarines moving in three dimensions, or shooting straight-running torpedoes against surface ships making radical course, bearing, and speed changes were all difficult propositions, requiring repeated attacks using heavy weapon salvos.

However, in 1943, three unrelated tactical engagements occurred: a German U-boat sank an allied merchant ship using a single acoustical homing torpedo; a US Navy patrol plane sank a

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[24] Watts, *Six Decades of Guided Weapons: An Assessment of Progress and Prospects,* p. 1.

[25] Watts, *Six Decades of Guided Weapons: An Assessment of Progress and Prospects,* p. 1.

German U-boat with a single air-dropped homing torpedo; and the German air force attacked and sank an Italian warship using just a few radio-guided bombs. Together, these three engagements introduced a new paradigm in force-on-force engagements—deadly accuracy independent of range, even against moving targets. The implications were profound. Since a single shot by a guided weapon had a good chance of destroying or neutralizing its intended target, instead of having to mass enough platforms or forces to ensure a single target hit, an attacker had only to fire enough weapons to saturate an opponent's defenses or to account for a weapon's less than perfect probability of kill (P_K). Moreover, since a delivery platform carrying six guided weapons was theoretically capable of engaging and destroying six different targets on a single mission, individual attack units could be made much smaller and attack forces could conduct dispersed operations across wide fronts or along multiple axes. Guided weapons thus promised to change fundamentally the requirements for battlefield massing.

If accuracy independent of range was the first defining characteristic of the new guided weapons warfare regime, then the second was the rise of *tactical engagement networks*—sensing, targeting, information exchange and fire control networks necessary to exploit the extended-range accuracy of guided weapons. Whenever a warfighting community elected to adopt and employ guided weapons, engagement networks were sure to follow. For example, the development of long-range, land-based surface-to-air missiles (SAMs) led to the development of automated and integrated continental air defense networks; naval SAMs led to the development of automated task force sensing, data exchange, targeting and engagement networks; beyond-visual range air-to-air missiles led to new naval and theater air battle management networks; and the combination of fixed and mobile tactical SAMs, radar-controlled guns, and interceptor aircraft spawned integrated air defense systems (networks).

To be sure, tactical engagement networks existed before the development of guided weapons; the World War II British and German integrated air defense networks and the US Navy's task force air defense networks were both developed to exploit the long-range sensing power of radar, not guided weapons.[26] But it is important to remember that these early air engagement networks were designed to direct manned fighter aircraft that fired *unguided* munitions into effective range of their intended targets. This meant that even when these platforms were well within the effective range of their onboard weapons, achieving a target kill was quite difficult. Thus, radar-directed air defense operations simply resulted in massed, attrition-style engagements between manned platforms (e.g., fighter against bombers; fighters against fighters; bombers against ships). Said another way, while these early engagement networks helped to take surprise out of tactical operations, they did not alter the inherent reliance on the massed forces and platforms so evident in unguided weapons warfare.

The general bias toward mass in battle did not begin to change fundamentally until engagement networks began to employ and control *individual weapons* that could guide themselves to targets. As one contemporary Air Force general explains, "I'm going to start with the thing that kills the target and invent in the network that locates it, identifies it, and instantly gets the information to

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[26] I would like to thank Dr. Andrew Krepinevich, Executive Director of CSBA, for making this key point.

the person or *the warhead* that is going to blow it up" (emphasis added).[27] The development of weapons that boasted accuracy independent of range thus naturally accelerated the development of increasingly capable sensing, targeting, and fire control networks that could fully exploit their maximum tactical potential.[28]

Between the end of the Second World War and the end of the Cold War, more and more US tactical communities embraced guided weapons. The warfighters who first gravitated toward guided weapons were those either confronted by threats that maneuvered freely in three dimensions, or those who often took beyond visual range shots against moving targets. Unsurprisingly, then, most Navy communities were "first movers" in the guided weapons warfare regime. The submarine, surface warfare, and naval air-to-air communities all pursued guided weapons to help address the emerging threats of high-speed, deep-diving submarines and high-performance jet aircraft and missiles. Both the submarine and surface warfare communities also later adopted guided weapons for anti-surface warfare (the *Harpoon* and *Tomahawk* anti-ship cruise missiles (ASCMs)) and strike (i.e., land-attack) operations (the *Tomahawk* land-attack cruise missile (TLAM) and the Stand-off Land Attack Missile (SLAM, a modified *Harpoon*)).

Also unsurprisingly, the US Navy was one of the earliest and most enthusiastic builders of *automated naval engagement networks*. After helping to develop the first standardized tactical battle link and one of the first effective means of storing electronic data, the Navy introduced the Navy Tactical Data System (NTDS), which could tie individual ships operating in task force formations into a single integrated air and missile engagement network.[29] This development will be discussed in greater detail later in the report. Here it is enough to say that in the guided weapons warfare regime naval warfare began to be defined less by battles between opposing groups of ships and more by battles between opposing naval engagement networks. It is no coincidence that Soviet military theorists, when pondering the war-changing implications of what they referred to as guided-weapon *reconnaissance-strike complexes* (i.e., networks of networks), were guided by the lessons learned in the ongoing competition between advancing US carrier battle groups and the Soviet's own anti-access/area-denial (A2/AD) network consisting of sensor nets that extended from under the sea into space, and guided-missile armed long-range strike aircraft, surface action groups, and submarines.[30]

Interestingly, the Navy air-to-ground community did not initially pursue guided weapons with the same enthusiasm as did the other naval warfare communities. Like the air-to-ground

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[27] Air Force Chief of Staff John Jumper, as cited in David A. Fulghum. "Network Warfare: Hope and Hype," *Aviation Week and Space Technology*, November 11, 2002, p. 33.

[28] Whether guided weapons spurred the development of networks or networks spurred the development of guided weapons is a chicken-and-the egg type of argument. Although I believe the historiography is clear that the advent of guided weapons is the dominant factor in the ongoing "revolution in war," for all intents and purposes guided weapons and battle networks are inseparable in the guided weapons warfare regime.

[29] Friedman, US Destroyers, *revised edition*, p. 207.

[30] From reading Watts, *Six Decades of Guided Weapons: An Assessment of Progress and Prospects*.

communities in all other Services, it preferred instead to invest in bombing computers that would better calculate the fall of unguided munitions. As a result, throughout the Cold War, Navy aviation strike operations continued to be characterized by massed "Alpha strikes" consisting of large numbers of electronic warfare, fighter, and fighter-bomber aircraft. Indeed, even after the relatively common use of air-to-ground guided weapons during the Vietnam War, the US tactical aviation community remained remarkably ambivalent about their war-changing potential.[31]

All this changed in a big way after Operation *Desert Storm.* Although guided weapons made up a relatively small percentage of the total number of weapons dropped during the First Gulf War (approximately seven percent), it is no exaggeration to say that the employment of air-to-ground guided weapons in the first Gulf War had the same electrifying effect on aviators as did the explosion of the atomic bomb in 1945. Moreover, because of the vital role that air-to-surface operations had long played in US combined arms and naval warfare,[32] after the war, more and more US military officers began speaking about a broader Revolution in Military Affairs (RMA) based on more and better guided weapons, better sensors, better information, and improved networking of forces.[33]

While all the Services accepted the emergence of the guided weapons warfare regime to some degree, the Air Force and the Navy unquestionably were the most enthusiastic among them. Admiral J.T. Howe, then Commander-in-Chief, US Naval Force Europe, spoke for many Navy officers when he said:

> *Desert Storm* demonstrated the necessity for…guided munitions. Laser guided bombs (and their advanced successors such as inertially-aided munitions), the SLAM and the TLAM have all proven their worth, both militarily and politically. We need to maintain the technological edge these weapons give, both through continued research and development, preplanned product improvement (P3I), and in maintenance of sufficient munitions in our arsenal *to cope with likely future contingencies* (emphasis added).[34]

The Navy's and Air Forces' enthusiastic embrace of guided weapons warfare was a natural result of two things. The first was their common institutional focus on *offensive* air and missile strike operations. The second was the potentially decisive role that guided weapons might play in the conflicts identified by the BUR as the "most likely future contingencies"—cross border

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[31] The general failure of the US air-to-ground community to embrace guided weapons until the very end of the Cold War is a complex tale of the power of institutional and cultural bias. From discussions with Barry Watts over his draft report, *Six Decades of Guided Weapons: An Assessment of Progress and Prospects*.

[32] For example, during the 1980s, the Army and Air Force developed the concept of AirLand Battle. See for example John L. Romjue, "The Evolution of the Battle Concept," *Air University Review*, May-June 1984, found online at http://www.airpower.maxwell.af.mil/airchronicles/aureview/1984/may-jun/romjue.html.

[33] For a good discussion on RMAs, see James R. Fitzsimonds and Jan M. van Tol, "Revolutions in Military Affairs," *Joint Forces Quarterly*, Spring 1994, pp. 24-31.

[34] In "The United States Navy in 'Desert Shield/Desert Storm'," found at http://www.history.navy.mil/wars/dstorm/index.html.

invasions of US allies by enemy combined-arms armies. US forward-deployed and rapid deployment forces employing guided weapon battle networks could "…minimize the territory and critical facilities that an invader can capture." Once the enemy's "attack had been stopped and the front stabilized," US and allied efforts would focus on building up combat forces and logistics support in the theater while reducing the enemy's capacity to fight—again by guided weapons bombardment. After the theater build up, the US would conduct a counter-offensive to restore the *status quo ante*.[35] In other words, the widespread use of guided weapons might allow the US armed forces—and the Air Force and Navy in particular—to perform the Cold War territorial defense mission more efficiently in the emerging post-Cold War world, without the need for large numbers of forward-based land forces.

Given the increased postwar priority placed on joint interoperability, the 1990s thus saw a concerted effort by both the Navy and Air Force to begin integrating their respective tactical engagement networks that had evolved over the Cold War. During Operation *Desert Storm*, US carrier battle groups designed largely for independent strike operations against the Soviet Union and its navy had neither the communication pathways nor planning systems to hook into the Air Force shore-based engagement network which was designed to create a single integrated Air Tasking Order (ATO). After the war was over, the Navy thus invested a great deal of money to improve long-range, ship-to-shore data connectivity, install planning systems compatible with the ATO, and fill its carrier magazines with increased numbers of guided weapons. These efforts resulted in the first nascent *Joint Multidimensional (Guided Weapon) Battle Networks*, the uniquely American version of what Soviet military theorists had first called reconnaissance-strike complexes.

These new battle networks led to a revolution in war, as marked by the percentage of guided weapons employed in battle. During four of five joint operations conducted between 1995 and 1999, conventional guided weapons ranged between 69 and 100 percent of all weapons dropped or fired by US air forces; in the fifth, the percentage was "only" 30 percent—but still four times greater than that observed during Operation *Desert Storm*.[36] No conventional adversary who continued to fight unguided weapons warfare could stand against these new operational-level battle networks. Moreover, no contemporary opponent or ally could hope to match the sheer scale of either US Joint Multidimensional Battle Networks or guided weapons warfare. As a result, US combat proficiency in conventional combat operations began to rapidly out-distance that of both adversaries and allies alike. Indeed, a key assumption in US post-Cold War thinking was that the US military would retain a lasting monopoly in the mature guided weapons warfare regime. As a result, US defense planners assumed future confrontations against traditional regional adversaries would be relatively quick and bloodless.

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[35] Aspin, *Report on the Bottom-Up Review*, especially Sections II and III.

[36] Michael G. Vickers and Robert C. Martinage, *The Revolution in War* (Washington, DC: Center for Strategic and Budgetary Assessments, December 2004), p. 16.

THE IMMEDIATE POSTWAR NAVAL PRIORITY: LAND-ATTACK

With this background in mind, it is easy to understand the subsequent direction of the Navy's surface combatant plans. Admiral Kelso ordered the aforementioned *21st Century Destroyer Technology Study* only one year after the conclusion of the First Gulf War. The surface warfare officers participating in the study were well aware of emerging requirement to fight two widely separated major regional contingencies as well as the increasingly powerful impact that guided weapons would have on conventional campaigns. However, they were equally aware of the unfavorable fiscal environment facing the Navy, as well as the expected block retirement of large numbers of Cold War destroyers and frigates in the early decades of the 21st century. In other words, the officers faced the daunting problem of transforming the Cold War surface combatant fleet to meet emerging postwar warfighting requirements on an extremely tight budget.

After considering this problem, the participants concluded that the future family of 21st century surface combatants (SC-21s) would not be affordable unless it consisted of a "high-low mix" of warships. However, to avoid the negative political and institutional baggage of the term "high-low mix," the surface warfare community opted to describe the SC-21 family as being composed of "multi-mission" or "focused-mission" ships. The multi-mission ships would include guided-missile cruisers (CGs) and destroyers (DDGs) with powerful all-around anti-air, anti-submarine, anti-surface, and land- attack capabilities. The focused-mission ships, modeled after Cold War destroyers (DDs), would be optimized for a particular mission.[37]

The SC-21 family of ships would be the first surface warfare program to be considered by the Joint Requirements Oversight Council (JROC), the *Burke* DDG having been designed before it was created. The JROC, mandated by the aforementioned 1986 Goldwater-Nichols Act and strengthened after Operation *Desert Storm*, was the principal forum in which senior military leaders (the Vice Chairman of the Joint Chiefs of Staff and the four Service vice chiefs) addressed requirements for new programs and systems from a joint perspective.[38] If the Navy wanted to build new SC-21s, it would first have to get the JROC to approve a Mission Needs Statement (MNS) for the SC-21 family, a general statement of what the ships had to do. This would allow naval technologists and architects to conduct a Cost and Operational Effectiveness Analysis (COEA) or an Analysis of Alternatives (AoA), which would help to identify and to scope down competing design approaches for the SC-21 missions. The winning alternative would then spur the development of individual Operational Requirements Documents (ORDs) that would lay out the Key Performance Parameters, or KPPs, which would drive the final design of any new ship in the SC-21 family.[39]

The JROC approved the MNS for the new SC-21 family of ships in June 1994, little more than three years after *Desert Storm* and only one year after the completion of the Bottom-Up Review.

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[37] Friedman, *US Destroyers*, revised edition, pp. 43-45.

[38] William A. Owens, "Harnessing the Revolution in Military Affairs, *Joint Forces Quarterly,* Summer 1994, pp. 50-57.

[39] Friedman, *US Destroyers*, pp. 435-448.

Unsurprisingly, then, the follow-on SC-21 COEA was heavily colored by the overall strategic requirement to defeat two nearly-simultaneous, cross-border invasions by regional combined arms armies. It was equally influenced by a contemporary RAND Study called *The New Calculus,* which argued that "Stopping enemy surface forces and establishing an 'assured defense' (that is, inflicting sufficient attrition on enemy ground forces so that there is a high probability enemy forces would have to stop their advance) depend critically upon the speed at which invading enemy surface forces can be destroyed and disrupted." The report further argued that guided weapon-enabled US naval and air power would be the best way to conduct rapid halts of enemy invasions and to set the conditions for a quick US victory. [40]

To counter any Air Force move to stake out the role as the primary "rapid halt force" (not to mention a larger share of the defense budget)—DoN planners touted the advantage of maintaining large floating batteries of guided missiles in forward theaters, consisting of ships armed with the new Mk-41 vertical launch (missile) system, or VLS, first installed onboard US surface warships in 1986 (and on submarines in 1985).[41] As will be discussed more fully later in this report, the Mk-41 VLS is very space-efficient and allows a ship to carry a large number of ready-to-fire guided missiles. Although it had given up on rearming VLS cells at sea, the Navy argued that by augmenting forward-deployed carrier air power with dedicated land-attack ships packed with VLS cells, it could provide prompt, large-scale guided-missile salvos against any invading force, especially during the time it would take to divert additional land-based joint airpower to the theater.

Given Admiral Kelso's success in continuing to build *Arleigh Burke* VLS-equipped DDGs after the Cold War ended, the fleet's total Mk-41 cell count was rapidly rising. However, the Navy considered these to be *multi-mission* VLS cells dedicated to Navy carrier battle group and surface action groups operations. Within a task group's VLS battery, land-attack missiles had to compete for cells with long-range surface-to-air, anti-submarine, and close-range self-defense missiles. In essence, then, the Navy proposed to build a large additional number of *focused-mission* VLS cells dedicated to the "rapid halt" and land-attack missions. One option explored during the COEA was to pack as many vertical launch cells (up to 512) into a Maritime Fire Support Ship—a minimally-crewed "missile barge."[42] Other options included traditional surface combatants optimized for the land-attack mission.

In the end, the COEA supported the Navy's conclusion that no single ship could meet all fleet warfighting requirements and that the future surface combatant fleet would need a mix of multi-

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[40] Chris Bowie, Fred Frostic, Kevin Lewis, David Ochmanek, Phillip Propper, *The New Calculus: Analyzing Airpower's Changing Role in Joint Campaigns* (Santa Monica, CA: RAND Corp, 1993). The entire report can be found online at http://www.rand.org/pubs/monograph_reports/MR149/index2.html.

[41] The *USS Providence*, SSN 719, was equipped with VLS when she was commissioned in 1985. The first surface combatant equipped with VLS was the *USS Bunker Hill*, CG-52, commissioned in 1986. See the respective ship data entries in Polmar, *Ships and Aircraft of the US Fleet*, 18th edition.

[42] The idea for the Maritime Fire Support Ship was inspired by the musing of Navy Admiral Joseph Metcalf, who argued for "turtle ships," or Large Capacity Missile Ships, which would provide naval fires until surging carrier and amphibious task forces could arrive in a theater. See Friedman, *US Destroyers*, pp. 442-444.

mission and focused-mission ships. It concluded a 70/30 capabilities split was the most desirable mix for the 21st century surface combatant fleet. In other words, the COEA recommended that 70 percent of all SC-21 ships be full-capability, multi-mission combatants, and the remaining 30 percent be limited-capability, focused-mission combatants. The clear understanding was that the focused-mission combatant would be focused on the land attack mission.[43]

At this point, the Navy and OSD began to develop the Operational Requirements Document for the first ship in the SC-21 family. While everyone agreed that the first SC-21 to be built would be a focused-mission, land-attack combatant, there was disagreement over what the ship should look like. Admiral Mike Boorda, a surface warfare officer who relieved Admiral Kelso as CNO in April 1994, liked the concept of a minimally-crewed Maritime Fire Support Ship, which he dubbed the *Arsenal Ship*.[44] However, after his tragic death in 1996, the surface warfare community—with DoN and OSD approval—quickly reduced the *Arsenal Ship* to a Maritime Fire Support Demonstrator Program and opted instead for a more traditional focused-mission combatant. The resulting DD-21 Land Attack Destroyer was to carry up to 128 vertical launch missile cells for TLAMs and other land- attack missiles, among them a new modular Advanced Land Attack Missile (ALAM) with a threshold range requirement of 200 nm and an objective range of 300 nm.[45] In addition, the ship would be armed with two new Advanced Gun Systems (AGSs), automated 155mm (6-inch) guns of a completely new design that could fire rocket-assisted guided projectiles out to ranges of approximately 100 miles.[46] Because this focused-mission ship was to be optimized for land-attack, it would *not* contribute to fleet air defense, carrying only self-defense missiles to protect itself from air or missile attack.[47]

The ORD for the DD-21 was approved by the Defense Acquisition Board only months after the end of the 1997 Quadrennial Defense Review (QDR). The 1997 QDR was the first of what was to become successive four-year reviews of the Department of Defense's overall strategy and program. As will be discussed presently, the review called for a TSBF of approximately 300 ships and a surface combatant force of 116 combatants.[48] At the time, the Navy had concluded

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[43] Friedman, *US Destroyers,* pp. 434-39. For the DoN rationale behind the SC-21 family of ships, see Rear Admiral Daniel J. Murphy, USN, "Like Thunder and Lightning," *Proceedings,* June 1997, pp. 57- 60.

[44] For a good discussion of the arsenal ship concept, see Norman Polmar, *Ships and Aircraft of the US Fleet,* 18th edition (Annapolis, MD: US Institute Press, 2005), pp. 645-646.

[45] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 510.

[46] The DD-21 was originally going to carry a modular Vertical Gun for Advanced Ships (VGAS) consisting of twin 155mm guns in a vertical configuration inside the hull, fed by a 1,400-round magazine. However, this configuration would have allowed the gun to fire only guided rounds. In 1999, the Navy cancelled further development of the VGAS in favor of two single, trainable 155mm gun mounts in stealthy, on-deck housings. These guns can fire either guided or ballistic rounds. See Polmar, *Ships and Aircraft of the US Fleet,* 18th edition, pp. 491-492. Also see "155mm (6.1") AGS," found online at http://www. navweaps.com/ Weapons/WNUS_61-62_ags.htm.

[47] Friedman, *US Destroyers,* revised edition, pp. 435-445. The land attack focus of DD-21 is clearly evident in Michael Lindemann, "DD-21 Brings Fundamental Changes to the Land Battle;" and "DD-21 and the Navy's Land Attack Renaissance," both in *Surface Warfare,* May/June, 2000.

[48] William S. Cohen, Secretary of Defense, *Report of the Quadrennial Defense Review* (Washington, D.C.: Office of the Secretary of Defense, May 1997), Section V. The report can be viewed online at http://www.defenselink.mil/ pubs/qdr/sec5.html.

that the future TSBF would have no smaller frigate-sized ships; all 116 surface combatants needed to be *battle force capable* (BFC) warships capable of operating as part of a carrier battle or surface action group. With 27 legacy *Ticonderoga*-class guided missile cruisers then in commission and 57 *Arleigh Burke*-class guided missile destroyers either in service, building, or planned, the initial DoN plan was thus to replace all residual Cold War *Spruance*-class general purpose destroyers and *Oliver Hazard Perry* guided-missile frigates with 32 new DD-21s. In the resulting 72/28 fleet mix, then, *the 32 DD-21s were to represent the low-cost, focused-mission component of the future surface combatant fleet.* The unit cost for the fifth ship in the class was not to exceed $750 million (in FY 1996 dollars).[49] After building the 32 DD-21s, the Navy would start replacing the 27 *Ticonderoga*-class guided missile cruisers with the second ship of the SC-21 family—a multi-mission CG-21. Presumably after that, the *Arleigh Burke* DDGs would be replaced with a new multi-mission DDG-21.[50]

THE "REQUIREMENTS SCHOOL" TAKES OVER

While the DD-21 was conceived by Navy leaders as the low-end component of the surface battle line's "high-low mix," representing a balance between warfighting requirements and affordable costs—the "Requirements School" within the surface and joint warfare communities quickly gained the upper hand during the ship's design phase. Members of this school typically argue that requirements derived from the expected demands of future naval combat should drive the size and shape of future ships, and nothing else. In their way of thinking, naval ship designers should be guided only by the key performance parameters identified in the ship's ORD, regardless of their potential impact on the ship's size or its overall unit procurement cost. Altering a ship's operational requirements or modifying its KPPs to limit overall ship procurement costs simply would not do; the future sailors who would crew the ships and take them into harm's way deserved the best the nation could give.

The dominance of the "Requirements School" was cemented by the rise of the postwar joint development process and the fall of the Navy's own internal Ship Characteristics Improvement Board (SCIB). For nearly 100 years, the SCIB (or as it was sometimes called, the Ship Characteristics Improvement Panel), a high-level group of officers and officials, had advised the Navy's senior leadership on ship design and configuration tradeoffs. This group was tasked with balancing mission requirements and ship characteristics with their projected cost impacts, and making sure that planned ships fit within the framework of an affordable battle fleet. After the passage of the Goldwater-Nichols Act, however, mission needs statements, operational requirements documents, and key performance parameters for all new weapon systems were approved by joint entities like the JROC. As a result, although the Navy's SCIB selected a new-

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[49] Polmar, *Ships and Aircraft of the US Fleet,* 18th edition, pp. 645-46; and Friedman, *US Destroyers,* revised edition, pp. 435-445.

[50] Murphy, USN, "Like Thunder and Lightning," p. 60.

design DD-21 over a modified *Arleigh Burke*, its influence within the Navy was on the wane. In fact, the board was officially disestablished in 2002.[51]

The demise of the Navy's SCIB had a profound impact on the subsequent development of the DD-21. For all ships prior to the DD-21, the SCIB would have overseen the development of a preliminary design to determine the cumulative costs of all ship requirements. The new joint development process had no such provision, and no organ to enforce a provision even if it had. Instead, the only thing the Navy had to do was to justify the ship's requirements in joint operational terms.[52] The result, at least from the perspective of "Requirements-Cost Balancing School," was an utter disaster: the blind pursuit of requirements largely unfettered by fiscal constraints.

With the "Requirements School" firmly in control of the ship's design, the DD-21 quickly became a technological pathfinder for the surface combatant fleet rather than a cost-constrained, focused-mission platform. It all began with the demanding requirements for low overall ship signatures. By the mid-1990s, it was widely accepted that the combination of improved shore-based intelligence, surveillance, and reconnaissance (ISR) systems, as well as improved anti-ship weapons such as long-range anti-ship missiles, would make operating ships close to shore increasingly dangerous. As one analyst boldly opined, "It can hardly be imagined, given the state of current designs, that ships will be able to fulfill mission profiles and cope with naval anti-ship missile threats after about 2005."[53] However, to unmask its powerful gun battery, a DD-21 would need to close to within about 25 miles of an adversary's coast. As a result, full-spectrum stealth was a critical design requirement for the ship; the KPPs called for a ship with an acoustic signature "as quiet as a submarine," and with similarly low magnetic and infrared signatures.[54]

Most important of all, the "Requirements School" demanded a ship radar cross section (RCS) at least 50 times smaller than a *Burke* DDG—the most modern Cold War combatant, and one with a relatively low RCS.[55] To achieve this ambitious goal, much of the ship's payload would need to be buried deep in its hull and the ship would need a composite deckhouse with embedded sensors and antennas in order to eliminate legacy shipboard masts and exposed sensors that acted as radar reflectors. However, these features would not be enough to achieve the ship's stringent RCS requirements. Accordingly, ship designers concluded the hull itself would have to be shaped so as to reflect incoming radar signals away from their receivers. In the end, this drove

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[51] Jason Sherman, "Mullen to Bring Back Panel to Control Ship Configuration, Cost," *Inside the Navy,* August 8, 2005, as cited in Ronald O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," Congressional Research Service Report for Congress, RL 32109, updated August 29, 2006, pp. 22-23.

[52] Friedman, *US Destroyers,* revised edition, pp. 447-448.

[53] Erbil Serter, "Warship Designs for the 21st Century," *International Defense Review,* December 1997, p. 3.

[54] For an excellent discussion of what stealth provides to surface combatants, see James H. King, "Stealth Means Survivability," *Proceedings*, December 2001, pp. 80-82.

[55] From "DD(X) Media Roundtable," a PowerPoint presentation developed by the Program Executive Office of Ships and the Program Executive Office for Integrated Warfare Systems, dated June 30, 2005.

them toward a tumblehome hull and a wave-piercing bow. The former flares inward from the waterline rather than outward as in typical displacement hull ships, while the latter slopes back from the waterline rather than forward; both features would help to deflect radar signals. But that was not all. To prevent the shaped hull from periodically presenting a vertical surface to incoming radar signals, ship designers decided to give the DD-21 ballast tanks, much like those found on a submarine. Instead of filling the tanks with water to submerge, however, a DD-21 would take on water simply to minimize its rolling.[56]

While all of these features helped to lower the DD-21's RCS substantially, they presented a problem of a different sort. A tumblehome hull carries less payload than a conventional hull of similar displacement, and in addition to the large internal volume required to make the DD-21 stealthy, the combat payload for the ship would be quite large. For example, each of the ship's two new 155mm AGSs consisted of an above-deck trainable gun mount that weighed over 200 tons. In addition, each mount was to be serviced by its own below-deck magazine with an automatic loading system. The feed system was designed to double ram what was, in essence, a small guided-missile, consisting of an 88-inch (7.5-foot) long Long-Range Land Attack Projectile (LRLAP) and a separate 3.5-foot long propellant cartridge. To provide a high level of sustained naval gun fire, requirements called for each mount magazine to hold between 600 to 750 binary gun-launched missiles (i.e., LRLAPs and propellant charges), which would add another 187 to 225 tons to the ship.[57] The combined space and weight (approximately 800 tons) devoted to the two AGSs and their magazines, plus the ship's sizeable VLS battery, demanded a warship capable of carrying a substantial combat payload. The combination of the DD-21's stealthy tumblehome hull and its high combat payload naturally meant that the ship would need to be considerably larger, and have more internal volume, than previous Cold War combatants. This helps to explain why the displacement of the DD-21 "destroyer" rapidly grew to between 16,000 and 18,000 tons—some 6,000 to 8,000 tons larger than the *Ticonderoga*-class guided-missile "cruiser," the largest US surface combatant then in commission, and close to the displacement of a World War II heavy cruiser.

It is impossible to know if a strong SCIB would have objected to the notion of a 16,000-18,000 "destroyer." However, as one noted naval analyst has written:

> In the end, whether the [DD-21] hull form is attractive depends on an evaluation of anti-radar stealth as a design driver. About a decade ago, the [DD-21] design concept was sold on the basis of a lengthy (and, incidentally, unclassified) analysis, the gist of which was that a heavily-armed surface combatant could play a decisive role in [a cross-border invasion involving heavy armored forces]...

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[56] Norman Friedman, "The New Shape of Ships," *Naval Forces*, No. II,/2006, Vol. XXVII, p. 57-58; "DD(X) Media Roundtable."

[57] For a discussion about how the AGS blurs the line between guns and missiles, see Captain Massimo Annati, Italian Navy, "Evolution of 'Smart' Naval Munitions—Blurring the Border Line Between Gun-fired Projectiles and Missiles," *Naval Forces*, Vol. 26, 2005, pp. 46-52. Gun and propellant weights were found in Lt. Julie Higgins, Lt. Jason Rhoades, and Lt. Michael Roach, "Advanced Gun System (AGS) Backfit," Massachusetts Institute of Technology 13.413, Project in Naval Ship Conversion, Spring 2003, found online at https://dspace.mit.edu/bitstream/1721.1/3531/2/AGS+Conversion+Study.pdf.

> The key analytic point... was that it would be very important for the ship to come reasonably close to enemy shores unobserved. That in turn meant anti-radar stealth…
>
> Without access to files of the time, it is impossible to say whether those approving the [DD-21] project realized that its stealth and survivability characteristics would produce [such a large] destroyer. About the same time that [DD-21] characteristics (requirements) were being approved, the decision was taken at the Defense Department (not Navy) level that there would be no internal feasibility design. In the past, the feasibility stage had the very useful role of showing those setting requirements what their implications would be. At the very least, the Navy's senior leadership would have been given warning that they would have to justify a drastic jump in destroyer size when they wanted to build the [DD-21]. That jump might well have been considered justified, but on the other hand the leadership might also have asked whether a somewhat less dramatic approach would have been acceptable.[58]

Whether or not the SCIB would have argued against such a large "destroyer," one thing seems certain: with no strong SCIB to check its gut instincts, the "Requirements School" could continue to pack the new DD-21 with advanced technologies without constraint. Cold War ships, designed during a period when the Navy generally considered people a "free good," had very large crews. For example, as originally designed, the *Ticonderoga* CGs carried a crew (counting the embarked helicopter detachment) of 400 officers and enlisted personnel, while the *Burke* DDG carried a crew of 380.[59] However, the costs to man the US all-volunteer force had risen steadily throughout the 1980s and early 1990s, to the point that the major contributor to a ship's total life cycle cost was the size of its crew. As a result, the DD-21 was the first ship ever with a KPP for crew size. The desired crew target was for 95 total personnel—a very ambitious goal for a 16,000-18,000 ton ship. This crew target would demand the highest possible level of onboard automation.[60]

The DD-21 would also be the first of a new generation of ships with an all-new electric propulsion and Integrated Power System (IPS), which the Navy believed would change naval operations as much as did the shift from sail to steam.[61] The *Burke* DDG, the newest addition to the Navy's family of gas-turbine powered warships, uses four gas turbines for ship propulsion (two per shaft) and three smaller ship-service gas turbine generators to provide electric power to the ship's combat systems and so-called hotel services (e.g., power for the galley, crew quality-of-life amenities, etc.). In contrast, the DD-21 would have two new electric drive (propulsion) motors coupled to an IPS which could distribute power from two main and two auxiliary gas

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[58] Norman Friedman, "The New Shape of Ships," *Naval Forces*, No. II,/2006, Vol. XXVII, pp. 57-58.

[59] From ship data entries in Polmar, *Ships and Aircraft of the US Fleet*, 18th edition.

[60] Friedman, *US Destroyers*, revised edition, p. 448.

[61] For two excellent and concise descriptions of the IPS, see Gordon I. Peterson, "The Future of Naval Warfare: The Integrated Power System and Revolution in Sea Warfare," *Naval Forces*, Vol. 6, 2004, pp. 46-52; and Rear Admiral Mark Edwards and Rear Admiral Charles Hamilton, "Destroyer That Creates Waves," *Armed Forces Journal*, October 2004, pp. 44-46.

turbines to any particular ship need, be it propulsion, combat systems, or hotel loads. When drawing their full measure of electric power, the ship's electric drive motors would propel the ship through the water at speeds up to 30 knots; when operating at lower speeds, the ship would draw much less electricity and use far less fuel than a comparable gas turbine-powered propulsion plant.[62] Most importantly, by having all of its gas turbines dedicated to electric power generation, the DD-21's IPS would be able to produce nearly 80 megawatts of power—ten times the total electrical output capacity of a *Burke* DDG.[63]

The shift to the IPS, along with the simultaneous introduction of electric drive motors, would provide at least four important advantages for the future surface battle line. First, because an IPS can more efficiently modulate power needs to the ship's propulsion motors, it is inherently more efficient in terms of fuel economy than a gas-turbine propulsion system, helping to reduce operations and maintenance (O&M) costs.[64] Second, the system opens the way toward future ship designs unconstrained by the requirement to align a ship's engine rooms with its propeller shafts, or even to have long propeller shafts at all. Electric motors and power distribution components can be located throughout the ship, or even in pods outside the ship, adding to ship survivability. Third, electric motors eliminate the need for complex reduction gears, resulting in much reduced ship acoustical signatures—an important consideration in ASW. Finally, because of their ample amounts of onboard power, IPS-equipped ships would allow the fleet to operate a variety of new and exotic weapons, such as electrically-powered directed-energy weapons (e.g., lasers) or electromagnetic rail guns.[65]

In addition to new automation technologies, electric motors, and IPS, the DD-21 would also carry a new VLS capable of handling larger, heavier, and longer missiles than the standard "multi-mission" Mk-41 VLS. The thinking was that if the new ALAM did not require the extra capability, future land-attack missiles most likely would. Moreover, unlike the Mk-41 VLS, which was packed in groups of 32 or 64 cells on the centerline of legacy combatants, the new VLS system would be distributed in groups of four cells along the deck edges. Designed to vent any inadvertent missile explosions up and away from the interior of the ship, this arrangement

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[62] Edward H. Lundquist, "All-Electric Propulsion—A Viable Way Ahead?" *Naval Forces*, No. IV/2005, Vol. XXVI, pp. 62-63.

[63] See Captain C.H. Goddard and Commander C.B. Marks, USN, "DD(X) Navigates Uncharted Waters," *Proceedings*, January 2005, pp. 32-33.

[64] Two types of defense spending are focused on maintaining high joint force operational readiness: operations and maintenance (O&M), and military pay and benefits. Half of O&M funding covers activities that are only indirectly related to readiness, such as administering the military and civilian payroll, providing peacetime health care for military and other eligible personnel, and subsidizing the cost of child care centers for military and civilian personnel. When used in this report, the term O&M is generally used in reference to the other half—that is, funds with a *direct* link to operational readiness, such as money used to support the purchase of fuel and spare parts, and to pay for routine maintenance, periodic overhauls of military equipment, and operational exercises.

[65] Hunter Keeter, "Lasers, Rail Gun Could Be Ready For DD(X) By 2010," *Defense Daily*, April 16, 2003, p. 9; Christopher J. Castelli, "Navy Envisions Surface Combatants With Powerful Laser Guns," *Inside the Navy*, December 9, 2002, p. 1; Lieutenant Commander David Allan Adams, US Navy, "Naval Rail Guns Are Revolutionary," *Proceedings*, February 2003, pp. 34-37; and Lundquist, "All-Electric Propulsion—A Viable Way Ahead?"

increased the ship's survivability. If this were not enough, the ship would also get a host of other improved and automated damage control features as well as a new underwater warfare suite optimized for shallow littoral waters.

All of the DD-21's its vastly improved capabilities, when viewed in isolation, could be easily argued on their own merits. The problem was that without a strong SCIB to assess the *cumulative* cost impacts of the ship's *combined c*apabilities, and to intervene to balance requirements against potential ship procurement costs, the "Requirements School" was able to quickly transform the DD-21 from a low-cost, focused-mission ship into a high-cost, 21st century technological flagship. As a result, the projected price for the ship began to climb rapidly.

WHEN BUDGETS AND REQUIREMENTS COLLIDE: COMING TO TERMS WITH A "300-SHIP NAVY"

At the very same time the Navy was losing cost control on the DD-21, it was also beginning to rebel against continued cuts to the battle fleet. As foreseen by Admiral Kelso, the BUR "anchor" was not strong enough to hold the size of the TSBF against the strong ebb tide of lower defense allocations. By September 30, 1993, the battle fleet had shrunk from its post-Vietnam War high of 594 ships to 454 ships, roughly the number called for in the BUR. One year later, the battle fleet had fallen to 404 ships; a year after that, to 392. As the 1997 Quadrennial Defense Review kicked off, the fleet was at 365 ships and still falling.[66] Alarmed, the Navy's leadership worked hard during the QDR to establish a new line below which the fleet should not be allowed to cross under any circumstances. In the event, they established the fleet "red line" at 300 ships, and they developed a TSBF requirement for approximately 302 vessels of all types, including 116 total surface combatants (see Figure 1).[67]

Although Navy leaders well understood the fiscal pressures on the battle fleet, they were simply psychologically unprepared to accept such a "small" fleet. They therefore turned to the "Requirements School" to help make a public a case for a larger force structure. As one would expect, school members developed the requirements for each of the battle fleet's separate components, without making any tradeoffs among submarines, surface combatants or amphibious ships. Thus, in 1999, in response to calls to increase the size of the battle fleet using small, cheap combatants called *Streetfighters*, the commander of the US Sixth Fleet contemptuously dismissed the potential contributions of small combatants and called for a fleet of 450 large warships, including more of the new DD-21s.[68] He was supported by a recently

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[66] All ship numbers come from Department of the Navy, Naval Historical Center, "US Navy Active Ship Force Levels, 1886-present."

[67] While the force target of 116 combatants was explicit, the 1997 QDR did not reveal the exact makeup of its approved TSBF target, describing the fleet only in general terms. As a result, the 1997 QDR fleet is variously described as having between 300 and 310 ships. Based on notes and interviews, I have settled on 302 ships as being the actual 1997 QDR fleet target. See William S. Cohen, Secretary of Defense, *Report of the [1997] Quadrennial Defense Review*.

[68] The *Streetfighter* was the brainchild of the late Vice Admiral Arthur Cebrowski, then-commander of the US Naval War College. It was to be a small, fast, modular ship that would operate close to shore in order to ensure access for larger naval combatants and vessels. In October 1999, at a breakfast for the Defense Writers Group, Admiral Daniel

completed Navy study that had concluded the nation's two-war strategy required 145 surface combatants, not the 116 called for in the QDR.[69] That same year, citing a Joint Chiefs of Staff study on future nuclear-powered attack submarine (SSN) requirements, active duty submariners began lobbying for a fleet of 68-72 boats, one considerably larger than the QDR's approved target of 50 submarines. Soon thereafter, in early 2000, the Navy submitted to Congress a 30-year shipbuilding plan to build the QDR-approved "300-ship" battle fleet. In a thinly veiled repudiation of the administration's plans, the report included a section that outlined a 360-ship "reduced risk fleet."[70]

Figure 1: Breakdown of the 1997 QDR Fleet

Type/Class	1997 QDR Fleet
Aircraft Carriers	**11 active +1 reserve**
Submarines	**68**
Ballistic Missile Submarines (SSBNs)	(18)
Attack Submarines (SSNs)	(50)
Surface Combatants	**116**
CGs/CG-21s	(27)
DDGs	(57)
DD-21s	(32)
Mine Warfare Ships	**16**[71]
Amphibious Landing Ships	**36**
Combat Logistics Force Ships	**29**
Support Vessels	**25**
Total Ship Battle Force (TSBF)	**302**

Murphy stated that the idea of *Streetfighter* "…is a wild idea…There is nothing behind it." See "Murphy Slams 'Streetfighter,' Navy Distances Itself From Comments," *Inside the Navy*, October 18, 1999, p. 3; and Hunter Keeter, "Murphy: 'Streetfighter' Concept Unsound," *Defense Daily*, October 15, 1999, p. 5.

[69] The study was entitled the "Surface Combatant Force Level Study II." The second such study conducted since the end of the Cold War, it called for no less than 165 surface combatants. See "Stated Requirements for Surface Combatants," in *Transforming the Navy's Surface Combatant Fleet* (Washington, DC: Congressional Budget Office, March 2003), found online at http://www.cbo.gov/showdoc.cfm?index= 4130&sequence=2&from=0.

