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Navy Ship Acquisition: Options for Lower-Cost Ship Designs — Issues for Congress

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Summary

Rising procurement costs for Navy ships have recently emerged as a matter of concern for both Navy officials and some Members of Congress who track Navy-related issues. Combined with constraints on ship-procurement funding, these rising costs have caused the Navy to reduce planned ship procurement rates.

The issue for Congress is how to respond to rising Navy ship procurement costs. Aside from reducing planned ship procurement rates, options include increasing annual ship-procurement funding, modifying how Navy ships are funded in the budget, making greater use of multiyear procurement (MYP), and changing the acquisition strategy for certain Navy ships. Another option, particularly if the previous options are not implemented or prove insufficient, would be to reduce Navy ship procurement costs by shifting from currently planned designs to designs with lower unit procurement costs. This report focuses on this option.

Lower-cost designs for attack submarines, aircraft carriers, larger surface combatants, and smaller surface combatants have been proposed in recent reports by the Congressional Budget Office (CBO), DOD's Office of Force Transformation (OFT), and the Center for Strategic and Budgetary Assessments (CSBA). Options for lower-cost designs can be generated by starting with currently planned designs and making one or more of the following changes: reducing ship size; shifting from nuclear to conventional propulsion; and shifting from a hull built to military survivability standards to a hull built to commercial-ship survivability standards.

Compared to the current Virginia-class nuclear-powered attack submarine (SSN) design, lower-cost options include a non-nuclear-powered submarine equipped with an air-independent propulsion (AIP) system and a reduced-cost SSN design using new technologies now being developed. Compared to today's large, nuclear-powered aircraft carriers, lower-cost options include a medium-sized, conventionally powered carrier based on either the LHA(R) amphibious assault ship design or a commercial-like hull, and a small, high-speed carrier using a surface effect ship (SES)/catamaran hull. Compared to the current 14,000-ton DD(X) destroyer design, lower-cost options include a new-design 9,000-ton surface combatant (SC(X)), a 6,000-ton frigate (FFG(X)), or a low-cost gunfire support ship. Compared to the current 2,500- to 3,000-ton Littoral Combat Ship (LCS) design, lower cost options include a 1,000- or 100-ton surface combatant.

The merits of lower-cost ship designs can be assessed in terms of cost (which includes development and design cost, procurement cost, operating and support cost, and end-of-life disposal cost), capability, technical risk, homeporting arrangements, and potential impact on the shipbuilding industrial base. In most cases, lower-cost ships would be individually less capable than more-expensive counterparts, but supporters of lower-cost ships could argue that they would offer advantages, particularly when considered as parts of a larger fleet. Shifting to lower-cost designs could change the distribution of Navy shipbuilding work among various shipyards. This report will be updated as events warrant.

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Introduction and Issue For Congress

Rising procurement costs for Navy ships have recently emerged as a matter of concern for both Navy officials and some Members of Congress who track Navy-related issues. Admiral Vernon Clark, the Chief of Naval Operations (CNO), has expressed strong concern, if not outright frustration, about the matter.[1] Combined with constraints on ship-procurement funding, rising ship procurement costs have caused the Navy to reduce planned ship procurement rates. Some Members of Congress have expressed concern about the effects these reduced rates would have on the future size of the Navy and on the shipyards that build the Navy's ships.[2]

The issue for Congress is how to respond to rising Navy ship procurement costs. Congress' decisions on this issue could affect future Navy capabilities, Navy funding requirements, and the shipbuilding industrial base.

Aside from reducing planned ship procurement rates, one option for responding to rising Navy ship procurement costs would be to increase annual ship-procurement funding.[3] Increasing annual ship-procurement funding substantially from current

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[1] See, for example, Statement of Admiral Vernon Clark, USN, Chief of Naval Operations, Before The Senate Armed Services Committee, Feb. 10, 2005, pp. 20-21. Ship procurement costs have been rising in part because the cost of materials and components delivered to shipyards, and the cost of shipyard labor, have risen more quickly than projected.

[2] See, for example, Dave Ahearn, "Lawmakers Assail Navy Ships Budget As Inadequate," *Defense Today Instant Update*, Mar. 14, 2005.