[70] Christopher J. Castelli, "Navy Sends 30-Year Shipbuilding Plan to Defense Secretary," *Inside the Navy*, March 6, 2000, p. 1; see also Congressional Budget Office, *Options for the Navy's Future Fleet* (Washington, DC: Congressional Budget Office, May 2006), pp. 5-8;

[71] This does not include an additional ten mine warfare ships in the Naval Reserve.

Finding that their calls for more ships were falling on deaf administration ears, Navy leaders took an even bolder step. No sooner than the ink had dried on the 2001 QDR, which essentially endorsed the 1997 QDR fleet reinforced with five additional SSNs, then-Chief of Naval Operations Admiral Vern Clark unveiled his plans for a new Global Concept of Operations (ConOps) Navy, consisting of no less than 375 ships of all types, a healthy 22 percent expansion over 307-ship QDR fleet.[72] To isolate the Navy from charges that it was rejecting the fleet just approved by the Bush administration, Admiral Clark cleverly used the review's own "1/4/2/1" force sizing and planning requirements to justify the larger fleet.[73]

Unfortunately, Admiral Clark's calls for a larger fleet were coming at a time when cost overruns were being reported in virtually every new warship and submarine then in design or production. The new *Virginia*-class SSN, the replacement for the *Nimitz*-class nuclear-powered aircraft carrier (CVN), and the *San Antonio*-class amphibious landing ship were all suffering cost overruns of varying degrees. The same was especially true for the newly named *Admiral Elmo Zumwalt*-class DD-21. By 2001, it was increasingly clear that because of all the new systems and technologies that had been packed into the ship, there was absolutely no way the fifth ship of the class could be purchased for $750 million (FY 1996 dollars). Indeed, the size and cost of the DD-21 had risen to the point that the Navy could no longer reasonably describe the ship as being part of the "low-end" mix in the Navy's future surface combatant fleet. Consequently, its plans and justification for the future battle line would have to be adjusted.

Accordingly, on November 1, 2001, Admiral Clark announced that the SC-21 family of ships would be replaced with a new DD(X) family of ships, consisting of a CG(X) multi-mission guided missile cruiser; a DD(X) *multi-mission* destroyer; and a small focused-mission warship called the Littoral Combat Ship, or LCS. In an instant, the new LCS became the "low-end" component of the future surface combatant fleet, while the "new" multi-mission DD(X) joined the Cold War guided-missile cruisers and destroyers in the "high-end" of the fleet.[74] The mid-term surface warship target for the 375-ship Global ConOps Navy called for 168 vice 116 ships: 88 legacy guided-missile cruisers and destroyers, 24 DD(X)s, and 56 LCSs.[75] This represented a

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[72] Vice Admiral Mike Mullen, USN, "Global Concept of Operations," *Proceedings*, April 2003, found online at http://www.usni.org/proceedings/Articles03/PROmullen04.htm; see also "Stated Requirements for Surface Combatants," in *Transforming the Navy's Surface Combatant Fleet* (Washington, DC: Congressional Budget Office, March 2003), found online at http://www.cbo.gov/showdoc.cfm?index= 4130&sequence=2&from=0.

[73] The 2001 QDR demanded a military large enough to defend the homeland (1); deter potential adversaries in four critical theaters with strong forward presence forces (4); rapidly win two overlapping "major combat operations" in two theaters (2); and be prepared to conduct "decisive operations (e.g., regime change) in one of the two major combat operations (1). See Mullen, "Global Concept of Operations," p. 1.

[74] For the rationale behind moving to a new family of ships, as well as brief descriptions of them, see Rear Admiral Charles Hamilton and Rear Admiral Donald Loren, USN, "It's All in the Family," *Proceedings,* August 2002, pp. 68-70; Rear Admiral Mark Edwards, USN, "New Realities Mean the Navy Must Dominate in the Littoral," *Seapower,* April 4, 2004, pp. 42-45; and Rear Admiral Sam Locklear, "LCS and DD(X)," *Defense News,* August 30, 2004.

[75] The original surface combatant target was 160 surface combatants, with just 16 DD(X)s. Subsequent shifting of numbers within the 375-ship target caused the Navy to raise the DD(X) objective requirement to 24 ships.

force split of 67 percent multi-mission combatants and 33 percent focused-mission combatants, one still generally consistent with the 70/30 split sought in the earlier SC-21 family of ships.

In the end, however, despite Admiral Clark's best efforts, he failed to garner additional resources to pay for a 375-ship fleet. While the Navy's budget steadily increased over his tenure, the bulk of the extra funds went to pay for rising personnel and operations and maintenance costs resulting from the unexpected "Global War on Terror," declared soon after the horrific attacks of September 11, 2001. Moreover, the Navy was having a hard time containing continued cost overruns in its shipbuilding programs. The combination of limited procurement budgets and rising ship procurement costs spurred Admiral Clark to decommission the last of the Cold War *Spruance* DDs as well as the oldest five *Ticonderoga*-class guided missile cruisers, all well before the end of their expected 35-year service lives. These and other early ship and submarine decommissionings caused the fleet to fall right through the "red line" of 300 ships established by the Navy in the 1997 QDR and to bottom out at around 280 ships.

In March 2005, resigned to the fact that support for his Global ConOps Navy was simply not there, Admiral Vern Clark notified Congress that the future fleet would fall somewhere between 260 to 325 ships, depending upon the extent of technology insertion, overseas home-porting of ships, and rotational crewing.[76] At the same time, he made an important pronouncement:

> The number of ships in the fleet is important. But it is no longer the only, nor the most meaningful, measure of combat capability. Just as the number of people is no longer the primary yardstick by which we measure the strength or productivity of an organization, the number of ships is not the only way to gauge the Navy's health or combat capability….In fact, today's Navy can deliver more combat power than we could twenty years ago when we had twice as many ships and half again as many people.[77]

In other words, Admiral Clark no longer considered the size of the TSBF to be the only determinant of fleet strength or combat capability. Whether a reluctant capitulation to budget realities or an acceptance of a new force planning paradigm, Admiral Clark's admission—nearly a decade in the making—was the first sign that the Navy was finally coming to terms with the idea of a "300-ship Navy."

Soon thereafter, on July 22, 2005, Admiral Michael G. Mullen became the 28th Chief of Naval Operations, succeeding Admiral Clark. Assuming his post in the midst of ongoing deliberations for the 2005 QDR, Admiral Mullen quickly announced that his three top priorities would be to sustain Navy readiness, build a fleet for the future, and develop 21st century leaders. As part of building a future fleet, Admiral Mullen promised to come up with a firm, fixed battle fleet target

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[76] Congressional Budget Office, "Resource Implications of the Navy's Interim Report on Shipbuilding," dated April 25, 2005, a report in response to a request by the Honorable Roscoe G. Bartlett, Chairman, Subcommittee on Projection Forces, House Armed Service Committee, p. 1.

[77] Statement of Admiral Vern Clark, US Navy, Chief of Naval Operations, before the Senate Armed Services Committee, April 12, 2005, p. 4. Admiral Clark's testimony can be found at http://www.navy.mil/navydata/cno/testimony/clark050412.pdf.

and to craft a stable, 30-year shipbuilding program. Late in 2005, he personally went to Capitol Hill to brief the results of his staff's deliberations and his final decisions. In the process, he implicitly endorsed Admiral Clark's judgment that a "300-ship Navy" was plenty capable, announcing a new fleet target of 313 ships (see Figure 2).[78]

As Figure 2 makes plain, Admiral Mullen's 313-ship battle fleet is remarkably similar in size and composition to the 1997 fleet, with the key difference being found in the makeup of the surface combatant and mine warfare categories.[79] However, the general reaction to Admiral Mullen's plan was quite different than the one that followed the 1997 QDR. With the battle fleet then at about 280 ships, and after confronting the prospect of the fleet shrinking further to 260 vessels, Admiral Mullen's "300-ship Navy" sounded pretty good to Navy officers and Congressional supporters. Indeed, the 313-ship fleet was near the top end of the range of possible future fleet numbers previously established by Admiral Clark, providing a welcome psychological boost to a service that had seen a decade-and-a half of steady fleet reductions. Unsurprisingly, then, the 313-ship battle fleet was roundly cheered both inside and outside the Navy, and its announcement was accompanied by little talk of trying to pursue a larger fleet. The Navy's quixotic decade-long search for a larger battle fleet was finally over.

PAYING FOR THE NEW "300-SHIP NAVY"

Although a battle fleet target of 313 ships was warmly welcomed by naval advocates, Admiral Mullen accompanied its announcement with a clear caution that achieving the target would require the Navy to make some dramatic adjustments. He decreed that the associated shipbuilding plan be built on the assumption of flat future defense budgets, thereby pointedly avoiding any hint that the execution of the Navy's plan would depend on an increased allocation of DoD resources. In other words, if building the 313-ship fleet required more procurement dollars, the Navy would need to reallocate money within its own expected budget top line.[80]

The Navy's own analysts had calculated that building the 313-ship Navy would require average yearly Ship Construction Navy (SCN) budgets of approximately $15.4 billion in FY 2007 dollars (counting nuclear refueling costs for aircraft carriers and submarines). Outside agencies, such as the Congressional Budget Office, put the SCN bill much higher, at over $21 billion a year.[81] Over the previous 20 years, the average yearly SCN budget, accounting for the effects of inflation, was about $11 billion a year.[82] In other words, depending on whether the DoN or CBO

[78] Secretary of Defense, "Report to Congress on the Annual Long-Range Plan for the Construction of Naval Vessels for FY 2007," March 23, 2005, submitted in response to Chapter 9, Section 231 of Title 10 of the US Code, and House Appropriations Committee (HAC) Report 109-119, p. 4.

[79] In the 313-ship fleet, in addition to littoral anti-submarine and anti-surface warfare, the new multi-purpose, focused-mission LCS would take over the countermine mission, resulting in the disappearance of dedicated mine warfare vessels.

[80] From Captain J.F. McCarthy, USN, "Recapitalizing the Navy's Battle Line," a PowerPoint presentation given at a Department of the Navy Media Roundtable on June 8, 2006, slide number 16.

[81] Congressional Budget Office, *Options for the Navy's Future Fleet*, pp. 25-26.

[82] McCarthy, USN, "Recapitalizing the Navy's Battle Line," slide number 18.

figures turn out to be correct, the Navy will need to receive somewhere between $4.5 to $10 billion more per year in shipbuilding funds than historical norms.

Figure 2: Comparison Between the 1997 and 2006/06 QDR Fleets

Type/Class	**1997 QDR Fleet**	**2006 QDR Fleet**
Aircraft Carriers	**11 active +1 reserve**	**11 active +1 spare**[83]
Submarines	**68**	**66**
Ballistic Missile Submarines (SSBNs)	(18)	(14)
Cruise Missile/Spec Ops Transport Submarines (SSGNs)	(0)	(4)
Attack Submarines (SSNs)	(50)	(48)
Surface Combatants	**116**	**143**
CGs/CG(X)s	(27)	(19)
DD-21s/DD(X)/DDG-1000s[84]	(32)	(7)
DDGs/DDG(X)s	(57)	(62)
Littoral Combat Ships	(0)	(55)
Mine Warfare Ships	**16**[85]	**0**
Expeditionary Warfare Ships	**36**	**43**
Amphibious Landing Ships	(36)	(31)
Future Maritime Prepositioning Ships MPF(F)	(0)	(12)
Combat Logistics Force Ships	**29**	**30**
Support Vessels	**25**	**20**
Total Ship Battle Force (TSBF)	**302**	**313 (+1)**

[83] The 313-ship fleet requirement for aircraft carriers is 11 CVNs. Since one is normally in long-term overhaul for up to three years, the Navy plans to maintain ten active carrier air wings for the 11 carriers. The Navy's accompanying 30-year shipbuilding plan shows a twelfth carrier in the fleet every year after 2019, and it is embedded in the yearly battle force count. However, because there are no current plans to assemble an eleventh to assemble a carrier air wing for this twelfth carrier, I show it as a non-countable active spare to provide an accurate comparison with the 1997 QDR fleet.

[84] As will soon be discussed, the Navy recently reclassified the *Zumwalt*-class DD(X) as the DDG-1000, a guided-missile destroyer.

[85] This does not include an additional 10 mine warfare ships in the Naval Reserve.

In order to free up the money to pay for even the most optimistic of these cost estimates (i.e., the Navy's), Admiral Mullen cautioned that the Navy would need to:

- *Limit real increases in personnel costs*. The average yearly costs for active duty personnel have long risen at rates higher than those for the overall Navy budget. To keep the amount of money spent on personnel flat (adjusted only for inflation), Admiral Mullen planned to continue the aggressive reduction in the Navy's overall active duty end strength started by Admiral Clark. In effect, he would try to offset any real increases in personnel costs by reducing the number of people serving on active duty.

- *Limit real increases in O&M costs.* The amount of money needed to operate and maintain the battle fleet has also been steadily increasing as a share of Navy topline. Achieving the 313-ship target would require that these costs be frozen at current levels, and then rise only enough to keep pace with inflation.

- *Reduce research and development (R&D) costs and keep them low*. In line with his predecessor's thinking, Admiral Mullen planned to shift money from R&D toward ship production, and to keep future R&D at much lower levels than in the recent past.

- *"Fence" shipbuilding funds.* The CNO decreed that maintaining stability in the yearly shipbuilding budgets and construction rates would be among his top procurement priorities. While Admiral Mullen sought to better balance the Navy's overall investment portfolio, this decree implied that should overall procurement funding be lower than expected, aviation and other programs would be among his first targets for adjustments.

- *Prevent further requirement and cost growth in any Navy shipbuilding program.* In addition to instituting stringent cost controls on existing ship programs, Admiral Mullen reconstituted the aforementioned Ship Characteristics Improvement Board. As outlined in a 2005 memorandum to the Vice Chief of Naval Operations, Admiral Mullen sought to put in place a "process that adequately defines warship requirements and manages changes to those requirements (e.g. Ship Characteristics Improvement Board) in a disciplined manner, with *cost and configuration control as the paramount considerations*" (emphasis added). In other words, the post-Cold War reign of the "Requirements School" was over; in the future, cost considerations would moderate the size and capability of future ships.

Admiral Mullen deserves great credit for dampening unrealistic expectations for a larger fleet, and implicitly telling the Navy's rank and file that if they wanted even a "300-ship fleet" everyone in the organization would have to work hard to get it. However, achieving any of the above objectives will be a stiff challenge, primarily because each depends to some degree on factors out of Admiral Mullen's and the Navy's direct control. For example, in the recently passed FY 2007 budget, Congress authorized a higher research and development allocation than the Navy requested. The Navy is obliged to cover these increased costs, regardless of their impact on its carefully balanced budget plans. More troubling, the first of the new Littoral Combat Ships—the least capable, most inexpensive warships now being built—have recently seen substantial cost overruns.[86] As the examples suggest, then, the chances that all of these objectives will or can be met simultaneously are extremely remote.[87]

THE BULL IN THE CHINA CLOSET: THE DDG-1000, AKA THE DD-21/DD(X)

Indeed, the chances that all assumptions will come true appear especially remote considering the disproportionate impact that the current plan for the future surface battle line is having and will continue to have on the Navy's overall transformation plans. The facts suggest that design decisions made over a decade ago now make the ship previously known as the DD-21 and DD(X) the proverbial bull in the Navy's shipbuilding china closet, threatening to break not only its delicate plans for the future surface battle line, but its entire 30-year shipbuilding plan.[88]

This will remain so despite the Navy's increasing efforts to rein in the cost of the ship. In a move to cut its unit procurement cost, the Navy recently cut the overall size of the DD-21/DD(X) by some 4,000 tons. In the process, the ship's planned VLS battery fell by over one-third, from 128 to 80 launch cells. Moreover, to help save weight, the designed rate of fire for the ship's two AGSs was cut from 12 to ten rounds per minute, and the ship's total magazine capacity was cut from 1200-1,500 rounds—first to 920 rounds, and yet again to 600 rounds.[89] The reduction in magazine size was justified by a new "infinite magazine concept" which asserted that, unlike previous surface combatants, DD(X)s would be constantly resupplied with gun rounds by helicopter without having to leave the gun line. What the ship lost in land-attack capabilities was offset, to some degree, by a substantial upgrade to its planned anti-air warfare system. The addition of a dual-band radar system with an S-band volume search radar and X-band multi-function radar would enable the ship to perform area air defense—a capability lacking in the earlier DD-21 and DD(X) designs. This prompted the Navy to reclassify the ship once again, this time as a multi-mission *guided-missile destroyer*, which it dubbed DDG-1000.[90]

However, even after losing approximately 4,000 tons displacement, one-third of its planned VLS battery, and at least half of its expected gun magazine capacity, given the previous decisions to

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[86] Due to rising costs, the Navy just issued a stop-work order on one of the two LCS designs. See Renae Merle, "Navy Halts Lockheed Martin Contract," *Washington Post*, January 13, 2007, and Christopher P. Cavas, "Stop Work Ordered for 3d LCS," *Navy Times*, posted January 13, 2007.

[87] For example, DFI International Corporate Services recently concluded that "pressures will prevent a wide range of acquisition programs from unfolding as the Navy and DoD desire." See DFI International Corporate Services, "Navy Investment Plans: Plans Versus Reality, and Implications for Market Opportunity," a PowerPoint presentation given to the National Defense Industrial Association, April 26, 2006.

[88] See the comments made in the Executive Overview of Commodore Stephen Saunders, RN, ed., *Jane's Fighting Ships 2006-2007* (Alexandria, VA: Jane's Information Group, Inc., 2006), p. 29.

[89] See "155mm (6.1") AGS."

[90] Never explained was how constant helicopter flights to and from the ship and the requirement to radiate its new air defense radar comported with the desire to minimize the ship's signature in coastal waters. These dichotomies will be explored more fully later in the report.

pursue a tumblehome hull and other ship survivability and technological advances, the current version of the DDG-1000 remains a very large ship in comparison to other contemporary combatants. Indeed, when commissioned, the DDG-1000 will be the largest surface combatant built by the US Navy since the nuclear-powered cruiser *Long Beach*, CGN-9, procured in FY 1957, and it will be the second largest combatant in the world.[91] The ship will be 600 feet long, have a beam of nearly 81 feet, a draft and full load displacement of 27.6 feet and 14,564 tons, respectively. However, when operating close to the coast and in its most stealthy configuration, the DDG-1000 will take on an additional 1,800 tons of seawater ballast, giving it a *battle load* of approximately 16,300 tons. The comparative figures for the current heavyweight in the US surface battle line, the *Ticonderoga*-class guided-missile cruiser, are: a length of 567 feet; a beam of 55 feet; a draft of 31.5 feet; and a full load displacement of approximately 9,500 tons.[92]

As a result of its still impressive size and technical sophistication, the DDG-1000 will be a very expensive ship—and considerably more expensive than originally expected. Adjusted for inflation, the original DoN cost projections for the fifth DD(X) were between $1.06 and $1.23 billion in FY 2007 dollars. In 2004, the DoN estimates for the fifth ship in the class jumped to $1.4 billion; in 2005, they jumped again to $2.1 billion. The Navy now projects that the first DDG-1000 will come in at $3.3 billion. However, the Cost Analysis Improvement Group (CAIG) within the Office of the Secretary of Defense (OSD) pegs the cost of the first ship at $4.1 billion, while the Congressional Budget Office (CBO) estimates a first-ship price of $4.7 billion.[93] Based on a *seven* ship production run—down from the 32 ships called for in the 1997 QDR fleet and the 24 ships called for in the 375-ship Global ConOps Navy—the Navy believes the average cost per ship will be $2.7 billion; the CBO projects the average cost of seven ships to be $3.7 billion.[94]

Even assuming the Navy's lower numbers are correct, the impact of the Navy's dogged pursuit of requirements unconstrained by costs is plain to see. *Even after shrinking the original DD-21 design by nearly 25 percent and slashing much of the ship's original combat capability, the*

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[91] The largest surface combatant is the Russian *Kirov*-class nuclear-powered battle cruiser, with a full load displacement exceeding 25,000 tons.

[92] Information on the DDG-1000 can be found at PEO Ships, "DDG-1000 Design," accessed online at http://peos.crane.navy.mil/DDG1000/DDG1000_design_hover.htm. Information on the ship's "battle load" was provided to the author by Dr Eric Labs, Congressional Budget Office. Information on the *Ticonderoga*-class can be found in Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 138.

[93] O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," pp. 15-20

[94]. See also Statement of J. Michael Gilmore, Assistant Director of National Security, Congressional Budget Office, in testimony before the House Armed Services Committee Projection Forces Subcommittee Hearing on the DD(X), July 19, 2005, found online at http://www.globalsecurity.org/ military/library/congress/2005hr/050719-gilmore.pdf. For more on the continual cost escalation on the ship, see Tony Capaccio, "Destroyer May Cost 33% More Than Navy Budgeted, Pentagon Says," *Bloomberg News*, May 4, 2005; and Christopher J. Castelli, "Pentagon Postpones DD(X) DAB Meeting to Resolve Cost Estimates," *Inside the Navy*, May 2, 2005.

average DDG-1000 will still have a budget impact between two and three times bigger than originally forecast.

Indeed, the ship's steady cost growth helps to explain why the Navy has been compelled to change its plans for its future surface battle line three times in the past ten years:

- During the 1997 Quadrennial Defense Review (QDR), the Navy planned to do away with small combatants entirely, opting instead for 116 large BFC combatants, divided into a "high-end" group composed of 84 legacy multi-mission guided-missile cruisers and destroyers (27 *Ticonderoga* CGs and 57 *Burke* DDGs) and a "low-end" group composed of 32 new *focused-mission* DD-21 land-attack destroyers. This represented a 72/28 "high-low" capability split among US Navy surface combatants.

- With the DD-21's costs steadily climbing, after the 2001 QDR the Navy reclassified the ship as a *multi-mission* destroyer (DD(X)). The planned new 375-ship Global Concept of Operations Navy included a battle line consisting of 88 Aegis/VLS ships and 24 DD(X)s. These 112 multi-mission ships would be augmented by 56 small, focused-mission Littoral Combat Ships (LCSs). This combined 168-ship surface combatant fleet had a 67/33 "high-low" surface combatant capability split.

- With the DD(X)'s costs still escalating, the Navy reclassified the ship yet again, this time as a *multi-mission* guided-missile destroyer (DDG-1000). However, the high cost of the ship required the Navy to dramatically reduce its planned production run. The recently announced 313-ship Navy includes a surface combatant fleet of 143 ships, split between a multi-mission battle line of seven DDG-1000s, 19 CG(X)s, and 62 DDGs or follow-on DDG(X)s, augmented by 55 of the new small, multi-purpose, focused-mission LCSs. This new plan now shoots for a 61/39 "high-low" capability split.

If nothing else, the tortured lineage of the DD-21/DD(X)/DDG-1000 clearly demonstrates the declining usefulness of classic ship designators such as "destroyer," "guided-missile destroyer," and "guided-missile cruiser." Such terms are now essentially decoupled from ship size and displacement. They are used instead to separate ships in terms of the overall capabilities of their combat systems. By using both size and capabilities to classify ships, however, one sheds light on the Navy's most recent transformation plan. With apologies to the Navy's current ship titles, under current plans the future surface battle line will have three distinct tiers. The top tier will consist of 26 large and expensive multi-mission "CG-21s" (21st century "cruisers) based on the "DDG-1000" hull: seven will carry two 155mm (6-inch) advance gun systems (on ships now known as the DDG-1000) and 19 will replace one or both gun systems with additional missile cells filled with new long-range SAMs and anti-tactical ballistic missile interceptors (on ships now known as CG(X)). The middle tier will be defined by 62 multi-mission *Arleigh Burke* DDGs or futuristic DDG(X)s. Finally, the bottom tier will consist of 55 focused-mission LCSs.

Regardless of the ship's ultimate designation, the evolution of the DD-21/DD(X)/DDG-1000 also helps to illuminate how the Navy's early failure to balance the ship's requirements with cost considerations has forced it to make repeated adjustments to its future surface combatant plans. Indeed, it seems certain that the 26 new combatants based on the DDG-1000 hull will continue to have inevitable, disproportionate impacts on plans for the future surface battle line and the larger 313-ship battle fleet. The first impact is readily seen in the planned split between the fleet's "high-end" multi-mission combatants and "low-end" focused-mission ships. The planned percentage split for the current 143-ship surface combatant fleet is now 61/39, a rather significant reduction from the 70/30 mix long pursued by naval planners. In other words, because of the unexpectedly high costs for future multi-mission ships, lower-cost, focused-mission ships will necessarily comprise a greater proportion of the future fleet.

The second evident impact is the long transition time needed to replace the legacy CGs. Although only 22 "*Ticos*" remain in service, recall that the class originally numbered 27 ships. These 27 ships were commissioned between January 1983 and July 1994, a period of about 11.5 years. In contrast, the first two DDG-1000s, the first two of 26 next-generation ships, were authorized in FY 2007, and the 26th and final ship (a CG(X)) will be authorized in FY 2023, with the ships being commissioned from 2012 through 2029—a period of 18 years.[95]

The slow cruiser transition will have cascading effects on replacement plans for the 62 *Burke* DDGs. The Navy does not plan to start authorizing new DDG(X)s until FY 2023, too late to have the first new ship in the fleet before the oldest *Burke* retires. As a result, the Navy falls below its objective requirement for DDGs in FY 2026. Worse, because the Navy plans to build the DDG(X)s at a rate of only two ships per year, the surface battle line falls below its combined requirement for 88 guided-missile cruisers and destroyers in FY 2027—*and never recovers*. Ron O'Rourke, a respected analyst at the Congressional Research Service, foresees the combined cruiser and destroyer fleet falling to 62 ships in FY 2042 (26 ships below the total 88-ship requirement) before rebounding to the steady-state force of 70 ships sometime after 2050 (assuming an expected ship service life of 35 years).[96] In other words, due in part to the high up front costs of the 26 DDG-1000s and CG(X)s, after FY 2027 the surface battle line will *never* reach its required numbers—clear evidence that the cost of the ships is inappropriate for the expected future budget environment.[97]

The high aggregate costs for the combined surface combatant fleet will also have a negative effect on the overall size of the battle fleet. The surface combatant component of the 1997 QDR fleet (116 total ships) was expected to cost approximately $37 billion (in FY 2007 dollars) from

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[95] Captain J.F. McCarthy, USN, "Recapitalizing the Navy's Battle Line," slide 20.

[96] O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," p. 19.

[97] The Navy just recently updated its 30-year shipbuilding plan. This plan indicates that the Navy will begin to build three DDG(X)s a year starting in FY 2025, reducing the ultimate cruiser-destroyer shortfall by half. See "Long Term Shipbuilding Plan Sets Ambitious Goal for Distant Future," *Inside the Navy*, February 12, 2007. However, it remains to be seen if this was simply an accounting ploy to silence criticism about their current plan, because the increase in the number of ships in the plan was not accompanied by an increase to the projected size of the annual shipbuilding budget. The CBO believes the new shipbuilding plan would cost over $1 billion more per year than last year's plan. See Congressional Budget Office, *Resource Implications of the Navy's FY 2008 30-Year Shipbuilding Plan*, (Washington, DC: Congress of the United States, March 23, 2007). This report therefore continues the FY 2007 shipbuilding plan for comparative purposes.

FY 2004 through FY 2016.[98] In contrast, the surface combatant component of the 2005/06 QDR fleet (143 total ships) is expected to cost approximately $58 billion (in FY 2007 dollars) between FY 2005 and FY 2016, inclusive.[99] In other words, the average shipbuilding budget allocation for the surface combatant fleet between 2004/05 and 2016 has jumped from a target of $2.84 billion per year in 1997 to $4.83 billion per year in 2006. Given that the total average annual shipbuilding budget for the 20 years prior to FY 2005 has totaled only about $11 billion a year, the jump in planned expenditures for surface combatant goes a long way toward explaining why the Navy needs a 40 percent increase in annual shipbuilding funds (to $15.4 billion) to build a total ship battle force only 12 ships larger than the 1997 QDR fleet.

The shape of the Navy's 30-year shipbuilding plan also necessarily reflects the accommodations necessary to account for the high up-front costs for surface combatants. Over the next five to ten years, the Navy intends to build many of the fleet's most inexpensive ships and then stops building whole classes of ships altogether. Under current plans, in the second decade of the 21st century, there will be almost no production of small combatants, large and medium-sized amphibious ships, and auxiliaries. Then, in the 2020s, the Navy must simultaneously begin to recapitalize its amphibious landing fleet, all ballistic missile submarines, and its tanker fleet—at the very same time it starts to replace the *Burkes* with new DDG(X)s. Needless to say, the build-up of fiscal pressure in the plan's "out-years" is substantial. As a result, even if the Navy's plans are executed to perfection, the plot of future TSBF ship numbers will resemble a roller-coaster: the battle force will climb to 330 ships in FY 2018, largely due to the arrival of 55 new and inexpensive LCSs, but then will fall all the way back to about 292 ships by FY 2031—only 14 ships above where the fleet stands today.[100]

TIME TO RETHINK THE CURRENT TRANSFORMATION STRATEGY?

Whatever you call the ship that has been variously known as DD-21, DD(X), or DDG-1000, given the unwelcome impact that it has had and will continue to have on the Navy's post-Cold War transformation plans, even the staunchest proponents of the ship have to question whether pursuing the ship continues to make sense. The arguments to go forward still have a definite appeal: the ship will mark a major advance in US surface combatant capability, especially in terms of stealth; the Navy needs to move toward improved automation to reduce the size of future ship crews in order to save on operating costs; the move to an integrated power system will result in quieter, more survivable ships and open the way toward exotic new weapon systems such as electromagnetic rail guns; building the ships will help to recover the Navy's

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[98] This plan assumed the last of 57 planned *Burke* DDGs and the first of 32 planned DD-21s would be authorized in FY 2004; that three DD-21s per year would be authorized between FYs 2006 and 2015; and that the last DD-21 and first CG-21 would be authorized in FY 2016.

[99] This plan assumes that 55 LCSs will be authorized from FY 2005 through FY 2016, at an average per unit cost of approximately $400 million, counting the ships' basic hull and combat systems and mission modules; and that seven DDG-1000s and six CG(X)s will be authorized between FY 2007 and FY 2016, inclusive.

[100] Captain J.F. McCarthy, USN, "Recapitalizing the Navy's Battle Line," slide 20.

considerable sunk costs in the ship; and building the ship will help maintain the US national shipbuilding industrial base. Indeed, in a bow to the Navy's "Requirements School," it is impossible to resist their claim that the DDG-1000s (and, presumably, the follow-on CG(X)s) will be among the most survivable and powerful surface combatants ever built.

However, these arguments and claims, despite their appeal, are secondary to a more important question: Will the disproportionate costs and impacts associated with the new surface combatants unduly threaten the Navy's broader goal of building an affordable, balanced, and effective future battle force? The foregoing analysis suggests the answer to this question is probably "yes." The question that immediately follows is: What should the Navy do about it?

In contemplating this important question, a gaming analogy might help. With apologies to naval purists, the US Navy finds itself in the very early stages of a high-stakes post-Cold War naval transformation game, patterned after Texas Hold 'Em.[101] The objective of this game is to emerge with the largest stack of naval capability "chips," representing fiscal resources, platforms, and battle fleet capabilities. In other words, the Navy seeks a future battle force more capable than any other player at the table. Its current stack of "chips" is quite high, including among them 22 *Ticonderoga*-class CGs, 62 programmed *Arleigh Burke* DDGs, 30 frigates, and 26 mine warfare ships. The Navy just "bet" the 56 frigates and mine warfare ships, and in the process "won" 55 new LCSs in return—a trade that will hopefully add to the size of the fleet's capabilities "stack."[102] Now, the Navy has just been dealt two DDG-1000s in the FY 2007 budget and it is considering going "all in," risking all of its remaining "chips" with the hope that the DDG-1000 (and the follow-on CG(X)) will add significantly to the Navy's overall capabilities "chip stack."

Is this a smart move? Is now really a good time for the Navy to push "all in" on a highly capable, but perhaps ruinously expensive, surface combatant? As any poker player will tell you, in games of chance every decision—even those made with an apparently dominating hand—entails some risk. Given the high stakes involved, should the Navy risk both its plans for the future surface battle line and the larger battle fleet so early in the post-Cold War transformation game on the apparent strength of one ship, or "hand"?

As poker players will also tell you, the answers to such questions are often suggested by observing how other players have reacted in similar game circumstances. In this regard, the strategy adopted and decisions made by an earlier generation of surface warriors—in a similar high-stakes postwar transformation game—appear to be particularly relevant and helpful. By

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[101] Texas Hold 'Em is a variation of seven-card stud. Each player is dealt two cards face down. After bets are made, three community cards are dealt face up (the "flop"). After bets are made, a fourth community card is placed face up ("the turn"). After bets are made, a fifth and final community card is placed face up (the "river"). After the final round of bets, the player with the best hand (the five best cards using a combination of the two hole cards and any three community cards) wins the pot. Players can go "all in" whenever they are able to bet, risking all of their chips to win the pot, and forcing other players to risk all or most of their chips in return.

[102] As mentioned earlier, due to rising costs, the Navy just issued a stop-work order on one of the two LCS designs, perhaps putting the expected "payoff" for the new ship at some risk. See Merle, "Navy Halts Lockheed Martin Contract," and Cavas, "Stop Work Ordered for 3d LCS."

reviewing both, some cogent answers to contemporary questions about next game moves are revealed.

II. Back to the Future: Planning for the Post-Second World War Surface Combatant Fleet

A Rapid Fall From Grace

The long, hard war against Nazi Germany and Imperial Japan had just been won.

By 1945, having helped to sweep the U-boats from the Atlantic and to transport and support the allied invasion forces in North Africa, Sicily, Italy, and France, and having fought its way all across the Pacific to Tokyo Bay, the US battle fleet numbered 6,768 ships of all types.[103] As acknowledged by the British at the postwar retirement of Admiral Ernest King, the wartime Chief of Naval Operations, the US Navy had surpassed the British Royal Navy as the largest and most powerful naval force in the world in terms of tonnage, number of ships, manpower, and overall warfighting capability.[104] The US battle fleet was, "incomparably, the finest navy in the world"—if not in all of history.[105]

The unchallenged power of the Navy threatened the Service in a way neither the Imperial Japanese nor German navies ever could. Immediately after the war, the fundamental arguments that powered the rise of the American Navy into first place among the world's naval powers were no longer germane. With no credible hostile navy or naval coalition left to fight, the Navy (and the Marine Corps) thus lost out in a period when the defense budget was already in a postwar free-fall. Worse, at least from a naval officer's perspective, the development of the atomic bomb had captured the attention of all US strategists and planners and helped to catapult the newly formed US Air Force to the top of the Service pecking order when it came to the allocation of scarce defense dollars. Indeed, for the first time in nearly six decades, naval officers found their very relevance being questioned. As one air power enthusiast explained:

> Why should we have a Navy at all? The Russians have little or no Navy, and the Japanese Navy has been sunk, the navies of the rest of the world are negligible, the Germans never did have much of a Navy. The point I am getting at is, who is this big Navy planning to fight? There are no enemies for it to fight except apparently the Army Air Force. In this day and age to talk about fighting the next war on the oceans is a ridiculous assumption. The only reason for us to have a Navy is just because

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[103] Department of the Navy, Naval Historical Center, "US Navy Active Ship Force Levels, 1886-present."

[104] Stephen Howarth, *To Shining Sea: A History of the United States Navy, 1775-1991* (New York, NY: Random House, 1991), p. 472. This is a great one-volume historical reference of the US Navy. It tells the story of how the US Navy came to be the number one naval power through the eyes of a British historian.

[105] The call for a Navy that was the "greatest in the world" came from none other than Woodrow Wilson, during his run for president. At the time, he was chided by many for being so bold as to challenge the primacy of the British Royal Navy. See Kenneth J. Hagan, *This People's Navy* (New York: The Free Press, 1991), p. 252. There are many superb one-volume histories of the Navy. I consider this book among the best of them.

> someone else has a Navy, and we certainly do not need to waste money on that.[106]

With such sentiment prevalent inside the newly created Department of the Defense, within five short years the powerful World War II battle force was effectively eviscerated. By 1949, the number of active aircraft carriers had fallen from its wartime high of 99 to just 18. To add insult to injury, DoD cancelled the Navy's planned new super-carrier, the *United States*, prompting both the furious resignation of the Secretary of the Navy and a "revolt of the admirals."[107] Also in that year, amphibious operations were declared obsolete, and the size of the amphibious fleet was excluded from Joint Chiefs of Staff (JCS) planning guidance.[108] By June 1950, just as the Korean War was breaking out, the TSBF had shrunk to just 634 ships—an order of magnitude reduction from its World War II high.[109]

PLANNING UNDER CONDITIONS OF SCARCE RESOURCES AND UNCERTAINTY

With the dramatic postwar fall in their prestige and overall budget allocation, Department of the Navy planners were forced to methodically cut ships and to prioritize their postwar shipbuilding plans. Complicating their efforts was the uncertainty over the exact nature of future naval threats and the rapid pace of technological change. Today's naval strategists often blame the difficulty they encounter in planning for the future on the fast pace of change in both naval technology and the tactical requirements for naval combat. It is an old complaint, likely made by every new generation of naval officers in the last 150 years. However, it is hard to imagine a time when the pace of change exceeded that seen during the years immediately following World War II. Naval officers (along with officers in all the Services) struggled to come to grips with the potential impact of the atomic bomb on fleet operations and tactics. If that were not daunting enough, three new conventional developments—jet aircraft, long-range robotic *kamikazes* (guided missiles), and high-speed, deep-diving submarines—promised to completely upend the battle-tested and proven tactical doctrine forged by the US fleet during the last two years of the just won global war. Moreover, the electronics revolution, embodied in the development and integration of radar, sonar, and electronic countermeasures into fleet operations, was proceeding

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[106] An unmanned Air Force officer cited in Samuel Huntington, "National Policy and the Transoceanic Navy," *US Naval Institute Proceedings*, May 1954, p. 484. This is a superb short article, written by Huntington nine years after the end of World War II. It is, in essence, a call to naval leaders to think more broadly about the Battle Force's role in a new national security policy era.

[107] See Hagan, *This People's Navy*, pp. 339-341; Howarth, *To Shining Sea*, p. 485. For a longer, more detailed account of the "revolt," see Jeffrey G. Barlow, *Revolt of the Admirals: The Fight for Naval Aviation* (Washington, DC: Naval Historical Center, 1994).

[108] Michael M. McCrea, Karen N. Domabyl, Alexander F. Parker, *The Offensive Navy Since World War II: How Big and Why?* (Alexandria, VA: Center for Naval Analysis, July 1989), p. 17; see also "Amphibious Warfare: Cold War Era," found at http://www.navy.mil/palib/cno/n75/Htm/8000PopE3.htm.

[109] Department of the Navy, Naval Historical Center, "US Navy Active Ship Force Levels, 1886-present." A great recount of the trying years for the Navy after World War II is found in Chapter 12, "In Search of a Mission," in Hagan, *This People's Navy*.

at a rapid pace, with newer electronic systems making older systems obsolete before the end of their initial production runs.

Blown by one wind caused by scarce resources and another by the apparent higher tactical demands that would be placed on future combatants, the Navy struggled to chart a course toward the future. It simply couldn't stop building ships; to maintain both its shipbuilding design and industrial base, it needed to make some immediate decisions about the right way forward. The only logical answer was to try to identify and prioritize the most likely future naval threats, and to then design the best ships to confront them.

THE IMMEDIATE POSTWAR NAVAL PRIORITY: ANTI-SUBMARINE WARFARE

Among the many conventional problems that confronted naval planners immediately after the end of the war, the development of the high-speed, deep-diving submarine initially stood at the top of the list. By mid-1943, the see-saw competition between the German submarine and allied anti-submarine warfare (ASW) forces in the Battle for the Atlantic had shifted decisively in favor of the latter. At the operational/strategic level, allied intelligence proved invaluable, directing convoys away from known submarine concentrations and cueing ASW forces. At the tactical level, however, it was the allies' ruthless exploitation of the submarine's limited underwater speed and endurance that helped turned the tide in their favor.[110]

World War II diesel-electric submarines ran strictly on battery power when submerged. The slower a boat's underwater speed, the lower the rate of battery discharge, and the longer the submarine could stay submerged and hidden from allied ASW forces. However, even when creeping along at very low speeds or "bottoming" on the ocean floor, a diesel-electric submarine could stay submerged only for about 48 hours before the crew used up all the oxygen inside the boat. Moreover, due to relatively low battery power outputs and hulls optimized for surface cruising, a submarine's top underwater speed was generally limited to only seven or eight knots, and at those speeds, its batteries would drain rapidly. [111] At that point, the submarine would have to surface and charge its batteries using its diesel engines, during which time it was extremely vulnerable to attack. As a consequence, submarines normally stayed submerged during the day and rose to the surface at night, to both hunt and recharge their batteries.

The submarine's limited underwater endurance and escape speeds proved to be its undoing in the hard-fought Battle of the Atlantic. In May 1943, by using both shipboard and airborne radars (carried on long-range ASW patrol aircraft) to deny submarines the luxury of operating on the surface at night, and by exploiting the inherent speed and endurance advantages that sonar-

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[110] See Clay Blair, *Hitler's U-Boat War: The Hunted—1942-1945* (New York, NY: Random House, 1998), pp. 310-15.

[111] A German U-boat traveling at 4 knots generally had an underwater range of only 60-90 miles. At its top speed, its range was far less. For a good description of submarine capabilities in World War II, see Drew Middleton, *Submarine: The Ultimate Naval Weapon—Its Past, Present, and Future* (Chicago, IL: Playboy Press, 1976).

equipped surface convoy escorts and airplanes held over submerged submarines, allied ASW forces sank 41 U-boats—nearly one-quarter of Germany's operational sub fleet. Unless the Germans could somehow solve the tactical vulnerabilities of limited underwater endurance and speeds, their U-boats would be driven out of the Atlantic.[112]

The German counter involved both short-term and a long-term fixes. The short-term fix was a technological innovation aimed at combating the surface and airborne radars that forced German submarines off the surface at night, thereby preventing them from charging their batteries. By 1944, German submarines were being retrofitted with the *Schnorchel*, or snorkel—a hinged air mast that allowed a boat to recharge its batteries while cruising at slow speeds underwater. However, the snorkel had several problems of its own. Newer millimeter-wave radars could spot even the small outline of the snorkel above the surface of the water. Moreover, while "snorkeling," the sound of the sub's diesel engines was transmitted directly into the surrounding water, simultaneously alerting listening ASW forces while deafening the submarine's own sound sensors. If that were not enough, during snorkeling operations special float valves designed to keep water from going down the airway and flooding the diesels caused constant pressure changes inside the boat, causing high levels of crew discomfort.[113]

The long-term fixes came with the design and development of three entirely new types of submarines. The first two were known as the Type 21 (ocean-going) and 23 (coastal) *electro-boats.* With newly streamlined hulls optimized for high underwater speeds and large battery banks capable of delivering three times the applied submerged power as previous submarines, the electro-boats could achieve underwater speeds of just over 17 knots for up to 30 minutes. The third new submarine, the Type 26, was equipped with a "closed-cycle" propulsion plant, capable of propelling the submarine through the water at speeds up to 24 knots for perhaps as long as ten hours. Since doubling a submarine's escape speed quadrupled the required ASW search area, such high underwater speeds would provide both electro-boats and the Type 26 with an important edge when evading convoy escorts after their torpedo attacks.[114]

However, high underwater speed was only one of the improvements found on the new boats. They also carried snorkels; new hydrophone arrays with detection ranges of up to 50 miles; and fire control systems allowing for submerged attacks using guided torpedoes. The subs could also dive to 1,000 feet. Deep diving depth was particularly important, since greater diving depths allowed the submarines to hide below sound-bending thermocline layers, and made them largely invulnerable to depth charges or other unguided, sinking ASW weapons. Given these new

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[112] See "U-boat Losses in May 1943," at http://uboat.net/fates/may43.htm.

[113] Blair, *Hitler's U-Boat War: The Hunted—1942-1945,* pp. 313-314.

[114] For a thorough discussion about the German electro-boats, see Norman Friedman, *US Submarines Through 1945: An Illustrated Design History* (Annapolis, MD: Naval Institute Press, 1995).

systems and capabilities, the Germans believed the new submarines would revolutionize undersea warfare, and enable them to regain the tactical advantage over allied ASW forces.[115]

Ironically, the boats did trigger the undersea revolution predicted by the Germans, but not in the way they had imagined. The war ended before they could produce either the two electro-boats or the Type 26s in the numbers needed to shift the tactical balance in their favor. However, upon war's end, the US, British, and Soviet navies all obtained copies of their radical new designs, spurring a frenetic period of submarine technological exploitation and experimentation. The result was the decisive reversal in fortune between submarine and ASW forces envisioned by the Germans.[116]

For example, the postwar US GUPPY (Greater Underwater Propulsion Power) program, designed to provide US ASW forces with experience against a Type 21-style adversary, saw the Navy modify several of its World War II diesel-electric boats to give them the same underwater performance as German electro-boats. The GUPPYs were given more streamlined hulls which both increased their underwater burst speeds to 16 knots and reduced the range at which the boat could be detected by active surface sonar by ten percent. In fleet exercises, when armed with long-range (10,000-yard) homing torpedoes, the GUPPYs "had devastating effects on existing ASW forces." The US Navy estimated that against a well-operated GUPPY, its best ASW tactics and weapons had a kill probability no better than five to 40 percent.[117]

If the heavily modified GUPPYs were a handful for US ASW forces, an entirely new generation of submarine designs promised to be even more formidable opponents. The first US postwar diesel-electric submarines, the *Tang*-class, had top submerged speeds of 18.3 knots and could sustain 17.5 knots for one hour—twice as long as the German electro-boats. Using improved snorkel gear, the new boats had a submerged range of 10,000 miles at 10 knots. Moreover, they could dive to 700 feet and fire homing torpedoes from both their bow and stern tubes. If these submarines were not daunting enough for the surface ASW community, US submarine designers were pursuing new forms of propulsion (nuclear-power) and new teardrop hull designs in which the submarine's surface performance was completely subordinated to high submerged speed and agility, promising even higher underwater performance for future submarines, and even more challenges for ASW forces.[118]

When Requirements and Budgets Collide

Given the stark results of fleet ASW exercises and the troubling direction of submarine design, both naval planners and civilian advisors concluded that Soviet high-speed, deep-diving

[115] For a good discussion on the advantages of underwater speed and diving depth, see Robert Gardiner, ed., *Navies of the Nuclear Age: Warships Since 1945* (Edison, NJ: Chartwell Books, Inc., 1993), pp. 73-74.

[116] Gardiner, ed., *Navies of the Nuclear Age: Warships Since 1945,* p. 75.

[117] Norman Friedman, *US Submarines Since 1945: An Illustrated Design History* (Annapolis, MD: Naval Institute Press, 1994), pp. 40-43 and 105.

[118] Friedman, *US Submarines Since 1945: An Illustrated Design History,* pp. 45-55.

submarines armed with homing torpedoes presented the most potent postwar naval threat to the battle fleet.[119] The initial postwar shipbuilding plans reflected this conclusion. The first six postwar surface combatants to be built by the Navy, all authorized in the FY 1948 shipbuilding budget, were focused-mission ASW ships.

As would be the case five decades later, the "Requirements School" at first held sway in the immediate postwar debates over the desired designs for these ASW ships. Unsurprisingly, then, the common characteristic shared by these six new ships was their very large size compared to the *Gearing*-class destroyer, the ultimate World War II DD, which was 391 feet long, with a beam of 41 foot beam and draft of 23 feet, and a full load displacement of 3,460 tons.[120]

Two of the six ships belonged to the new *Norfolk*-class. As first envisioned, these ships would lead hunter-killer groups on offensive ASW patrols, actively seeking out and hunting down enemy submarines. They would operate with CVSs, aircraft carriers carrying air wings optimized for anti-submarine warfare, and DDKs, or "hunter-killer destroyers" (modified Second World War destroyers). At the time, the "Requirements School" argued that the *Norfolks* had to have a five-knot advantage over a 25-knot submarine even in heavy seas, and have a deep draft to improve sonar efficiency. This would require a large, sturdy hull with good sea-keeping characteristics. In addition, special shaping of the hull was required to account for the likely use of nuclear weapons at sea. For example, a large camber in the deck was adopted to allow rapid deck wash-downs after a nuclear attack.[121]

A large hull was also necessary to accommodate the vessel's main and secondary batteries. The main battery would consist of eight torpedo tubes and 30 high-speed, deep-diving, homing torpedoes, enclosed within the skin of the ship to allow for rapid handling and loading even in rough weather. The secondary battery had to be capable of firing accurate volume fires of rapidly sinking, but unguided, depth charges out to ranges of approximately 800-1,000 yards from the ship. The ultimate battery consisted of four new Mk 108 ASW rocket launchers (two forward, two aft), known Weapon Alfa. As each Mk 108 installation, which consisted of the rocket launcher and a magazine of 72 rounds (22 in a ready-service magazine), weighed no less than 85,000 pounds, the ship would need to be large enough to accommodate a payload of 340,000 pounds located relatively high on the ship.[122]

In addition, the *Norfolk*, designed by the "Requirements School" to be the "ideal" postwar submarine killer, would be packed with new technologies. The ship would have an elaborate dual-band sonar installation; a high-frequency fire control system; a sonar identification-friend-or-foe system; a search receiver for active sonar emissions; an underwater object locator; sonar countermeasures and counter-counter measures; and the capability to tow a deep-water sonar.

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[119] "Submarine History—20th Century," at http://www.globalsecurity.org/military/systems/ship/sub-history5.htm.

[120] Friedman, *US Destroyers*, revised edition, p. 473.

[121] Friedman, *US Destroyers*, revised edition, p. 255.

[122] Friedman, *US Destroyers*, revised edition, pp. 255-257.

The systems would be controlled from a special ASW control center located next to the ship's Combat Information Center (CIC). In addition, the ship would have special silencing features.[123]

Given the *Norfolk's* impressive key performance parameters and new technologies, the size of the ship—and its procurement cost—kept growing. Even after replacing the heavier 5-inch gun mounts found on most World War II escorts with lighter 3-inch mounts, the smallest hull capable of meeting the mission requirements was that of a light cruiser. The *Norfolk*'s ultimate design saw a ship that was 540 feet long with a 54-foot beam and 34 foot draft. Its trail displacement was 6,626 tons—making it roughly twice the size of a World War II *Gearing* DD, and earning it the designation of hunter-killer *light cruiser*, or CLK.[124]

The remaining four ships authorized in the FY 1948 shipbuilding budget belonged to the new *Mitscher*-class of destroyers, which were considered experimental ships. As first envisioned, these ships would perform the same role as the *Norfolks*, but as flagships of the destroyer squadrons assigned as escorts for each aircraft carrier battle group—a mission that also demanded high speed in a seaway. Along with DDKs and "DDEs," or escort destroyers (also modified Second World War destroyers), the *Mitschers* would accompany and screen fast carrier task forces from submarine attack. In this role, the ships would carry only two Weapon Alfas, but the large size of the mounts still demanded a relatively big ship. At 490 feet long, with a beam over 46 feet, a depth of 28 feet, and a full load displacement of 4,758 tons, the ships were about 40 percent larger than the WWII *Gearings.*[125]

Even before it became clear that the assumptions that drove the requirements for the *Norfolks* and the *Mitschers* had been made prematurely, it was obvious given the postwar budget environment that the Navy could not afford to build such large and expensive dedicated ASW ships in any sort of numbers. Indeed, fleet planners concluded the ships were too big and complex to build even under conditions of mass mobilization. As a result, as the debate over the future direction of the postwar battle fleet continued, the "requirements-cost balancing school" started to gain the upper hand over those who focused only on ship requirements. In the end, the Navy bowed to their cogent arguments, deferring the second *Norfolk* in 1949. Then, one year after the start of the Korean War, it cancelled the second ship outright and shelved plans for any more. In the end, the *Norfolk* was commissioned as a single-ship class and reclassified as a destroyer leader (DL). She spent the bulk of her service life as an ASW test ship. A similar fate befell the *Mitschers*. No more were ordered after the four original ships, which were also reclassified as destroyer leaders (DLs). However, unlike the *Norfolk,* all spent their lives as active fleet ships; two were ultimately converted into guided-missile destroyers, and the other two ended their service as basic DDs.[126]

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[123] Friedman, *US Destroyers*, revised edition, pp. 255-257.

[124] Friedman, *US Destroyers*, revised edition, p. 257.

[125] Friedman, *US Destroyers*, revised edition, pp. 244-246 and 477.

[126] Friedman, *US Destroyers*, revised edition, pp. 255-265.

A New Way Forward

The cancellation of further large ASW escorts occurred during a period of contemplation and experimentation inside the Navy. This period of reflection was no doubt influenced by the unexpected onset of the Korean War, which saw a rapid expansion of the fleet from its 1949 post-World War II low of 634 ships to 1,122 ships in just three years, primarily by recommissioning mothballed World War II ships.[127] This war helped to put to rest any question over the utility of naval forces in the atomic age, especially for naval aviation and amphibious forces. Unsurprisingly, then, the 1950s saw Congress authorize no fewer than three new classes of "super carriers" (seven carriers total) as well as three new classes of amphibious ships.[128]

Even though the Korean War seemed to settle any question about the battle force's post-World War II relevance, the 1950s remained a very tough budget environment for the Department of the Navy. The Eisenhower administration's strategy of massive retaliation and its supporting New Look Defense Program continued to divert the majority of defense resources to the US Air Force and to nuclear warfighting forces throughout the 1950s. To ensure its share of defense resources, the DoN began shifting its own internal priorities toward the building of aircraft carriers equipped with jets capable of delivering atomic bombs and toward the development of sea-based ballistic and cruise missiles that could be employed from both surface ships and submarines. Moreover, as mentioned earlier, the Navy began experimenting with nuclear power as a means of propulsion in submarines, aircraft carriers, as well as surface ships.

For a variety of reasons, this period of contemplation and reprioritization paid great dividends. For example, it soon became evident that the immediate postwar judgments and assumptions made by surface warfare officers about fleet ASW requirements, which led to the development of a new generation of larger and more expensive ASW escorts, were as wrong as they were fiscally unrealistic. The unexpectedly rapid development of nuclear-powered attack submarines in the early 1950s promised to further shift the balance between submarines and ASW forces in the submarine's favor. In theory, nuclear boats could travel underwater at speeds greater than 25 knots for unlimited time periods, and would never need to surface or to "snorkel" to recharge their batteries. One possible counter would be to design surface ships with even higher speeds, and the Navy spent over a decade experimenting with ocean-going, high-speed hydrofoils. However, this option promised to be as expensive as the very large ASW ship option that had already been rejected. Another approach would be to limit an ASW escort's speed to that which would enable it to keep up with either a 30-knot aircraft carrier or a 20-knot convoy or amphibious task force, and to develop long-range shipboard sonars for localization of submarine threats and long-range shipboard and "off-board" weapon systems that employed *guided* ASW weapons for attack.

In the end, the latter approach proved to be the most cost-effective solution. Not only were guided ASW weapons the only way to attack fast, deep-diving nuclear submarines that could maneuver rapidly in three dimensions, because of their increased accuracies a ship had only to

[127] Department of the Navy, Naval Historical Center, "US Navy Active Ship Force Levels, 1886-present."

[128] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, Appendix B.

fire one or two guided weapons per tactical engagement.[129] As a result, the magazine space required for shipboard ASW ordnance went down dramatically. Weapons such as the Mk 108, which fired large salvos of unguided munitions, were literally a waste of space and weight. Moreover, improved long-range hull-mounted sonars like the SQS-23, and new ASW weapons the Drone Anti-submarine Helicopter (DASH), which was designed to deliver two homing torpedoes up to 30 miles from its mothership; the ship-launched Antisubmarine Rocket (ASROC), which delivered a homing torpedo out to about ten miles from the firing ship; and surface vessel torpedo tubes (SVTTs) that fired homing torpedoes at close-in submarine targets could all be placed on ships far smaller (and cheaper) than the *Norfolk* and the *Mitschers*.[130] Indeed, the systems could fit on legacy World War II destroyers, potentially allowing the Navy to build a relatively large fleet of effective surface ASW escorts both rapidly and for a bargain price.

At the same time, it was becoming increasingly apparent that the threat to future carrier battle groups, convoys, and amphibious task forces from attacks by jet aircraft armed with long-range guided weapons promised to be as serious as that of high-speed submarines. As a consequence, improvements to fleet anti-air warfare capabilities would be as important as those made to fleet ASW capabilities. Once again, guided weapons would be key to the Navy's transformation plans; its postwar Bumblebee program ultimately led to the development of its first generation of surface-to-air missiles, which included the *Talos* long-range, the *Terrier* medium-range, and the *Tarter* short-range SAMs.[131]

Recognizing and accepting that their initial postwar judgments had been made prematurely, Navy planners wisely changed the entire surface combatant transformation strategy. In essence, they opted to pursue an entirely new family of *multi-mission* surface combatants designed for high-intensity guided weapons warfare in the jet, missile, and nuclear submarine age. To save money, the family ultimately included two different types of warships: large guided-missile "frigates" (DLGs, later called "cruisers") with main batteries of SAMs and secondary batteries of anti-submarine and, later, anti-surface (ship) weapons; and mid-size, "guided-missile destroyers" (DDGs) armed with a balanced mix of anti-air, anti-submarine, and anti-ship weapons. These two new classes of multi-mission ships, along with modernized *focused-mission* "destroyers" (DDs) optimized for anti-submarine warfare, would all be designed for operations with high-speed carrier battle groups. As mentioned earlier in the report, these ships collectively became known as *BFC* combatants.

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[129] It must be noted, however, that guided ASW weapons have never been used in any great numbers, so their true combat effectiveness remains unknown. As will be discussed later in the report, in the only case since World War II in which guided ASW weapons were used—the 1982 Falklands campaign—the British task force operating off of the Falklands expended many homing torpedoes on what turned out to be false sonar contacts.

[130] Of the systems listed, the DASH proved to be the most disappointing in operational service, as it was difficult to control and plagued by reliability problems. For a complete description of the new ASW systems, see Friedman, *US Destroyers, revised edition,* Chapter 12.

[131] Friedman, *US Destroyers, revised edition,* pp. 220-224.

The three large BFC combatants would be augmented by two smaller, less capable and less expensive *protection of shipping* (POS) combatants, which would escort convoys, amphibious task forces, and underway replenishment groups. One would be armed only with guns and guided ASW and anti-ship weapons (DEs, later known as "frigates," or FFs); the other would also carry a small SAM battery (DEGs, later known as "guided-missile frigates," or FFGs). Although the classifications of all five BFC and POS ships changed in 1975, the division of the surface combatant fleet into three BFC and two POS combatants did not change for the remainder of the Cold War.[132] The ultimate Cold War "600-ship Navy" called for 137 BFC and 101 POS combatants, for a fleet "high-low" capability split of 58/42; or, looked at in a different way, the "600-ship Navy" called for 100 multi-mission ships and 138 focused-mission ships, resulting in a multi-mission/focused-mission split of 42/58.[133]

In the mid-1950s, however, the Navy had no multi-mission missile ships designed for combat in the guided missile era, and the first of the new generation of ships would not be commissioned until around 1960. While they were being designed and built, the Navy decided to convert several of its legacy ships into interim multi-mission combatants. For the emerging fleet air defense mission, given the large size of early naval surface-to-air missile systems, the Navy modified 11 World War II heavy and light gun cruisers to carry SAM batteries. Three heavy cruisers were converted to an all-missile configuration while the remaining eight heavy and light cruisers retained their forward 8-inch or 6-inch gun turrets, respectively, with SAM launchers replacing only their aft turrets.[134] Similarly, the Navy's first guided missile destroyer, the USS *Gyatt,* was a World War II *Gearing*-class destroyer modified to carry a twin launcher for the medium-range *Terrier* SAM.[135] These conversions helped to get needed combat capability in the fleet faster than any other option. Moreover, the conversions helped the Navy to understand more fully the requirements for future surface combatants, because they allowed fleet operators to experiment with a variety of new propulsion and electronic systems and weapons, especially anti-aircraft warfare (AAW) and ASW combat systems, before "locking in" on any given solution.

These cruiser conversion efforts were complemented by a much larger program to convert World War II destroyers into focused-mission BFC ASW escorts. Under the so-called Fleet Rehabilitation and Maintenance (FRAM) program, destroyers received extensive upgrades to their hull, machinery and electrical (HM&E) systems, which extended their expected effective service lives to 30 years. In addition, they received new long-range sonar systems like the

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[132] In 1975, after most World War II cruisers had finally been retired from service, the Navy opted to re-classify most of its guided-missile "frigates" as "guided missile cruisers" (CGs) and to re-classify all protection of shipping escorts as either "guided missile frigates" (FFGs) or frigates (FFs). It retained the "guided missile destroyer" (DDG) and "destroyer" (DD) designations.

[133] The "600-ship Navy" called for 100 multi-mission BFC combatants (33 CG/CGNs, 67 DDGs); 37 focused-mission BFC combatants (DDs); and 101 focused-mission POS combatants. One can view this mix as either one between BFC and POS ships (137:101) or between multi-mission and focused-mission ships (100:138), with the 37 DDs swinging between categories.

[134] Polmar, *Ships and Aircraft of the US Fleet,* 13th edition, p. 136.

[135] See "USS *Gyatt* (DD-712)," at http://en.wikipedia.org/wiki/USS_Gyatt_(DD-712).

aforementioned SQS-23 hull-mounted sonar, as well as DASHs to prosecute long-range ASW engagements, ASROCs for medium-range engagements, and SVTTs for close-in engagements.[136] In the end, close to 200 World War II destroyers from three different classes received the FRAM upgrades.[137]

While these two conversion and modernization programs helped to get new combat capability more quickly into the battle fleet, they were not enough to sustain the industrial base and skills necessary to build complex surface combatants while the Navy was designing its next generation of multi-mission combatants. As a result, the Navy ordered 18 *Forrest Sherman*-class destroyers—ships just slightly bigger than the wartime *Gearing* DDs and armed only with improved versions of Second World War weapons.[138] Also ordered were 17 smaller destroyer escorts, which likewise were just improved versions of similar Second World War ships. These moves helped to keep the US shipbuilding base hot until the newer, more capable multi-mission warships were ready for production.

LESSONS FOR THE PRESENT?

One would be hard-pressed to find fault with the decisions made by Navy leadership and surface warfare community in the decade-and-a half after the end of World War II. The results speak for themselves. Their willingness to admit that their first plans were based on faulty assumptions, and to change the direction of their initial transformation plans, ultimately helped pave the way toward a "600-ship Navy" that, despite being an order of magnitude smaller than the one that ended World War II, was likely the most powerful battle fleet in all of naval history. Moreover, the decisions were made in a budget environment every bit as tough as the one seen today, and under conditions of uncertainty which were at least as great, if not greater, than those that now vex naval planners. The stakes were likewise as high; a hasty "fold" of existing fleet platforms or an ill-considered "bet" on a powerful new ship may have altered the outcome of the subsequent show-down with the most powerful player left at the naval transformation table—the Soviet Navy.

As the responsibility for playing the naval transformation game and choosing a correct new fleet transformation strategy falls on their shoulders, the current generation of surface warfare officers now participating in an equally high-stakes game appear ready to make a fateful decision to go "all in" with the DDG-1000, just as their predecessors were ready to do with the *Norfolks* and *Mitschers*. Before doing so, they would do well to review carefully and consider the tactical judgments and decisions made by this earlier generation of players:

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[136] In every case, the payload delivered by these three systems was the same: a homing ASW torpedo.

[137] See "FRAM Program" at http://www.gyrodynehelicopters.com/fram_program.htm.

[138] The 18 *Forrest Shermans* were only 27 feet longer than the World War II *Gearing* DD, with a five-foot wider beam and a full load displacement of 4,080 tons, compared to the *Gearing's* full load displacement of 3,460 tons. When first built, they carried three new 5-inch single turrets in place of the *Gearing's* three dual mounts; four, 3-inch guns in place of the *Gearing's* 20mm and 40mm anti-aircraft cannon; a similar 21-inch torpedo battery; and two "hedgehogs," or ASW spigot mortars.

- Game strategies dependent on assumptions about future fleet or battle line requirements made early in the game, before all opponents and their game strategies are known, are as likely to be as wrong as they are right. In other words, in the early years of any new strategic era, when uncertainties over future threats and technological requirements are at their highest, initial judgments about future fleet platforms are likely to be questionable, if not plain wrong.

- One must be wary of prematurely folding a strong "hand" composed of legacy warships for the promise of getting a marginally better "hand" composed of new warships. It is often smarter to "stand pat," especially when modernized legacy platforms are generally strong enough to win against most opponents.

- When making large "bets" (i.e., fiscal obligations) on apparently strong "hands" (i.e., new warships or capabilities), one must always be focused on the game objective: ending up with the largest "stack" of naval capabilities at the end of the game. A decision to take high fiscal risks on any given new ship or capability—no matter how strong they might look at first—may work against the ultimate goal: being the player with the most balanced and effectively transformed battle fleet, or surface battle line.

- One has to be willing to walk away from an attractive "pot" when it becomes apparent an earlier "bet" or decision to continue playing was ill-advised or inappropriate. Naval players must always consider the long-term impact that any one "hand" (i.e., individual ship or capability) may have on the size of the current and future "stacks" of naval capabilities, and be willing to "fold" the hand if a loss unduly threatens either one, or would unduly constrain their options in future play. Said another way, it is far better to walk away from sunk costs rather than to sink any hope of ultimately winning the game.

- "Playing online"—that is, building dedicated test ships and prototypes derived from modified legacy platforms—is a smart way to test out game strategies and capability bets before having to make them in the real game.

- The worst game players, especially in tight budget environments, come from the "Requirements School." The best players are those that can balance future fleet and ship design requirements, no matter how logical or necessary the requirements might first appear to be, with clear-eyed and hard-headed fiscal calculations and probabilities. The best game players in unfavorable budget environments are those that consistently make good "value bets"—betting on "hands" that are good enough to "win" (resulting in improved fleet capabilities) more often than they lose (resulting in reduced fleet capabilities).

The play of these earlier players also suggests another valuable lesson. That is, early in a new "game" (i.e., a new strategic era), naval planners must be willing to separate the problem of maintaining the industrial base from the exact *timing* of the introduction of a new generation of combatants. By so doing, different industrial base bridging strategies emerge that can help to maintain the base until the next-generation ships can be designed and built.

So, do these valuable lessons still have relevance at today's table? Do they apply to a new generation of players participating in a new naval transformation game with equally high stakes? Do they suggest a change in contemporary game strategy?

You bet they do.

III. "FOLDING" THE DDG-1000/CG(X)

NUMBERS COUNT, BUT CAPABILITIES MATTER

When considering the question about whether to "fold" the DDG-1000, the first order of business is to assess the Navy's strength vis-à-vis the other players at the table. In other words, one must ask how the Navy's current "chip stack"—composed of its fiscal resources, platforms, and capabilities—compares against those held by the other naval competitors still in the naval transformation game. After all, the strategy for a chip leader should be much different than the strategy adopted by a player who finds himself playing with a "short stack."

In terms of fiscal "chips," there is simply no contest. With yearly budgets over $125 billion, the US Navy can call on fiscal resources that are much higher than any other naval competitor, or even group of competitors, at the table. True, the Navy's high level of resources must be viewed within the context of its much greater set of global responsibilities. Moreover, the Navy compensates its people more than any other naval force. Therefore, although its has a commanding stack of fiscal "chips," the Navy must still make judicious "bets" on future capabilities. It does not have money to burn.

What about its current stash of capability "chips"? If the number of ships in the TSBF tell the whole story, the US capabilities "stack" has been steadily diminishing since the end of the Cold War. Certainly, at some point, the total number of ships in the battle fleet becomes operationally relevant, since a lack of overall numbers or a deficiency in specific types of ships or platforms will constrain a commander's options in developing plans and responses to contingencies. But those who dwell solely on the number of ships in the fleet, or those who compare numbers between current and past US battle fleets, fail to take into account other metrics that indicate the contemporary "300-ship Navy" is a force with combat capability to spare.

For example, because of advances made during the 1990s in the realm of guided weapons warfare, and because of the widespread proliferation of the aforementioned Mk-41 shipboard VLS, fleet firepower has dramatically increased. In 1989, the 108 battle force capable combatants then in commission carried a total of 1,525 VLS cells and had an aggregate magazine capacity of 7,133 battle force missiles (i.e., long-range surface-to-air missiles, antisubmarine rockets, *Harpoon* anti-ship missiles, and TLAMs).[139] Today's BFC fleet of 72 warships, despite having 36 fewer ships overall, carries no less than 7,316 VLS cells, and a fleet magazine capacity of 7,716 battle force missiles. Similarly, the maximum theoretical daily strike capacity for the Navy's 1989 aircraft carrier fleet of 13 deployable carriers (with another in long-term overhaul) was 2,106 aimpoints. In early 2007, because every tactical aircraft on a carrier deck is now capable of dropping guided weapons, the comparative figure for 11 deployable carriers

[139] See Colonel Robert O. Work, USMC (ret), *The Challenge of Maritime Transformation: Is Bigger Better?* (Washington, DC: Center for Strategic and Budgetary Assessments, 2002), p. 70.

(with another in long-term overhaul) is more than 7,600 aimpoints.[140] In other words, as Admiral Clark noted earlier, today's 278-ship fleet boasts over 60 percent more aggregate striking power than a 1989 fleet nearly twice its size.[141]

Moreover, although the number of ships in the US fleet is the smallest it has been in over 70 years, the same hold true for the rest of the world's navies—only more so. Additionally, individual US warships are far more capable than the majority of their foreign counterparts. A comparison of the aggregate displacement of world warship fleets is instructive in this regard. As naval analyst Geoffrey Till explains, "[t]here is a rough correlation between the ambitions of a navy and the size and individual fighting capacity of its main units, provided they are properly maintained and manned."[142] Aggregate fleet warship tonnage can therefore be used as a simple proxy for a navy's overall degree of aggregate warfighting capabilities, and to help identify the key players now sitting at the naval transformation table.[143]

The results of such a comparison are telling. Only seven foreign countries operate war fleets that displace more than 100,000 aggregate tons, and ten more operate fleets that displace between 50,000 and 100,000 tons. The largest foreign war fleet, at least in terms of tonnage (but not necessarily operable ships), is the Russian Navy, which comes in at approximately 630,000 tons. In contrast, the US Navy alone operates a battle fleet in excess of 2.85 *million* tons—greater than the aggregate warship tonnage of the next 17 largest foreign navies combined. In other words, in terms of aggregate warship tonnage, the United States enjoys a "17-navy standard." Moreover, 14 of the 17 countries are allied with or friendly to the United States, with a fifteenth, India, emerging as a new strategic partner. Only two of the 17 countries can now reasonably be considered as *potential* naval competitors—Russia and the People's Republic of China—and the US battle fleet out-displaces their combined fleets by over three-to-one.[144]

One could reasonably object to the foregoing analysis, pointing out that the US Navy might be pitted against a continental power which has exported much of its naval power ashore. In other words, comparing the US TSBF against other fleets misses important shore-based naval anti-

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[140] The calculations are as follows. 1989: 13 carriers x 162 aimpoints a day = 2,106 aimpoints; 2007: 11 carriers x 693 aimpoints a day = 7,623 aimpoints at day. Again, it is important to emphasize these are simply theoretical maximums used for comparative purposes only. The number of aimpoints hit per day in a real world operation, over long ranges, or in the face of credible air defense, would be much less. For a more sober view on the number of aimpoints that can be hit per day, see Lieutenant B.W. Stone, USN, "A Bridge Too Far," *Proceedings,* February 2005, pp. 31-35.

[141] Current TSBF numbers are found at the "Naval Vessel Register," found online at http://www.nvr navy. mil/nvrships/index.htm.

[142] Geoffrey Till, "Can Small Navies Stay Afloat?" *Jane's Navy International,* May 1, 2003.

[143] For the purposes of this comparison, the following types of warships are included: aviation power-projection platforms (ships that can support either fixed-wing and/or vertical take-off and landing (VTOL) or short take-off and vertical landing (STOVL) tactical aircraft); surface combatants with a full load displacement (FLD) greater than 2,000 tons (considered capable of overseas deployment); and submarines with submerged displacements greater than 450 tons (i.e., a German *Type 205* coastal defense submarine equivalent).

[144] Saunders, ed., *Jane's Fighting Ships, 2006-2007*; Wertheim, ed., *Combat Fleets of the World 2005-2006*.

access/area-denial (A2/AD) capabilities such as over-the-horizon radars; long-range, land-based maritime strike aircraft; and long-range, shore-fired anti-ship missiles. However, while this observation is a fair one, the opposite is also true; that is, the best comparison would be between the aggregate capabilities of an adversary's naval A2/AD network and the relevant capabilities of the entire Joint Multidimensional Battle Network. For example, in a collision between these two opposing networks, one would have to factor in the contributions of a B-2 stealth bomber delivering 16 one-ton guided bombs on naval A2/AD network targets in advance of arriving naval task forces. Under any reasonable comparison, then, when considering its aggregate "stack" of resources, platforms, and capabilities, as well as those "chips" it can draw on from the other Services, the US Navy is far and away the dominant "chip leader" in the naval transformation game. Despite being smaller in numbers than some past US battle fleets, in terms of combat capability—relative and absolute—today's 278-ship total ship battle force remains the most powerful battle fleet in the world by a wide margin. Moreover, because of its strong position, it appears to be in no immediate danger of losing its place at the top of the global naval pecking order. In the near- to mid-term, all the Navy has to do to remain on top is to leverage the capabilities and resources in its "chip stack," and continue to play smart by not playing any risky "hands" or making any risky capability "bets."

THE CURRENT SURFACE BATTLE LINE: SECOND TO NONE

In addition to having a commanding "chip" lead, with regard to "hands" played over future surface combatants, the Navy has had an incredibly good run of "cards." Starting in 1983, even before the end of the Cold War, and propelled by Admiral Kelso's shrewd move to continue "playing" with Cold War warships after the war was over, the US surface combatant community has drawn 72 consecutive "face cards"—multi-mission "ships-of-the-line" (i.e., BFC combatants designed to operate as part of a fast carrier strike group). Moreover, unlike the World War II battle line combatants, whose "face value" declined dramatically in a new postwar naval transformation game, these 72 warships "easily [remain] the most combat capable and technologically advanced ships at sea today"[145]—more than a decade-and-a-half into the post-Cold War era.

This should come as no surprise. Each of the 72 BFC ships come from the ultimate generation of Cold War multi-mission surface combatants, designed for high-intensity open-ocean warfare against a Soviet Navy equipped with high-speed nuclear attack submarines armed with long-range torpedoes and anti-ship cruise missiles (ASCMs), surface combatants with heavy ASCM batteries, and long-range maritime strike aircraft armed with their own deadly anti-ship missiles. Packed with a range of combat capabilities, and built for extended duration patrols and sustained high-speed combat operations alongside nuclear-powered aircraft carriers, they are generally larger than the warships found in foreign navies, with full load displacements between 8,300 and 10,000 tons. Just as Geoffrey Till would predict, then, every one of the ships is equipped with basic engineering and combat systems that remain very much at the cutting edge of naval

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[145] Admiral Robert J. Natter, USN (retired) and Admiral Donald Pilling, USN (retired), "Achieving the Right Mix," *Proceedings*, October 2006, p. 15.

warfare, and they thus retain a much higher "face value" than most other surface combatants in the world today.

For example, all 72 warships are equipped with a version of the Aegis anti-air warfare combat system, first introduced into fleet service in 1983.[146] The heart of the system is the SPY-1 phased array multi-function radar. Unlike older rotating radars, the SPY-1 has four, fixed, flat- panel arrays that send out numerous "pencil-like" search beams 360 degrees around the ship. When a beam encounters an object, the system's computers immediately divert additional beams to establish a "target track." Additionally, the SPY-1 combines azimuth and height search, target acquisition, classification, and tracking functions, and provides command guidance to missiles. As a result, the Aegis combat system replaces several single-purpose radars, reducing the number of required system interfaces with the ship's combat systems.[147]

Perhaps more importantly, in earlier missile ships, SAMs had to be guided from the time of their launch to the time of target intercept. The number of missiles a ship could fire and control was therefore limited by the total number of separate fire control directors carried by the ship (two to four in early generation missile ships). In contrast, the Aegis is specifically designed to work with missiles that have "commandable autopilots." Once the missiles' autopilots are set at launch, the Aegis system needs only to periodically update them during flight, providing specific radar guidance only during the last seconds before they intercept a target. Consequently, an Aegis-equipped ship can control many more outbound missiles at once—at least four times more than previous missile defense ships. The Aegis system thus enables a tremendous increase in fleet defensive firepower.[148] Although now over two decades old, successive upgrades to the Aegis system—marked by new hardware and software "baselines"—make it "the most advanced anti-air system in existence, land-based or naval."[149]

Each of the 72 BFC combatants also carries a version of the SQQ-89 digital anti-submarine warfare combat system. The "Squeak-89" is the first integrated ASW combat system for surface combatants, combining sensors and fire control systems with state-of-the-art digital signal processing and display technology. The system correlates acoustic data provided by hull-mounted or dipping sonars employed from helicopters, towed arrays, and expendable sonobuoys; produces tracks of enemy submarines; and then forwards this data to the ship's ASW combat direction and fire control systems. Shipboard ASW weapons carried aboard all of the ships include the 10 nm range vertical-launched anti-submarine rocket (VLA ASROC) armed with a single Mk 50 homing torpedo, and two triple deck-mounted SVTTs that fire homing torpedoes at close-in targets (out to about 8,000 yards). Given its all-around capability, the Squeak-89 and the

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[146] The first ship to carry Aegis to sea was the USS *Ticonderoga*, CG-47, commissioned in 1983.

[147] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, pp. 134-35, 552-553; and "AN/SPY-1 Radar," at http://www. fas.org/man/dod-101/sys/ ship/weaps/an-spy-1.htm.

[148] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, pp. 134-135, 552-553. For more information about Aegis, see "Aegis Weapons System Mk-7," at http://www.fas.org/man/dod-101/sys/ship/weaps/ aegis.htm.

[149] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 134.

ASW weapons it controls form the "most advanced ASW system in the world today, and makes the Aegis [ships] the best equipped anti-submarine warfare platforms in the world today."[150]

Finally, every BFC ship carries a version of the AN/SLQ-32 digital electronic warfare suite. The "Slick-32" is a short-range, omni-directional, self-defense electronic warfare system that evaluates electronic emissions around the ship. Depending on the version, the system can provide warning, identification, and bearing for incoming radar-guided anti-ship missiles; actively jam the missiles' seekers; or launch either passive countermeasures such as super-rapid blooming off-board chaff (SRBOC) or active expendable decoys like the NULKA (Australian Aborigine for "be quick") to confuse the missiles and lure them away from their intended target.[151]

With regard to their basic engineering systems, all 72 Aegis/VLS ships have different variations of the same LM2500 gas turbine propulsion system. The LM2500s have high power-to-weight ratios, can be started in less than a minute, and can be quickly brought to full power. As a result, US BFC combatants boast good acceleration and an ability to get underway quickly. In addition, an engine module totally encapsulates the LM2500 to provide both thermal and acoustic insulation, and the module itself is shock-mounted. This helps to prevent engine battle damage and also to reduce hull-borne noise transmission, an important factor when hunting, or evading, enemy submarines.[152]

Perhaps the biggest payoff that comes from having a single propulsion plant for all US BFC combatants, however, is the huge benefit derived from having a *standardized fleet-wide training, maintenance, and logistics support chain*. The late Cold War battle line, which was comprised of a heterogeneous mix of oil-fired steam, nuclear-fired steam, and gas-turbine powered ships, required three different support chains. Moreover, gas turbines are inherently more reliable, are easier to maintain, and require fewer people to operate than both steam and nuclear propulsion plants. As just one example, gas turbines can be removed and changed out with a replacement in a relatively short period of time (approximately 72 hours).[153] The positive impact that a standardized fleet-wide gas turbine propulsion system has on overall operations and maintenance costs is self-evident.

In addition to carrying state-of-the-art combat and engineering systems, all of the ships also carry a powerful combat punch, owing primarily to their large "main batteries" built around the aforementioned Mk-41 vertical launch system, which remains the most flexible and adaptable naval missile launch system in the world today. The building block for the system is a missile module consisting of eight individual VLS cells. A ship's main battery consists of groups of

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[150] Polmar, *Ships and Aircraft of the US Flee*t, 18th edition, p. 558; and "AN/SQQ-89 ASW Combat System," at http://www.fas.org/man/dod-101/sys/ship/ weaps/an-sqq-89.htm.

[151] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 543.

[152] See "LM2500 Gas Turbine Engine," at http://www.fas.org/man/dod-101/ sys/ ship/eng/lm2500.htm.

[153] "LM2500 Gas Turbine Engine."

eight-cell modules nestled in the hull along the ship's centerline.[154] Since the missile cells serve as both storage magazine and launcher for their missiles, the Mk-41 eliminates the need to move missiles from below-deck rotary magazines to the launch rails on above-deck trainable missile launchers. As its name implies, missiles launched by the VLS simply shoot straight up from their cell and away from the ship before tipping over and speeding toward their targets.

The Mk-41 VLS provides several important advantages over legacy missile launch systems. First, as mentioned earlier in the report, the VLS makes very efficient use of space in a ship's hull, allowing a ship so equipped to carry over 40 percent more missiles than a legacy missile ship of equal size. For example, the first five "rail-armed" *Ticonderog*a-class cruisers, since retired, carried 88 missiles in their below-deck magazines, while the remaining 22 VLS-armed *Ticonderoga*-class cruisers each carry 128 VLS cells in a virtually identical hull.[155] The Mk-41's efficient use of space and weight helps to make US VLS-equipped warships among the most heavily armed surface combatants in the world.