[3] The Navy estimates that roughly $12 billion to $15 billion per year in shipbuilding funds could be required to maintain a Navy of 260 to 325 ships, which is the number of ships that the Navy has said it might need in future years to meet operational demands. The figure of $12 billion to $15 billion per year includes funding for construction of new ships and for conversions of existing ships, but does not include funding for refueling nuclear-powered ships. (Source: Telephone conversation with Navy Office of Legislative Affairs, April 14, 2005. The Navy states that this is a preliminary estimate subject to further refinement.) CBO estimates that the Navy's 260- and 325-ship fleet plans would require $14 billion to $17 billion per year in constant 2005 dollars in shipbuilding funds (or $15 billion to $18 billion per year if funding for refueling nuclear-powered ships is included). Between FY2000 and FY2005, CBO notes, annual funding for construction of new ships and conversions of existing ships has averaged $9.5 billion in constant 2005 dollars. (Source: Congressional Budget Office, *Resource Implications of the Navy's Interim Report on*

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levels, however, may not be easy. In a situation of finite defense funding, increasing funding for Navy ship procurement could require reducing funding for other Navy or Department of Defense (DOD) priorities. The Navy has worked in recent years to operate more efficiently on a day-to-day basis so that the resulting savings could be applied to Navy procurement programs. In practice, however, savings from these efficiencies have been offset by rising Navy costs in other areas, such as personnel-related costs.

A second option would be to modify the way in which new Navy ships are funded in the budget. Possible changes that have been suggested include making greater use of incremental funding or starting to use advance appropriations. This option, which is examined in CRS Report RL32776,[4] might marginally increase the number of ships that could be procured for a given total amount of money. As discussed in that report, however, it could also pose potentially significant issues relating to Congress' power of the purse and Congress' responsibility for conducting effective oversight of DOD activities.

A third option would be to make greater use in Navy ship-procurement programs of a contracting method known as multiyear procurement (MYP). This option, like the previous one, might marginally increase the number of ships that could be procured for a given total amount of money. Not all Navy ship-procurement programs, however, would meet the legal requirements for MYP,[5] and making greater use of MYP could reduce DOD's and Congress's flexibility to adjust ship-procurement plans in future years to respond to changing strategic and budgetary circumstances.[6]

A fourth option would be to change the acquisition strategy for building certain Navy ships. For example, changing from the current strategy of building each Virginia (SSN-774) class attack submarine jointly by two yards to a strategy of using a single yard to build all Virginia-class boats might eventually reduce the cost of each boat by roughly $60 million to $180 million.[7] As another example, the Navy estimates that changing from the currently planned strategy of dividing DD(X) destroyers evenly between two yards to a strategy of having all DD(X)s built by a single yard could reduce the cost for building 10 DD(X)s by a total of $3 billion, or

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[3] (...continued)
Shipbuilding, Apr. 2005. For more on the Navy's statement about needing a fleet of 260 to 325 ships, see CRS Report RL32665, *Potential Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress,* by Ronald O'Rourke.

[4] CRS Report RL32776, *Navy Ship Procurement: Alternative Funding Approaches — Background and Options for Congress*, by Ronald O'Rourke.

[5] These requirements are set forth in 10 U.S.C. 2306b, the statute governing MYP arrangements.

[6] For further discussion, see CRS Report RL32776, op. cit.

[7] For further discussion, see the section entitled "Joint-Production Arrangement" in CRS Report RL32418, *Navy Attack Submarine Force-Level Goal and Procurement Rate: Background and Issues for Congress,* by Ronald O'Rourke.

an average of $300 million per ship.[8] In either case, however, shifting to a single-yard acquisition strategy could cause the second yard to permanently exit the business of building that kind of ship. That could leave the Navy with a single source for building that kind of ship, which could prevent the Navy in the future from using competition or benchmarking[9] to spur design innovation, constrain costs, maintain production quality, and ensure adherence to scheduled delivery dates.

A fifth option, particularly if the previous options are not implemented or prove insufficient, would be to reduce Navy ship procurement costs by shifting from currently planned designs to designs with lower unit procurement costs. This report focuses on this option.[10]

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[8] See CRS Report RS21059, *Navy DD(X) and CG(X) Programs: Background and Issues for Congress*, by Ronald O'Rourke and CRS Report RL32109, *Navy DD(X), CG(X), and LCS Ship Acquisition Programs: Oversight Issues and Options for Congress*, by Ronald O'Rourke.

[9] Benchmarking, which can take place in the absence of active competition, is the process of using one yard's performance in building a certain kind of ship to help measure or judge the performance of another yard in building that kind of ship.

[10] Additional options for reducing ship procurement costs that are not discussed in detail in this report include building ships without some of their planned equipment (or with less expensive substitute equipment) and building ships in foreign shipyards where construction costs may be lower to due lower wages and material prices or other factors. The option of building ships without some of their planned equipment (or with less expensive replacement equipment) has been proposed as a way to reduce the cost of the first few DD(X) destroyers. See Rebecca Christie, "General Dynamics Offers Alternate Plan For New Destroyer," *Wall Street Journal*, Apr. 12, 2005.

Building a ship without some of its planned equipment (or with less expensive substitute equipment) would likely reduce its capabilities. Equipment not installed during the original construction process could be added back later, after the ship had entered service. This would restore the ship's lost capability but add back the cost of this equipment, in which case the ship's procurement cost, instead of being reduced, would have been partially deferred into the future. Installing this equipment on an in-service ship, moreover, may be more expensive than building it into the ship during its original construction process. As a consequence, this strategy over the long run could increase the procurement total cost of the ship above what it would have been if the ship had been built from the beginning with all its planned equipment.

Regarding the option of building ships in foreign shipyards, 10 USC 7309 states that "no vessel to be constructed for any of the armed forces, and no major component of the hull or superstructure of any such vessel, may be constructed in a foreign shipyard." The provision permits the President to authorize exceptions when the President determines that it is in the national security interest. In such cases, the President is to notify Congress of the determination, and no contract may be made until the end of the 30-day period beginning on the date on which the notice is received. The provision also exempts inflatable boats and rigid inflatable boats.

In addition to 10 U.S.C. 7309, the annual DOD appropriations act contains a provision in the section entitled "Shipbuilding and Conversion, Navy," stating that funds for Navy shipbuilding are made available for the fiscal year in question provided, among other things,
(continued...)

The following section of the report provides background information on notional options for lower-cost attack submarines, aircraft carriers, larger surface combatants, and smaller surface combatants. The final section of the report discusses issues that Congress may consider in assessing the merits — the potential advantages and disadvantages — of shifting to lower-cost designs.

Background

Recent Reports Proposing Lower-Cost Designs

Lower-cost designs for attack submarines, aircraft carriers, larger surface combatants, and smaller surface combatants have been proposed in three recent reports discussing the future of the Navy. The reports were authored by the Congressional Budget Office (CBO),[11] DOD's Office of Force Transformation (OFT),[12] and an independent policy-research organization called the Center for Strategic and Budgetary Assessments (CSBA).[13] Several of the lower-cost ship designs discussed below are taken from these reports.

Basic Approaches For Arriving At Lower-Cost Designs

Options for lower-cost Navy ship designs can be generated by starting with currently planned Navy ship designs and making one or more of the following changes:

- **Reducing ship size.** For a given type of ship, procurement cost tends to be broadly proportional to ship size.

- **Shifting from nuclear to conventional propulsion.** This is a strategy that can be considered for the Navy's submarines and aircraft carriers, whose current designs are nuclear-powered.

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[10] (...continued)
"That none of the funds provided under this heading for the construction or conversion of any naval vessel to be constructed in shipyards in the United States shall be expended in foreign facilities for the construction of major components of such vessel: Provided further, That none of the funds provided under this heading shall be used for the construction of any naval vessel in foreign shipyards."

[11] Congressional Budget Office, *Budget Options*, Feb. 2005, pp. 18-19; and Congressional Budget Office, *Transforming the Navy's Surface Combatant Force*, Mar. 2003, pp. 27-28, 63. (Hereafter CBO 2005 report and CBO 2003 report, respectively.)

[12] Department of Defense, Office of the Secretary of Defense, *Alternative Fleet Architecture Design*, 2005. (Report for the Congressional Defense Committees, Office of Force Transformation; hereafter OFT report.)

[13] Robert O. Work, *Winning the Race: A Naval Fleet Platform Architecture for Enduring Maritime Supremacy*, Center for Strategic and Budgetary Assessments, Washington, 2005. (Version as of March 1, 2005, which is in the form of a slide briefing with 322 slides. Hereafter CSBA report.)

Equipping a Navy ship with a conventional (i.e., fossil-fuel) propulsion plant rather than a nuclear propulsion plant can reduce the ship's procurement cost by several hundred million dollars.

- **Shifting from a hull built to military survivability standards to a hull built to commercial-ship survivability standards.** A hull built to military survivability standards has more internal compartmentalization and armoring than a hull built to commercial-ship standards, making it more expensive to build than a commercial-like hull. The Navy is considering building Maritime Prepositioning Force (Future), or MPF(F), ships, with commercial-like hulls.