Second, every VLS cell found on US BFC ships are the longest, most flexible "strike length" cells, which can be adapted to carry either one *Tomahawk* land-attack cruise missile; one anti-ballistic missile interceptor; one long-range *Standard* SAM; one anti-submarine rocket (ASROC); four "quad-packed" short-range *Evolved Sea Sparrow Missile*s (ESSMs); or almost any missile that is less than 21.4 feet long and 21-inches in diameter.[156] This flexibility allows US BFC combatants to change their missile load-outs relatively quickly to account for the most likely threat.[157] Indeed, only three commonly used US naval missiles are *not* normally stored and fired by the Mk-41: the *Harpoon* anti-ship cruise missile and its land-attack variant, the SLAM, both of which are fired from fixed, deck-mounted canisters; and the Rolling Airframe Missile (RAM), a short-range SAM fired from a small, deck-mounted, trainable box launcher.[158] The Mk-41 VLS thus led to a reduction in the number of special-purpose missile launchers required aboard US combatants, which further reduced the fleet's maintenance and logistics load.

[154] US batteries consist of either four or eight VLS modules, numbering 32 or 64 cells. Foreign navies that operate the Mk-41 VLS have batteries consisting of one, two, four, five, six, or eight modules, numbering 8, 16, 32, 40, 48, and 64 cells.

[155] Originally, these ships were to have an ability to rearm their VLS cells at sea. A group of three cells in both the forward and after VLS batteries formed "strike-down modules" with a missile handling system, reducing the number of missiles in each magazine from 64 to 61, and total capacity from 128 to 122.

[156] Mk-41 missile cells come in three different types. The shortest "self-defense" cells can accommodate only short-range missiles such as the NATO *Sea Sparrow* or the ESSM. In addition to self-defense missiles, "tactical-length" cells can store and shoot most *Standard* SAMs and ASROCs. The longest "strike length" cells carry all these missiles as well as longer-range *Standard* SAMs, TLAMs, and anti-ballistic missile interceptors. See "Mk-41 Missile Capabilities Today," a chart provided to the author by the Lockheed Martin Corporation. See also Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, pp. 506 and 508-509.

[157] Changing the missile load-outs can take a day or more at pierside, in good weather. From an interview with Captain Jan van Tol, USN (ret), on March 8, 2007. Captain van Tol is a former Navy surface warfare officer who is now a Senior Fellow at CSBA.

[158] Both the *Harpoon* and SLAM could easily be adapted to the VLS.

Finally, older combatants had to remove a missile from their below-deck rotary magazines and to then slide them onto the missile "rails" on the above deck launchers via a complicated hydraulic transfer system. As VLS cells serve as both missile magazine and launcher, the shift to VLS resulted in a far less maintenance intensive and more reliable main missile battery than surface combatants equipped with launch rails and below-deck magazines. One consequence is that VLS-equipped ships require fewer technicians to maintain and operate than legacy "rail"-equipped combatants. Another is that every missile carried aboard a VLS-equipped ship is essentially in a "ready-to-fire" condition, needing only targeting data and a firing command to be sent on its way. By foregoing the need to move missiles from below-deck magazines to above-deck launchers, VLS-equipped ships can achieve higher rates of fire than legacy missile ships. Indeed, one of the reasons the Navy shifted over to the Mk-41 VLS was to take advantage of the Aegis combat system's ability to control multiple missiles in flight.[159]

As a result of their many advantages, vertical launch systems are now standard on most newly constructed surface combatants the world over, and they can also be found on an increasing number of modified legacy ships. However, because it was one of only two early movers toward VLS systems (the other being the Soviet Navy), the US battle fleet now enjoys a commanding lead in the number of fleet VLS cells. As mentioned earlier, the 72 Aegis/VLS combatants now in commission carry among them 7,316 Mk-41 cells, each capable of firing one battle force missile or four short-range defense missiles; the Japanese Maritime Self-Defense Force has the next largest number of operable VLS cells, but its aggregate count now stands at only 632 cells.

The battle line's "secondary battery" is no less impressive, including:

- Either eight deck-mounted canister-launchers for *Harpoon* anti-ship cruise missiles or the land-attack variant of the missile, the SLAM, or space and weight for the same.[160]

- Either one or two 5-inch naval guns, either with 54-caliber or longer 62-caliber barrels. The newer 5-inch/62 version of the gun is intended to fire a GPS-guided, extended range munition, although it has yet to be fielded due to technical difficulties.[161]

- Two *Phalanx* Close-in Weapons Systems (CIWSs), which consist of totally integrated weapon systems including a K_u-band search and track radar, a multi-barrel gatling gun with a rate of fire exceeding 3,000 rounds per minute, a 1,550-round magazine, and

[159] See Polmar, *Ships and Aircraft of the US Fleet,* 18th edition, pp. 506 and 509, and "Mk-41 Vertical Launch System," at http://www.globalsecurity.org/ military systems/ ship/systems/mk-41-vls.htm.

[160] The newest Block 1D version of the *Harpoon* anti-ship cruise missile has a range of 75 nautical miles (nm) and a guidance system that allows for the re-attack of a target if the missile does not acquire it on the first approach. The SLAM has a range or approximately 50 nm. Both missiles carry a 510-pound high-explosive warhead. See data entries for the weapons in Polmar, *Ships and Aircraft of the US Fleet,* 18th edition.

[161] Development on the 5-inch Extended Range Guided Munition (ERGM) began in the 1990s, but the munition has been bedeviled by technical problems. The Navy continues to develop an Extended Range Munition, but technical challenges remain. For a thorough discussion of the development of these rounds, see Government Accountability Office, "Defense Acquisitions: Challenges Remain in Developing Capabilities for Naval Surface Fire Support," GAO-07-115, a report dated November 30, 2006.

supporting electronics in an above-deck mounting. The system, in fleet service since 1980, was originally intended to provide the ship with a last-ditch defense against incoming anti-ship cruise missiles. Today, in addition to protecting the ship from ASCMs, the newest 1B version of the system has been updated to give it an engagement capability against both helicopters and slow-moving aircraft as well as small, fast-moving ("swarming") surface craft.[162]

Finally, each of the ships is able to either hangar or support MH-60R multi-purpose helicopters or MH-60S fleet combat support helicopters. The ships would normally work with MH-60R *Seahawk*, which provides the ship with an over-the-horizon ASW and surface surveillance and attack capability. For surface surveillance, the *Seahawks* are equipped with a multi-mode radar, a forward-looking infrared radar, and an electronic support and countermeasure system. For ASW warfare, the helicopters have a periscope detection mode on their multi-mode radar, a magnetic anomaly detector, low-frequency dipping sonar, and sonobuoys for submarine detection. They can be armed with combinations of ASW homing torpedoes, guns, or small air-to-surface guided missiles.[163]

A Strong Hand, Getting Stronger

While every one of these ships represents a "face card" relative to the vast majority of foreign surface combatants, they can be separated into different types. These types are characterized by the respective "baselines" of their Aegis combat system, which reflect successive upgrades to the system's software, hardware, and combat capability.[164] For example, although all 22 *Ticonderogas* have average full load displacements of 9,877 tons, are commanded by captains, and are configured to perform the Area Air Defense Coordinator (AADC) role for either a Carrier Strike Group (CSG) or Expeditionary Strike Group (ESG),[165] they can be divided into two types.

- The seven "Baseline 2" cruisers are the oldest surviving "*Ticos*," the five earlier "Baseline 0" and "Baseline 1" cruisers having been retired as a cost-saving measure. For the purposes of this report, these seven ships will be referred to as the CG-52 class. Each of the CG-52s is equipped with the earliest version of the SPY-1 radar, the SPY-1A; the oldest and least capable Navy-proprietary computers, known as UYK-7s and UYK-20s; and four fire control illuminators. Their main battery consists of 122 Mk-41 VLS cells. Their secondary battery consists of eight *Harpoons* or SLAMs, two 5-inch/54 naval guns, and two *Phalanx* CIWSs. They can hangar and support two MH-60R (or MH-60S) helicopters.

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[162] See "Phalanx CIWS," assessed online at http://en.wikipedia.org/wiki/Phalanx_CIWS on February 2, 2007.

[163] See "SH-60 Seahawk," accessed online at http://en.wikipedia.org/wiki/Sikorsky_SH-60_Seahawk on February 2, 2007.

[164] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 135.

[165] See LCDR Irene Smith, "AADC Onboard *USS Shiloh* (CG-67)," *Surface Warfare*, July/August 2000, pp. 20-22.

- The 15 "Baseline 3" or "Baseline 4" cruisers, referred to in this report as the CG-59 class, carry the same armament as the "Baseline 2" cruisers. However, they are equipped with the second version of the SPY-1 radar, the SPY-1B, have newer and more capable UYK-43/44 computers, and more advanced combat systems. As one would expect, the 15 more modern cruisers are more capable than the seven older cruisers.

Similarly, the 50 *Arleigh Burke* DDGs in commission today can also be divided into two different types:

- The first 28 "Baseline 4" and "Baseline 5" guided-missile destroyers, referred to hereafter as the DDG-51 class, have average full load displacements of 8,900 tons. They are equipped with the third, more compact SPY-1D version of the SPY-1 radar, a more capable version of the Aegis combat system, a towed-array sonar, 90 VLS cells, eight *Harpoons* or SLAMs, one 5-inch/54 gun, and two *Phalanx* CIWSs.[166] They carry only three missile illuminators rather than the four carried on the guided missile cruisers. They have a landing pad for helicopters, but no hangar. As a result, they can only refuel and rearm helicopters based aboard other ships.

- The remaining 22 DDGs are "Baseline 6" and "Baseline 7" destroyers. Although a variation of the DDG-51, these ships have substantially better combat capabilities, and deserve a separate class designator—the DDG-79 class. The DDG-79s have average full load displacements of 9,250 tons. In addition to having the most up-to-date and most capable versions of the Aegis combat system, compared to the DDG-52s they carry six more VLS cells (for a total of 96 cells), have two helicopter hangars and facilities to support two MH-60 helicopters, and have a new combat direction finding capability. All but the first two of these ships also carry the improved 5-inch/62 gun. To get these improvements, the ships give up the DDG-51's eight *Harpoons* and towed array sonar, although they still have the space and weight to carry both systems.

As if these 72 ships were not enough, the US Navy has even more "cards" up its sleeve: 12 additional DDG-79s under various stages of construction. When the last of these ships are commissioned in late 2010, the US surface battle line will count seven CG-52s, 15 CG-59s, 28 DDG-51s, and 34 DDG-79s. With the seven planned DDG-1000s not yet in the fleet, the 84 Aegis/VLS warships will be only four ships short of the 313-ship fleet's combined objective of 88 guided-missile cruisers and destroyers. With regard to specific ship types, the battle line will be three CGs over the battle fleet's objective requirement for guided-missile cruisers, and right on its objective requirement for legacy DDGs.

THE DDG-1000/CG(X): TIME TO GO "ALL IN"?

One of the defining institutional characteristics of the US Navy is that it is ever-fearful that an opposing player might draw some higher "cards" and win even a single "hand" in the naval

[166] The first 28 *Burkes* carry a 32-cell VLS battery forward and a 64-cell battery aft. Like the *Ticonderogas,* each of the batteries has a 3-cell strike-down module, reducing the total ship cell count by six.

transformation game. In some instances, this inner fear of losing has positive effects. For example, once the Navy decided to compete against other naval powers, it helped to power the US Navy from having the twelfth biggest "stack" of naval capabilities in 1883 to the second biggest "stack" in little more than 20 years, and to take the "chip lead" away from the British Royal Navy in 1945. However, the institutional fear of losing even a single "hand" can also have a negative effect on way the Navy approaches its transformation plans—chief among them an inability to play conservatively even when holding a big capabilities lead.

The move toward the DDG-1000/CG(X) is a case in point. As discussed earlier, the Navy has just been dealt a "pair" of DDG-1000s—a hand for which it has been impatiently waiting for over a decade. As discussed in the first chapter, despite its already commanding capability lead, the Navy appears ready to raise the stakes and to go "all in," seeking to run more and more competitors out of the naval transformation game and adding to its already imposing stack of capability "chips." While bullying the other players at the table with a big chip lead is certainly a tried and true poker tactic, as an earlier generation of players found out in the years immediately following World War II, "playing loose" so early in a new game and making big "bets" on the lure of a promising new combat platform or capability can be a risky move.

As a result, the Navy would do well to take its time and carefully reconsider its next move. As was the case in the early post-World War II era, the first post-Cold War assumptions made about the DD-21/DD(X)/DDG-1000's primary mission now appear outdated, if not wrong; assumptions made about radar stealth that drove the selection of the ship's unique hull form are now open to new interpretation; and ship design decisions made during a period when requirements were generally unconstrained by budget considerations now put the Navy's overall transformation strategy at risk. All of these circumstances should make current players pause before mindlessly betting more on the new ship.

Recall that the basic mission that drove the original design of the DD-21 was the "rapid halt" of two cross-border armored invasions of US allies using guided weapons bombardment. However, the attacks of 9/11 and the subsequent war on terror challenged both the basic assumptions of the two-war strategy as well as the strategic implications of the guided weapons warfare revolution. As was written in the new *National Security Strategy*, published one year after the September 11, 2001 attacks, "America is now threatened less by conquering states than we are by failing ones. We are menaced less by fleets and armies than by catastrophic technologies in the hands of the embittered few."[167] The strategy's clear de-emphasis on "conquering states" was picked up and amplified in the subsequent *National Military Strategy of the United States of America*, published in 2004, and again in the new *National Defense Strategy of the United States*, published in 2005.[168] These documents identified a much wider range of potential *non-*

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[167] President George W. Bush, *The National Security Strategy of the United States of America* (Washington, DC: The White House, September 17, 2002), found at http://www.globalsecurity.org/military/library/policy/national/nss-020920.pdf.

[168] General Richard B. Myers, USAF, Chairman of the Joint Chiefs of Staff, *National Military Strategy of the United States of America: A Strategy for Today, a Vision For Tomorrow* (Washington, DC: Joint Chiefs of Staff, 2004), found at http://www.globalsecurity.org/military/library/policy/dod/d20050318nms.pdf; and Donald H. Rumsfeld, Secretary of Defense, *The National Defense Strategy of the United States of America* (Washington, DC: Office of

traditional defense challenges than those "posed by states employing recognized military capabilities and forces in well understood forms of military competition and conflict."[169]

These new non-traditional challenges include:

- *Irregular challenges* involving state and non-state actors employing "unconventional" methods such as terrorism, insurgency, and civil war, to counter stronger state opponents;

- *Catastrophic challenges* involving terrorists or rogue states employing weapons of mass destruction, or WMD-like effects against the United States or its allies; and

- *Disruptive challenges* involving competitors employing "breakout technologies or methods" like directed energy or space weapons that canceled US traditional military superiority.[170]

Upon reflection, these new challenges describe the three most logical reactions to the US superiority in *traditional* conventional campaigns in the mature guided weapons warfare regime. Irregular challengers seek to avoid US superiority in guided weapons warfare by refusing to mass, thereby denying US battle networks a clear target, and by employing unconventional operational approaches that often emphasize close-in "ambush tactics" using improvised explosive devices, rocket-propelled grenades, and man-portable surface-to-air missiles. Catastrophic challengers seek to deter or offset US conventional guided weapons superiority with weapons of mass destruction. Finally, disruptive challengers seek to leapfrog US guided weapons dominance by seeking an alternative revolution, perhaps by harnessing the power of robotics, nanotechnology, or directed energy weapons. The key link between these three challenges is that they all seek to change the rules of guided weapons warfare which favor the US military in conventional one-on-one fights. The basic message of this new framework thus seems quite clear: *while the Department of Defense (DoD) may implicitly anticipate an enduring US superiority in the guided weapons warfare regime, it is now more interested in planning for adversary reactions to this superiority rather than counting on their acquiescence to it.*

Given this major change in strategic thinking, is the production of a super-expensive, stealthy guided-missile "destroyer" armed with 80 VLS cells and two 155mm guns really the best next step toward a transformed surface battle line? Isn't there a good chance that the post-Cold War Navy is about to repeat the same initial mistake made by the post-World War II Navy, confronting the wrong threat with the wrong ship—and one too big and expensive to buy in quantity in any case?

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the Secretary of Defense, March 2005), found at http://www.globalsecurity.org/military/library/policy/dod/nds-usa_mar2005.htm.

[169] See both Myers, *National Military Strategy of the United States of America: A Strategy for Today, a Vision For Tomorrow;* and Rumsfeld, *The National Defense Strategy of the United States of America.*

[170] Myers, *National Military Strategy of the United States of America: A Strategy for Today, a Vision For Tomorrow,* pp. 4-5.

Proponents of the ship could reasonably argue that the Navy has already corrected its initial mistake, as evidenced by its redesign of the ship's combat system to make it a multi-mission air defense ship. In line with this thinking, the Navy states that although the DDG-51/79 and DDG-1000 can support roughly equal numbers of simultaneous missile engagements, and that the radars on the DDG-1000 and DDG-51 are roughly equivalent in terms of sensitivity and target resolution, the "firm track range" of the DDG-1000's newer dual-band radar—the range at which it can maintain firm tracks on targets—is 25 percent greater for that of the DDG-51's SPY-1D radar when the ships are operating amidst littoral clutter. In addition, the DDG-1000's radar has much more capability for resisting enemy electronic countermeasures. When combined with the ship's much-greater communications and networking bandwidth capabilities, the Navy believes that by replacing one DDG-51 with a DDG-1000, a carrier strike group's AAW capability would be improved by about 20 percent.[171]

Even if these claims prove to be true, their significance may be less than meets the eye. For example, the very same dual-band multi-function radar that gives the DDG-1000 so much of its improved air defense capabilities will soon go on the battle fleet's new nuclear-powered aircraft carrier, the CVN-21. In other words, over time, every carrier strike group will get one of the new radars—whether the Navy builds the DDG-1000 or not. Moreover, the Navy could easily put the radar on the newest amphibious warship, the LHAR, giving each future expeditionary strike group a SPY-3 of their own. In any event, if the Navy wants to put the radar on a surface combatant, does it really need to go on a 14,500-ton ship? Not likely. Unfortunately, however, the DDG-1000 can't get much smaller, primarily because of the design characteristics of its wave-piercing tumblehome hull, a design choice based on some key assumptions about radar stealth. The ship has already been reduced by some 4,000 tons, losing one-third of its planned missile battery and one-half of its planned gun magazine capacity in the process. Indeed, the cut in its displacement may have also rendered the ship incapable of carrying the follow-on CG(X) combat system, although until the combat system is down-selected in late 2008 or early 2009, the Navy will not be sure one way or the other. In any event, the key point is this: while the hull can likely be "stretched" to accommodate the CG(X) combat system, it cannot be further reduced.

Those in the "Requirements School," who a decade ago argued so forcefully for a low ship radar cross section, would likely say that the ship's new hull form and size is more than worth it, no matter what its fiscal ramifications. But this argument, debatable even ten years ago, may now be based on assumptions about radar stealth that are outdated. As one respected naval analyst recently wrote:

> About a decade after the requirements were chosen, with [DDG-1000] well advanced, the situation with regard to stealth may be changing. Shaping is relevant only at relatively short [radar] wavelengths. For about a quarter-century, there has been talk of HF surface wave radars, which operate at wavelengths of about 10 to 200 meters—i.e., at

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[171] Points taken from Statements of Admiral Vern Clark, US Navy, Chief of Naval Operations, The Honorable John J. Young, Jr., Assistant Secretary of the Navy (Research, Development and Acquisition), and RADM Charles S. Hamilton, II, Program Executive Officer for Ships, given before The House Armed Services Committee Projection Forces Subcommittee, July 19, 2005, as cited in O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," pp. 17-18.

> wavelengths the size of a ship. Canada currently operates this type of radar, made by Raytheon, for surveillance of the Grand Banks; another is being tested in the Caribbean. Australia has bought this kind of radar to fill gaps in over-the-horizon radar coverage. In 2005 it was reported unofficially that China had bought [a] Russian HF surface wave radar the previous year.
>
> It seems almost certain that HF surface wave radar can defeat any kind of stealth shaping designed primarily to deal with shorter-wave[length] radars. Moreover, [HF surface wave] radars have an inherent maximum range (due to the way they operate) of about 180nm.... At long range [the radar's beam] is not nearly accurate enough to aim a missile. However, we can easily imagine a netted system which would use the long-range [HF surface wave] radar to define a small box within which the target ship would be. A missile with [Global Positioning System] guidance could be flown to that box, and ordered to search it....
>
> If the argument given here is realistic, then the considerable sacrifices inherent in the [DDG-1000] design no longer seem nearly as attractive. It can still be argued that a design like the DD(X) is attractive well out to sea, beyond the reach of coastal radars. In that case, however, there may be other signatures which can be exploited. For example, ships proceeding at any speed create massive wakes....it is clear that the wake produces a radar return very visible from an airplane or, probably, from a space-based radar....
>
> In the end, then, how much is stealth worth? As a way of avoiding detection altogether, probably less than imagined. That leaves the rather important endgame, the hope being that decoys of some sort greatly exceed actual ship radar cross-section. That is probably not a foolish hope, but it does not require the sort of treatment reflected in [the DDG-1000]. Now, it may be that the United States typically faces countries which have not had the sense to buy anti-stealth radars (though we would hate to bet on that). In that case, [DDG-1000] may well be effectively invisible to them. So will a lot of less thoroughly stealthy ships.[172]

As this passage suggests, then, the requirements and assumptions about radar stealth that drove the design of the DD-21—and which still dominate the design of the DDG-1000—no longer appear so pressing or valid. These circumstances are similar to the ones associated with the *USS Norfolk* roughly six decades ago, when the diminishing need to maintain 30 knots in rough seas and the shift from unguided to guided ASW weapons meant that the money invested in the *Norfolk's* extra size, space and weight would not pay off over time. In a like way, improvements in ISR suggest the money invested to make the ship so stealthy will pay less and less dividends over time. This is especially true since the ship's conversion into, and reclassification as, a fleet air defense ship. Since the ship's radar will need to be constantly radiating to accomplish its new mission, it will be easily trackable by even the most basic electronic support measures (ESM). Moreover, instead of patrolling independently close to shore, standing ready to blunt a surprise armored invasion—circumstances where stealth might make a major difference, the ship will now most often operate as part of an expeditionary strike group of very high value, high-

[172] Friedman, "The New Shape of Ships," pp. 62-63.

signature ships. Under these circumstances, "indistinguishability" among the ships in the ESG formation may be a better approach than stealth for the escorting ship, which may actually work against its reason for being—that is, protecting the formation's high-value units.[173]

Second, and perhaps more importantly, how much can the Navy *afford* to pay for a ship like the DDG-1000 in a fiscal environment that is now tight and likely only to get tighter? The Navy can be heartened that several lawmakers are now arguing for an increase in the Navy's shipbuilding rate.[174] However, it is difficult to see where this money would come from, or how a major increase in shipbuilding could be sustained over time. While Congressional and Navy leaders can hope that the additional costs will be paid for by major increases to future defense budgets, this does not seem to be a safe bet. Although the US defense budget is now a relatively low percentage of Gross Domestic Product (GDP), counting the supplementals needed to pay for operations in Afghanistan and Iraq, the United States is now spending more per year in inflation-adjusted dollars than at any time since World War II.[175] At the same time, the pressure on government mandatory spending—due primarily to increases in personal entitlement programs such as Social Security—is now much higher than at any time in the past, and it will get even higher as the first of the "baby boomers" begin to reach retirement in 2008. Of course, as mandatory spending increases, discretionary spending naturally decreases. The Government Accounting Office, the investigative arm of Congress that audits and evaluates the performance of the federal government, forecasts that increases in mandatory spending for entitlement programs and continuing deficit spending will result in a "fiscal tsunami" in the next decade unless major changes are made.[176] Perhaps as a result, President Bush has recently stated his intention to balance the federal budget within five years, and the House is pressing for so-called "pay-go" legislation that requires increases to the federal budget to be offset by either spending reductions or revenue increases.[177] All these circumstances indicate that a major sustained defense budget build-up is not in the cards, and that a real decrease in overall defense spending is a distinct possibility.

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[173] In a study on carrier vulnerability, the authors noted that of the 135 Navy ships involved in *Desert Storm,* only six were aircraft carriers. If all would have been indistinguishable in terms of signature, at worst there would have been only a 5 percent chance the aircraft carrier could have been targeted and attacked. Costa S. Vatikiotis and Thomas D. Taylor, *Signature Management Alternatives for Future Aircraft Carrier Survivability,* a Center for Naval Analysis report cited in Roger W. Barnett, "Surface Ship Survivability Risk Management and Network Centric Warfare," Strategic Research Department Research Report 12-98, US Naval War College, July 1998, p. 5.

[174] See for example Jen DiMascio, "Murtha Seeks Additional Funding For Air Force Planes, Navy Ships," Defense Daily, February 13, 2007.

[175] See Graph 3, "National Defense Outlays as a Share of GDP," and Table 2, "National Defense (050) Budget Authority, FY 1946-FY 2011," in Steve Kosiak, Analysis of the FY 2007 Defense Budget Request (Washington, DC: Center for Strategic and Budgetary Assessments, April 2006).

[176] Matt Crenson, "GAO Chief Warns Economic Disaster Looms," accessed online at http://www.examiner.com/ a-367406~GAO_Chief_Warns_Economic_Disaster_Looms.html on October 30, 2006. See also Government Accounting Office, "The Nation's Long-Term Fiscal Outlook, September 2006 Update; The Bottom Line: Today's Fiscal Policy Remains Unsustainable," GAO publication GAO-06-1077R.

[177] Peter Baker, "Bush Signals Budget Accord," *Washington Post*, January 4, 2007, p. A1; and Richard Kogan, "The New Pay-As-You-Go Rules in the House of Representatives," Center on Budget and Policy Priorities, January 12, 2007, accessed online at http://www.cbpp.org/1-12-07bud.htm on February 2, 2007.

Even assuming that future defense budgets remain relatively flat rather than decline, the shipbuilding budget will compete with equally pressing DoD priorities. For example, Congressional leaders on both sides of the aisle are arguing for more money to "reset" the ground forces and to increase their overall size.[178] The Army alone will need $70 billion over the next five years to increase in size to 547,000 active personnel, and additional tens of billions of dollars to pay for replacement or rebuilt equipment damaged during operations in Afghanistan and Iraq. [179] Indeed, bowing to Congressional pressure, the President recently ordered that money requested for aircraft found in recent supplementals be redirected to pay for the immediate costs associated with ground force needs.[180] It is thus difficult to conclude that building extra ships the Navy says it does not immediately need to build toward its 313-ship goal will survive budget scrutiny. On balance, then, even if the prospects for short-term shipbuilding increases may at first glance be going up, the probability that the Navy will be able to maintain an average shipbuilding budget of $15.4 billion a year over the next 30 years appears to be going down.

In sum, the opportunity costs associated with building the large, technologically sophisticated, and expensive DDG-1000s and CG(X)s appear to be too high given the likely future budget environment—just as was the case with the USS *Norfolk* six decades ago.

THE DDG-1000/CG(X): OR TIME TO "FOLD"?

Given these circumstances, the logical follow-on question is: Wouldn't it be wiser for contemporary surface warriors to follow the lead of an earlier generation of players and "fold its hand"—that is, to stop producing the DDG-1000, and instead opt to pursue a different, more affordable battle line combatant?

Admittedly, after sinking so much time and effort into building the DDG-1000, "folding" (i.e., cancelling) the ship would be a tough pill to swallow, especially for those from the "Requirements School," who would undoubtedly argue that the Navy is already "pot committed" to the DDG-1000/CG(X). In other words, it simply can't afford to just walk away from fiscal and capability "chips" it has already "bet" on the ship. This would be an especially powerful argument if walking away from the DDG-1000 threatened in any way to cut into the dominant "chip lead" now held by the US Navy. However, it would be difficult, if not impossible, to make such a case.

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[178] For a good synopsis of the issues surrounding the increase in US ground forces, "Expanding the US Army: Costs, Constraints, and Future Commitments," *International Institute for Strategic Studies*, Vol. 13, Issue 1, February 2007.

[179] The Department of Defense recently announced the expansion of the US Army and Marine Corps by 92,000 troops. The costs for the Army alone will be $70 billion over the next five years. The Army has also testified that even if the was in Iraq stopped today, it would take three years to replace or rebuild damaged equipment; next year's request for replacing equipment will be "at least" $13.5 billion. See "Larger Army to Cost $70 Billion," found at ausa.org on March 6, 2007.

[180] See "Bush Seeks to Redirect Some Defense Outlays," *Wall Street Journal*, March 13, 2007.

The combat capability of 2011 surface battle line will be astounding. With each BFC warship carrying between 90 and 122 individual VLS cells, the entire 84-ship force will form a distributed, guided-missile battery of 8,468 multi-mission VLS cells. *This is a greater cumulative magazine capacity than that found on 366 major surface combatants in the world's next 17 largest navies.*[181] Indeed, the fleet's aggregate missile magazine is so large that it is unlikely that the Navy can afford to maintain the weapons inventory necessary to provide one weapon for each cell in the fleet. Nevertheless, the large magazine capacity is useful should the US find itself in a major naval competition, since it will be easier to build additional weapons rather than additional ships to carry and employ them.

Moreover, the surface fleet's combat capability is multiplied because the Mk-41, unlike VLS systems in other some other navies—the Russian and Chinese among them—is a true *modular* missile system. That is, it can easily accept a wide range of *battle force missiles*, including anti-submarine, anti-air, anti-missile, and land-attack missiles.[182] As a result of its multi-mission, modular weapons battery, the US battle line can therefore be optimized to meet the most likely tactical threats in any campaign. Even if faced by a range of threats, because of its sheer number of VLS cells, the battle line will be able to protect both itself and other ships in the battle force, from attacks in three dimensions (air, surface, and subsurface), while at the same time conducting guided-missile weapon strikes out to ranges of about 1,000 nautical miles. The fleet's combined secondary battery will be equally impressive, as it will include 106 5-inch naval guns, up to 672 *Harpoons* or SLAMs, 168 *Phalanx* CIWSs, and 504 ready-to-fire homing ASW torpedoes (with more in their magazines). The force will also be able to hangar up to 112 MH-60R *Seahawk* helicopters.

For at least the next two decades, it is very unlikely that there will be another navy that will be able to compete with this formidable line of battle. The Navy's own shipbuilding plan for surface combatants supports this claim. Given the planned slow procurement rate for DDG-1000s and CG(X)s, the same 84 ships will still be in commission in 2020, along with just ten new generation ships; 20 years from now, in FY 2027, the numbers will be 65 and 23, respectively. The planned new generation of ships will not surpass the old one in terms of numbers until FY 2034, and the fleet will be 15 ships below the requirement for 88 guided-missile cruisers and destroyers when it does. In other words, the Navy is *betting* that the current generation of Aegis/VLS ships will retain their "face value" and be able to best all potential future opponents through 2030.

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[181] The data represents the magazine capacity found in major warships in the rest of the world navies on January 1, 2005. See Robert O. Work, *To Take and Keep the Lead: A Naval Fleet Platform Architecture for Enduring Maritime Supremacy* (Washington, DC: Center for Strategic and Budgetary Assessments, December 2005).

[182] For the purpose of the this report, battle force missiles include long-range SAMs, anti-submarine rockets, anti-ship cruise missiles, land attack cruise missiles, and ballistic missile interceptors. Ship self-defense missiles such as the *Evolved Sea Sparrow Missile* (ESSM) and the Rolling Airframe Missile (RAM) are not included in this category. While the RAM is fired from an above-deck, trainable launcher, on US BFC combatants ESSMs are fired from VLS cells. As mentioned earlier, four ESSMs can be carried in a single VLS cell in place of a single battle force missile.

While all this may be true, the "Requirements School" would undoubtedly lament the loss of the DDG-1000's new stealthy land-attack capabilities. However, by virtue of the Navy's decision to equip its attack submarines with VLS cells, and to convert four former strategic ballistic missile submarines into conventional cruise missile/special operations transport submarines (SSGNs)—each capable of carrying up to 154 TLAMs—the US submarine fleet will soon reinforce the 8,468 VLS cells carried on 2011 surface battle line with more than 1,000 additional covert VLS cells. Although the VLS cells found on fleet SSNs and SSGNs cannot at this time fire surface-to-air missiles or ASROCs, they don't need to. The platforms that carry them are the stealthiest in the fleet; they are impervious to anti-ship cruise missiles and quite capable of defending themselves against submarine targets. Said another way, submarines do not have to waste missile magazine space on defensive missiles. They can instead optimize their missile loads for offensive land- attack.[183] Accordingly, the best way to look at the combined submarine VLS magazine is that it represents the equivalent land-attack missile firepower of more than 12 *less stealthy* DDG-1000s.

When the VLS missile firepower carried on the battle fleet's surface combatants and submarines are combined with the aviation and missile firepower carried by the aircraft found on each of the Navy's 10 deployable nuclear-powered aircraft carriers, the combined 2011 battle force will number nearly 10,000 VLS cells and have the theoretical aviation strike capacity to attack over 10,000 aimpoints *a day*. As suggested by these staggering numbers, the "10,000-cell/10,000-aimpoint" fleet will have striking power to spare. It seems apparent that a decision to walk away from the DDG-1000 would have no impact whatsoever on the fleet's overmatching offensive firepower against any conceivable near- or mid-term opponent. The two possible exceptions to this conclusion are the loss of the DDG-1000's new AGS and its ability to handle larger, longer, and heavier land-attack missiles by virtue of its new peripheral vertical launch system. But even these losses are not as significant as they first appear.

With regard to naval surface fire support, the Navy continues to pursue a 5-inch guided munition for its new 5-inch/62 gun with an objective range of 63 nm. Although the range and lethality of this round will not rival that of the DDG-1000's 6-inch LRLAP, the 84-ship Aegis/VLS fleet will carry a total of 106 5-inch guns compared to the 14 6-inch AGSs carried on seven DDG-1000s—providing joint forces operating ashore with a far more flexible offshore fire support force. In any event, if fleet planners decided they needed the added capabilities of the AGS, they could backfit the gun on existing platforms.[184] Alternatively, it could also forward-fit the guns on platforms now in production. One option, for example, would be to modify a LPD-17 amphibious landing ship to carry two of the AGSs. True, the guns would not be on a hull as stealthy as the DDG-1000. However, the acoustical signature of its guns, the emissions from its air defense radars, as well as the constant flights of helicopters to and from a DDG-1000 necessary to keep its "infinite magazine" filled would under any circumstances negate many of

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[183] Moreover, in the future the submarines may gain a similar measure of multi-mission VLS capabilities with the ongoing development of buoyant launch canisters that float to the surface, right themselves, and fire their weapon. These canisters could carry and fire virtually any type of weapon.

[184] For example, three naval officers determined that the AGS could be back-fitted on Cold War *Spruance*-class destroyers. See Higgins Rhoades, and Roach, "Advanced Gun System (AGS) Backfit."

the ship's stealth advantages while operating on a gun line, except when defending itself from missile attack.

A similar argument can be made for the DDG-1000's new VLS system. The current standard "strike length" Mk-41 VLS handles weapons up to 21.3 feet in length, 21 inches in diameter, and 3,000 pounds. The new VLS system will be able to handle weapons up to 22 feet in length, 24 inches in diameter, and 4,000 pounds.[185] Notwithstanding the fact that there are no new larger land-attack missiles planned, much less in production, the Mk-41 VLS system has already demonstrated the ability to fire larger-diameter and heavier missiles. At one time the Navy planned to incorporate the Army Tactical Missile System (ATACMS) into the battle fleet. Using a specially-designed, thin-walled VLS launch canister, engineers were able to fire the 24-inch diameter, 3,647-pound missile from the Mk-41 VLS.[186] Alternatively, a 6x6 battery of 28-inch square VLS cells (same size as those found on the DDG-1000) could easily fit in the same hull space now dedicated to an 8x8 battery of 25-inch square Mk-41 cells found on every Aegis/VLS combatant. If these new 28-inch cells were designed to "dual-pack" 13-inch missiles, like the current Mk-41 cells "quad-pack" 10-inch diameter ESSMs, the battery could carry either 36 large-diameter missiles or 72 SAMs, or ASROCs, or anti-ballistic missile interceptors, or a combination thereof. The point here is that just as an earlier generation of surface warfare officers discovered when they placed a new generation of ASW weapons on legacy World War II destroyers, there are ways to get the same missile firepower capabilities into the legacy Aegis/VLS fleet without building the larger DDG-1000.[187]

Being unable to change their basic instincts, those in the "Requirements School" would next likely point out that the introduction of the DDG-1000's new integrated electric power and propulsion system, a shift the Navy believes will be as profound as it's earlier shift from sail to steam, will more than justify the ship's high up-front costs. At first glance, this is another attractive argument. It is impossible to ignore the potential fleet-wide benefits that would come from moving toward an all-electric fleet. Being able to distribute an IPS's components around the ship, as well as decoupling the ship's propulsion train from long, fixed propeller shafts and complicated reduction gears, would result in quieter, more survivable ships with higher fuel efficiencies. Additionally, a move toward IPSs will surely open the way toward a new generation of electrically-powered weapons. Nevertheless, there are several good reasons why the Navy might want to delay the DDG-1000 and the fleet-wide transition towards an IPS.

First, while electric propulsion systems have been long used on commercial ships and naval auxiliaries, electric propulsion systems for warships are still very much on the lower part of the

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[185] O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," p. 20.

[186] Norman Polmar, *Ships and Aircraft of the US Fleet,* 16th Edition (Annapolis, MD: Naval Institute Press, 1997), p. 444, and discussions between this author and Lockheed Martin VLS engineers on December 13, 2006.

[187] While there are no plans to do so, there would be no reason why such an option, or one like it, could not be pursued. From discussions between this author and Lockheed Martin VLS engineers on December 13, 2006.

technological “S-curve.”[188] For example, the objective electric motor for the DDG-1000 was the permanent magnet motor (PMM). Due to its higher power densities, variations of the PMM can likely be used in both surface combatants and submarines, offering the prospect of substantial reductions in fleet-wide operations and maintenance costs. Unfortunately, technical issues with the PMM, primarily with the motor’s insulation, caused unexpected delays in its development. As a result, the Navy was forced to go to the heavier, less efficient, but more mature Advanced Induction Motor (AIM) on at least the first two DDG-1000s.[189] The Navy still hopes to shift to the PMM in the future, but that would result in two different electric motors in fleet service. In other words, the Navy’s current plan will magnify the problems associated with the fleet-wide transition from gas turbine to electric propulsion motors by establishing *two* new logistics and support tails. Moreover, it is not yet clear that the PMM is itself the final, best answer for warship electric drive systems. Two other potential options are the high-temperature superconductor motor and the superconducting homopolar motor. The earliest these newer, more capable electric drive technologies will be ready for operational service is 2009 to 2012.[190] Delaying the building of the next surface combatant for several years would allow electric motor technology to more fully mature before the Navy “down-selects” to *one* best electric motor option.

Second, weapons such as the electro-magnetic rail gun or shipboard lasers are still years away from being perfected, much less being converted into operational systems. Using the undeniable promise of these weapons as grounds to make a move toward the DDG-1000 and its IPS now is therefore a stretch.

Third, delaying the building of the next surface combatant would also have another benefit: the Navy could revisit its previous decision to forego building *nuclear-powered* BFC combatants. All US submarines commissioned since 1959 and aircraft carriers commissioned since 1975 have been nuclear-powered. Up through the mid-1970s, the Navy’s nuclear propulsion community had sought to build up to four nuclear-powered multi-mission guided-missile cruisers for each carrier. Through sheer force of personality, the legendary Admiral H.G. Rickover, long-head of naval nuclear propulsion programs, convinced Congress to specify in the FY 1975 Defense Appropriation Authorization Act that all future multi-mission surface combatants be nuclear powered. Ironically, however, the last US nuclear-powered cruiser (CGN) was authorized in FY 1975. Moreover, because of their limited capabilities—none were equipped with the Aegis combat system, VLS, or an ASW helicopter capability—the last of the nine US guided-missile

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[188] The development of new technologies has long been described by an S-shaped curve. Because the understanding of and theoretical and engineering concepts behind new technologies develop at a slow rate, the rate of early technological development is slow, as represented by the shallow curve on the lower portion of the “S-curve.” This is followed by a period of rapid change as the theoretical and engineering concepts needed to exploit the technology are rapidly translated into practical solutions. As the technology matures, however, the rate of change begins to slow, as represented by the flatter portion of the upper part of the “S-curve.”

[189] Lundquist, “All-Electric Propulsion—A Viable Way Ahead?,” p. 63.