Most of the lower-cost ship options presented below use one or more of these three approaches. Information on the estimated procurement costs of the lower-cost designs is presented when available. Lower-cost ship designs using these approaches will in most cases be individually less capable than the currently planned ship designs from which they are derived, and this is one of the assessment factors that is discussed in the final section of the report.

Options for Lower-Cost Ships

For each category of ship below, the discussion describes the current design and then outlines potential lower-cost options. The discussions are descriptive only; the potential advantages and disadvantages of shifting to the lower-cost designs are discussed in the final section of the report.

Attack Submarines.

Current design:
- *Virginia (SSN-774) class nuclear-powered submarine*

Potential lower-cost options:
- *AIP-equipped non-nuclear-powered submarine*
- *Reduced-cost "Tango Bravo" nuclear-powered submarine*

Virginia-Class (SSN-774) Nuclear-Powered Submarine.[14] The Navy is currently procuring one Virginia (SSN-774) class nuclear-powered attack submarine (SSN) per year. Each submarine costs about $2.4 billion to $3.0 billion to procure ($2.4 billion for the FY2006 boat, rising to $3.0 billion for the FY2011 boat). The FY2006-FY2011 Future Years Defense Plan (FYDP) maintains Virginia-class procurement at one per year through FY2011 rather than increasing it to two per year starting in FY2009, as previously planned.

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[14] For more on the Virginia-class program, see See CRS Report RL32418, *Navy Attack Submarine Force-Level Goal and Procurement Rate: Background and Issues for Congress*, by Ronald O'Rourke.

A March 2005 Navy report to Congress on potential future Navy force levels states that the Navy in the future may need to maintain a force of 37 to 41 SSNs.[15] To maintain a force of at least 40 SSNs, the SSN procurement rate would need to increase to two per year starting in FY2012 or FY2013 and remain at that level for about a dozen years.[16]

The reduction in planned Virginia-class procurement to one per year through FY2011 can be viewed as a signal that, unless budget conditions change, Virginia-class procurement may never be more than one per year. A continued one-per-year rate could reduce the SSN force to fewer than 30 boats by about 2030, before recovering to a steady-state level of 33 boats.[17]

Two options for lower-cost attack submarines have recently emerged. One option involves designing a non-nuclear-powered submarine equipped with an air-independent propulsion (AIP) system that could be procured in tandem with Virginia-class SSNs. The other option involves designing a reduced-cost SSN using new "Tango Bravo" technologies being developed by the Navy and the Defense Advanced Research Projects Agency (DARPA) that would be procured as a successor to the Virginia-class design. Some or all of a $600-million fund included in the FY2006-FY2011 FYDP for "a future undersea superiority system" could be used to help finance either option.

AIP-Equipped Non-Nuclear-Powered Submarine. Non-nuclear-powered submarines are less expensive than nuclear-powered submarines not only because of the difference in propulsion systems, but also because non-nuclear-powered submarines tend to be smaller than nuclear-powered submarines.

The OFT report proposed a future Navy consisting of several new kinds of ships, including air-independent propulsion (AIP)-equipped non-nuclear-powered submarines.[18] An AIP system such as a fuel-cell or closed-cycle diesel engine extends the stationary or low-speed submerged endurance of a non-nuclear-powered submarine. AIP-equipped submarines are currently being acquired by certain foreign navies.

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[15] Department of the Navy, *An Interim Report To Congress on Annual Long-Range Plan For The Construction Of Naval Vessels For FY 2006*, Washington, 2005. (This report was delivered to the defense committees of Congress on March 23, 2005. Defense trade publications obtained copies of the report, and at least one publication posted the report on its website.)

[16] See CRS Report RL32418, op. cit., Table 5.

[17] See CRS Report RL32418, op. cit., graph entitled "Potential SSN Force Levels, 2000-2050."

[18] See also Christopher J. Castelli, "Defense Department Nudges Navy Toward Developing Diesel Subs," *Inside the Navy*, Mar. 7, 2005; Dave Ahearn, "Lawmakers Assail Navy Budget, But Eye Non-Nuke Subs," *Defense Today*, Mar. 3, 2005.

AIP submarines could be procured in tandem with Virginia-class boats. One possibility, for example, would be to procure one Virginia-class boat plus one or more AIP submarines each year.