[190] See John Kenkel, “Drive Time: Firing Up Electric Propulsion,” *Jane’s Navy International*, November 2006. pp. 16-18; and Andrew Koch and Richard Scott, “US Navy Signal Intentions for Provision of DD(X) Propulsion,” *Jane’s International Defense Review*, June 2005, p. 12.

cruisers the Navy actually built was decommissioned in 1999 after only 25 years of service. Indeed, only two of the nine ships remained in commissioned service for more than 30 years, and four were retired before they saw their twentieth year.[191]

It is generally accepted that nuclear-powered ships cost more to build than conventionally-powered ships, but have lower operating and support costs when lifetime ship fuel costs are considered. The Navy estimates that the break even costs per barrel of crude oil at which nuclear propulsion becomes economical are more than $200 per barrel of oil for small surface combatants and amphibious ships and $70 per barrel for medium surface combatants. With fuel costs climbing, demands for shipboard electrical generation capacity rising rapidly, and new combat systems and weapons gaining weight, it may make sense to revisit the decision on nuclear power for large, multi-mission BFC combatants. This is especially true given recent Congressional interest in pursuing more nuclear-powered ships. A delay would allow a more thorough detailed design process to better determine the tradeoffs of trading gas turbines for nuclear reactors in future major surface combatants.[192]

Fourth, even if the Navy determines it is best to start the general transition toward an IPS sooner rather than later, the system is not limited to a 14,500-ton hull. Indeed, the new British Type 45 destroyer, with a full load displacement about half that of the DDG-1000, will have an IPS using the same AIM technology found on the first two DDG-100s.[193] Any decision to pursue the IPS can therefore be effectively separated from the decision to continue building the DDG-1000.

In the 1950s, the pause between the *Norfolk* and the *Mitschers* and the new Cold War generation of ships designed for combat against jets, missiles, and nuclear submarines helped the Navy work out bugs in new propulsion systems, combat systems, and weapons. In a similar way, "folding" the DDG-1000 would give the Navy more time to identify the most promising new electric propulsion motors, work out the bugs in new electrically-powered weapons, determine if future BFC combatants should be nuclear powered, and explore smaller, perhaps less expensive ship designs.

The last argument of the "Requirements School" would likely be that cancelling the DDG-1000 would squander the money already "bet" on improving surface combatant survivability. Their argument that the ship's extremely low all-round signature, new damage control features such a an autonomic fire suppression system, and peripheral VLS cells will make the new combatant "significantly" more survivable than the DDG-51/79 is most likely true.[194] But once again, even

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[191] See Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 137.

[192] Geoff Fein, "Nuclear Surface Ships Have Lower Operating Costs But More Expensive to Build, Navy Says," *Defense Daily*, March 5, 2007; see also Rebecca Christie, "US Rep. Expects Congress to Add Ships to Defense Budget," *Dow Jones Market Watch*, January 7, 2007.

[193] Kenkel, "Drive Time: Firing Up Electric Propulsion," p. 16; Lundquist, "All-Electric Propulsion—A Viable Way Ahead?," p. 63.

[194] O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," p. 18.

if that is the case, the most important question facing current players in the naval transformation game is whether the *marginal* increase in the DDG-1000's survivability is worth its much greater costs and its potential negative impact on the Navy's overall shipbuilding and transformation plans.

It is not as if the *Burkes* have glass jaws. If they are not the toughest warships in the world today in terms of active and passive defenses, they are among the top contenders. As the last surface combatant designed during the Cold War, the DDG-51 took into account the lessons learned from the naval battles fought during the 1982 Falklands War.[195] As a consequence, it was the first US post-World War II combatant for which a concerted effort was made to reduce its overall radar cross section. The result was a low observable warship that is 50 times more difficult to detect with radar than a CG-52/59.[196] The ship was also built to take a hit and continue to fight. Constructed entirely of steel, the ship was given special features to increase its resistance to blast, shock, fragmentation and fire damage, including 130 tons of Kevlar armor over the ship's vital spaces. Its Combat Information Center (CIC) is located within the hull below the main deck, and its combat system is designed as a distributed architecture that "degrades gracefully" with combat damage. Additionally, the ship has a wide passageway that runs down the outer hull on both sides of the ship, providing additional standoff blast and fragment protection for internal ship compartments. Finally, the ship is specially protected against nuclear electromagnetic pulse effects and blast overpressure, and has a full-time, full-coverage, four-zone collective protective system (CPS), which protects the crew from chemical, biological, and radiological contamination.[197]

The DDG-79 class is tougher still, incorporating lessons learned during the Operation *Desert Storm*. While the ships lost one CPS zone, they gained five additional blast-hardened bulkheads. Four of them were placed fore and aft of the ship's two engine rooms for added survivability. Additional damage control features and improvements were also included. Besides being able to better take a hit, the DDG-79s can better slip punches and have a longer reach than the DDG-51s. With regard to the former, based on the experience of operating ships in the confines of the northern Arabian Gulf—waters mined by the Iraqi Navy—the Navy gave the new class the Kingfisher mine avoidance sonar. With regard to the latter, the ship gained two helicopter hangars, giving it a full helicopter capability lacking on the earlier *Burkes*. When operating independently, the addition of an onboard helicopter allows a DDG-79 to expand its sensor horizon and to address both submarine and surface threats at far greater ranges from the ship.[198]

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[195] Secretary of the Navy John Lehman convened a special board to consider design revisions on the DDG-51 suggested by the naval battles off of the Falkland Islands in 1982. These battles saw a British naval task force at the end of a distant supply tether fighting off determined air attacks by Argentinean jet aircraft. Friedman, *US Destroyers*, revised edition, p. 419. For a description of the naval battles off the Falklands, see Max Hastings and Simon Jenkins, *The Battle for the Falklands* (London: WW Norton & Company, 1983).

[196] "DD(X) Media Roundtable," a PowerPoint presentation developed by the Program Executive Office of Ships and the Program Executive Office for Integrated Warfare Systems, dated June 30, 2005.

[197] Friedman, *US Destroyers*, revised edition, pp. 417-421.

[198] Friedman, *US Destroyers*, revised edition, pp. 426-427.

Of course, using active ship defenses to counter-punch out of trouble also contributes to a ship's survivability. In this regard, both *Burkes* stand up very well to the DDG-1000. They carry a heavier missile armament—96 to 98 battle force missiles to the DDG-1000's 80.[199] After stripping out all the requirements speak, by the Navy's own reckoning, the DDG-1000s will have better littoral anti-air warfare capabilities than the *Arleigh Burke* DDGs, while the *Burkes* will be better open ocean air defenders than the newer ships. Depending on the type of threat and operational scenario, the two ships run neck and neck as cruise missile defenders, and they are roughly comparable in anti-submarine warfare capabilities.[200] Moreover, as discussed earlier, while a DDG 1000's 6-in guns will fire more lethal rounds over longer ranges than either the *Burke's* or *Tico's* smaller 5-inch guns, 106 smaller guns distributed across 84 ships provide a far more flexible gunfire support force than having 14 larger guns on the just seven DDG-1000s.

As a result of Admiral Kelso's wise decision to continue building these superb, robust guided-missile destroyers after the Cold War ended, in 2011 the US battle line will boast 62 of these all-steel, low-observable, extremely powerful, and extremely tough surface combatants—all far tougher than most, if not all other combatants in the world. Indeed, because of rising ship construction costs, more and more navies are building surface combatants to commercial standards; duplicating the damage limitation features of even the DDG-51s and -79s are simply beyond their means. The *relative* toughness of these warships is thus growing, not shrinking. While the *Burkes* may not be as individually survivable as a DDG-1000, might not their own high degree of survivability be "good enough" for the next two decades or so? One would hope so. As the Navy's own transition plan suggests, the successful outcome of any war at sea fought over the next 20 years will rest on the offensive and defensive capabilities of these 62 ships, as well as those of the 22 *Ticos*.

Even after responding to the predictable arguments of the "Requirements School," there are undoubtedly some in the "Requirements-Cost Balancing School" that would likely argue that a decision to walk away from the DDG-1000 based solely on concerns over its high procurement costs would be grossly unfair, because the ship "is going to cost dramatically less to operate" than legacy combatants.[201] The DDG-1000 is projected to have a crew of only 143, compared to crews of 350 to 400 on legacy Cold War combatants. For this and other reasons, the Navy claims that ten DDG-1000s will cost $4.2-4.5 billion less to operate over 35 years than a similar number of DDGs.[202] Therefore, proponents for the ship argue that the high procurement cost of the new ship must be viewed within the context of the "life cycle cost for the next navy," of which annual

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[199] The DDG-51 carries 90 VLS cells and eight *Harpoons* or SLAMs. The DDG-79 carries 96 VLS cells; while it has space and weight for eight *Harpoons,* it does not normally carry them.

[200] As relayed to the author by Dr. Eric J. Labs, Congressional Budget Office, after receiving Navy presentations on the DD(X) program.

[201] See Dave Ahearn, "Clark Says DD(X) Cost Not Fairly Weighted."

[202] "O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," p. 15. See also Christopher P. Cavas, "US Navy Rises to Defend DD(X)," *Defense News,* June 27, 2005, p. 20, as well as the "DD(X) Media Roundtable."

operations and support (O&S) costs are an important part.[203] In this light, the bold technological steps taken on the DDG-1000, and their high associated costs, will make the future force far more affordable. Thus, the argument goes, even if the long-term payoff from ship stealth is less than expected, the ship's higher procurement cost will pay off handsomely over the long run.[204]

This is perhaps one of the most compelling arguments for continuing to play the DDG-1000 "hand," and to build the new warships as now planned, the other being the potential negative impact that cancelling the ship would have on the US shipbuilding industrial base. This second argument will be addressed later in the report. Here, it is enough to say that the reduced life-cycle cost argument for the new ship is not as strong as it first appears. When calculating future funding flows using the present-value basis approved by the Office of Management and Budget, the CBO projects that 35-year life cycle costs for a DDG-1000 will be, *at best*, $10 million less than a DDG-51/79. However, it is also possible the new ship will generate no savings at all.[205] Moreover, even if the Navy's O&S cost savings prove to be accurate, they will not make up for the higher procurement costs for the ship. Indeed, using the Navy's own optimistic cost estimates, the total life-cycle cost for a DDG-1000 (procurement plus 35-year O&S costs) will be 116 percent higher than those for a DDG-51/79. Using CBO estimates for O&S costs, a DDG-1000's life-cycle costs will be between 191-201 percent that of the legacy warship.[206]

In any event, because the high procurement costs for the DDG-1000 and CG(X) will necessarily make the first phase of the transition to the "next navy" so long, any major *fleet-wide* savings in operations and maintenance costs associated with the introduction of the two new ships are *at least* two decades away, if then. In the meantime:

- The baseline for fleet-wide O&S savings are the costs needed to man, operate, and maintain the 72 Aegis/VLS combatants now in commissioned service. The 12 authorized DDG-79s to be added to the battle line between now and 2010/11 will increase the fleet manning requirement by more than 3,000 personnel, and a 17 percent increase in the number of active ships will obviously increase the maintenance burden on the fleet. As should be readily apparent, then, the resources needed to man, operate, and maintain 84 Aegis/VLS ships will necessarily be greater than those needed to operate 72.

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[203] Operations and support (O&S) costs include the money needed to operate and maintain the ship—operations and maintenance (O&M) funds—plus associated personnel costs such as the military pay and benefits needed to pay a ship's crew. When referring only to costs related to operations and maintenance, this report uses the term O&M. When referring to ship life cycle costs or personnel savings, the report uses the term O&S.

[204] See Cavas, "Retiring USN Leader Defends DD(X)."

[205] Statement of J. Michael Gilmore in testimony before the House Armed Services Committee Projection Forces Subcommittee Hearing on the DD(X), July 19, 2005. See also O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," p. 16.

[206] "O'Rourke, "Navy DDG-1000 (DDG(X)), CG(X), and LCS Acquisition Programs: Oversight Issues and Options for Congress," p. 17.

- The first DDG-1000s and CG(X)s will make the near-term rise in fleet manning requirements worse, not better. Because the planned transition to 7 DDG-1000s and 19 CG(X)s will take more than 20 years to complete, the Navy plans to modernize the 22 remaining *Ticonderoga* CGs and operate them to the end of their 35-year service lives. Because these legacy ships will not be retired until the early to mid-2020s, building new DDG-1000s and CG(X)s in the interim will cause the battle line to grow to 95 BFC combatants in FY 2021 before falling to its objective requirement of 88 ships in FY 2027.[207] Therefore, even if the yearly operating costs of the two new ships prove to be less than the current generation of surface combatants, aggregate *fleet-wide* O&S costs will continue to climb through FY 2021 before starting to fall. In other words, under the best of circumstances, any substantial fleet-wide O&S savings attributed to the two new ships will not come until after 2021.

- Finally, throughout the long transition period to the "next navy," the Department of the Navy will need to simultaneously maintain both legacy and new-generation radars, propulsion plants, and combat and weapons systems. The move away from a single support tail for a standardized line of battle will inevitably place additional training, maintenance, and logistics burdens on the fleet, which will likely be reflected in increased O&S costs

In fact, if keeping O&S costs down were a top fleet priority, a much smarter approach would be to "fold" the DDG-1000 and begin to design an entirely new BFC combatant, to be ready for production in FY 2015, six years before the first *Ticonderoga*-class CG is scheduled to retire from the fleet. This is not exactly a radical change in strategy. It was part of the Navy's earlier plan to build the 1997 QDR fleet. By designing a less expensive, optimally-manned ship that could be built at a rate of five ships every two years; authorizing two of the ships in FY 2015; skipping a year; and thereafter authorizing five ships every two years, the last "*Tico*" and the first *Burke* replacement would be built in FY 2023, very similar to the current plan. In the interim, however, this approach would hold the surface battle line at the 84 ships now programmed rather than building to a peak battle line of 95 ships. By capping the size of the battle line, making a concerted effort to reduce the size of these ships' crews, and delaying the time at which it needs to introduce a second logistics and maintenance chain for its major combatants, the Navy would garner immediate and major fleet-wide O&S savings. Of course, consistent with the current plan, the biggest fleet-wide savings would not accrue until the 2020s, when large numbers of legacy Cold War combatants will be replaced by new generation warships.

Betting on the Network

As the foregoing discussion suggests, then, the arguments and logic that support a decision to "discard" the DDG-1000 are at least as compelling as those that support continuing to "bet" on the ship. Given these circumstances, how might the Navy determine its best next move? By

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[207] The 2021 battle line will consist of 12 DDG-1000s/CG(X)s, 21 CG-52/59s, 62 DDG-51/79s; the 2027 battle line will consist of 23 DDG-1000s/CG(X)s, 4 CG-59s, and 61 DDG-51/79s. From Captain J.F. McCarthy, USN, "Recapitalizing the Navy's Battle Line," slide 20.

answering another key question: will the legacy Aegis/VLS fleet represent a good "value bet" while the Navy is redesigning a new next-generation surface combatant? That is to say, over the next two to three decades, will these 84 ships have a better chance of winning future naval battles more often than losing them?

As discussed earlier, the Navy's own plan suggests that naval officers could answer this question with a confident "yes." Their confidence is explained by the Navy's growing confidence in the power of future naval battle networks. Recall that the US Navy was one of the first fighting organizations to develop tactical engagement networks. During World War II, first in the great carrier battles in the early years of the war, and later when defending against the first long-range guided-weapon saturation raids known as *kamikaze* attacks, the Navy developed a highly effectively human-centric task force air defense network. This network was built around radar, radio, manned fighter interceptors, radar-directed gunfire, and proximity fuzes. Radar data was fused by human operators and interpreted by commanders in ship CICs. The raw sensor data collected by one ship could not be shared among the ships in the carrier task force. However, officers in CICs located in outlying picket ships could transmit the range and bearing of inbound attacks to the central task force CIC, which in turn could transmit engagement commands to fleet interceptors, which would mass on the bearing of attack, and to task force escorts, which would position themselves to optimally configure the task force's close-in air defenses. While highly effective, this engagement network was extremely manpower intensive.[208]

As discussed earlier in the report, the Navy was an early mover in the guided weapons warfare regime. Faced with the prospect of saturation attacks from fast-moving jets and missiles, it soon realized that the "speed of the fight would rapidly outstrip the speed of voice."[209] It therefore readily embraced the need to extend a task group's radar horizon, using both more powerful shipboard radars as well as airborne radars, and to replace the guns on its air interceptors and ships with air-to-air and surface-to-air missiles, respectively. Once they did all these things, however, fleet operators immediately recognized that machine-to-machine tactical data networks could fuse data, prioritize threats, and pass engagement commands more quickly than could the World War II-style, human-centric, voice-dependent CIC network. Unsurprisingly, then, the Navy was central to the development of several new networking technologies, among them the first standard naval tactical data link, Link 11—an information link transmitted over high-frequency (HF) radio;[210] shipboard tactical computers like the AN/USQ-20;[211] and the Electronic

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[208] For a good description of these early naval battle networks, see Chapter 10 in Friedman, *US Destroyers*, revised edition, especially pp. 206-207.

[209] Kernan Chaisson, "Network Enabled Communications," *Naval Forces*, No. VI/2005, Vol. XXVI, p. 76.

[210] The NATO Air Defense Ground Link, or Link 1, was perhaps the first tactical data link, transmitting data from ground-based radar sites to Combined Air Operations Centers. Link 4A, called the Tactical Digital Information Link-C (TADIL-C), was the first tactical data link to control tactical aircraft. Link 11 was the first naval tactical data link. It was first conceived in 1954 and subsequently adopted by US and NATO navies See Chaisson, "Network Enabled Communications," pp. 73-74.

[211] The An/USQ-20 was based on the early, heavy UNIVAC 1206 computer. To get an idea of its impressive size, see Chaisson, "Network Enabled Communications," p. 73.

Data System (EDS), a data storage system designed to cope with the problem of electronic information overload.[212]

The development of these new network capabilities spurred the subsequent development of the aforementioned Navy Tactical Data System, which enabled to formation of the first *automated* naval engagement networks.[213] The AN/USQ-20s on the first NTDS ships typically had core memories of just 32,000 30-bit "words." Even so, this represented far more information than could be found on the typical hand-generated plotting boards in World War II CICs. Moreover, information could be sent to and exchanged among nearby computers over Link 11 far faster than could human voice.[214] Finally, because of Link 11's nominal 180-mile HF range, naval formations could more widely disperse without sacrificing their defensive integrity. This was an important consideration in the 1950s, when fleet operators assumed they would always be under threat of atomic attack. A task group could disperse for passive nuclear defense and still operate as a coherent engagement network.[215]

As this short discussion hopefully makes clear, these early automated engagement networks were less a new communications system or computer system and more a "social structure of networking, protocols, and rules of interaction applied to multiple machines so they [could] collaborate and provide mutual support to one another."[216] Ships in a NTDS engagement network could share their radar and sensor data, establish common target tracks, assign common threat priorities, and together settle on the best missile shots from individual ships that would provide the best defense for the entire network. In terms of fleet air defense operations against inbound air and missile attacks, engagement networks aimed for effects "similar to pitting the Roman legions against disorganized tribes."[217]

The shift to these early automated engagement networks was not without problems. Due to the limited amount of data contained in the original Link 11 and the low throughput of HF signals, early NTDS networks were limited to only a few ships, and the data refresh cycle among the ships was relatively slow. Moreover, if two task groups were operating as independent networks within 180 miles of one another, their data could inadvertently merge, causing false tracks and confusion in both networks.[218] Despite these early problems, however, through trial and operational experimentation the Navy was continually able to perfect Link 11-enabled NTDS

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[212] The EDS was itself developed from a British-developed Comprehensive Display System (CDS). See Friedman, *US Destroyers*, revised edition, pp. 206-07.

[213] Friedman, *US Destroyers*, revised edition, pp. 206-207.

[214] "Naval Tactical Data System," found online at http://en.wikipedia.org/wiki/Naval_Tactical_ Data_ System.

[215] Dr. Norman Friedman, "They Link it Together—Data Exchange Requirements and Systems in Naval Warfare," *Naval Forces*, No. III/2005, Vol. XXVI, p. 35.

[216] Fulghum, "Network Warfare: Hope and Hype," p. 33.

[217] Fulghum, "Network Warfare: Hope and Hype," p. 33.

[218] Friedman, "They Link it Together—Data Exchange Requirements and Systems in Naval Warfare," pp. 36-40.

engagement networks and to develop new network battle doctrine—with increasingly effective results. For example, in addition to spurring ever-greater combat system automation, by virtue of their far faster reaction times, computer-aided engagement networks helped naval task forces to cope with unexpected "pop-up" cruise missile attacks from Soviet submarines. Similarly, the automated networks were central to new fleet battle tactics such as the Outer Air Battle concept, which helped to counter potential coordinated Soviet guided-missile saturation attacks conducted by submarines and long-range *Backfire* bombers operating from airfields in Eastern Europe and the Soviet Union.[219]

The Navy first adopted automated naval engagement networks to combine the inputs from widely separated sensors on multiple platforms—on ships, submarines, manned or unmanned aircraft, space-based systems, and national and regional command centers—in order to expand dramatically a naval task force's *defensive* perimeter and to exploit fully the extended-range accuracy of guided weapons. Later, after the "defining battle" known as *Desert Storm*, the Navy began to see engagement networks composed of sensors, targeting systems, and fire control systems as being equally effective for *offensive* air and missile strike operations. The goal of these offensive engagement networks was to develop precise targeting coordinates for guided weapons and to compress the "sensor-to-shooter" timeline as much as possible. The combination of defensive and offensive engagement networks helped to spur the development of the first Joint Multidimensional Battle Networks, referred to in this report as *battle-centric networks*.[220] Indeed, the Navy now conceives of itself as one extended battle network, called FORCEnet, which it defines as "the architecture and building blocks of sensors, networks, decision aids, weapons, Warriors, and supporting systems integrated into a highly adaptive, human-centric comprehensive maritime system that operates from seabed to space and from sea to land."[221]

For any battle network to be effective, especially a force-wide network as bold and far-reaching as FORCEnet:

> …a commonly agreed understanding of the tactical situation is necessary. This enables C2 functions to be exercised with the knowledge that those involved share a common appreciation of the tactical context, and hence are more likely to act appropriately. Without this shared understanding, it is highly probable that misinterpretation of the tactical

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[219] Friedman, *US Destroyers*, revised edition, pp. 207 and 392-95.

[220] I see the rise of battle-centric networks as the natural consequence of the shift from unguided to guided weapons warfare. Others use them to espouse an entirely new theory of warfare, commonly referred to as *network centric warfare*. See, for example, Vice Admiral Arthur K. Cebrowski, USN, and John J. Garstka, "Network-Centric Warfare: Its Origins and Future," *Proceedings*, January 1998, found at http://www.usni.org/Proceedings/Articles03/PROmayo 02.htm; and John J. Garstka, "Network Centric Warfare: An Overview of Emerging Theory," *Phalanx: the Bulletin of Military Operations Research*, December 2000, pp. 1; 28-33. While the rise of battle-centric networks is historically incontrovertible, the idea that they have fundamentally altered the nature of war is still a matter of some debate. See for example Milan Vego, "The NCW Illusion," *Armed Forces Journal*, January 2007, p. 17.

[221] *FORCEnet and the 21st Century Warrior* (Newport, RI: CNO Strategic Studies Group XX, November 2001), p. xvii.

> situation will arise, which can lead to instances of fratricide, avoidable collateral damage, or exposure to unnecessary hostile actions.[222]

Indeed, ever since the creation of the first Link 11-enabled NTDS naval battle networks, the Navy has been continuously searching for the best means to provide a *common tactical picture* for the greatest possible number of widely dispersed network platforms "operating from seabed to space and from sea to land." This search included two complementary approaches. The first approach led to the expansion of the sensor envelope around every naval task battle group. This has been done by a variety of means, such as leveraging space-based sensors; introducing better carrier-based airborne surveillance aircraft; and introducing better, long-range shipboard sensors such as the SPY-1 radar. The second approach involved improving the information-sharing capability of US warships. In this regard, Link 11 pathways have been expanded to include ultra-high-frequency (UHF) line-of-sight links, and the information content of Link 11 messages and the overall throughput capacity of link channels have been increased. These efforts have been accompanied by constant improvements to the hardware and software components of the NTDS, and the development of human-friendly tactical displays and data consoles. The common goal of all these efforts has been to forge ever better common battle network awareness and tighter, more synchronized, and more effective cooperative network action.[223]

The job of forming an integrated joint air-sea battle picture got a little tougher in the 1990s, with the introduction of the new Link 16 and the Joint Tactical Information Data System (JTIDS), which were designed primarily to provide better situational awareness and direction to air interceptors in air-to-air engagement networks. Link 16/JTIDS employed a frequency-hopping line-of-sight link, transmitted at higher frequencies and with much higher data content than the shipboard Link 11. These advances made ground-to-air and air-to-air network links more resistant to jamming and spoofing, and also enabled the digital transmission of voice signals.[224] To connect the new Link 16/JTIDs networks with naval battle networks, in 1992 the US and NATO navies developed NATO Improved Link 11 (NILE), known today as Link 22, and began development of smaller Multifunction Information Distribution System (MIDS) terminals. The NILE/Link 22/MIDS network forms what is, in essence, an over-the-horizon version of the Link 16/JCIDS network, combining the richer information content of the Link 16 messages with new multiplexed Link 11 HF signals to form tightly-connected, information rich, and jam resistant beyond-visual-range battle networks.[225] The combined air, sea, and surface picture provided by modern Joint Multidimensional Battle Networks would likely stun the operators in a World War II shipboard combat information center.

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[222] Richard Scott, "Joining the Dots: Networked Platforms Extend Air Defense, *Jane's Navy International*, December 2005, p. 26.

[223] Chaisson, "Network Enabled Communications," pp. 74-76.

[224] Chaisson, "Network Enabled Communications," pp. 74-76.

[225] Friedman, "They Link it Together—Data Exchange Requirements and Systems in Naval Warfare," pp. 40-42; and Chaisson, "Network Enabled Communications," pp. 74-76.

Despite these advances, as well as new doctrinal concepts to exploit improved network awareness, the anticipated development of post-Soviet Union A2/AD networks employing multi-phenomenology, over-the-horizon-range sensors; ballistic missiles; and long-range, supersonic, stealthy anti-ship cruise missiles will present even the most cohesive naval battle networks with a daunting challenge. As Air Force and Naval aviators who have had to operate against modern integrated air defense networks have already learned, it will take a Joint Multidimensional Battle Network to beat an A2/AD network.[226] To ensure they will have an overmatching capability against future A2/AD complexes, Navy planners are thus seeking an even more dramatic improvement in shared situational awareness and cooperative battle network action. On the defensive side of the equation, these improvements will come in the form of the new cooperative engagement capability, or CEC.

Unlike the NTDS, which uses Links 11 and 16 to transmit *commands* among network platforms, which then fire defensive missiles based on fire control data from their own onboard sensors, a CEC-equipped platform uses directional antennas to transmit the *raw radar data* from its onboard radars to nearby ships and aircraft in the local CEC-network. These platforms, in turn, pass the data onto other ships and aircraft. In each ship or aircraft receiving the data, CEC hardware and software integrates the data of all SPY-1 Aegis radars—as well as other radar sensors such as the APS-145 surveillance radar on the E-2C *Hawkeye* carrier-based air battle management aircraft—to form "composite tracks" for all potential targets. By then sharing and integrating the "composite tracks," a CEC engagement network can form a "single, real-time, fire-control-quality composite track picture."[227]

In other words, CEC engagement networks should be able to achieve a single integrated air picture (SIAP)—the holy grail for naval (and air and ground) air defenses. If so, the implications for task force defense will be profound. CEC-enabled engagement networks will extend the range at which any given ship can engage a target to well beyond its own radar horizon. Indeed, a CEC-equipped ship will be able to fire at a target that would not normally be seen, much less tracked, by its own sensors. Said another way, a CEC-equipped ship operating near shore, well inside an enemy's A2/AD network, will be able to use data from airborne sensors like those carried by the E-2C *Hawkeye* to see "through" terrain that would normally mask its own sensors. With weapons that can *engage on remote*—that is, be guided toward their targets using offboard sensors like the E-2C's radar—a ship will be able to fire at air and missile threats while they are still deep inland, long before they are in their terminal attack runs. This will allow the surface combatant fleet to protect naval units operating in close-in littoral waters, offshore, and to extend its own air defense umbrella over joint forces operating ashore. Moreover, because most stealthy platforms are only "invisible" from certain radar aspects (e.g., head-on), and because CEC tracks

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[226] David A. Fulghum, "It Takes a Network to Beat a Network," *Aviation Week and Space Technology*, pp. 28-31.

[227] "Cooperative Engagement Capability," at http://www.fas.org/man/dod-101/sys/ship/weaps/cec.htm.

will be developed along multiple radar bearings, CEC also promises to be able to detect and track stealthy aircraft and cruise missiles over both land and sea.[228]

Like early NTDS engagement networks, early CEC engagement networks have some limitations. Each platform in a current CEC network only communicates with the two platforms nearest to it, passing on all plots it receives. Because none of the plots passing through the sending platform are edited out, the data load on the system rises as the square of the number of participants. As a result, in order to keep the data current, today's CEC networks are currently limited to only 19 participants.[229] However, as was also the case with the NTDS, with further doctrinal, technical, and experimental development, the CEC seems certain to expand in both capability and effectiveness over time. For example, CEC engagement networks will soon be able to integrate non-radar sensor data from electronic intelligence or other links to further improve the quality of air and missile tracks.[230] Future CEC networks, equipped with even more powerful processing capabilities, will likely be able to expand beyond the current 19-ship limit.

To exploit the power of new CEC-enabled engagement networks, naval Area Air Defense Coordinators onboard *Ticonderoga*-class CGs will soon be assisted by the new Area Air Defense Command Capability System (AADCCS). The AADCCS is a three-dimensional collaborative force planning tool designed to give a "god's eye view" of the air and surface space around a CEC-equipped task group, including friendly forces, neutral contacts, and hostile aircraft, cruise missiles, and ballistic missiles—along with their headings and impact zones. Using this information, the AADCCS can generate new network air defense plans in minutes. The Navy hopes that the introduction of the AADCCS and CEC will substantially improve the ability of naval battle networks to withstand attacks from enemy A2/AD networks—at least long enough until joint offensive counter-network operations can beat them down.[231]

Similar improvements are being developed for the battle fleet's offensive engagement networks. For example, the Navy and the Air Force are working to develop a *Joint Fires Network* to prosecute land targets.[232] Now, this network is being extended to cover targets at sea. In this regard, using a new Affordable Moving Surface Target Engagement (AMSTE) capability, the Air Force's Joint Surveillance Target Attack Radar System (JSTARS) can terminally guide GPS-guided weapons dropped by naval carrier or Air Force tactical aircraft onto ships moving at sea.

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[228] Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, p. 136; Daniel Busch and Conrad J. Grant, "Changing the Face of War—the Cooperative Engagement Capability," at http://www.ccii.co.za/company/pressreleases/faceofwar.html; Friedman, "They Link it Together—Data Exchange Requirements and Systems in Naval Warfare," p. 42.

[229] Friedman, "They Link it Together—Data Exchange Requirements and Systems in Naval Warfare," p. 42.

[230] Scott, "Joining the Dots: Networked Platforms Extend Air Defense," pp. 28-30.

[231] Scott, "Joining the Dots: Networked Platforms Extend Air Defense," pp. 28-30; and Fulghum, "It Takes a Network to Beat a Network."

[232] Sandra I. Erwin, "Navy, Air Force Team Up in 'Joint Fires Network'," *National Defense*, March 2003, p. 22.

Before, GPS-guided weapons were effective only against fixed land targets.[233] For its part, the Navy's new Tactical *Tomahawk* land attack missile and its associated weapons control system allows fleet operators to execute preplanned fires, make *en route* mission changes, and even to loiter the missile over an area until a target is identified. All of these new capabilities will dramatically increase the missile's offensive flexibility.[234]

As these examples indicate, while a true force-wide FORCEnet is a long way off, the steps toward it are now plain to see.

FROM TSBF TO TFBN

The lure of FORCEnet and naval battle-centric networks is quite powerful, and, to date, experimental data appears to support many of the claims made by the "Network School." However, it should be noted that any electronic network is vulnerable to denial of service (e.g., shutting down communications and data links via jamming or attacks by high-powered microwaves) and all forms of information warfare. Naval battle networks will also be vulnerable to spoofing—particularly the generation of false targets. As British ASW escorts found out while screening high value units from Argentinean submarines in the Falklands campaign, no matter how effective a guided weapon is, it can't destroy what isn't there.[235] Indeed, the British Falklands experience points out one of the key vulnerabilities of a modern naval task force: the depletion of its own relatively limited magazine space (especially when compared to a continental power) by firing on false targets. As this discussion suggests, then, the pursuit of ever better and more powerful fleet battle networks is not without risks. It will be important for naval operators and planners to continue to refine the tactics, techniques, and procedures for network-versus-network warfare, and to better understand the vulnerabilities of networks to electronic disruption and spoofing, to ensure that the move toward battle networks proves effective over the long run.

Clearly, however, the Navy has judged that the benefits of moving toward and improving naval battle networks are well worth the risks. Assuming their vulnerabilities can be mitigated and fleet exercises confirm their continued effectiveness, the Navy will thus continue its ongoing evolution from naval engagement networks to task force battle-centric networks to a force-wide

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[233] See Major General Dave Deptula, *Resultant Fury Post Mission Initial Debrief*, a PowerPoint briefing by the the Pacific Air Forces, November 23, 2004. See also Richard Mullen, in "'Result Fury' Successful, DoD Says," *Defense Today,* November 24, 2004.

[234] See "Tactical Tomahawk Eapons Control System, accessed online at http://www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=11269&rsbci=7&fti=0&ti=0&sc=400 on February 4, 2006.

[235] The *San Luis*, an Argentine diesel-electric boat (German Type 209), moved into the main operating area of the British task force during a 36-day patrol. Because the fire-control panel malfunctioned, the submarine fired all of its torpedoes on incorrect bearings. The firing of the torpedoes alerted the British task force to the fact that that an enemy submarine was in the area, but British ASW forces were unable to find her, and they expended more than 150 depth charges and torpedoes against what are now believed to have been false sonar targets. See John R. Benedict, "The Unraveling and Revitalization of US Navy Antisubmarine Warfare," *Naval War College Review*, Spring 2005, found online at http://www.findarticles.com/p/articles/mi_m0JIW/is_2_58/ ai_n14705062/pg_5.

FORCEnet. As it does, a debate over whether the DDG-1000 will be the most powerful ship in the Navy's future Total Ship Battle Force is no longer worth having. Instead, the debate should center over what new capabilities offer the greatest payoffs and contributions as the Navy transforms from a TSBF to a *Total Force Battle Network* (TFBN)—the collection of sensors, platforms, data links, weapons and force capabilities that comprise FORCEnet.

By recasting the debate in this way, one is better able to judge the true contributions of the DDG-1000 to future naval battle networks. For example, recall that the Navy claims a single DDG-1000 will improve a CSG's battle network air defenses by 20 percent. In the evolving transition to FORCEnet, this is a mischaracterization. The DDG-1000's new dual-band radar system with its multi-function SPY-3 radar will be the source of network improvement, not the DDG-1000 itself. CEC-equipped CVN-21s and LHARs will or could carry the same radar, providing every future CSG or ESG with its superior track data. Moreover, while the SPY-3 radar system may be 20 percent better than detecting and tracking cruise missiles in the littoral than a *Burke's* Aegis SPY-1 radar, the E-2C Hawkeye's APS-145 radar, by virtue of its greater operating height, can monitor more than six million cubic miles of airspace and 150,000 square miles of ocean out to 300 miles.[236] The new E-2D *Advanced Hawkeye* now in development, with its new active electronically scanned array (AESA) radar, will have even greater range and discrimination capability against both air and surface targets, and will have a much improved overland detection capability.[237] Including the E-2D's radar data in a CEC network will increase battle network detection volumes by 250 percent, and will provide a "look down" capability against stealthy cruise missiles that hug the terrain or ocean surface to remain out of sight of shipboard radars.[238] Since the E-2D will provide track data to both the DDG-1000 and Aegis/VLS combatants, a strong case can be made that its radar is far more important to future battle networks—at least in the near term—than the SPY-3. As this discussion suggests, then, as the Total Ship Battle Force evolves into a Total Force Battle Network, straight-up comparisons between the DDG-1000 and DDG-51/79 are not nearly as relevant as proponents of the ship claim them to be.

Given this fact, the question of whether the DDG-1000 is more capable than the DDG-51/79 is therefore far less important than this one: in the Navy's ongoing transformation to a Total Force Battle Network would building *seven* DDG-1000s or diverting some of that money to improve the *84* Aegis/VLS combatants that are already bought and paid for provide the biggest near-term TFBN payoff?

TIME TO THROW IN THE CARDS AND PLAY A NEW HAND

The answer to this question seems apparent. Based on the major changes to the strategic, operational, and tactical assumptions that drove the design of the DD-21/DD(X)/DDG-1000, and

[236] See "APS-145 Radar," in the 2007 Almanac, *Seapower,* January 2007, p. 80.

[237] See "E-2D Advanced Hawkeye," at http://www.globalsecurity.org/military/ systems/aircraft/e-2d.htm.

[238] "Theater Missile Defense: The Cruise Missile Threat," a PowerPoint presentation presented by the Northrop Grumman Corporation to CSBA on July 6, 2004.

upon review of all the arguments for and against the new ship, it is easy to conclude that Navy's next best move is to follow the example of the post-World War II Navy and walk away from its previous "bets" on the DDG-1000 and CG(X) and to focus first on modernizing and upgrading its sizeable Aegis/VLS fleet. "Folding" the new ships and "holding" on to the legacy ships will in no way threaten the Navy's current position as the number one player at the naval transformation table. In fact, by heeding the lessons learned from earlier players in the naval transformation game, the Navy will have a rare opportunity to change its current game strategy and actually improve its long-term prospects for retaining the naval capabilities "chip lead."

In a nod to the changes made by an earlier generation of officers to post-World War II plans for the future surface combatant fleet, the Navy should cancel all DDG-1000s and CG(X)s beyond the two DDG-1000s already authorized, and perhaps beyond just one of the ships. By doing exactly what their predecessors did with the *Norfolk*—making one or two DDG-1000s into fleet test ships—naval planners can recoup most of the previous "bet" laid down of the new ship. Recall that the *Norfolk* spent the bulk of its two-decade long service life as an ASW test platform. In a like way, one or two DDG-1000s would provide the fleet with two valuable operational test beds for surface combatant stealth, integrated propulsions systems, and new electric-powered weapons.

In this regard, it is interesting that the Navy often likens the DDG-1000's expected revolutionary impact to that of the *HMS Dreadnought*—an all-big gun armored battleship commissioned in 1906 that "in one generation set the Royal Navy apart from its peers."[239] However, it is worth noting that the *Dreadnought* was a one-ship class. It was the ship's design philosophy and innovative combination of technologies and that pointed the way ahead for all subsequent future battleships.[240] Using the *Dreadnought* experience as a guide, it thus seems likely that the Navy would get as much value out of building just two DDG-1000 technology demonstrators as building seven operational warships.

Next, consistent with its ongoing transformation from a Total Ship Battle Force to a Total Ship Battle Network, the Navy should immediately kick-start a clean-sheet competition to develop and design a family of next-generation *Large Battle Network Combatants*, or LBNCs. "LBNC" is a far better description of future TFBN BFC combatants than the multi-mission guided-missile "cruisers" and "destroyers" or general-purpose "destroyers" associated with today's legacy TSBF. With a chance to start from a clean sheet of paper, naval design architects could leverage an additional decade of experience in the post-Cold War era to design an entirely new family of more affordable, next-generation LBNCs. All future LBNCs would likely be modular, with the capability to employ both onboard and offboard manned and unmanned systems. Some might be optimized to carry unmanned vehicles or helicopters; others might be optimized to perform traditional combatant missions and to carry guided weapons and other offensive attack systems.

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[239] Captain C.H. Goddard and Commander C.B. Marks, USN, "DD(X) Navigates Uncharted Waters," *Proceedings*, January 2005, pp 30-31.

[240] I am indebted to Dr. Andrew F. Krepinevich for pointing this out.

While the basic combatant would likely have many of the capabilities of the DDG-1000, given the opportunity to start from a clean-sheet design, and guided by a newly re-installed SCIB, naval designers might design a ship that looks far different. For example, the French have recently unveiled a futuristic surface combatant designed from the keel up to be a component in a larger naval battle network. The so-called *Swordship* would boast a radar cross-section below a typical sea clutter threshold; a composite superstructure with embedded antenna; various sensors including both S-band and X-band radars; an all-electric drive using high-temperature superconducting motors; and 48 vertical launch missile cells, a triple 155mm gun, and provisions to operate a range of helicopter and unmanned air and surface vehicles. While sounding very much like the DDG-1000 in terms of capabilities, the *Swordship's* designed full load displacement is only 5,300 tons—just over one-third the displacement of the larger ship.[241]

As discussed earlier, the goal would be to have the first of the new LBNCs ready for production in FY 2015 in order to commission the first of the class before the first *Ticonderoga*-class CG retires—similar to the goal outlined in plans for the 1997 QDR fleet. A further aim would be to design a ship affordable enough to produce five every two years, and one with a modular hull and combat system architecture that would allow the Navy to replace both the *Ticos* and the *Burkes* with a common platform. With a design hull life of 35 years, the Navy could replace all legacy ships with new LBNCs in about 35 years—all the while maintaining the battle line close to its combined requirement for 88 battle network combatants.

Finally, the Navy should divert the savings derived from cancelling the five remaining DDG-1000s to convert the 84 Aegis/VLS warships now bought and paid for into Interim Battle Network Combatants (I-LBNCs). Betting an additional $10-15 billion on five or six additional DDG-1000s would appear to provide far less of a TFBN payoff than making a similar sized or even smaller bet on a well-thought out and executed program to convert the 84 programmed Aegis/VLS warships into more powerful I-LBNCs. This conversion program would be patterned after earlier modernization and conversion efforts, like the aforementioned FRAM program, which converted the large legacy fleet of World War II destroyers into effective Cold War ASW escorts.