The OFT report recommended substituting four AIP submarines for one Virginia-class submarine in each carrier strike group, suggesting that four AIP submarines might be procured for the same cost ($2.4 billion to $3.0 billion in the FY2006-FY2011 FYDP) as one Virginia-class submarine. This suggests an average unit procurement cost for an AIP submarine of roughly $600 million to $750 million each. Although AIP submarines being built by other countries might cost this much to procure, a U.S. Navy AIP submarine might be built to higher capability standards and consequently cost more to procure, possibly reducing the equal-cost ratio of substitution to three to one or possibly something closer two to one. If so, then the annual cost of procuring one Virginia-class SSN plus one, two, or perhaps three AIP submarines could be equal to or less than that of procuring two Virginia-class boats per year.

Reduced-Cost "Tango Bravo" SSN. The Virginia class was designed in the early to mid-1990s, using technologies that were available at the time. New technologies that have emerged since that time may now permit the design of a new SSN that is equivalent in capability to the Virginia class design, but substantially less expensive to procure. The Navy and DARPA are now pursuing the development of these technologies under a program called Tango Bravo, a name derived from the initial letters of the term "technology barriers." As described by the Navy,

> TANGO BRAVO will execute a technology demonstration program to enable design options for a reduced-size submarine with equivalent capability as the VIRGINIA Class design. Implicit in this focus is the goal to reduce platform infrastructure and, ultimately, the cost of future design and production. Additionally, reduced platform infrastructure provides the opportunity for greater payload volume.
>
> The intent of this collaborative effort is to overcome selected technology barriers that are judged to have a significant impact on submarine platform infrastructure cost. Specifically, DARPA and the Navy will jointly formulate technical objectives for critical technology demonstrations in (a) shaftless propulsion, (b) external weapons, (c) conformal alternatives to the existing spherical array, (d) technologies that eliminate or substantially simplify existing submarine systems, and (e) automation to reduce crew workload for standard tasks.[19]

Some Navy and industry officials believe that if these technologies are developed, it would be possible to design a new submarine equivalent in capability to the Virginia class, but with a procurement cost of perhaps 75% of the Virginia

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[19] Navy information paper on advanced submarine system development provided to CRS by Navy Office of Legislative Affairs, Jan. 21, 2005. For additional discussion of the Tango Bravo program, see Aarti Shah, "Tango Bravo Technology Contract Awards Expected This Spring," *Inside the Navy*, Mar. 14, 2005; Andrew Koch, "US Navy In Bid To Overhaul Undersea Combat," *Jane's Defence Weekly*, Mar. 9, 2005: 11; Lolita C. Baldor, "Smaller Subs Could Ride Waves Of The Future," *NavyTimes.com*, Feb. 4, 2005; Robert A. Hamilton, "Navy, DARPA Seek Smaller Submarines," *Seapower*, Feb. 2005, pp. 22, 24-25.

class. Such a submarine could more easily be procured within available resources at a rate of two per year.

Consequently, as an alternative to the option of procuring AIP submarines, another option would be to start design work now on a new "Tango Bravo" SSN. The idea of designing a submarine with capability equivalent to that of Virginia-class and a procurement cost that is less than that of the Virginia class has been discussed by Navy and industry officials. Under this option, Virginia-class procurement could continue at one per year until the Tango Bravo submarine was ready for procurement, at which point Virginia-class procurement would end, and procurement of the Tango Bravo submarine would begin.

If design work on a Tango Bravo submarine is begun now and pursued in a concerted manner, the first Tango Bravo submarine might be ready for procurement by FY2011. (Some industry officials believe that under ideal program conditions, the lead ship could be procured earlier than FY2011; conversely, some Navy officials believe the lead ship might not be ready for procurement until after FY2011.) If the lead ship is procured in FY2011, then the procurement rate could be increased to two per year starting in FY2012 or FY2013, meeting the time line needed to avoid falling below 40 boats.

Aircraft Carriers.

Current design:
- *Large nuclear-powered carrier, as exemplified by the George H.W. Bush (CVN-77) and the planned next carrier, called CVN-21*

Potential lower-cost options:
- *Medium-sized, conventionally powered carrier based on LHA(R) amphibious assault ship design*
- *Medium-sized, conventionally powered carrier based on a commercial-like hull design*
- *Small carrier based on high-speed surface effect ship (SES)/ catamaran hull design*

CVN-77 and CVN-21.[20] The Navy is currently building large nuclear-powered aircraft carriers (CVNs). These ships have a full load displacement of about 100,000 tons and can embark an air wing of about 75 conventional takeoff and landing (CTOL) airplanes and helicopters.

The George H. W. Bush (CVN-77) was procured in FY2001 at a total cost of $4.975 billion, but the ship's estimated construction cost has since risen to $6.35 billion. The ship is scheduled to enter service in 2008.

The FY2006-FY2011 FYDP defers the planned procurement of the next aircraft carrier, called CVN-21 (or CVN-78), by one year, to FY2008. Navy officials have

[20] For more on CVN-77 and the CVN-21 program, see CRS Report RS20643, *Navy CVN-21 Aircraft Carrier Program: Background and Issues for Congress*, by Ronald O'Rourke.

explained that the one-year deferral was due to an inability to fund the procurement of CVN-21 in FY2007 while also funding the procurement of other ships planned for FY2007.

CVN-21's estimated procurement cost has increased about $1.9 billion since 2004 and is now $10.51 billion, including $2.355 billion in detailed design and nonrecurring engineering (DD/NRE) costs and $8.155 billion in hands-on construction costs.[21] The Navy estimates that about $400 million of the $1.9-billion increase was due to the decision to defer the procurement of the ship to FY2008.

Advance procurement funding for CVN-21 has been provided since FY2001. If the ship is procured in FY2008, it would enter service in 2015.

The next carrier, called CVN-79, is currently planned for procurement in FY2012. Its currently estimated procurement cost is $9.548 billion, including $651 million in DD/NRE costs and $8.897 billion in hands-on construction costs. If the ship is procured in FY2012, it would enter service around 2019.

Three options for lower-cost aircraft carriers have recently emerged. One option involves designing a medium-sized, conventionally powered aircraft carrier based on the design for a new amphibious assault ship called the LHA Replacement ship, or LHA(R), that is currently being developed by the Navy.[22] A second option involves designing a medium-sized, conventionally powered aircraft carrier based on a commercial-like hull design. The third option involves designing a small, high-speed, conventionally powered aircraft carrier built on a surface effect ship (SES)/catamaran hull design.[23]

Medium-Sized Carrier Based on LHA(R) Design. The CSBA report recommended procuring CVN-21-class aircraft carriers as needed to maintain a force of 10 large carriers (two ships less than the current 12-ship force). It also recommended procuring an additional four medium-sized, conventionally powered aircraft carriers based on the LHA(R) design. This ship might displace about 40,000 tons and embark an air wing of perhaps about two dozen vertical/short takeoff or landing (VSTOL) versions of the F-35 Joint Strike Fighter (JSF). Its unit procurement cost might be roughly $2.7 billion, which is the approximate estimated cost of the LHA(R) ship that is scheduled for procurement in FY2007.[24]

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[21] The total estimated acquisition cost of CVN-21, which also includes $3.2 billion in research and development funding for the ship, is $13.7 billion.

[22] Navy amphibious ships are given designations beginning with the letter L, which stands for landing, as in amphibious landing. LHA can be translated as amphibious ship (L), helicopter platform (H), assault (A). Navy LHAs and closely related ships designated LHDs (the D standing for well deck, an opening in the stern of the ship for landing craft that the LHAs also have) have flight decks that run the length of the ship, giving these ships an aircraft-carrier-like appearance.

[23] A surface effect ship is supported above the water by a cushion of air that is trapped beneath the ship.

[24] For more on the LHA(R), see CRS Report RL32513, *Navy-Marine Corps Amphibious and*

(continued...)

Medium-Sized Carrier Based on Commercial-Like Hull. The OFT report recommended procuring a medium-sized carrier based on a relatively inexpensive, commercial-like hull design developed in 2004 for the Navy's Maritime Prepositioning Force (Future), or MPF(F), analysis of alternatives.[25] This carrier, which would have a full load displacement of about 57,000 tons, would embark a notional air wing of 36 manned aircraft — 30 Joint Strike Fighters (JSFs) and 6 MV-22 Osprey tilt-rotor aircraft — and 15 unmanned air vehicles (UAVs).

This ship would be somewhat larger than the LHA(R)-based carrier recommended in the CSBA report, and roughly the same size as the United Kingdom's new aircraft carrier design. (The LHA(R)-based ship and the UK carrier, however, would use military hulls.) The OFT report recommended substituting two of these 57,000-ton carriers for each of the Navy's current large carriers, so that the number of manned aircraft based at sea would remain about the same.