This chapter laid out the logic behind the first two recommendations. The next will thus focus on the rationale behind a comprehensive Aegis/VLS modernization and conversion program, its minimal requirements, and steps needed to make the 84 Aegis/VLS combatants into even better I-LBNCs.

The next chapter will also address an obvious objection to the above plan: given the inherent delay associated with designing and building a new family of LBNCs, this approach would put extraordinary pressure on a US shipbuilding industrial base already under pressure due to low post-Cold War ship orders. However, as demonstrated by the surface warfare officers who played an earlier naval transformation game during an equally unsettling transition period from guns, propeller aircraft, and diesel-electric submarines to guided missiles, jets, and nuclear-

[241] Richard Scott, "Swordship Sets a Net-centric Course," *Jane's Navy International*, December 2006, pp. 11-12.

powered submarines, by separating the question of maintaining the industrial base from the question about the best timing for the transition to a new generation of combatants, a whole new range of industrial base maintenance options open up.

IV. "HOLDING" THE AEGIS/VLS FLEET

A CRITICAL ASSUMPTION

The 84 Aegis/VLS ships already bought and paid for represent a $100 billion taxpayer investment. Regardless of whether or not the Navy ultimately decides to "fold" the DDG-1000, it makes great sense to try to maximize the payoff associated with this hefty commitment of taxpayer funds. However, holding on to these 84 ships and upgrading them into interim Large Battle Network Combatants is much more than the common sense maximization of a sunk investment—*it is the single most critical aspect of the Navy's plans to transform its surface battle line and 313-ship fleet into combat capable components of the evolving Total Force Battle Network.*

The justification for this claim is straight-forward. A critical implicit assumption embedded in the Navy's transformation plans is that over the next three decades most ships now in commission—and all those to be procured—will serve to the very end of their expected service lives (or ESLs; see Figure 3).

Figure 3: Planned Expected Service Lives (in years of active service)[242]

Ship Type	ESL
Nuclear-powered Aircraft Carriers (CVNs)	50
Strategic Ballistic Missile Submarines (SSBNs)	42
Cruise Missile and SOF Transport Subs (SSGNs)	42
Nuclear-powered Attack Submarines (SSNs)	33
Cruisers and Destroyers (CGs, DDGs, and DDs)	35
Littoral Combat Ships (LCSs)	25
Amphibious Warships (LHDs/LHARs/LPDs/LSDs)	35
Mine Countermeasure Ships (MCMs)	30
Auxiliary and support ships	35

The only way to compensate for ships being retired before the end of their ESLs is to increase the Navy's steady-state ship procurement rate. However, as discussed earlier in the report, expectations for ship procurement funds are already at the very limit of prudent planning. Therefore, barring a major change in the long-term fiscal outlook, the rise of a powerful shipbuilding bloc in Congress, or a change in the perceived naval threat, the chances of the Navy

[242] Ronald O'Rourke, "Navy Force Structure and Shipbuilding Plans: Backgrounds and Issues for Congress," Congressional Research Service Report RL 32665, dated February 14, 2004, p. 16, Table 3.

being able to sustain a major increase in future ship procurement rates—at least for the very expensive ships now planned—appear to be relatively low. To keep the TFBN from falling far below its 313-ship requirement, every ship that is now either in commission, authorized, or planned must therefore serve the full extent of its expected service life.

The steady-state FORCEnet target of 88 LBNCs can be divided into 19 CG(X)s and 67 DDGs (seven DDG-1000s and 62 *Burke* DDGs or DDG(X)s). These 88 warships represent the single largest number of ships in the TFBN, comprising just over 28 percent of the total 313-ship count. The next two closest TFBN ship components are the small combatant fleet, where 55 LCSs (or Small Battle Network Combatants) contribute 17.6 percent of the total ship requirement, and the attack submarine fleet, where 48 boats contribute 15.3 percent.[243] The Navy's ultimate success in maintaining 313 FORCEnet ships will thus rest, to a great degree, on its ability to keep approximately 88 large surface combatants in commissioned service.

As previously discussed, when the last of the authorized 84 Aegis/VLS ships are commissioned in 2011, the Navy will be only four large combatants short of its 88-ship target. Having entered service between 1986 and 2011 at an average rate of 3.32 ships per year (i.e., 10 ships every three years), these 84 ships will be relatively young in terms of ship life. Indeed, the 2011 surface battle line will boast an average age of about 14 years. That means that, on average, Aegis/VLS ships have over two decades of expected service life remaining. This explains why the same 84 ships will still be in commissioned service in 2020 and 65 of the ships—nearly 80 percent of the current force—will contribute to the TFBN ship count in FY 2027. As these figures attest, then, the 84 Aegis/VLS combatants form the nucleus around which the Navy's near-term TFBN transformation plans revolve.

Over the longer-term, recall that the combined numbers for large surface combatants begins to fall rapidly after 2027. The fall will occur due to the confluence of two events: the block retirement of large numbers of *Arleigh Burke* DDGs; and the slow building rate of the DDG(X)s scheduled to replace them. As a result, the combined CG/DDG fleet falls to just 62 ships in FY 2042 (26 ships below the total 88-ship requirement) before rebounding to a steady-state force of 70 ships (18 below requirement) sometime after 2050. *These already sobering numbers assume that every* Burke *will serve a full 35 years in fleet service*. If that proves not to be the case, the guided-missile cruiser and destroyer fleet will fall even more rapidly and more deeply below its warfighting requirement, and the TFBN's overall combat capability will be crippled.[244]

Keeping all 84 Aegis/VLS ships in service for a full 35 years is therefore absolutely critical to both the near-term and long-term health of the TFBN. Indeed, it is far more critical than the need to immediately build 26 DDG-1000s and CG(X)s. Look at it this way: based on expected service

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[243] Secretary of Defense, "Report to Congress on the Annual Long-Range Plan for the Construction of Naval Vessels for FY 2007," p. 4.

[244] To reiterate the earlier point, the Navy's FY 2008 shipbuilding plan shows that the DDG(X)s will now be built at the rate of three per year rather than two per year, which would ameliorate the extent of the cruiser-destroyer shortfall. However, because the plan to increase the ship build rate was not accompanied by an increase in annual funding, I continue to use the FY 2007 shipbuilding plan as a basis for this report.

lives of 35 years, the seven DDG-1000s and 19 CG(X)s found in current shipbuilding plans together represent 910 years of planned future ship life; in contrast, the 84 Aegis/VLS surface combatants now bought and paid for represent approximately 2,200 years of future commissioned service. In other words, the programmed Aegis/VLS fleet has a service-life return rate nearly 2.5 times that of the newer ships. This high return rate provides a key hedge in case the average yearly shipbuilding account falls substantially below the $15.4 billion per year the Navy brass says it needs to build the 313-ship fleet. More importantly, should Navy planners decide to leverage this high return rate, they will find they have enormous flexibility in changing current surface combatant transformation plans.

A BLIND BET

However, while getting 35 years of commissioned service out of every one of the 84 programmed Aegis/VLS "ships-of-the-line" is a clear TFBN imperative, whether the Navy will be able to do so is anything but a sure thing. Recall that on September 30, 1989, just months before the demolition of the Berlin Wall, the battle fleet stood at 592 warships. With the collapse of the Soviet Union and the subsequent dismantlement of the Soviet Navy, the US Navy began a gradual fleet demobilization that ended with the establishment of Admiral Mullen's 313-ship fleet over a decade-and-a-half later. During the demobilization, large surface combatants (as well as submarines and other ships) were retired well before the end of their expected service lives. For example, throughout the entire Cold War, only one guided-missile cruiser remained in commissioned service for more than 35 years—the *USS Long Beach,* CGN-9, which was decommissioned after 37.9 years of active service. In contrast, the average age at retirement for all Cold War cruisers was only 28-29 years.[245] Similarly, the oldest guided missile destroyers served for approximately 33 years, and most were decommissioned after only 25-30 years of active service. The oldest of 31 Cold War *Spruance*-class DDs remained in commission for 29 years; some were retired after less than 20. Finally, the first five *Ticonderoga* CGs left the fleet after only 18 to 21 years of commissioned service.[246]

For the reasons outlined above, and as indicated by its current 30-year planning profile, the Navy is betting that none of the 84 Aegis/VLS ships will suffer the same fate as these previous Cold War combatants and be decommissioned before the end of their 35-year design lives. As the previous paragraph suggests, however, the surface warfare community has little recent experience upon which to base this bet. Since the oldest Cold War ships were among the first ships to be decommissioned in the post-Cold War drawdown, the most current maintenance planning data is based on a period of time when the average surface warship was retired with only 16-28 years of service. Even during the Cold War, when maintaining high ship counts was a key institutional goal, most surface combatants served no longer than 25-29 years. The current generation of surface warfare officers therefore has little idea what it will take to keep surface

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[245] Department of the Navy, *Aegis Cruiser Conversions: New Capabilities for the 21st Century,* an undated color brochure produced by the US Navy, p. 14. Embedded quotes indicate the brochure was likely published in 2000.

[246] Ship retirement dates were derived from ship data entries in Polmar, *Ships and Aircraft of the US Fleet.*

combatants combat ready and effective during the last five to ten years of a long and arduous 35-year service life.

Said another way, the Navy's plans to operate all Aegis/VLS ships for 35 years represent a blind bet. If this bet has any reasonable chance of paying off, the surface warfare community will need to expend considerable time, effort, and resources to make sure it happens. Moreover history shows that unless a surface combatant undergoes a thorough mid-life modernization after 14-17 years of commissioned service, the ships are normally decommissioned.[247] Given that the average age of the Aegis/VLS battle line will be 14 years just four years from now, the Navy can delay no longer before taking action.

BACKING THE BET

For this reason, the absolute top priority for the surface warfare enterprise is to plan and execute a comprehensive Aegis/VLS midlife upgrade program, patterned after earlier programs like the Fleet Reliability and Maintenance Program. At a minimum, such a program would aim to give new life and capabilities to the ships' aging HM&E and combat systems.

Mid-life HM&E Upgrades

Since the end of World War II, the US Navy has maintained high peacetime operating tempos, routinely deploying ships on rotational six-month deployments. Because of both hard use and the natural aging of equipment, US combatants inevitably see their HM&E systems begin to deteriorate over time. As a result, the Navy routinely plans for mid-life upgrades to a ship's basic systems—which involve repairing its hull, replacing outdated equipment, and replacing and upgrading such things as piping, cabling, and electrical systems. For example, during the 1980s, when the Navy was expanding toward a battle fleet target of 600 ships, fleet planners were reluctant to decommission any ships before the end of their service lives. They therefore spent considerable sums to upgrade the HM&E systems of ships commissioned in the 1960s, renovating all their spaces, refurbishing their berthing and food service areas, and completely overhauling their steam engineering plants.[248]

During the 1990s, as the number of the ships in commission fell dramatically, the difference between Navy "peacetime" and "wartime" operating tempos began to blur. In order to maintain the size and health of its current fleet, the Navy is therefore planning a mid-life upgrade for all of its legacy combatants. It is now in the process of performing an HM&E systems upgrade on its 30 remaining *Oliver Hazard Perry* frigates to extend their useful service lives. As will soon be discussed in more detail, a similar H&ME upgrade program for the fleet's 22 *Ticonderoga*-class CGs is in the final planning stages. This will be followed, in turn, by a planned HM&E upgrade to the 62-strong DDG fleet.

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[247] Department of the Navy, *Aegis Cruiser Conversions: New Capabilities for the 21st Century*, p. 14.

[248] See for example "CG-16 *Leahy* Class," at http://www.globalsecurity.org/ military/systems/ship/cg-16.htm.

Mid-life Combat System Upgrades

A mid-life upgrade to a ship's HM&E systems is often, but not always, accompanied by a thorough upgrade to its combat systems. For example, in addition to upgrading the HM&E systems on selected World War II destroyers, the 1950s FRAM program also equipped the ships with the SQS-23 sonar, ASROC, and DASH, enabling them to take on Soviet high-speed submarines. Similarly, in the late 1980s, in addition to HM&E improvements, 24 of the original 31 *Spruance*-class destroyers exchanged their ASROC systems—consisting of an above-deck eight-round box launcher and a 16-missile, below-deck magazine (for a maximum ship missile load of 24 ASROCs)—with eight, 8-cell VLS modules capable of firing 61 ASROCs, or 61 *Tomahawk* land-attack missiles, or a combination thereof.[249] Along with the addition of a towed sonar array and other updates to their ASW combat systems, this ship-wide combat systems upgrade transformed the *Spruances*, long criticized for being under-armed, into the most powerful general-purpose "destroyers" in history, with a larger missile battery than a modernized, 57,000-ton, *Iowa*-class battleship.[250]

In contrast, the 30 aforementioned *Perrys*, while now receiving an upgrade to their HM&E systems, are receiving a minimal mid-life combat systems refit. If anything, the ships will be less capable than originally designed, as they are losing their ability to fire either SAMs or *Harpoons*. In other words, the ships are being transformed into nothing more than interim 4,000-ton Littoral Combat Ships, with much larger crews (and higher O&S costs). Unsurprisingly, then, they will be decommissioned as fast as the LCSs can be commissioned. Indeed, under current plans, ten of the 30 *Perrys* now in commission will be less than 35 years old when retired, even after receiving an HM&E upgrade.

As has been thoroughly discussed, even if so inclined, the Navy does not have the luxury of skipping a mid-life combat systems upgrade for its Aegis/VLS fleet. Under current plans, the DDG-1000s, CG(X)s, and DDG(X)s slated to replace them arrive far too slowly to allow their rapid retirement. Indeed, under the best of circumstances, these ships will constitute the largest percentage of TFBN BFC combatants through the mid-2030s. While they are highly capable ships, if they are to be able to defeat all the threats expected to materialize over the next two to three decades, the Aegis/VLS ships will all need a thorough combat system upgrade as extensive as those given the earlier FRAM and *Spruance* destroyers.

An Additional Critical Requirement: A Battle Network Upgrade

Recall that the Navy's overall transformation strategy counts less on the capability of any given ship or platform and more on the power of future naval battle networks. As the 84 Aegis/VLS ships will serve throughout the Navy's early transition from a Total Ship Battle Force to a Total

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[249] Like all early VLS installations, three of the cells were devoted to a missile strike-down module, reducing the actual number of operational VLS cells to 61.

[250] Four *Iowa*-class battle ships were recommissioned in the 1980s as part of the build up towards the "600-ship Navy." The modernized ships carried 32 TLAMs in eight, four-cell, deck-mounted armored box launchers (ABLs), and 16 *Harpoon* ASCMs in above deck canisters, for a total missile capacity of 48 missiles. In addition to the 61 missiles carried in their VLS battery, the *Spruances* also carried eight *Harpoons*, for a total missile capacity of 69 missiles.

Force Battle Network, the normal mid-life upgrades to their HM&E and combat systems must therefore also be accompanied by an additional Battle Network Upgrade (BNU), patterned after an earlier program called the New Threat Upgrade (NTU). Between 1983 and 1986, the Navy's surface battle line began a long transition from engagement networks that relied on rotating air search, height-finding, and fire control radars, early-generation anti-air warfare combat systems, and above-deck rail missile launchers to networks that incorporated the new SPY-1 phased array radar, Aegis combat system, and VLS. The legacy ships in the fleet that had been commissioned in the 1960s and 70s and had much hull life left in them. Because it was responding to a serious Soviet maritime challenge, the Navy could not afford to decommission the older ships, because doing so would cripple the fighting power of the fleet. Accordingly, along with their mid-life HM&E and combat system upgrades, the legacy BFC ships received special improvements to their NTDS network engagement capabilities, allowing them to operate effectively as part of new-generation battle networks with Aegis and the SPY-1. By making capability improvements to the ships' older rotating air search radars and fire control radars, combat systems, and combat direction centers, the NTU program allowed the ships to better complement the Aegis ships, and to conduct and coordinate engagements of multiple air and missile targets with extended-range *Standard* SAMs. The combination of Aegis and NTU ships greatly improved the overall performance of US naval battle networks against potential Soviet *Backfire* bomber and submarine ASCM raids.[251]

Just as the NTU took legacy anti-air warfare combatants and upgraded them to perform effectively alongside Aegis/VLS combatants, the BNU would take legacy Aegis/VLS combatants and upgrade them so that they will be better able to slot into and function in new FORCEnet-style Joint Multidimensional Battle Networks. At a minimum, the BNU would aim to equip every Aegis/VLS ship with the hardware and software necessary to allow them to operate as part of CEC-enabled engagement networks. However, the broader, more ambitious goal would be to replace as many components of the ships' government-owned or proprietary combat and weapons systems with commercial-off-the-shelf (COTS) items, and to move them all into an open architecture computing environment (OACE).

The Aegis combat system was designed during a period when the military market for advanced computing, communications, and combat systems was big enough to stimulate the research and development efforts of large defense and communications firms. Combat systems like Aegis were at the cutting edge of technology and a lucrative source of commercial business. By establishing rigid, requirements-driven, military specifications ("Mil-Specs"), the Navy could largely dictate and control the pace of change in both fleet combat systems and the micro-electronics industry.[252] Gaining control over and enforcing stability in the development process imposed some costs, however. First, it resulted in custom hardware and software solutions and unique combat systems architectures for almost every problem. Second, either the government or the system architect had proprietary control over both. As a consequence, combat systems like

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[251] See "CG-16 *Leahy* Class," and "New Threat Upgrade," at http://en.wikipedia.org/wiki/NewThreat Upgrade.

[252] Otto Kreisher, "COTS Technology Plays Increasing Role in Naval C3 Systems," *Naval Forces,* No. III/2005, Vol. XXVI, pp. 43-44.

the Aegis that remained in service for some time were characterized by multiple “baselines,” each with its own unique set of codes, and impossible to change without paying the proper proprietary agent additional money to do so. Obviously, enforcing fleet-wide standardization under such circumstances was a challenging task.[253]

By the end of the Cold War, however, the situation was completely different. The explosion in the consumer electronics business meant that the DoD’s demand for communications, computing, processing, and networking systems represented a smaller and smaller share of the total market. As a result, the Navy—as well as all the other armed services (and all other government information users)—discovered that commercial firms were driving the most advanced information and networking solutions. Moreover, they were producing upgrades and innovations at a much faster rate than possible in the conservative, risk-averse government procurement process.[254] In an era when computer processing capabilities doubled every 18 months, unless the government changed the way it was doing business, new US military systems would have hardware and software components that were obsolete before they even reached initial operational status. As one Navy admiral recently admitted:

> Frankly, we’re never going to be a big driver in the [future] informational technology business because we can’t invest as much as the commercial market place. We have to recognize that as a fact and evolve our FORCEnet capability and let industry drive that train for us…The information technology business, as everybody I think recognizes, is a huge engine being driven by many sectors. The DoD is now just a part of that.[255]

The first warfare community to understand the implications of a commercially-driven information marketplace and to then seek to exploit it was the Navy’s attack submarine community. Throughout most of the Cold War, US submarines had enjoyed a significant acoustic silencing advantage over their potential Soviet opponents. As a result, they could count on a “first-shot advantage” in most tactical undersea encounters, which in an age of homing torpedoes was thought to be a decisive one. After the Walker spy ring alerted the Soviets to this war-winning advantage, the Soviet submarine fleet rapidly implemented improvements which began to close the acoustic gap between US and Soviet submarines. This presented a major challenge for the US submarine fleet, which had long counted on its qualitative advantage in acoustics to overcome Soviet quantity in any potential undersea fight.[256]

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[253] Rear Admiral Mike Frick, USN, “PEO IWS: Vision for the Future,” a PowerPoint presentation given to the American Society of Naval Engineers (ASNE) Combat Systems Symposium on January 3, 2007; Chaisson, “Network Enabled Communications,” p. 73.

[254] Kreisher, “COTS Technology Plays Increasing Role in Naval C3 Systems,” pp. 43-44.

[255] Rear Admiral Kenneth Slaught, USN, as cited in Kreisher, “COTS Technology Plays Increasing Role in Naval C3 Systems,” p. 44.

[256] For information about the Walker spy ring, see “Family of Spies: the John Walker Jr. Spy Case,” at http://www.crimelibrary.com/terroristsspies/spies/walker/1.html. The best unclassified account of the US-Soviet undersea competition, the fight for acoustical superiority, and the effect that steady improvements to Soviet acoustical silencing had on US ASW strategy and operations is found in Owen R. Cote, Jr., *The Third Battle:*

The problem did not go away after the Soviet Union and its powerful submarine fleet imploded. US submariners continued to encounter extremely quiet Russian submarines like the *Akula*. Moreover, when venturing into shallow littoral waters, US submarines began to encounter, with much higher regularity, extremely quiet diesel-electric submarines, some with new air independent propulsion systems that dramatically reduced their requirement to snorkel while operating in a patrol area. To regain a first-shot tactical advantage against these very stealthy nuclear and battery-operated targets, the US submarine fleet sought to "buy back battlespace" by jumping on the coattails of the rampaging commercial information sector to make rapid, dramatic improvements to its sonars and signal processing equipment. The result was the Acoustic Rapid COTS Insertion (ARCI) program.[257]

As its acronym implies, the ARCI program sought to exploit the rapid innovation in the commercial information world by converting all US undersea combat systems to commercial-off-the-shelf components, and by adopting an open architecture computing environment for its signal processing and combat system software.[258] In a four-step process, the submarine community began shifting every one of its submarine sonar systems over to available off-the-shelf hardware and to open software with modular components that could be easily swapped out without the need for a complete computer code re-write. By the end of the process, US submariners had taken five different active submarine sonars, five different passive submarine sonars, and two different surveillance sonars (one land-based, one surface ship-based) and created two common processing "supersets"—one for active sonar processing software and one for passive sonar processing software. [259]

In the end, the ARCI program created a single submarine COTS/OACE sonar system—the AN/BQQ-10(V)—that is being forward-fitted and back-fitted into every US submarine, regardless of type or class. This allows US submariners to make improvements and insert new capabilities into their undersea combat systems much more rapidly than they could under the legacy Mil-Spec-driven approach. Moreover, block combat system upgrades could be instituted more rapidly across the entire force. In other words, the ARCI model helped to eliminate the large number of submarine combat system baselines associated with government-owned and company proprietary equipment.[260]

Innovation and the U.S. Navy's Silent Cold War Struggle with Soviet Submarines (Newport, RI: Naval War College, 2004), Newport Paper 16. See especially pp. 41-67.

[257] Captain Gib Kerr, USN, and Robert W. Miller, "A Revolutionary Use of COTS in a Submarine Sonar System," *Crosstalk: the Journal of Defense Software Engineering,* November 2004, found online at http://www.stsc.hill.af.mil/crosstalk/2004/11/0411Kerr.html.

[258] Mark Hewish, "COTS Approach Pays Off for US Navy ASW," *Jane's International Defense Review,* August 2000.

[259] Frick, USN, "PEO IWS: Vision for the Future," slide 12.

[260] Kerr and Miller, "A Revolutionary Use of COTS in a Submarine Sonar System;" and Hewish, "COTS Approach Pays Off for US Navy ASW."

More importantly, by extending the COTS/OACE paradigm to the sonar systems on its homing torpedoes, the US submarine force regained both its tactical advantage and became infinitely more tactically flexible. Theoretically, a submarine on patrol could pick up a new acoustical signal not found in its existing threat data base. It could go to periscope depth, raise an antenna above the ocean's surface, and "reach-back" to a shore-based ARCI test site where software engineers could write a new program to give the submarine a better chance of finding, engaging, and destroying the target. Once the program was tested, the software upgrade could be transmitted back to the submarine, where crew members could upload the new software into the open architectures of both the sub's undersea combat system and its torpedo guidance systems.[261]

Better yet, the whole process of rapidly improving fleet-wide signal processing and combat capabilities could be done far more cheaply than in the past. Based on fleet experience, ARCI ship-sets cost about 20 percent of the price of their government predecessors, yet they improved the sub's processing power by an order of magnitude.[262] As was recently written:

> The lower hardware cost and the continuous improvement cycle associated with commercial computer hardware is what allows the ARCI technology insertion process to succeed. If the cost of hardware components were equivalent to the [Mil-Spec] hardware used in the past, the pace of system upgrades would be unaffordable and the Navy would soon be behind the technology curve like it was in the mid-90s. Using a COTS technology insertion process has enabled a 10x increase in system throughput and an 86 percent reduction in hardware cost per billion floating point operations per second in a six-year period. Low hardware cost has also allowed the ARCI sonar program to purchase system equipment from several vendors, ensuring that a continuous price competition exists.[263]

Indeed, so successful was the ARCI program that the US submarine community decided to expand the program to include the entire non-propulsion electronics suite on the new *Virginia*-class attack submarine. Said another way, the ARCI process has expanded from a single sonar sensor and processor to a 20-million source lines of code system of systems that includes *all* of the submarine's sensors, navigation, combat/fire control, and ship monitoring functions.[264]

The obvious cross-warfare community applicability of ARCI-type programs quickly captured the imagination of surface warfare officers, who decided to follow the submarine community's lead and to shift the Aegis combat system over to a COTS/OACE system. The results rivaled the success of the earlier program. In 1997, there were 52 Aegis combatants with multiple Aegis

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[261] The Navy began development of a COTS/OACE Common Broadband Advanced Sonar System (CBASS) upgrade for its homing torpedoes in FY 1998. The system is now being inserted into fleet torpedoes. See Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, pp. 534-536.

[262] See Chief of Naval Operations Submarine Warfare Division, "Submarine Themes: Submarine Innovation," found online at http://www.navy.mil/navydata/cno/n87/themes/subinno.html.

[263] Kerr and Miller, "A Revolutionary Use of COTS in a Submarine Sonar System."

[264] Kerr and Miller, "A Revolutionary Use of COTS in a Submarine Sonar System."

baselines, supported by no less than 16 different processors, costing a billion dollars, which ran monolithic software programs off of shared system memory. Aegis R&D cost $395 million in FY 2007 dollars, and lifetime support for existing versions was estimated to be an additional $126 million. Ten years later, in 2007, well into its COTS/OACE transition, the Aegis system uses one processor that costs about $4,000, and reusable, modular, and open software components. With 72 Aegis VLS ships now in commission, the Navy is spending only $102 million (FY 2007 dollars) on Aegis R&D, and the estimated lifetime support for the ships is $54 million.[265]

Unsurprisingly, given the great success of both the ARCI and Aegis open architecture (Aegis OA) programs, Navy leaders vowed to expand the benefits of a COTS/OACE approach aggressively across the entire FORCEnet enterprise. Perhaps no leader has embraced COTS/OACE combat systems more than Admiral Mullen, the current CNO, who said, "As Aegis expands to open architecture, [open architecture] will be introduced throughout the fleet…When I say open, I mean open systems, open competition, and open the throttle. I want to move as fast as we can."[266] This means, among other things, that in addition to Aegis, the surface warfare community will convert VLS, CEC, and all other surface ship combat systems into COTS/OACE systems. By doing so, it will, in effect, transform the legacy Aegis/VLS warships into Interim Large Battle Network Combatants. While the I-LBNCs will look no different than earlier CGs and DDGs on the outside, they essentially will be new ships on the inside, configured to support a fleet-wide rapid capability insertion regime that sees a combat system's hardware updated every four years and its software every two. The result will be a constantly evolving and transforming TFBN battle line much more powerful and flexible than the TSBF battle line already in service.[267]

Admiral Mullen's COTS/OACE vision has also been embraced by the Department of the Navy's senior civilian leadership. As Dr. Dolores Etter, the current Assistant Secretary of the Navy for Research, Development, and Acquisition, said on November 28, 2006, "We are transforming our acquisition organization and culture by making open architecture a business strategy, not just a philosophy."[268] The strategy is breathtaking in scope, with an ultimate goal of creating a TFBN Common Computer Code Library of non-proprietary, open, modular software components. Any interested vendor will have access to any component in order to improve their functionality or to develop new computer applications and capabilities. When combined with combat system laboratories that can test new COTS systems and blocks of code before incorporating them in active ships, platforms, or systems, the Navy hopes to create an engine for constant competition

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[265] From "Surface Open Architecture," a PowerPoint briefing given to the author by Lockheed Martin Corporation on December 13, 2006, particularly slides 5 through 11.

[266] Frick, USN, "PEO IWS: Vision for the Future," slide 5.

[267] From "Surface Open Architecture."

[268] Frick, USN, "PEO IWS: Vision for the Future," slide 5.

and innovation, with an eye toward creating a continually evolving and improving common family of combat system and applications.[269]

How far this exciting idea will go remains an open question. For example, the goal of Lockheed Martin engineers is to convert the entire Aegis system, with the exception of some core software programs designed in an era of 4-megahertz computer processors, over to open architecture by 2008, and to form an Aegis library consisting of a master common core and unique plug-in capability extensions. Every one of the capability extensions would be available to other companies for their inspection, review, and improvement.[270] Other companies, such as General Dynamics, want even the core Aegis software programs to be open to their inspection, arguing that the only possible outcome will be even better and cheaper Aegis capabilities as different companies compete to improve the source code.[271] In this spirit, the company recently delivered its Littoral Combat Ship Open Data Model, with unrestricted rights to both the Navy and other commercial companies to the entire mission architecture, enabling any company to inspect, test, and improve its components, and to integrate new capabilities into the system.[272]

Regardless of whether or not the Aegis core modules ultimately become fully open, however, it is clear that the Navy is intent on speeding a general conversion of all fleet combat systems to COTS/OACE architectures.[273] The final result will be a future Total Force Battle Network that is both different and more powerful than any past US TSBF. For example, one sure result will be a dramatic neckdown in the number of unique TFBN combat systems. For example, in ASW, the goal is to merge 38 different airborne, surface ship, submarine, and surveillance combat systems into one open architecture system with two processing supersets—one active, one passive—that can be used interchangeably on all legacy and future TFBN ASW platforms.[274] With common COTs hardware and modular OACE software, it will be possible to make rolling combat system upgrades across the entire TFBN. New threats will be met first by new modular software applications to existing combat and weapon systems and weapons, or with new weapons that can be fired by existing systems, rather than building entirely new platforms. Another sure result is a dramatic savings in fleet-wide O&M costs for the maintenance of TFBN information and combat systems. Lockheed Martin engineers estimate the shift to COTS/OACE components for ARCI and Aegis combat systems alone will result in more than $11 billion in savings over the lives of

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[269] Frick, USN, “PEO IWS: Vision for the Future,” slide 11; and Kreisher, “COTS Technology Plays Increasing Role in Naval C3 Systems,” pp. 46-50.

[270] From “Surface Open Architecture,” a PowerPoint briefing given to the author by Lockheed Martin Corporation on December 13, 2006, particularly slides 5 through 11.

[271] “Surface Navy Rapid Capability Insertion (SNRCI),” a PowerPoint Presentation provided to the author by General Dynamics Advanced Information System personnel in May and December 2006.

[272] Geoff Fein, “General Dynamics Gives Navy Unrestricted Rights to LCS Mission Architecture,” *Defense Daily*, January 7, 2007.

[273] Geoff Fein, “Working Group Focused on Accelerating Open Architecture Effort,” *Defense Daily*, January 24, 2007.

[274] Frick, USN, “PEO IWS: Vision for the Future,” slides 11 and 12.

the platforms that carry them.[275] It is no exaggeration to say that the Navy's enterprise-wide embrace of a COTS/OACE strategy is the single most important discriminator between the legacy Total Ship Battle Force and the evolving Total Force Battle Network.[276]

The Navy is not the only Service that has recognized the business and warfighting payoffs of a COTS/OACE network strategy; the Air Force, Army, Marine Corps, and Coast Guard are all pursuing similar strategies to varying degrees. Indeed, the Defense Department has concluded that the fastest and most effective way to build interoperable Joint Multidimensional Battle Networks is to devise common battle network technical standards based on commercial standards and systems, and allow the individual Services to pursue commercial-off-the-shelf and open architecture solutions for their own unique requirements. As was written in a recent edition of *COTS Journal*, "What's making jointness a reality today is commercial-off-the-shelf hardware and software."[277]

As this discussion makes clear, then, any mid-life Aegis/VLS FRAM-like program must be accompanied by a Battle Network Upgrade program. In other words, the Navy needs to plan, design, and execute a combined Battle Network Reliability and Maintenance (BNRAM) program for its Aegis/VLS fleet. However, to be fully complete, the Aegis/VLS BNRAM program will need two additional things: a concerted effort to reduce the size of legacy ship crews and a sustained follow-on maintenance regime.

Crew-Reduction Measures

To help build the TFBN fleet of the future, recall that the Navy is counting on keeping O&M costs flat over time. The move to a COTS/OACE TFBN architecture will certainly help to achieve this ambitious goal. However, as previously discussed, the main contributor to fleet-wide O&S life-cycle costs is the size of the crews needed man, operate, maintain, and fight TFBN warships. A Navy study in 2001 determined that the average yearly operating cost for an Aegis combatant was approximately $32.5 million a year, which included the annualized cost for the ship's crew, fuel, overhaul and repair, repair parts, fleet modernization efforts, engineering and technical services, crew training, and training ammunition. Of that, personnel costs alone accounted for half the total yearly operating cost.[278] Therefore, a key goal of a combined BNRAM program should be to reduce Aegis/VLS crew sizes, which now number 300 or more. As evidenced by plans for the *Perrys*, older ships with large crews are prime candidates for the

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[275] "Surface Open Architecture," slide 12.

[276] For an excellent and thorough discussion of the importance of COTS/OACE, see Captain Richard T. Rushton, USN, Michael McCrave, Mark Klett, and Timothy Sorber, *Open Architecture, the Critical Network Centric Warfare Enabler*, 2nd edition, a monograph written for the US Navy dated June 29, 2004.

[277] Kreisher, "COTS Technology Plays Increasing Role in Naval C3 Systems," pp. 43-44.

[278] Glen Sturdevant, "Aegis SMARTSHIP Program," a PowerPoint presentation given to the Marine Machinery Association on May 2, 2001, found online at http://www.marmach.org/pdf/minutes/arlington010522/smartship.pdf#search=%22Navy%20 SMARTSHIP%20personnel%20reductions%22.

budget ax. Failing to reduce the crews on Aegis/VLS ships will likely guarantee they will never see their 35th year of service.

The Navy's long interest in controlling O&S costs through crew reductions has been reflected in its so-called Aegis SMARTSHIP program, as well as efforts to identify the "optimal" (minimum acceptable) manning requirements for both legacy CGs and DDGs. These efforts focused on reducing the number of personnel needed to man watches in the propulsion plant, in damage control central, and on the bridge. By pursuing Integrated Ship Controls (ISC), establishing multifunction workstations connected by fiber optic cables, and adding shipboard video surveillance systems and wireless communications, the Navy has been able to pare down the size of an Aegis/VLS combatant's crew without impairing its ability to man the ship.[279]

The BNRAM program should continue this trend, exploiting technology to the maximum extent possible to reduce the size of the Aegis/VLS crews still further. Why? Because the Navy will get a much higher interim O&S pay-off by reducing the crew size for Aegis/VLS ships than it will by pursuing the DDG-1000 or CG(X). A crew reduction of 50 personnel per ship would cut the fleet-wide crew requirement for the 84-ship fleet by 4,200. Reducing ship crew size by 100 per ship would drop fleet manning requirements by another 4,200, saving nearly a billion dollars a year in recurring O&S costs. In other words, due to the large size of the Aegis/VLS battle savings due to crew reductions will accrue much faster than by introducing new generation combatants with smaller crews over a 40-year period.

A Sustained Follow-on Maintenance Regime

While ships are inherently maintenance intensive, US Navy warships are especially so. In addition to being among the most complex federated system of systems built by the Department of Defense, warships spend a great deal of time operating under demanding conditions in a very harsh environment. Under these circumstances, even after a thorough mid-life upgrade, Navy planners can count on gradually having to spend more O&M dollars to keep the Aegis/VLS fleet in good operating condition, especially as they age past 20 to 25 years of service. As discussed earlier, the upward pressure on fleet-wide maintenance will be especially high after 2015, when the oldest remaining *"Tico"* reaches 30 years of service, and the number of ships with greater than 25-28 years of service starts rapidly to climb.

One way to keep these maintenance costs from getting out of hand will be to fashion a serious and sustained maintenance program that aims to prevent cascading fleet-wide reliability problems as the average age of the fleet climbs above 25 years. Failing to do so will cause the ships to age far more rapidly than expected, as was seen during the 1980s and 1990s when basic operations and maintenance funds for surface combatants were continually diverted to pay for other fleet requirements. One result was that the *Spruance*-class DDs wore out more rapidly than planned. By the late 1990s, long-delayed or canceled maintenance work made these ships a

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[279] Sturdevant, "Aegis SMARTSHIP Program."

nightmare to maintain, which, along with their large crews, prompted then-CNO Admiral Clark to order their early retirements.[280]

The need for a well thought out maintenance regime will be especially important in an era of relatively small crews optimized to fight the ship but not necessarily to maintain it. In addition to trying to reduce Aegis/VLS crews to save on spiraling personnel costs, the Navy is introducing a new generation of combatants designed from the keel up with small crews. As was discussed earlier, the DDG-1000, despite being a 14,500-ton ship, is designed for a crew of 143 people. The smaller Littoral Combat Ship will carry a core crew (not counting the personnel associated with its modular mission packages) of only 40. However, while minimizing crew size will be a key goal for all future TFBN warships, the maintenance concepts of operations for a fleet of leanly crewed combatants have yet to be fully worked out. For example, when discussing the maintenance ConOps for the new LCS, Vice Admiral Terrance Etnyre, Commander, Naval Surface Forces, recently remarked, “Do I have the crew do it? When I look at the crew being as small as they are, probably not.” He then went on to talk about the need to institute a blended maintenance regime involving the ships’ crews, contractors, and Navy shipyards.[281]

A key part of any good maintenance regime will be a serious inspection effort to identify maintenance and reliability problems before they become serious or have class-wide effects. In this regard, the Navy recently teamed with the American Bureau of Shipping (ABS) to institute an inspection program for the new LCS to ensure its enduring high operational availability. The program would include annual surveys of the ships’ HM&E and distributed systems, augmented by more extensive surveys every eight years or so. The effort could eventually lead to similar efforts for other warships, including the Aegis/VLS combatants.[282]

However, while a rigorous inspection regime has long been practiced by the US submarine community, it is a relatively new idea for surface warships, especially those with crews too small to perform maintenance. The force structure and O&M implications for such new maintenance regimes designed to accommodate small ship crews are unknown at this time. Will ship squadrons need to have new shore-based maintenance units? If so, will these shore-based units be manned by active duty Navy personnel, or contractors, or both? How much will it cost to stand up and operate them?

All of these questions remain to be answered. One thing seems certain, however: given the Navy’s firm commitment to building future combatants with small crews, it seems likely that the future ship inspection and maintenance regime will be carried out by outside agents like ABS,

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[280] Maintenance problems were by no means the only reason the ships were decommissioned. They had large crews and were a focused mission ASW ship. By retiring the ships early, the Navy was able to divert about $1.25 billion over the Future Years Defense Plan (FYDP) toward other fleet priorities. See “DD-963 *Spruance*-Destroyer,” at http://www.globalsecurity.org/military/systems/ship/dd-963.htm.

[281] Geoff Fein, “Surface Warfare Enterprise Tackling LCS Manning, Training Challenges,” *Defense Daily*, January 19, 2007.

[282] Geoff Fein, “Navy, ABS Team to Ensure High Operational Availability of the LCS,” *Defense Daily*, January 22, 2007.

shore-based maintenance units, or contractors. Unless these efforts are properly funded, the likelihood that ships will serve to the end of the expected service lives will be small.

The Importance of Being Earnest

Scrimping on any one of the five BNRAM components—an HM&E upgrade; a combat system upgrade; a battle network upgrade; crew reduction initiatives; and a sustained follow-on maintenance regime—will likely lead to unwanted early Aegis/VLS ship retirements. For example, despite getting a thorough combat system upgrade, the *Spruance*-class destroyers were retired far before the end of their expected service lives, in part, by a shoddy maintenance regime and large crews. The NTU ships were compromised by their large crews and their steam propulsion plants, for which no amount of rehabbing made economic sense. The first five *Ticonderoga* CGs were retired after the Navy concluded that the cost to replace their old rail-style missile launchers with VLS batteries would make their combat system upgrade prohibitively expensive. Finally, one-third of the 30 *Perrys* now in commission, even after getting a mid-life HM&E upgrade, will serve less than 35 years because of their minimal combat systems capabilities and large crew sizes.

There are simply no two ways about it: if the Navy's broader plan to assemble a future TFBN with 313 ships has any reasonable chance of success, the surface warfare community will have to back its bet that all 84 Aegis/VLS ships will complete 35 years of TFBN service. This will require that they plan, fully fund, and diligently execute a comprehensive, five-part Aegis/VLS Battle Network Reliability and Maintenance program.

BUT CAN THEY FIGHT?