Small Carrier Using High-Speed SES/Catamaran Hull Design. As an alternative to the 57,000-ton medium-sized carrier, the OFT report recommended procuring a small, high-speed carrier displacing 13,500 tons that would use a surface effect ship (SES)/catamaran hull. The ship was based on a design for an unmanned aerial vehicle/unmanned combat aerial vehicle (UAV/UCAV) carrier that was developed in 2000-2002 by a team at the Naval Postgraduate School.[26] The OFT report recommended using the ship to embark a notional air wing of 10 manned aircraft — 8 JSFs and 2 MV-22s — and 8 UAVs, and have a maximum speed of 50 to 60 knots.

This ship would be slightly larger than Thailand's 11,500-ton aircraft carrier, which was commissioned in 1997. It would be smaller than Spain's 17,000 aircraft carrier, which was based on a U.S. design[27] and was commissioned in 1988, or the UK's three existing 20,600-ton carriers, which were commissioned between 1980 and 1985. The OFT-recommended ship would be much faster than the Thai,

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[24] (...continued)
Maritime Prepositioning Ship Programs: Background and Oversight Issues for Congress, by Ronald O'Rourke.

[25] The MPF(F) is a planned ship that would preposition combat equipment and supplies at sea. For more on the MPF(F) program, see CRS Report RL32513, op. cit. The OFT report also recommended using this same 57,000-ton hull as the basis for a missile-and-rocket ship, an amphibious ship, and a small-combatant mother ship.

[26] The design was developed by the Total Ship Systems Engineering group at the Naval Postgraduate School under an effort called the Crossbow project. Within that project, the carrier was referred to as Sea Archer. For more on the Sea Archer, see [http://web.nps.navy.mil/~me/tsse/files/2001.htm]. See also Jason Ma, "Naval Postgraduate School Issues Report on Crossbow Project," *Inside the Navy*, Oct. 28, 2002; Randy Woods, "Students Design Small, Fast Carrier At Projected Cost Of $1.5 Billion," *Inside the Navy*, Jan. 7, 2002. The latter article quoted the leader of the project as saying that if the ship's speed were reduced from 60 knots to 40 knots, the ship's estimated procurement cost of $1.5 billion could be reduced substantially.

[27] The U.S. design, which was called the Sea Control Ship, was never built for the U.S. Navy.

Spanish, or existing UK carriers, or any other aircraft carrier now in operation. The OFT report recommended substituting eight of these 13,500-ton carriers for each of the Navy's current large carriers, so that the number of manned aircraft based at sea would remain about the same.

Additional Potential Options. Studies of aircraft carrier acquisition options over the years have discussed many other potential designs, including the following:

- **A large, conventionally powered carrier.** Such a ship, which might use the same hull design as the CVN-21, might displace about 100,000 tons. It would be broadly similar to the Kitty Hawk (CV-63) and John F. Kennedy (CV-67), the Navy's two remaining conventionally powered carriers, which displace roughly 82,000 tons and embark air wings similar to those embarked by the Navy's large nuclear-powered carriers. The ship might have a procurement cost several hundred million dollars less than that of CVN-21.

- **A medium-sized nuclear-powered carrier.** Such a ship might be based on the LHA(R) hull and use a half-sized version of the CVN-21 nuclear propulsion plant.[28] Like the CSBA-recommended conventionally powered carrier based on the LHA(R) design, this ship might displace about 40,000 tons and embark about two dozen VSTOL JSFs. If the CSBA-recommended conventionally powered carrier would cost roughly $2.7 billion, a nuclear-powered version would cost more than $3 billion. The ship might be considered broadly similar to the France's nuclear-powered carrier, the Charles de Gaulle, which was commissioned in 2001, displaces 42,000 tons, and embarks an air wing of about 34 conventional takeoff and landing (CTOL) airplanes and two helicopters.

Matrix of Possible Designs. **Table 1** below shows how ship size, propulsion type, and hull type create a matrix of notional aircraft carrier options, including the large nuclear-powered carriers currently being procured and the potential alternatives described above.

Medium-sized carriers of 40,000 to 70,000 tons might operate either VSTOL or CTOL aircraft, though ships at the higher end of this size range might be able to operate CTOL aircraft more easily or efficiently. Small carriers, because of their shorter length, would likely be limited to VSTOL aircraft.