When discussing the necessary components of an Aegis/VLS BNRAM, it is important not to miss the forest for the trees. The acid test for the BNRAM program is not whether it allows Aegis/VLS ships to survive for 35 years and lowers fleet O&S costs in the process. Just as was the case in the 1950s FRAM, the 1980s NTU, and the 1990s ARCI programs, the most important result of any BNRAM program will be modernized and upgraded surface combatants that are capable of defeating the most severe tactical threats while they remain in commissioned service. In this regard, there are at least three emerging tactical challenges that BNRAM combatants must be able to overcome if they are to have any prospect of contributing to future TFBN operations: ballistic missiles attacks, including those with maneuvering anti-ship warheads; attacks from stealthy, supersonic land-attack and anti-ship cruise missiles; and torpedo and ASCM attacks from quiet, air-independent submarines operating in shallow and noisy littoral waters.

How would BNRAM Aegis/VLS combatants stack up against these three challenges? The initial judgment is quite well, indeed.

Ballistic Missile Attacks

Since 1998-1999, ballistic missile development, testing, and fielding have accelerated throughout the world. Ballistic missiles are an attractive force option because they can penetrate all but the most sophisticated integrated air defense networks, against which attacks using manned aircraft are too risky or costly. Missile forces also have the advantage of having fewer overall maintenance, training, and logistic requirements than an air force. As a result, the National Air Intelligence Center (NAIC) now reports a total of 25 countries have ballistic missile arsenals with either short-, medium-, intermediate-, or intercontinental-range ballistic missiles, or combinations thereof.[283] Besides the United States, Russia, China, Britain, France, India, Pakistan, North Korea, and Iran have the largest and most capable ballistic missile forces in the world today. Seven of these eight foreign nations are acknowledged nuclear powers, and the eighth—Iran—is actively trying to become one. Given the degree of ballistic missile proliferation seen to this point, it is not a stretch to predict that even some non-state actors may someday have small arsenals of these weapons. In its recent 34-day war with Israel, Hezbollah employed both battlefield-range unguided rockets and guided anti-ship cruise missiles.[284] A further step toward a ballistic missile capability, especially considering the prominent role ballistic missiles play in the armed forces of their state sponsor, Iran, would not be a large one.

All ballistic missiles fly high-altitude trajectories divided into three phases: boost (ascent), midcourse (climb and descent through the trajectory's apex), and terminal (descent toward the target). The longer a missile's range, the longer the time spent in all phases of its flight, and the longer the time the missile spends outside the earth's atmosphere (i.e., in exoatmospheric flight). Regardless of range, ballistic missiles are easiest to sense and engage when they are in their ascent phase, during which their rocket plumes are the most intense and they are struggling against gravity to reach their maximum velocities. Unfortunately, boost phase interceptors must be relatively close to the missile's launch site to have a reasonable chance of intercepting an outbound missile during its climb out of the atmosphere. Once in their midcourse phase, ballistic missiles can release multiple reentry vehicles (RVs) and decoys, making target discrimination within the "RV/decoy complex" a difficult problem. When the RV/decoy complex reenters the atmosphere in its terminal phase of flight, the decoys are stripped away. The bad news is that the RVs themselves present very fast, very small, and sometimes maneuverable targets.[285]

As this discussion suggests, then, intercepting a ballistic missile in any phase of its flight is a tough problem, and positioning the "shooters" of ballistic missile interceptors is a critical consideration in ballistic missile defense (BMD) planning. Moreover, any ballistic missile defense interceptor must be a relatively large and "hot" missile, with high velocities and long ranges, either to catch its target during the ascent phase, or to reach out and make a midcourse, exoatmospheric interception, or to quickly climb out and destroy the RV as high up in the atmosphere as possible once it reaches its terminal phase.

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283 See National Air Intelligence Center, "Ballistic and Cruise Missile Threat," at http://www.mda.mil/mdalink/bcmt/bcmt.html. According to the NAIC, a short-range ballistic missile has a range less than 1,000 kilometers (km) (621 miles); a medium-range ballistic missile has a range between 1,000 and 3,000 km (621-1864 miles); an intermediate-range ballistic missile has a range between 3,000 and 5,500 km (1,864-3,418 miles); and an intercontinental ballistic missile has a range greater than 5,500 km (3,418 miles).

284 For a quick overview of the war, see "2006 Israel-Lebanon War," at http://en.wikipedia.org/wiki/ 2006 Israel-Lebanon_conflict.

285 For a discussion of ballistic missile flight phases, see the Missile Defense Agency website at http://www.mda.mil.

Unsurprisingly, given both their global mobility and large sensor and weapon capacities, US naval warships play an integral part in US plans to address the growing threat of ballistic missiles to its forward bases and forces, allied forces and population centers, and even the continental United States itself. These plans, developed by the Missile Defense Agency (MDA), foresee a multilayered Ballistic Missile Defense System (BMDS)—in essence, a *global* Joint Multidimensional Ballistic Missile Defense Network—comprised of overlapping sensors and weapons capable of countering the entire array of emerging ballistic missile threats in all phases of their flight.[286] As part of the BMDS, the MDA has funded a spiral development program to convert 18 Aegis/VLS ships (three *Ticonderoga*-class CGs and 15 *Burke* DDGs) into ballistic missile defense ships. Between now and 2010, the ships will receive a new open architecture Aegis BMD signal processor (Aegis BSP) to improve both their tracking and range resolution of ballistic missile trajectories as well as their ability to discriminate targets in an RV/decoy complex. This new processor is being accompanied by successive COTS/OACE upgrades to other Aegis and VLS hardware and software components. These improvements will ultimately enable all 18 ships to track all types of ballistic missiles, and to engage them with increasingly capable versions of the *Standard* SM-3 exoatmospheric ballistic missile defense interceptor.[287]

The first converted ballistic missile defense ships became operational in 2004. All of these early BMD ships could conduct long-range surveillance and tracking of ballistic missiles, but only a few were capable of engaging short- and medium-range ballistic missiles with the earliest, Block IA version of the SM-3.[288] Moreover, when performing in the BMD role, the ships could not perform any other battle network defensive duties such as anti-air warfare. However, by 2006, improvements to both the Aegis BSP and other software components of the Aegis combat system meant that a steadily growing number of the BMD ships could track and engage short- and medium-range missiles, and some intermediate range missiles, while performing all of their normal battle network duties.[289] By 2010, all 18 ships, armed with the most capable version of the SM-3, will be able to track, classify, and engage most ballistic missile threats—to include some intercontinental ballistic missiles.[290] Consistent with battle network precepts, the ships will

[286] For a thorough overview of the evolving US Ballistic Missile Defense System, see "A Day in the Life of the BMDS," at http://www.mda.mil/mdalink/pdf/bmdsbook.pdf.

[287] From "Aegis Ballistic Missile Defense Status Overview," a PowerPoint briefing provided to the author by Lockheed Martin Corporation on December 13, 2006.

[288] The Block IA version of the SM-3 has a 21-inch diameter booster rocket, a GPS/inertial guidance system, and a kinetic hit-to-kill warhead. See "RIM-66C/RIM-156/RIM-161 Standard Missile," in "Ship Weapons," 2007 Almanac, *Seapower*, January 2007, p. 67.

[289] By 2006, the Block IB version of the SM-3 was operational, with an advanced two-color infrared seeker to help discriminate between RVs and decoys, and a throttling divert-and-attitude control system for increased maneuverability against sophisticated warheads and intermediate-range missiles. See "RIM-66C/RIM-156/RIM-161 Standard Missile," p. 67. Although the 2006 Aegis BSP upgrade allows an Aegis combatant to perform BMD and AAW missions simultaneously, the ship cannot engage as many simultaneous air targets as an Aegis combatant in a stand-alone AAW role. From "Aegis Ballistic Missile Defense Status Overview."

[290] The Block IIA version of the SM-3, a cooperative program with the Japanese Missile Defense Agency, increases the diameter of both the missile's second-stage booster and warhead section to a full 21 inches, giving the missile a higher burn-out velocity, longer range, and better divert capability than earlier versions of the interceptor. See "Aegis Ballistic Missile Defense Status Overview."

be able to *launch on remote*, using data provided by other BMDS sensors to initiate the engagement, but using onboard sensors to conduct the final intercept, and to *engage on remote*, turning over missile guidance and intercept entirely to offboard BMDS sensors. At that point, the 18 ships will be "an integral part of the BMDS—all ranges, all phases, all regions."[291]

Although an impressive new capability, 18 ballistic missile defense ships are not nearly enough to counter the expanding threat of ballistic missiles to US and allied population centers, bases, and forces. Yet the Navy has to this point been noticeably ambivalent about fully embracing the ballistic missile defense mission, apparently because it is afraid that the mission will consume a disproportionate share of its own resources and divert an increasing proportion of the battle fleet to national, rather than joint and naval, requirements. Consistent with this thinking, it cancelled its own Navy Area Defense program in 2001 and has yet to start a replacement program. It has been more than content to rely on MDA funding to develop fleet ballistic missile defense capabilities.[292]

It seems unlikely the Navy will be able to continue down this path. Given the proliferation of ballistic missiles, as the Navy demonstrates an improved ability to intercept and destroy them from the sea, it will likely be increasingly expected to provide defensive fires against them for joint forces operating ashore—at least for as long as it takes to establish joint BMD units ashore. Moreover, fleet ballistic missile defenses will soon be required to counter a growing ballistic missile threat to ships at sea. While using ballistic missiles to target ships at sea is not a new idea, the technical challenges that have to be overcome to make the idea a reality have heretofore prevented any operational systems form being fielded. The Soviet Navy first experimented with anti-ship ballistic missiles (ASBMs) in the 1960s and 1970s. However, due to the contemporary lack of *maneuverable* reentry vehicles with high-definition terminal seekers, they were forced to arm the missiles with 550-kiloton to one megaton nuclear warheads, limiting their tactical use. Today, given the dramatic improvements to reentry vehicles and seeker technologies, the idea of pursuing ASBMs is both more practical and attractive to some nations, especially because of the high stresses the missiles would impose on opposing naval battle networks. Due to the high costs necessary to erect a supporting over-the-horizon battle network infrastructure, however, only the Chinese appear to be seriously pursuing ASBMs, apparently armed with maneuverable, hit-to-kill, conventional kinetic warheads. It is not yet clear whether they are also planning to equip the missiles with an optional nuclear warhead.[293]

In any event, given the rising threat of both land-attack ballistic missiles and ASBMs, being able to mount an effective area and terminal defense against these weapons appears to be a high priority for future CEC-enabled battle networks. Unfortunately, the Navy's area defensive

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[291] Otto Kreisher, "Bigger Shield," *Seapower*, December 2006, pp. 44-43; and "AEGIS Ballistic Missile Defense Status Overview."

[292] Commander L. Paul James III, USN (retired), "Should the Navy Do Missile Defense?" *Proceedings*, February 2007, pp. 36-39.

[293] Office of Naval Intelligence, *Worldwide Maritime Challenges 2004*, p. 22; and Norman Polmar, "Antiship Ballistic Missiles…Again," *Proceedings*, July 2005, pp. 86-87.

capability is restricted to a relatively small number of missiles funded by MDA, and the only terminal capability that now exists—the interim Sea-Based Terminal (SBT) system—is a modified Standard SAM that represents only "a near-term, limited emergency capability."[294] Moreover, the DDG-1000 will not have a BMD capability; that is not expected to come until the first CG(X) is commissioned, late in the next decade. To stay ahead of the evolving ballistic missile threat, it seems clear that the Navy needs to pursue other avenues to improve TFBN ballistic missile defenses more rapidly.

The fastest way to do this is for the Navy to leverage the MDA-funded Aegis improvements and to use DoN money to convert more Aegis/VLS combatants into BMD-capable warships. In this regard, the final stage of development in the MDA-funded Aegis BSP effort and Navy-funded COTS/OACE initiatives will be a multi-function signal processor (MFSP) and an open architecture Aegis combat system that, when installed, will allow 18 TFBN Aegis/VLS combatant to perform the missile defense mission as well as its other battle network duties.[295] The BNRAM program should aim to equip *all 84* Aegis/VLS ships with the MFSP and other hardware and software upgrades necessary for them to engage ballistic missiles. This effort should be supported by a complementary development program for an expanded family of anti-ballistic missiles that can fit inside the current Mk-41 VLS cells.

Cruise Missile Attacks

In addition to protecting joint forces operating ashore and allied territory from ballistic missile attacks, future surface combatants will also be expected to defend against land-attack cruise missiles (LACMs). Although LACMs have not proliferated as rapidly as ballistic missiles, the NAIC estimates that within the next decade nine countries will produce them and as many as 20 countries will operate them. In contrast to ballistic missiles, a LACM is an unmanned, armed aerial vehicle that spends the majority of its flight time in low-altitude, level flight through the atmosphere (i.e., in endoatmospheric flight). Propulsion is usually provided by a small jet engine. New guidance technologies allow LACMs to fly preprogrammed paths to their targets and to strike them with pinpoint accuracy.[296]

Because of their unique flight profiles, future LACMs will stress air-, land-, and sea-based air defense systems as severely as ballistic missiles, but in a different way. Most cruise missiles will use their low-altitude, terrain-hugging mission profiles to stay below, or to mask themselves from, an adversary's radar and infrared sensors. Moreover, all LACMs will be able to fly circuitous routes to get to their targets. With smart mission planning, they can therefore be programmed to avoid land-based radar and air defense installations. To make matters more difficult for defenses, some missiles will employ stealth features to make them even less visible to tracking radars, infrared detectors, and missile guidance radars. If that were not enough, flights

[294] Missile Defense Agency, *For Your Information*, "First At-Sea Demonstration of Sea-Based Terminal Capability Successfully Completed," May 24, 2006, as cited in James III, "Should the Navy Do Missile Defense?," p. 37.

[295] "Aegis Ballistic Missile Defense Status Overview."

[296] See "Land Attack Cruise Missiles" in National Air Intelligence Center, "Ballistic and Cruise Missile Threat."

of LACMs can be programmed to attack a target simultaneously from different directions, in order to overwhelm its terminal air defenses. Future LACMs packed with chaff or decoys will make the job of terminal defenses even more difficult, especially when the defenses are located at sea.[297]

Future naval battle networks must also be prepared to blunt the direct attacks of anti-ship cruise missiles. During the World War II Pacific campaign, the earliest US naval battle networks were attacked by the first guided "anti-ship cruise missiles," although these *kamikaze* ASCMs generally came in the form of propeller-driven airplanes guided in their terminal attack runs by a human pilot bent on suicide. The first true combat use of an anti-ship cruise *missile* came two decades later, when in 1967 the Israeli destroyer *Eilat* was sunk by four Soviet-designed *Styx* ASCMs fired from Egyptian fast missile boats. These early ASCMs were large, slow, ungainly in flight, and relatively easy to intercept once navies became aware of them. However, over time, ASCMs have become smaller, more maneuverable, and more difficult to counter.

For example, modern ASCMs now routinely fly at high subsonic speeds at low "sea-skimming" altitudes, which make them difficult to track on radar, especially against the low-altitude radar "clutter" caused by normal wave action. Some ASCMs use supersonic speed and sharp "pop-up" terminal dives to further complicate battle network defenses. As naval engagement networks have improved, new ASCMs incorporate stealth features making them even more difficult to detect. For example, the new Russian/Indian SS-N-26 has a frontal aspect radar cross section of 0.25 meter squared (m^2)—about 20 percent that of a standing human. Perhaps the most dangerous contemporary ASCMs is the SS-N-27 *Sizzler*. *Sizzlers* are stealthy, three-stage missiles that fly at high subsonic speed at sea-skimming altitudes until they get to within 20 km of their designated target area. They then pop up to acquire their target using onboard radars before firing a terminal supersonic "combat stage" powered by a solid-fuel rocket.[298] The missile's unique combination of flight and weapon characteristics makes it a very difficult target for any *single* ship to defend against.

Top DoN officials thus see the "brass ring" for future TFBN battle networks as being the ability to protect future naval task forces and joint and allied forces operating ashore from stealthy, high-speed LACM and ASCM attacks. Since the Navy often justifies its programs in terms of unique platform characteristics, it thus now touts the DDG-1000 as the bridge to the CG(X), its preferred future theater aerospace dominance platform. They argue that unless the ship is built, the TFBN will never achieve the ability to defend against future cruise missile threats.[299] However, as has been discussed, this line of argument is incongruent with the whole idea of FORCEnet and the Total Force Battle Network, which will approach all future tactical problems from a comprehensive network, rather than a platform-centric, perspective.

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[297] "Land Attack Cruise Missiles" in National Air Intelligence Center, "Ballistic and Cruise Missile Threat."

[298] Stephan Nitschke, "Air-, Surface-, and Subsurface-Launched Naval Cruise Missiles," *Naval Forces*, No. VI/2006, Vol. XXVII, pp. 32-41.

[299] See remarks made by Vice Admiral Joseph Sestak, DCNO for Warfare Requirements and Programs, in Andrew Koch, "US Shipbuilding Plan Takes On Water," *Jane's Defense Weekly*, June 29, 2005.

This approach is readily evident in the Navy's announced plans to defeat the future LACM and ASCM threat, as well as all future air threats. In essence, the Navy intends to expand the capability of CEC naval battle networks through the Navy Integrated Fire Control-Counter Air (NIFC-CA) program. Touted as the key component to the Navy's future "Sea Shield" efforts, the NIFC-CA is reliant neither on the DDG-1000 nor its new SPY-3 radar. Instead, the program combines current and emerging technology such as the Aegis combat system, CEC, and the E-2D *Advanced Hawkeye* with its new AESA radar to greatly expand the sensor envelope around future naval battle networks. To exploit the expanded sensor envelope, the program also provides future CEC networks with new long-range engagement options, such as AESA-equipped carrier fighters armed with new versions of the Advanced Medium-Range Air-to-Air Missile (AMRAAM), and new long-range VLS-launched SAMs like the SM-6 Extended Range Active Missile (ERAM) with an engage-on-remote range of 200 nautical miles.[300] The objective is a capabilities-based network solution to air and cruise missile defense that extends the defensive depth of a naval battle network "well beyond the existing, stand-alone capability of surface ship-controlled air defense weapons."[301]

Once again, it is important to remember that there is little combat data to help determine if NIFC-CA battle networks will be able to defeat the evolving advanced, stealthy ASCM threat. However, as the quote above suggests, it seems readily apparent that single ships and non-networked task groups are already overmatched by the most deadly modern ASCMs. Therefore, the Navy's move toward new battle network programs such as NIFC-CA appears well justified. However, for future naval battle networks to function as predicted, they will need as many participating platforms as possible to provide the best radar geometries and the best chance of detecting attacking cruise missiles at long range. Therefore, if the Navy is serious about defeating the threat of anti-ship cruise missiles, a Battle Network Upgrade which allows all 84 Aegis/VLS combatants to operate as NIFC-CA nodes will provide as big a near-term payoff, if not bigger, than building seven DDG-1000s.

Attacks from Quiet, Air-Independent Submarines Operating in Noisy Littoral Waters

Recall that one reason that US submariners confidently thought they could win the Cold War undersea competition was because Soviet early submarines, particularly their nuclear boats, were relatively noisy. Indeed, these early Soviet submarines were so noisy the US Navy developed the Sound Surveillance System, or SOSUS, composed of long fixed hydrophone arrays, located on the ocean floor and connected to shore-based acoustic processing facilities. This system, focused on maritime chokepoints, could pick up the noisy Soviet submarines at extremely long ranges,

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[300] The SM-6 combines the SM-2 Block IV missile stack with advanced active seeker technology taken from the AMRAAM. This allows the missile to *engage on remote*—using only offboard ship sensors—which will allow a firing ship to take full advantage of the missile's improved kinematics and long range. To make clear, however, the missile will still need some sort of external guidance until it is close enough to the target for its active seeker to take over. This guidance may come from an E-2D's AESA radar rather than a shipboard SPY-1.See Patricia Kime, "Navy Pursues SM-6 as Defense Against Cruise Missile Threats," *Seapower,* November 2004, p. 19.

[301] From Exhibit R-2, Fiscal Year 2007 RDT&E Justification for Naval Integrated Fire Control-Counter Air Engineering, dated February 2006, found online at http://www.dtic.mil/descriptivesum/Y2007/Navy/ 0604378N.pdf.

and be used to cue long-range P-3 ASW patrol aircraft and SSNs toward Soviet submarines, greatly facilitating their search and attack operations.[302] If the submarines were able to evade US P-3s and SSNs, US warships using both active and passive shipboard sonars, augmented by helicopters equipped with dipping sonars and expendable sonobuoys, would try to find and sink them before they got within weapons range.

As the Soviets developed long-range ASCMs that could be fired from submerged submarines, the problem for fleet ASW escorts got progressively more difficult. Worse, after the aforementioned Walker spy ring warned the Soviets about their acoustic vulnerabilities, the Soviets made rapid strides in submarine acoustic quieting which negated to a great degree the effectiveness of the US ocean surveillance network, as well as all US ASW sensors and weapons—whether carried on submarines or surface warships. The subsequent relative decline in the battle fleet's ASW tactical overmatch against Soviet nuclear submarines started to undermine the high confidence that had typically accompanied US calculations about the Cold War undersea correlation of forces.

As mentioned earlier, the US submarine community quickly learned that the demise of the Soviet Union did not substantially arrest the relative decline in US ASW effectiveness. The *Akula*-class SSN operated by the new Russian Federation Navy is quiet enough to reliably avoid detection by the US ocean surveillance system. Moreover, as the Navy shifted its focus from open ocean warfare to joint littoral warfare in waters close to a potential adversary's coast, the US submarine community quickly discovered that modern diesel-electric boats were as difficult to detect and track as the Russian SSNs. For example, *Kilo*-class SSKs operated by the Russian, Chinese, and Indian navies are reported to have an acoustical signature equivalent to early US *Los Angeles*-class SSNs. The even newer Russian *Lada* SSKs are expected to be eight-to-ten times quieter than early *Kilos*.[303] When running on their batteries at slow speeds, these modern diesel-electric boats are extremely difficult to pick out of the ambient ocean background noise, especially in shallow littoral waters with large amounts of costal shipping traffic. Consequently, US submariners were alarmed to find SSN and SSK detection ranges in the littorals had fallen to a few thousand yards—far too close for comfort in an undersea combat arena with guided weapons.

Recall that US ASW counter-diesel submarine tactics had long revolved around exploiting the relatively low undersea endurance of submarines operating on battery power. At some point, a diesel-electric boat always has to surface or snorkel to recharge its batteries by running its diesel engines, an unavoidably noisy operation that often makes its presence known to ASW forces. However, in the post-Cold War era, US submariners began to encounter new diesel-electric attack submarines equipped with new air-independent propulsion (AIP) plants. Such submarines are typified by the German-designed Type 212A submarine, or its export version, the Type 214. In addition to diesel engines and electric batteries, these subs are equipped with a solid-polymer,

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[302] See "Sound Surveillance System (SOSUS)," at http://www.fas.org/irp/program/collect/sosus.htm; and "Acoustics Monitoring," at http://www.pmel.noaa.gov/vents/acoustics/sosus.html.

[303] See "*Lada* Class, Russian Navy," in *Combat Fleets of the World,* 2005-2006.

metal-hydride fuel cell. This combination allows them to sail to a patrol area under diesel power, and then to revert to slow-speed patrol operations using the AIP fuel cell, reserving their batteries for high-speed evasive maneuvers after an attack. While operating on the fuel cell at slow 3-4 knot patrol speeds, a Type 212A can remain submerged for 17 days without having to come up to use its snorkel. This greatly reduces the submarine's "indiscretion rate" in its patrol area. Moreover, while operating in the AIP mode, the submarine remains extremely quiet.[304] Of course, in shallower littoral waters, any diesel-electric boat can also "bottom," simultaneously eliminating its propulsion noise and extending its underwater endurance.[305]

Under these conditions, US submariners found that traditional tactics against diesel submarines operating in littoral waters no longer applied. In the past, a US SSN could arrive in an operating area and listen for 24-48 hours. If it had not heard any battery recharging operations over that time period, its commander could assume that no diesel-electric boats were operating in the area. Now, a US submarine commander can no longer make this assumption, and he would have to actively search and sanitize an area before concluding a diesel-electric submarine was not operating there. As this discussion suggests, then, operating against extremely quiet, air-independent submarines—both SSNs and AIP-equipped diesel-electric submarines—in littoral waters is a challenge for even the best US attack boats.

Of course, the surface warfare community also routinely operates in littoral waters, and it confronts the same quiet, air-independent submarine threat faced by US submariners. Indeed, the threat to surface ships from these type submarines is higher than it is to US submarines. Given the added requirements necessary for a submarine and its crew to become proficient in ASW, especially against ultra-quiet US attack boats, most foreign submarine fleets opt to concentrate on sinking surface ships. Their submarines can easily track surface ships from their electronic emissions at scores of miles, with sufficient accuracies to fire their ASCMs while remaining submerged. Moreover, many submarines are now equipped with extremely long-range wake-homing torpedoes that are effective only against surface ships. The threat of quiet, air-independent submarines equipped with ASCMs and long-range guided torpedoes is thus a very challenging one for surface combatants.

Following the lead of US submariners, surface warriors are trying to "buy back battlespace" with an ARCI-like approach for their surface ASW combat systems. Under current plans, they intend to convert all surface combatant ASW combat systems baselines to a single common COTS/OACE version called the AN/SQQ-89(V), and to introduce new COTS/OACE improved performance sonars, particularly a new Multi-Function Towed Array (MFTA). In the process, they will exploit the active and passive acoustic processing supersets that evolved out of the

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[304] The Type 212 submarine has been described as "the quietest submarine money can buy." See Charles A. Thibo, "U-Boat!" *Proceedings,* June 2005, p. 24. For more information on the German designed AIP boats, see "U212/U214 Attack Submarines, Germany," at http://www.naval-technology.com/projects/type_212/; and "The Gray Wolf: Deutsche Unterseeboot U212," at http://www.military.com/soldiertech.

[305] I am indebted to Karl Hasslinger, General Dynamic's Vice President for Washington Operations, for pointing out the advantages of diesel-electric boats bottoming in shallow waters.

ARCI program, seeking the same rapid capability insertion cycles seen in that earlier effort. As described by the Navy:

> The open system architecture developed into the AN/SQQ-89(V) will enable further affordable performance growth to meet fleet requirements. Additionally, this program supports the efforts to develop adjunct processing capability to process transmissions bi-statically using the AN/SQS-53C or Towed Active Receiver Subsystem (TARS) as the receiver. Adjunct processing capability will be further enhanced by the development of the Multi-Function Towed Array (MFTA). The MFTA system will be engineered to perform as the receive array for the mid-frequency active sonar, torpedo defense, and Broadband Variable Depth Sonar which will increase bandwidth over existing AN/SQQ-89(V) sensors and improve Measures Of Performance (MOP) in detection, tracking and classification. These efforts will provide a fully integrated AN/SQQ-89(V) ASW Combat System, with improved performance in the shallow, littoral environment.[306]

Of course, surface combatant ASW systems will be just one component of the TFBN's overall ASW architecture. In the same way the NIFC-CA strives to solve the evolving air and cruise missile defense problem with a networked solution, Navy ASW planning is counting on the development of more powerful multidimensional undersea battle networks composed of surface ships operating in concert with deployable fixed undersea arrays, unmanned vehicles, SSNs, ocean surveillance ships, and helicopters and aircraft. If successful, the sensors carried on these disparate network platforms will work together to form a single integrated undersea picture, just like the CEC network works to create a single integrated air picture. Using their interoperable combat and weapons systems, naval battle networks will work together cooperatively to engage and sink submarine threats. Once again, under these circumstances, the payoff from installing the AN/SQQ-89(V), improved performance sonars, and the MFTA on all 84 Aegis/VLS appears to be much higher than pursuing seven DDG-1000s.

CURRENT PLANS: TOO CONSERVATIVE A BET?

As can be seen, then, the 84 programmed Aegis/VLS combatants not only have a lot of life left in them, they have a lot of fight left in them, too. Provided it is suitably resourced, an Aegis/VLS BNRAM program will thus surely result in an interim TFBN surface battle line that extends the US Navy's already staggering lead among world naval powers. While the outcome of any future naval confrontation is inherently uncertain, a well-funded, five-component Battle Network Reliability and Maintenance program should increase the Navy's confidence that the Aegis/VLS fleet will be able to keep pace with evolving tactical challenges for the at least the next two decades.

The Navy has long recognized the need to get a full 35 years of effective commissioned service out of each and every one of its Aegis/VLS ships. Therefore, the basis for an effective BNRAM program exists in its planned Cruiser and Destroyer Modernization Programs. Unfortunately, the

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[306] See "AN-SQQ-89(V) ASW Combat System," at http://www.fas.org/man/dod-101/sys/ship/weaps/an-sqq-89.htm.

separate funding profiles for these two complementary but separate programs make clear that they will result not in 84 largely interchangeable I-LBNCs, but in 84 modernized guided-missile cruisers and destroyers with varying degrees of combat capability. The distinction, while subtle, is an important one, with implications for the evolving TFBN. As the next paragraphs show, by making too conservative a bet on the legacy Aegis/VLS fleet, the Navy is threatening the outcome of its broader transformation plans.

Both the CG and DDG modernization programs include a HM&E upgrade and crew reduction efforts to extend the lives of the ships to 35 years and to reduce their future O&S life-cycle costs. The HM&E program for the 22 *Ticonderoga*-class CGs will correct weight and moment problems caused by the successive additions of new systems, as well as: hull and deckhouse structural improvements; corrosion control enhancements; strengthened flight decks; digital fuel controls for their gas turbines; new reverse osmosis water production units; and many quality-of-life upgrades for their crews. The program will also replace all of the ships' legacy steam-operated systems such as potable water heaters, washers and dryers in the ship's laundry, and kettles and dishwashers in the ship's galley with equivalent electric systems, converting the ships' hotel services to an "all-electric" configuration.[307] As for the DDGs, their HM&E upgrade includes installing a ship-wide fiber optic gigabit Ethernet and data multiplexing local area network; multifunction ISC consoles with embedded training modules; a digital video surveillance system; wireless communications; an advanced all-electric galley; an integrated bridge system with steering controls; and other quality-of-life improvements. The HM&E programs for both ships will result in updated ship systems that will be both more effective and cheaper to maintain over the remainder of their 35 year service lives.

Both modernization programs aim to reduce the size of the ships' crews. As part of their crew reduction efforts, the cruisers will all receive the most up-to-date version of the SMARTSHIP-derived integrated ship control modifications, resulting in an aggregate crew savings of 18-20 personnel per ship.[308] With regard to the destroyers, the original Ship's Manning Document (SMD) for DDG-51/79s called for a crew of 32 officers, 27 Chief Petty Officers, and 321 enlisted, for a combined ship's complement of 380 personnel. On the helicopter-carrying DDG-79, the additional flight detachment of 23 people (including flight deck crews and crews for two helicopters) give that ship a combined combat crew of over 400. Because of previous SMARTSHIP and optimal manning initiatives, the current SMD for a *Burke* has been cut to 344 total personnel (not counting a flight detachment, or "det")—a reduction of 36 from the original manning target. Further crew reduction initiatives for the DDG BNRAM program aim to get the SMD down to 277 personnel. In other words, the combat crews on BNRAM DDG-51s and DDG-79s should be over 100 personnel smaller than the original *Burkes*.[309]

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[307] Edward Lundquist, "Navy Upgrades Aegis Cruisers," *Surface Warfare,* Fall 2005, pp. 20-21.

[308] Lundquist, "Navy Upgrades Aegis Cruisers," p. 21.

[309] From presentations to the author by Bath Iron Work employees during a shipyard visit on November 13, 2006.

The combat systems upgrades now planned for the two different ship types have somewhat different scopes. The programs do share several common threads: both ship types will see the computer hardware and software components of their MK-41 vertical launch systems and their SLQ-32 electronic warfare systems converted to COTS/OACE architectures, and they will both get the latest Block IB version of the *Phalanx* CIWS. After that, however, plans begin to diverge. For example, while both ships are slated to receive the new Mk-160 digital fire control systems for their 5-inch guns, only the cruisers will receive the new optical sighting system. Similarly, while the 22 cruisers will see their two old 5-inch/54s replaced with newer 5-inch/62 guns, the first 32 *Burkes* are not scheduled to receive them, meaning the Aegis/VLS battle line will need to maintain two similar but nonetheless different gun systems. Moreover, none of the ships will receive the magazine modifications to allow them to handle extended range guided munitions.[310]

With regard to cruise missile defenses, the cruisers will receive a SPQ-9B X-band surface surveillance and tracking radar that can detect sea-skimming anti-ship cruise missiles breaking the horizon even in heavy sea and land clutter, while simultaneously providing detection and tracking of surface targets.[311] The ships will also receive VLS modifications to enable them to fire the highly maneuverable Evolved Sea Sparrow Missile, which is a horizon-range missile equipped with a dual-mode semi-active radar and infrared guidance system. Together, the SPQ-9B and the ESSM will provide the cruisers with greatly improved ASCM defenses. In contrast, the DDGs are not currently slated to get the SPQ-9B, and only the DDG-79 class is slated to receive the ESSM.[312] In addition, only 77 of the 84 ships will receive the new AN/SQQ-89(V) ASW system with the MFTA; the seven “Baseline 2” CGs will not. Most troubling, beyond the 18 BMD conversions funded by the Missile Defense Agency, none of the Aegis/VLS combatants will receive the Multifunction Signal Processor necessary to allow them to track and engage ballistic missiles.[313]

The greatest difference between the CG and DDG modernization programs is found in a comparison between their respective Battle Network Upgrades, which can be described in terms of the “good, the bad, and the ugly.” The good: consistent with a shift to a Total Force Battle Network, both programs aim to implement fully a COTS/OACE architecture for the Aegis combat system by 2012, with identical Aegis signal processors; common radar control, command and decision, display, fire control, and weapons/fire control components; and new COTS/OACE multifunction consoles. A supporting goal is for all ships to be upgraded to a single common Aegis baseline with the same tracking capability as the most up-to-date version of the SPY-

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[310] From interviews with surface warfare officers on the CNO’s staff, conducted by the author between November 2006 and January 2007. The thinking is that until the 5-inch guided round is perfected, the Navy would do best to forego the magazine alterations to use them. However, Marines see this decision as further evidence that the Navy is not serious about improving naval surface fire support.

[311] See “AN/SPQ-9B Radar,” at http://www.fas.org/man/dod-101/sys/ship/weaps/an-spq-9.htm.

[312] The decision not to install the SPQ-9B on the DDGs was influenced by a potential ship self-masking problem that has yet to be worked out. From interviews with surface warfare officers on the CNO’s staff on January 3, 2007.

[313] “CG/DDG Modernization,” a PowerPoint briefing given to the author by N86, Surface Warfare Requirements Division, Office of the Chief of Naval Operations, on January 3, 2007; Lundquist, “Navy Upgrades AEGIS Cruisers;” and “AEGIS Ballistic Missile Defense Status Overview.”

1D(V) radar. The original SPY-1 was optimized for open ocean anti-air warfare. The SPY-1D, also known as the Littoral Warfare Radar, was designed after the end of the Cold War in order to improve the original SPY-1's ability to operate in close-in littoral waters. As such, the updated radar was designed to track low-altitude, reduced-RCS targets in heavy clutter environments and in the presence of intense electronic countermeasures. The open architecture SPY-1D(V), forward fitted on the last 22 *Burke* DDGs, has even better performance against targets in the littoral environment. With its additional, improved moving target indicator (MTI) waveforms, the radar has both a greater ability to discriminate targets in and amongst littoral clutter and a greater ability to counter jamming or deceptive electronic attacks. Of course, because of its open architecture, the radar is also better able to receive rapid capability insertions in response to new threats.[314]

The bad: because their systems are so old, the first seven "Baseline 2" CGs cannot be easily upgraded to the SPY-1D(V) standard. Recall that these seven ships will not receive the SQQ-89(V) for similar reasons. As a result, the near-term TFBN battle line will consist of two different classes of Interim Large Battle Network Combatants with much different anti-air warfare capabilities.

The ugly: more consistent with a TSBF battle line made up of guided-missile "cruisers" and "destroyers" than a TFBN battle line consisting of interchangeable LBNCs, only the CGs will receive the full suite of potential battle network improvements, including the CEC; the Shipboard Advanced Radar Target ID System (SARTIS), and the Integrated Architectural Behavioral Model (IABM). The latter two improvements are software programs essential to the formation of a single integrated air picture and to achieve the full potential of the NIFC-CA, particularly the ability to fully exploit the engage on remote capability of the 200-nm range SM-6 ERAM. In contrast, only some of the DDGs will receive CEC suites, and none are currently programmed to receive all the improvements to fully participate in NIFC-CA naval battle networks.[315]

The decision not to upgrade the old SPY-1A radars and combat systems on the "Baseline 2" CGs is likely a prudent one, based on rational cost-effectiveness calculations. However, plans that fail to provide the most modern 62 Aegis/VLS combatants a full Battle Network Upgrade appear to be a serious mistake. What accounts for this failure? Simple: the Navy finds itself on the horns of a dilemma of its own making. To free up the money to build seven very expensive DDG-1000s and 19 equally expensive CG(X)s, the Navy must limit its expenditures of O&M dollars. Moreover, the greatest operating savings will not be felt until after 2020. In the meantime, however, a mid-life BNRAM upgrade and follow-on maintenance regime will be paid for out of O&M dollars. As a result of the tight budget environment and the Navy's stubborn insistence on pursuing the expensive DDG-1000 (and follow-on CG(X)), then, the Navy must forego giving its 62 highly capable *Burke* combatants a complete and thorough Battle Network Upgrade. Given the foregoing analysis, it is hard to comprehend this outcome, much less defend it.

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[314] See "AN/SPY-1 Radar," found at http://www.globalsecurity.org/military/systems/ship/systems/an-spy-1.htm.

[315] "CG/DDG Modernization;" and Lundquist, "Navy Upgrades Aegis Cruisers."

Perhaps for this reason, two respected retired admirals, Admiral Donald Pilling, a former Vice Chief of Naval Operations, and Admiral Robert J. Natter, the first commander of the Navy's Combined Fleet Forces Command, recently recommended that a Aegis combatant Service Life Extension Program (SLEP), with both HM&E and combat system upgrades, be funded out of the Ship Construction Navy funds rather than O&M funds. They argued that since the SCN budget is far less volatile than the O&M account, especially in times of war, it would provide a more stable "safe haven" for SLEP planning and budget execution. Moreover, because SCN dollars have the longest "spend out" period of any major defense appropriation (seven years), the surface warfare community could spend SLEP dollars with a maximum of flexibility.[316]

This idea was quickly seconded by retired Rear Admiral Riley D. Mixson, a former Deputy Chief of Naval Operations (Air Warfare), who saw parallels between the situation the surface warfare community finds itself in today and the situation confronting the naval aviation community in the early 1990s. In the first years of the post-Cold War era, cost overruns in two new stealthy carrier aircraft programs—the *Avenger II* (also known as the A-12) and a Navy Stealth Fighter (NSF)—were placing the then-objective 12-carrier fleet, its associated air wings, and surface escort plans in jeopardy. In recognition of the tight budget environment, the naval aviation community reluctantly but wisely opted to cancel both new programs and to instead pursue a less risky, less expensive, but quite capable growth version of its 14-year old F/A-18 *Hornet*, pushing off its pursuit of a radically new stealthy carrier aircraft until both future warfighting requirements and technology further settled. Far from resulting in the demise of carrier air power, the affordable F/A-18 E/F *Super Hornet* armed with guided weapons proved to be "adaptable, versatile, and capable for the immediate future while providing the numbers needed to fulfill tactical…requirements."[317] Moreover, as it turns out, delaying the move to a stealthy carrier aircraft replacement resulted in the F-35 Joint Strike Fighter (JSF), which now looks to be a better solution for US carrier needs than either the *Avenger II* or the NSF.

Congress, the Navy, and the surface warfare community would do well to follow the lead of the naval aviation community. As discussed in the previous chapter, they should agree to fold the Navy's current "hand," cancelling any further DDG-1000s beyond the two already authorized, and commencing a design competition for a clean-sheet, next-generation Large Battle Network Combatant. Until the new LBNC is ready for production, they should play the "cards" they have already been dealt, and up their bet on a comprehensive Aegis/VLS Battle Network Reliability and Maintenance program by combining the "chips" earmarked for additional DDG-100s with those associated with the current CG and DDG Modernization Programs. The additional funds would allow for a BNRAM with five expanded and fully funded components. Four of the components—a through HM&E upgrade, a combat system upgrade, a battle network upgrade, and a concerted crew reduction program—should be paid for using SCN dollars. The fifth, a sustained follow-on maintenance program, should continue to be funded out of O&M accounts.

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[316] Admiral Donald Pilling, USN (retired) and Admiral Robert J. Natter, USN (retired), "Achieving the Right Mix," *Proceedings*, October 2006, pp. 14-15.

[317] Rear Admiral Riley D. Mixson, USN (retired), "Comment and Discussion on 'Achieving the Right Mix'," *Proceedings*, December 2006, pp. 6-8.

As suggested by the naval aviation communities experience with the F/A-18 and JSF, making a bet on an Aegis/VLS BNRAM Program will likely result in an I-LBNC fleet that is “adaptable, versatile, and capable for the immediate future while providing the numbers needed to fulfill tactical…requirements.” The bet appears certain to increase the size of the Navy’s overall “capabilities stack,” and allow it to continue to beat all comers until the more capable, next generation Large Battle Network Combatant is ready for production.

BUT WHAT ABOUT THE SURFACE COMBATANT INDUSTRIAL BASE?

As mentioned in the last chapter, the last and possibly strongest argument against this change in game strategy is that cancelling the DDG-1000 and CG(X) would put even more pressure on a shipbuilding industry already under great pressure due to the dramatic reduction in ship orders since the end of the Cold War. Indeed, the post-Cold War fleet demobilization caused a broad wave of consolidations in the US shipbuilding industry. When the wave finally receded, there remained only two large naval shipbuilding companies, which operate just six major Tier I yards between them. Northrop Grumman owns and operates three yards: Newport News (in Virginia), which builds nuclear-power aircraft carriers and submarines; Ingalls (in Mississippi), which builds large Navy surface combatants, amphibious landing ships, and Coast Guard cutters; and Avondale (Louisiana), which builds amphibious, auxiliary, and sealift ships. General Dynamics also controls three yards: Electric Boat (Connecticut), which builds nuclear-powered submarines; Bath Iron Works (Maine), which builds large surface combatants; and NASSCO (California), which builds auxiliaries and sealift ships (and commercial tankers). In conjunction with the five remaining US Navy shipyards, all six of the privately-owned commercial yards perform life-cycle support and maintenance work on US Navy warships.[318]

Because Navy shipbuilding plans are based on the ship and submarine expected service lives listed at the beginning of this chapter (33-50 years), the total number of yearly orders for aircraft carriers, submarines, surface combatants, amphibious ships, and auxiliary and sealift needed to maintain a TFBN force of 300 or so ships is relatively low. The average number of total orders necessary to maintain a steady-state force of 313 ships is just over nine ships. As a result, at this point in time, even six commercial shipyards represent a substantial overcapacity in the US shipbuilding industrial base.[319] For this reason, the Navy planned a “winner take all” competition for the seven DDG-1000s. While building the seven ships in one yard would have cut overhead and saved the Navy an estimated $300 million per ship, it would also have had the effect of driving one of the major surface combatant yards out of business.[320]

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[318] The US Navy operates four shipyards: Newport News, Virginia; Portsmouth, New Hampshire; Puget Sound, Washington, and Pearl Harbor, Hawaii. It also jointly operates the Ship Repair Facility in Yokosuka, Japan, with the Japanese. See United States Navy Shipyards, at http://www.shipyards.navy.mil.

[319] Industrial College of the Armed Forces Staff, “Shipbuilding Sector Remains Uncompetitive,” *National Defense*, March 2002, found at http://www.nationaldefensemagazine.org/issues/2002/Mar/Shipbuilding.htm.

[320] Dave Ahearn, “England Says Congressional Strictures Could Reduce Ship Purchases,” *Defense Today*, May 18, 2005, p. 1.

The Navy's plan to "single up" to one surface combatant yard was ultimately rejected by DoD after it became clear that Congress, which has long jealously protected the US shipbuilding base, objected strongly to the plan.[321] Although keeping extra yards in business adds costs for every submarine and surface combatant built, Congress considers the extra costs an insurance premium as a hedge against the onset of a serious maritime challenge. When combined with an earlier decision to keep two submarine yards in production, the decision to deny the Navy's plan to build the DDG-1000 in one yard signaled Congress' uneasiness over falling below two submarine and two large surface combatant yards. The damage caused by Hurricane Katrina to Northrop Grumman's Ingalls Mississippi shipyard vividly underscored the validity of Congressional concerns, and demonstrated the wisdom of having two different, and geographically separated, surface combatant construction yards.[322]

Adjusting to Low-rate Ship Construction

While US shipbuilders would obviously like more orders, they have gradually adjusted to an era of lean shipbuilding activity. In the process, they have made significant investments to improve manufacturing process efficiencies and to earn modest profits in spite of small quantity production runs. By leveraging lessons-learned from the manufacturing innovations used by leading commercial shipyards—both domestic and international—the two remaining US shipbuilding conglomerates, General Dynamics and Northrop Grumman, have successfully integrated a wide range of both military and commercial best-practices into their predominantly warship-focused production facilities.[323]

As just one of many concrete examples, General Dynamics has invested over $300 million in Bath Iron Works (BIW) since 1995 to improve the construction of surface combatants, particularly DDG-51/79s. The focus of this investment has been on two key projects: enabling shipyard workers to build and outfit increasingly larger combinations of "hull units"— sections of ship complete with piping, cabling, and equipment—inside climate-controlled building halls; and then mating and erecting these units into completed hulls on a new Land-level Transfer Facility (LLTF).

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[321] See Reuters, "Pentagon Calls Bid to Change Contract Strategy Premature," *Los Angeles Times*, April 21, 2005; and Edmond Lococo and Tony Capaccio, "Pentagon Delays Navy Competition for New Destroyer," *Bloomberg News*, April 20, 2005.

[322] For a thorough review of Congressional concerns over US Navy shipbuilding programs, see Ronald O'Rourke, "Navy DD(X), CG(X), and LCS Ship Acquisition Programs: Oversight Issues and Options for Congress."

[323] I have now personally visited four of the six major shipyards: Ingalls and Newport News (Northrop Grumman) and Electric Boat and Bath Iron Works (General Dynamics). The level of attention to, and investment in, instituting lean manufacturing processes in each of the yards is uniformly impressive. Even more impressive is the commitment of the shipyard management teams and workers to build quality warships. My most recent trip was to Bath Iron Works in November 2006, where I toured the shipyard and attended working level meetings focused on the evolving DDG-1000 Program; planning for the DDG-51/79 Modernization Program; and implementing manufacturing process improvements on the remaining DDG-79 construction contracts. Because this was my most recent trip, and because of this report's focus on surface combatants, I have elected to emphasize information gathered from BIW in this section. I could easily have given additional examples from the other three yards, which are equally as impressive.

The production plan for the currently-building DDG-106, the *USS Stockdale*, called for the construction of two so-called “mega-units,” each consisting of multiple numbers of smaller machinery and ship units, in a building hall prior to being transported onto the LLTF for mating and erection. By moving work that was once performed outside on the LLTF back into a climate-controlled facility where the shipbuilders have more room to work and better access to the individual units, BIW is able to achieve both greater construction efficiencies as well as safer work environment.

These benefits are further extended by mating and erecting the fully outfitted mega-units on the LLTF, which is designed to provide workers with convenient, multi-level access to adjacent, full-service Outfit Support Towers. These towers contain offices, work shops, tool rooms, integrated maintenance shops and food service areas, allowing workers to perform their construction tasks quickly and efficiently. The combination of building larger hull units in building halls and mating them in the LLTF allows BIW workers to complete much more final construction work and fitting while the ship is still out of the water. Today, before the ship is translated from the LLTF onto a floating dry dock for launching, BIW completes a ship’s final propulsion train alignment, activates all of its service generators, installs any 5-inch/62 gun mounts and VLS cells, and completes final painting of the hull.

The cumulative effect of these two complementary process improvements has been dramatic. Compared to the previous best construction performance with smaller assembled units and final construction on inclined ways, BIW now completes 33 percent more of its construction tasks before launching the ship in the water. This has allowed BIW to drive down the ship’s production costs, primarily by cutting the number of man-hours necessary to complete the ship. Indeed, since 2001, when it replaced the inclined shipbuilding ways with the LLTF and began building larger hull units inside their building halls, BIW has reduced manufacturing labor content by a million hours over the last five DDGs they have delivered. This accomplishment is especially impressive given that the shipyard is well down the construction learning curve for these ships, having recently delivered its 27th *Burke* to the Navy. It is doubly impressive given that the Navy continues to inject more and more combat capability into each new ship in the *Burke* production run.

However, BIW is not resting on its own laurels. This year, BIW began constructing a 67,000-square foot Ultra Hall, designed to accommodate the construction of “ultra units” weighing up to 5,000 tons apiece. The production plan for each of the last two Bath-built DDG-79-class ships—DDG-111 and DDG-112—calls for the construction of three ultra units inside the Ultra Hall, which will then be joined and erected on the LLTF. Each of these ultra units will form complete ship girths (from keel to weather deck), and weigh up to 2,600 tons apiece. Not only will this result in further production cost savings for the two ships, the experience will help BIW to refine the techniques necessary to construct and integrate even larger ultra units planned for the DDG-1000 program. By so doing, BIW hopes to save the Navy upwards of $340 million in total future construction costs. This is a powerful example of the efficiency and cost benefits of getting a good basic design into production, and exploiting learning curve knowledge and construction efficiencies to drive down unit costs.

The shared commitment to process improvement has also led to improved levels of cooperation between the two surface combatant shipyards, BIW and Ingalls. This improved cooperation is evident in the thoroughly integrated planning and design effort for the new DDG-1000, as well as in the continuing construction of legacy combatants. For example, BIW recently shipped a deckhouse for a *Burke* DDG to Ingalls to replace a deckhouse damaged by fire, allowing ship construction on the "rival" Northrop Grumman DDG to continue on schedule.

Building BNRAM Prototypes

The commitment to excellence evident in both surface combatant shipyards is also reflected in their careful planning for the CG and DDG Modernization Programs. Ingalls is the Planning Yard for CG-52s/59s, while Bath Iron Works is the Planning Yard for the DDG-51/79s. As such, the former is responsible for the technical development and availability planning for the Navy's CG Modernization Program, while the latter performs the same role for the DDG Modernization Program.

The yards have put a great deal of time and effort into planning and preparing for these two programs. For example, to date, Congress has appropriated over $100 million to develop the technical and planning processes for the mid-life HM&E, combat system, battle network and crew reduction enhancements for the 62 programmed *Burke* DDGs. These efforts share common aims: to keep all 62 programmed DDGs *Burkes* in commissioned service for 35 years; to reduce total DDG ownership costs through significant reductions in manning requirements and improved maintainability; to increase ship survivability; and to achieve improved quality of life for the ships' crews.

DDG-51 will be the first *Burke* to receive the mid-life upgrade, in FY 2010. Since the current Navy implementation plan calls for the HM&E mods to be installed on the last two DDGs (DDGs-111 and -112) during the new construction cycle, these two ships will serve, in essence, as DDG BNRAM prototypes, used to identify the lowest risk/highest reward back-fit strategies for upgrading all other ships of the class. For example, these two ships will have a new Integrated Decision Support System and Automated Monitoring and Control System consisting of 33 computers and 33 consoles, tied together by the ship's new gigabit Ethernet data multiplexing local area network. The consoles will all have embedded training routines with canned scenarios, tied into the Integrated Bridge System, which will allow ship-wide training without the ship having to leave the pier. All of these improvements, embedded in the SCN costs for DDG-111/112, are explicitly designed for back-fit on earlier *Burkes*.[324] Indeed, in order to distinguish their many internal differences, these two ships warrant a separate class designator: DDG-111s.

As the planning yard for the DDG BNRAM, engineers at Bath Iron Works—working in concert with the Navy—have also been conducting studies and analyses to assess the feasibility of extending the service lives of the *Burkes* from 35 to 40 years. The original DDG-51 class had a

[324] "CG/DDG Modernization;" also from presentations to the author by Bath Iron Work employees during a shipyard visit on November 13, 2006.

designed full load displacement of 8,600 tons; over time, the class average has crept up to over 8,900 tons. The subsequent DDG-79 class has an average displacement of 9,250 tons. However, the hull still retains substantial growth margins. The preliminary conclusion of BIW engineers is that a Service Life Extension Program could very likely get an extra five years service life out of the ships, although it would require work in a shipyard to strengthen the ships' bows, repair or prevent rudder cracking, correct weight and moment problems, institute more comprehensive corrosion prevention programs, and provide the ship with a more robust and powerful electrical generation system.[325]

In parallel with ongoing BIW Planning Yard activities focused on supporting the DDG Modernization Program, existing DDG-51-class ship systems and equipment vendors have been developing independent performance improvement recommendations. For example, one company recommends adding a permanent magnet motor and using it to power a single shaft during low-speed operations. The company claims the arrangement would improve the ship's low-speed fuel economy by 30 percent. If true, the advertised $10 million cost to install a single ship PMM could likely be recouped in as little as three years. Other vendors likely have similar ideas for improving the ships, with some focused—like the above example—on improving HM&E systems and lowering O&M costs; some focused on upgrading ship combat systems (e.g., advanced open architecture electronic warfare systems); and some focused on making further crew reductions.

The planning for mid-life upgrades to the 22 CG-52/59s has been similarly detailed. The key point here is that both Ingalls (Northrop Grumman) and BIW (General Dynamics) have put considerable effort to improving the legacy Aegis/VLS fleet, and in identifying further steps which would improve them even more.

Combining New Ship Construction and a BNRAM Program to Support the Transition to New LBNCs

The corporate leadership at Northrop Grumman and General Dynamics, as well as their designers, management teams, and shipyard workers, are fully committed to the DDG-1000, and all are confident that they can build the ships for the cost targets established by the Navy. However, the preceding discussion suggests a new transformation strategy for the Navy's surface battle line. This new strategy, introduced in the last chapter, is informed by the one adopted by the post-World War II surface community, and it consists of five complementary steps:

- ***First, "fold" the DDG-1000 hand: cancel all DDG-1000s and CG(X)s planned beyond the two DDG-1000s already authorized in the FY 2007 shipbuilding budget.*** These ships are the modern-day equivalents of the post-World War II *USS Norfolk*—large, technically advanced ships that are simply too expensive to build given the expected future budget environment. Because the two ships are being split funded in FY 2007 and FY 2008, there are two possible branches to this step:

[325] From presentations to the author by Bath Iron Work employees during a shipyard visit on November 13, 2006.

- Cancel the second DDG-1000, and fully fund just one DDG-1000 as a fleet technology, combat system, and IPS test ship. While saving somewhere on the order of $3 billion in SCN, this option would prevent one of the two surface combatant yards from gaining valuable experience in constructing stealthy, electric-drive ships. Thus, perhaps a second, more logical branch would be to:

- Complete both ships as planned, and assign them as fleet technological and IPS test ships, one for both the 2nd Fleet (East Coast) and the 3rd Fleet (West Coast). Because the DDG-1000 has onboard flag quarters—a first for a "destroyer," a variation of this branch would be to complete both ships as fleet flagships.

This move would be accompanied by a DDG-1000 Technology migration program. For example, the SPY-3 radar is currently scheduled to migrate to the new CVN-21. It could also go aboard other ships such as the LHAR. The new autonomic fire suppression system found in the design of the DDG-1000 might also be transferred to other ships. Finally, as discussed earlier, should fleet operators need the added capabilities of the 6-inch Advanced Gun System, it could be mounted on a different hull, perhaps a modified version of the LPD-17.

- ***Second, "hold" the Aegis/VLS fleet: design a comprehensive, Aegis/VLS Battle Network Reliability and Maintenance program, with the goal of producing the maximum number of interchangeable, Interim Large Battle Network Combatants.*** As discussed, the BNRAM program would include a thorough mid-life upgrade to the ships' hull, machinery and electrical systems; an equally thorough combat systems upgrade to allow the ships to counter emerging threats; and a battle network upgrade to allow the ships to operate as part of a coherent naval battle network. Consistent with battle network precepts, the intent of the battle network upgrade would be to bring as many ships as possible to a common I-LBNC combat system baseline. The BNRAM program would also aim to lower substantially costs necessary to operate the legacy Aegis/VLS fleet, in order to save money in the near term and to offset to some degree the added costs necessary to keep older ships in service over the longer term. A key part of this effort centers on reducing the crew size needed to operate, maintain, and fight the ships. Importantly, because this effort can justifiably be seen as converting legacy Aegis/VLS ships into more capable I-LBNCs, these four components of the BNRAM program should be funded out of the more stable Ship Construction Navy (SCN) account rather than the more volatile operations and maintenance (O&M) account, used to pay for activities associated with the ongoing "Global War on Terror."

- ***Third, immediately kick-start a clean-sheet competition to develop and design a family of next-generation Large Battle Network Combatants, with close oversight by the newly reconstituted Ship Capability Improvement Board.*** With a chance to start from a clean sheet of paper, and benefiting from supervision by the SCIB, naval design architects could leverage an additional decade of experience in the post-Cold War era to design an entirely new family of next-generation LBNCs. These new warships would have a common gas turbine or perhaps even a nuclear power plant; common electric motors; a common integrated power system that supplies enormous shipboard electrical generating capacity; and advanced automation to enable them to operate with relatively small crews. Their single common hulls, or large sea frames, should be large and easily produced, based on the best ideas of naval engineers, with an affordable degree of stealth. The sea frames would be able to accept a range of open architecture battle network mission modules consisting of sensors and onboard and offboard weapons designed explicitly to support a battle network rapid capability improvement strategy. The cost-constrained goal for the combination of sea frames and network mission modules would be to build new LBNCs at a rate of five every two years, allowing the complete transition from Aegis/VLS I-LBNCs to next-generation LBNCs in 35 years. The ships would be built using a profits-related-to-offer competition between the two remaining surface combatant shipyards. Under this arrangement, while each yard could count on building one LBNC per year, they would compete for an extra ship every other year. The yard with the lowest bid would be able to claim higher profit margins on the two LBNCs it would build until the next bi-annual competition. In this way, in addition to the natural cost savings due to learning curve efficiencies, the Navy would be able to spark continuous competition between the two building yards.

- ***Fourth, starting in FY 2008, build a minimum of seven modified Burke DDGs to help sustain the industrial base until the new LBNC is ready for production.*** In effect, building one modified DDG-111-class ship each year between FYs 2008 and 2014 would replace the seven DDG-1000s in the current plan. For reasons that will be explained more fully in a moment, the first four additional ships would be configured with the same Area Air Defense Command Capability System (AADCCS) found on the *Ticonderoga*-class CGs. In addition, all seven ships would serve as active test beds for DDG improvements identified as possible candidates for further BNRAM backfits, or to test next-generation LBNC technologies. As such, the ships would serve much the same purpose as both the *Forrest Sherman*-class destroyers, which helped to bridge the shipbuilding gap between World War II and Cold War combatants, and modified legacy combatants like the *USS Gyatt*, DDG-1, which helped to illuminate the way forward toward a new generation of warships. Provided all went as planned, Congress would authorize two of the next-generation LBNCs in FY 2015, split funded as in the current arrangement for the DDG-1000, giving each of the two construction yards one ship. The general fleet-wide transition from Aegis/VLS I-LBNCs to the new design would then begin in FY 2017, with three ships authorized after a bidding competition. Of course, if the design was not ready, additional *Burkes* could be built until it was.

- ***Finally, task each of the planning yards for CG and DDG modernization to design and implement a comprehensive follow-on maintenance regime to ensure all Aegis/VLS combatants are able to serve out the remainder of their 35-year service lives effectively.*** Unless the BNRAM program includes a sustained maintenance regime beyond its mid-life HM&E, combat systems, and battle network upgrades and crew reduction measures, it is unlikely that the Aegis/VLS ships will see their 35th year of service. The building yards seem to be the logical candidate to implement this new maintenance regime; BIW would remain the planning yard, engineer agent, and ship improvement agent for the DDGs, while Ingalls would perform the same role for the CGs. By establishing financial incentives that provide the yards with bonuses for every year a ship stays in service beyond 25 years, the Navy will maximize the probability that the ships will remain in service. Moreover, as ship improvement agents, in addition to planning the backfit and BNRAM upgrades for their respective ships, BIW and Ingalls, in conjunction with the Navy, would solicit ideas for further ship improvements from vendors, and complete the trade studies for an expanded service life extension program (SLEP) of existing ships, with a goal of extending their expected service lives to 40 years. This would provide a hedge should design work on the next-generation LBNC be delayed for any reason, or if a future maritime challenge spurs the need to rapidly expand the number of LBNCs beyond the 88 included in the 313-ship Navy.

THE INTERIM TFBN BATTLE LINE

Implementing an Aegis/VLS BNRAM program while simultaneously building a minimum of seven additional modified DDG-111/112s would allow the Navy to do two important things. First, recall that that the Aegis/VLS fleet currently tops out at 84 ships, four below the TFBN requirement for 88 LBNCs. The 88 LBNC fleet target is broken down between 19 guided-missile cruisers and 69 guided missile destroyers (62 DDG-51/79s and seven DDG-1000s). Second, remember that the seven "Baseline 2" CG-52s now in commission are the least capable ships in battle line; because of their age, their Aegis combat systems cannot be upgraded to the desired SPY-1D(V) configuration, and they will not receive the SQQ-89(V) ASW system or Multi-function Towed Array. Given these circumstances, all seven CG-52s should be redesignated as DDGs and *not* be given the ACCDS. The three oldest "Baseline 2" CG-52s (or the three ships in the worst material condition) should be retired immediately, saving the costs associated with their BNRAM upgrades. The other four would receive a modified BNRAM and be transferred to the Naval Reserve on a one-for-one basis as the first four additional *Burke* DDGs—each equipped with the ACCDS and, if possible, the fourth missile fire control illuminator normally found on a CG—are commissioned into service.

Because of their mature production designs, these four surrogate "cruisers" can be built in little more than two years, meaning that all four would be in service by 2013, when the TFBN battle line would consist of 19 "cruiser equivalents" (15 CG-59s and 4 modified *Burkes*) and 62 *Burke* DDGs, all with a common Aegis and ASW combat system baselines, backed up by four, less capable "DDG-52s" in the Naval Reserve. By FY 2016, after the final three of seven new *Burkes* are commissioned, the combined TFBN battle line would consist of 84 active Aegis/VLS I-LBNCs with a common combat system baseline and four reserve I-LBNCs, meeting the TFBN's objective requirement for a total of 88 LBNCs. At that point, the fleet-wide transition to the next-generation LBNC would begin.

This plan achieves the 88-ship combined battle force capable combatant target only one year later than the current plan. However, by purposely planning for a next-generation LBNC that can be built at a sustained rate of five every two years, the surface battle line would never fall much below its overall 88-LBNC force objective during the 35-year transition cycle.

More importantly, the money saved by foregoing the more expensive DDG-1000s could be diverted to fully fund a more comprehensive BNRAM program for all active Aegis/VLS ships, with the goal of establishing 84 essentially interchangeable I-LBNCs with a single common combat capability baseline. In other words, all 84 active I-LBNCs (15 CG-59s, 28 DDG-51s, 32 DDG-79s, and nine DDG-111s) would get:

- A comprehensive mid-life HM&E upgrade designed to get the ships to 35 years of service;

- A COTS/OACE Aegis combat system upgrade to the SPY-1D(V) baseline;

- The Aegis BSP, allowing all ships to engage ballistic missiles;

- The most modern anti-ship cruise missile defense package, including the SPQ-9B, the ESSM, and the most modern version of the *Phalanx* CIWS—the *Phalanx* IB;[326]

- The Mk-160 Digital Gunfire Control System with Optical Sighting System, the most up-to-date naval gun, the 5-inch/62 capable of firing guided munitions—and the magazine modifications to allow the ships to carry and handle them;

- The SQQ-89(V) ASW combat system with Improved Performance Sonars and MFTA;

- The most up-to-date version of the COTS/OACE version of the AN/SLQ-32(V) electronic warfare system;

- VLS open architecture and modifications to allow every ship to employ all weapons now in the inventory, including: TLAM; the entire family of *Standard* SAMs, including the long-range SM-6 ERAM; all versions of the SM-3 ballistic missile interceptor; Vertical-Launched ASROC; and the *Evolved Sea Sparrow Missile*; and finally

- A common Battle Network Upgrade, including CEC, the Shipboard Advanced Radar Target ID System, the Integrated Architectural Behavioral Model, and all other modifications necessary to configure every ship to operate as a node in a NIFA-CA battle network.

All ships would also receive a new close-in defense system consisting of two to four Mk38 Mod 2 25mm gun systems, derived from the Mk25 *Typhoon* developed by the Israeli firm Rafael. These are stand-alone, stabilized, rapid-fire 25mm cannon mounts with an onboard Electro-Optical Fire Control System, including an optical and infrared video, eye-safe laser range finder, automatic tracker, and fire control computer. The guns can be fired from remote control panels located anywhere on the ship with deadly accuracy. At a recent at-sea trial onboard the *USS Port Royal*, a *Ticonderoga*-class CG, untrained individuals could routinely hit floating 55 gallon drums at 1,700 yards (about one mile).[327] Two to four of these mounts, in conjunction with the

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[326] Interviews with members of the Navy staff indicate that the DDGs would have to have some special provisions for the SPQ-9B because of topside masking problems.

[327] "*USS Port Royal* Performs Mk-38 Mk 2 ORDALT Testing," *Surface Warfare,* Fall 2005, pp. 22-25.

Block IB version of the CIWS, would provide all I-LBNCs with close-in, 360 degree protection against attacks by small surface craft.

The BNRAM program would be complemented by additional investment and effort to develop a low-cost guided round for the fleet's 99 active 5-inch/62 guns (and the eight in the Naval Reserve), as well as an Mk-41 ordnance expansion program to allow all 84 I-LBNCs to employ the widest possible range of available US missiles beyond those they already can. For example, with some minor modifications to the missiles, the Mk-41 could also fire both *Harpoon* ASCM*s* and SLAMs. To provide the ships with better terminal defense against ballistic missiles and their RVs, the Mk-41 could be modified to take the PAC-3 Segment Missile Enhancement, a variant of the Army's highly effective Patriot PAC-3 SAM with a hit-to-kill warhead.[328] As far as land-attack weapons go, the Mk-41 has already demonstrated the ability to fire navalized versions of the Army's 24-inch Advanced Tactical Missile System. Other candidates for incorporation might be versions of the Guided Multiple Launch Rocket System (GMLRS)[329] and a vertical-launch version of the stealthy Joint Air-to-Surface Standoff Missile (JASSM).[330] Indeed, for maximum flexibility, the Mk-41 should also be modified to allow it to carry and fire allied weapons—such as the new *Aster* family of SAMs soon to be carried aboard British, French, and Italian warships, and perhaps allied land-attack cruise missiles as well, like the Storm Shadow/SCALP.[331] The point here is that with the Navy has not yet come close to exploiting fully VLS open architecture, which will soon allow the TFBN to employ a range of effective weapons already in production, as well as to accept new weapons designed to counter new threats.

INCLUDING THE ALLIES

The idea of modifying the Mk-41 to accept allied weapons suggests another important reason to plan and execute a comprehensive Aegis/VLS BNRAM program: it might also allow the future TFBN to better operate with the growing allied Aegis/VLS fleet and to leverage the steadily growing foreign Mk-41 VLS cell count. As current plans stand, there will soon be 11 Aegis/VLS combatants in Europe—six Spanish F-100 guided-missile "frigates" equipped with Aegis and 48 Mk-41 VLS cells, and five Norwegian guided-missile "frigates" with Aegis and eight Mk-41 cells (and space and weight for eight more). In the Pacific, current plans call for a minimum of 14 more Aegis/VLS combatants: four Japanese *Kongo*-class guided missile "destroyers," virtual copies of the US DDG-51 class with Aegis and 90 VLS cells; four improved Japanese *Kongo*-class guided missile "destroyers," roughly equivalent to the US DDG-79 class with Aegis and 96

[328] See "PAC-3 Segment Missile Enhancement," found online at http://www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=17426&rsbci=5&fti=0&ti=0&sc=400.

[329] See "Guided MLRS XM-30 Rocket," at http://www.missilesandfirecontrol.com/our_products/firesupport/Guided_MLRS_XM30/product-Guided_MLRS-XM30.html.

[330] See "AGM-158 Joint Air-to-Surface Standoff Missile," at http://www.fas.org/man/dod-101/sys/smart/ jassm.htm.

[331] The *Aste*r family of SAMs was designed to be fired from the European Sylver VLS system. See "MBDA Aster," at http://en.wikipedia.org/wiki/MBDA_Aster. The Storm Shadow/SCALP is a stealthy European land attack cruise missile that can also be fired from the Sylver VLS. See "Storm Shadow/SCALP," at http://www.defense-update.com/products/s/storm-shadow.htm.

VLS cells; three Korean KDX-III guided missile "destroyers" with Aegis and 80 Mk-41 cells; and three Australian "air warfare destroyers" with Aegis and 48-64 VLS cells. In addition to these 25 allied Aegis/VLS combatants, numerous other allied warships are equipped with the Mk-41 VLS. Indeed, the total rest-of-world Mk-41 cell count, including those ships in service, building, and planned, will soon top 3,000.[332]

The US has already demonstrated the value of working cooperatively with allied navies that operate Aegis/VLS combatants. For example, the Japanese Maritime Self Defense Force was the first foreign navy to build an Aegis/VLS combatant. Because of Japanese concerns over the proliferation of ballistic missiles in East Asia, it has been working closely with the US Missile Defense Agency on Aegis ballistic missile defense programs, particularly the SM-3 interceptor. They are cooperatively funding improved versions of the missile, and the Japanese were recently cleared to purchase the Block IA version of the SM-3 for its *Kongo*-class DDGs, which will also receive the necessary Aegis BSP modifications to allow the ship to employ the missiles.[333] Building on this model, it might be worthwhile to include as part of the BNRAM's battle network upgrade a supporting program that offers to convert the combat systems on allied Aegis/VLS warships to COTS/OACE architectures, and to provide them with CEC sets, for a nominal price. Alternatively, the US might offer to help navies pay for the COTS/OACE conversion in return for other offsets. Such moves would allow allied Aegis/VLS and VLS-equipped ships to easily slot into a future *Combined* Multidimensional Battle Network, thereby strengthening the power of both US and allied naval capabilities.

Indeed, the US Navy might be able to increase further the foreign Aegis/VLS fleet by offering a COTS/OACE version of its newest Aegis combat system, built around the SPY-1F radar. The SPY-1F is a smaller version of the highly capable SPY-1D Littoral Warfare Radar, specifically designed to fit on smaller guided-missile "frigates." The first of the new radars are being installed on five Norwegian F-310 frigates, with full load displacements just over 5,000 tons.[334] However, the radar is small enough to fit on even smaller ships. In this regard, several foreign countries, including Israel and Saudi Arabia, have expressed interest in a SPY-1F-equipped LCS. In response, builders of both LCS models (Lockheed Martin and General Dynamics) now offer SPY-1F versions of the ships, neither of which have a full load displacement much larger than 3,000 tons. By offering a COTS/OACE version of the SPY-1F(V) version, with guaranteed future combat system upgrades, the US Navy might be able to substantially increase their international appeal, which may work to build up the combined US-allied Aegis/VLS fleet. The result would be even more powerful, more interoperable Combined Multidimensional Naval Battle Networks.

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[332] Based on a review of Saunders, ed., *Jane's Fighting Ships 2006-2007,* and discussion with Lockheed Martin VLS engineers on December 13, 2006.

[333] Nick Brown, "Pentagon Clears SM-3 Ballistic Missile Sale to Japan," *Jane's Navy International,* July/August 2006, p. 5; "Bigger Shield," pp. 42-43.

[334] See "*Fridtjof Nansen* class frigate," at http://en.wikipedia.org/wiki/Fridtjof_Nansen_class_frigate.

V. YOU'VE GOT TO KNOW WHEN TO HOLD 'EM, KNOW WHEN TO FOLD 'EM

In the words of a famous Kenny Rogers song, the Navy has "got to know when to fold 'em, know when to hold 'em." Cancelling further DDG-1000s beyond the two now authorized, and instead planning, budgeting, and executing a balanced Aegis/VLS BNRAM program; starting a clean-sheet design for the next 21st century LBNC; building additional *Burke* DDGs until the new LBNC is ready for production; and following up the BNRAM program with a sustained maintenance regime for the Aegis/VLS fleet would be a smart move in the early post-Cold War naval transformation game.

No game plan is perfect, and this one is no exception. Indeed, rather than viewing the recommendations found in this report as prescription, they should be viewed as a point-of-departure to guide efforts to develop a new transformation approach for the Navy's future battle line. This new approach is wholly consistent with the Navy's broader transition from a Total Ship Battle Force to a Total Force Battle Network. Moreover, it results in a more formidable near-term surface battle line; ensures the viability of both the design and industrial base for large, complex surface combatants; maximizes near-term O&S savings; provides a smoother, more easily manageable transition to the next generation of Large Battle Network Combatants; and better positions the Navy to respond to any future maritime challenge. Better yet, it is less fiscally risky than the current plan, with ample built-in flexibility to adjust to unexpected changes in the threat and in future shipbuilding budgets.

Importantly, however, regardless of whether or not the Navy and Congress agree with this approach and "fold" the DDG-1000, the requirement to design and execute a comprehensive Aegis/VLS Battle Network Reliability and Maintenance program will remain. These ships represent a $100 billion taxpayer investment. More importantly, keeping them in service for 35 years is absolutely critical if the Navy has any chance of building to, and sustaining, a 313-ship TFBN fleet. Put another way, making sure the Navy can count on over 2000 years of future fleet ship life for the Aegis/VLS fleet is far more important to the Navy's future than building seven DDG-1000s, which promise just 245 years of future fleet ship life.

The FY 2008 budget will be the first complete new budget since the CNO's announcement that fleet O&M dollars are to be maintained at current levels and that research and development money must be reduced to build a TFBN fleet of 313 ships. As discussed in this report, the former ensures that *any* fleet-wide sustainment program for the Aegis/VLS ships will be difficult to execute, while the latter may make it hard for the ships to keep up with pacing threats over the next two decades. It is therefore important that Congress be an early and interested observer when the Navy's FY 2008 budget is presented, and that it asks penetrating questions about the full extent of Navy's plans for improving and sustaining its Aegis/VLS fleet.

Among the most critical questions to be asked are:

- What are the Navy's plans for a balanced Aegis/VLS modernization and sustainment program? Do plans for their fleet-wide HM&E upgrades guarantee all 84 Aegis/VLS combatants will remain in service for a full 35 years? If not, what needs to be done to assure this?

- What are the most likely operational threats to naval battle forces over the next 25-35 years? Are the Navy's plans for Aegis/VLS combat system upgrades consistent with the evolution of likely future threats? Does the Navy have a robust R&D line to make sure the Aegis/VLS fleet can meet these projected threats?

- Are planned battle network upgrades sufficient to allow all 84 Aegis/VLS ships to seamlessly operate in improved future naval battle networks? If not, why not?

- Are planned crew reduction efforts taking full advantage of all technological options? If not, why not?

- What HM&E, combat system, and battle network upgrades are being cut to stay within established O&M caps? What will the effect of these cuts be on fleet combat capability?

- Should Aegis/VLS modernization programs be funded out of SCN accounts instead of O&M accounts?

- Are studies for possible expanded SLEPs for these ships adequately funded? What desirable HM&E, combat system, and battle network upgrades are not being pursued due to lack of funds? How would these upgrades improve fleet combat capability? How much would these additional improvements cost?

Getting the answers to these questions will help ensure the US Navy doesn't inadvertently "fold" a winning hand. The 84 Aegis/VLS ships soon to be in commissioned service will represent perhaps the most powerful surface battle line in naval history. With the proper planning, they will only get better. However, as this report suggests, keeping the ships combat effective for a full 35 years of commissioned service, as is now planned, is by no means a sure bet. Scrimping on any of the five components of a Battle Network Reliability of Maintenance program—thorough mid-life upgrade to the ships' HM&E systems; an equally thorough combat system upgrade; battle network upgrade to make sure the ships can operate in future naval battle networks; additional crew reduction efforts; and a sustained follow-on maintenance regime—will sink the Navy's plans for both its future surface battle line as well as its larger plans for TFBN fleet of 313 ships.

The bottom line: cancelling further DDG-1000s beyond the two now authorized, and instead planning, budgeting, and executing a balanced Aegis/VLS BNRAM program supported by a sustained follow-on maintenance regime; starting a clean-sheet design for the next 21st century LBNC; and building additional *Burke* DDGs until the new LBNC is ready for production is an affordable, executable, and effective transformation strategy which will help to ensure continued US naval superiority for the foreseeable future.

GLOSSARY

A2/AD	Anti-Access/Area-Denial
AADC	Area Air Defense Commander
AADCCS	Area Air Defense Command Capability System
AAW	Anti-Aircraft Warfare
ABS	American Bureau of Shipping
AESA	Active Electronically-Scanned Array
AGS	Advanced Gun System
AIM	Advanced Induction Motor
AIP	Air Independent Propulsion
ALAM	Advanced Land Attack Cruise Missile
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AoA	Analysis of Alternatives
ARCI	Acoustic Rapid COTS Insertion
ASBM	Anti-Ship Ballistic Missile
ASCM	Anti-Ship Cruise Missile
ASW	Anti-Submarine Warfare
ASROC	Anti-Submarine Rocket
ASuW	Anti-Surface Warfare
ATO	Air Tasking Order
BFC	Battle Force Capable
BMD	Ballistic Missile Defense
BNRAM	Battle Network Reliability and Maintenance
BNU	Battle Network Upgrade
BSP	Ballistic Signal Porcessor
BUR	Bottom-Up Review
CAIG	Cost Analysis Improvement Group
CBO	Congressional Budget Office
CEC	Cooperative Engagement Capability
CG	Guided-Missile Cruiser
CGN	Nuclear-powered Guided-Missile Cruiser
CG(X)	21st Century Guided-Missile Cruiser
CIC	Combat Information Center
CIWS	Close-in Weapon System
CLK	Hunter-killer Light Cruiser
CNO	Chief of Naval Operations
COEA	Cost and Operational Effectiveness Analysis
COTS	Commercial-off-the-shelf
CPS	Collective Protection System
CRS	Congressional Research Service
CSG	Carrier Strike Group
CV	Aircraft Carrier

CVN	Nuclear-powered Aircraft Carrier
DASH	Drone Antisubmarine Helicopter
DD	General Purpose Destroyer
DD-21	Focused-mission Land Attack Destroyer
DD(X)	Multi-mission 21st Century Destroyer
DDE	Escort Destroyer
DDG	Guided-Missile Destroyer
DDG-1000	*Zumwalt*-class Guided-Missile Destroyer
DDG(X)	21st Century Guided-Missile Destroyer
DDK	Hunter-killer Destroyer
DL	Destroyer Leader
DoD	Department of Defense
DoN	Department of Navy
EDS	Electronic Data System
ERAM	Extended Range Active Missile
ERGM	Extended Range Guided Munition
ESG	Expeditionary Strike Group
ESM	Electronic Support Measures
ESSM	Evolved Sea Sparrow Missile
ForceNet	Navy Service-wide Battle-Centric Network
FF	Frigate
FFG	Guided-Missile Frigate
FRAM	Fleet Rehabilitation and Maintenance Program
FY	Fiscal Year
GUPPY	Greater Underwater Propulsion and Power
HF	High Frequency
HM+E	Hull, Machinery, and Electrical Systems
IABM	Integrated Architectural Behavioral Model
IFF	Identification Friend or Foe
I-LBNC	Interim Large Battle Network Combatants
IPS	Integrated Power System
JCS	Joint Chiefs of Staff
JROC	Joint Requirements Oversight Council
JTIDS	Joint Tactical Information Data System
KPP	Key Performance Parameter
LACM	Land Attack Cruise Missile
LCS	Littoral Combat Ship
LBNC	Large Battle Network Combatant
LHAR	Amphibious Assault Ship Replacement
LM2500	Standard US Navy gas turbine engine
LRLAP	Long-Range Land Attack Projectile
MDA	Missile Defense Agency
MFTA	Multi-Function Towed Array

MIDS	Multifunctional Information Distribution System
Mil-Spec	Military Specifications
MFSP	Multi-Function Signal Processor
MNS	Mission Need Statement
MPF(F)	Maritime Prepositioning Force (Future)
MRC	Major Regional Contingency
NAIC	National Air Intelligence Center
NIFC-CA	Navy Integrated Fire Control-Counter Air
NILE	NATO Improved Link 11
NSF	Naval Strike Fighter
NTDS	Navy Tactical Data System
NTU	New Threat Upgrade
O&M	Operations and Maintenance
O&S	Operations and Support
OACE	Open Architecture Computing Environment
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
P_k	Probability of Kill
PMM	Permanent Magnet Motor
POS	Protection of Shipping
QDR	Quadrennial Defense Review
RAM	Rolling Airframe Missile
RCS	Radar Cross Section
SAG	Surface Action Group
SAM	Surface-to-Air Missile
SARTIS	Shipboard Advanced Radar Target Identification System
SBT	Sea-Based Terminal
SCIB	Ship Characteristics Improvement Board
SCN	Ship Construction, Navy (Budget)
SC-21	21st Century Surface Combatant
SIAP	Single Integrated Air Picture
SLAM	Stand-off Land Attack Missile
SM	Standard Missile (US Naval SAM)
SM-3	Standard Ballistic Missile Interceptor
SOSUS	Sound Surveillance System
SRBOC	Super Rapid Blooming Offboard Chaff
SSBN	Nuclear-powered Strategic Ballistic Missile Submarine
SSGN	Nuclear-powered Cruise Missile/Special Operations Transport Submarine
SSN	Nuclear-powered Attack Submarine
SVTT	Surface Vessel Torpedo Tube
TFBN	Total Force Battle Network
TLAM	Tomahawk Land Attack Missile
TSBF	Total Ship Battle Force

UHF	Ultra-High Frequency
VLS	Vertical Launch System
WMD	Weapons of Mass Destruction