Although the table does not provide any examples of large or small conventionally powered carriers using a commercial-like hulls, or any examples of

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[28] The nuclear propulsion plant planned for CVN-21, like those on almost all the Navy's nuclear-powered aircraft carriers, includes two nuclear reactors and two sets of associated propulsion equipment. (The sole Navy carrier with a different propulsion plant arrangement is the Enterprise [CVN-65], the Navy's first nuclear-powered carrier, whose plant includes eight smaller nuclear reactors.) A half-sized version of the CVN-21 plant would use one reactor and one set of associated equipment.

a small nuclear-powered carrier, such ships are possible. Regarding the possibility of a small nuclear-powered carrier, the Navy between FY1957 and FY1975 procured a total of nine nuclear-powered cruisers with displacements ranging from about 9,000 tons to about 17,500 tons.[29]

The table also does not provide examples of ships combining a nuclear propulsion plant with a commercial-like hull. Although a small number of nuclear-powered commercial cargo ships were built years ago, a combat ship such as an aircraft carrier that combined a relatively expensive nuclear propulsion plant with a commercial-like hull having relatively limited survivability features might be viewed as a contradictory design.

[29] The nine cruisers — three one-of-a-kind ships, a class of two ships, and a class of four ships — entered service between 1961 and 1980 and were decommissioned between 1993 and 1999. Procurement of nuclear-powered cruisers was halted after FY1975 due largely to a desire to constrain the procurement costs of future cruisers. In deciding in the late 1970s on the design for the new cruiser that would carry the Aegis defense system, two nuclear-powered design options were rejected in favor of the option of placing the Aegis system onto the smaller, conventionally powered hull developed for the Spruance (DD-963) class destroyer. The resulting design became the Ticonderoga (CG-47) class Aegis cruiser. The first Aegis cruiser was procured in FY1978. Although nuclear power was abandoned for Navy cruisers, it was retained for the Navy's large aircraft carriers because adding nuclear power increases total ship procurement cost in percentage terms less for a large carrier than for a cruiser, and because the mobility advantages of nuclear power for a surface ship (see the discussion on mobility in the next section of the report) were viewed as important for carriers in light of their combat capabilities and limited numbers. Some observers believe that if oil prices are deemed likely to remain high, the option of nuclear-powered surface combatants might bear revisiting.

Table 1. Matrix of Notional Options For Aircraft Carriers

Ship size (full load displacement)	Military hull		Commercial-like hull	
	Nuclear-powered	Conventionally powered	Nuclear-powered	Conventionally powered
Large CTOL carrier (~80,000 to ~100,000tons)	CVN-77 or CVN-21	Ship broadly similar to CV-63 and CV-67		
Medium CTOL or VSTOL carrier (~40,000 to ~70,000 tons)	Carrier based on LHA(R) design (CSBA) or ship similar to new French carrier	Carrier based on LHA(R) design (CSBA) or ship similar to new UK carrier design		57,000-ton carrier (OFT)
Small VSTOL carrier (~10,000 to ~30,000 tons)		13,500-ton high-speed carrier (OFT) or ship similar to Spanish, Thai, or existing UK carriers		

Source: Table prepared by CRS based on Navy data, OFT and CSBA reports, and *Jane's Fighting Ships 2004-2005*.
CTOL = conventional takeoff land landing aircraft
VSTOL = vertical/short takeoff and landing aircraft

Larger Surface Combatants.

Current design:
- *14,000-ton DD(X) destroyer/CG(X) cruiser*

Potential lower-cost options:
- *Roughly 9,000-ton surface combatant (SC(X))*
- *Roughly 6,000-ton frigate (FFG(X))*
- *Low-cost gunfire support ship*

14,000-ton DD(X) Destroyer/CG(X) Cruiser.[30] The Navy currently plans to procure DD(X) destroyers and, starting in FY2011, CG(X) cruisers. The CG(X) would be based on the DD(X) design and could be somewhat larger and more expensive than the DD(X). Congress for FY2005 approved $220 million in advance procurement funding for the first DD(X), which is planned for FY2007, and $84 million in advance procurement funding for the second DD(X), which is planned for FY2008. The FY2006 budget requests $666 million in additional advanced procurement funding for the first DD(X), $50 million in additional advance

[30] For more on the DD(X) and CG(X) programs, see CRS Report RS21059, *Navy DD(X) and CG(X) Programs: Background and Issues for Congress*, by Ronald O'Rourke and CRS Report RL32109, *Navy DD(X), CG(X), and LCS Ship Acquisition Programs: Oversight Issues and Options for Congress*, by Ronald O'Rourke.

procurement funding for the second DD(X), and $1,115 million for DD(X)/CG(X) research and development.

The DD(X) would have a full-load displacement of about 14,000 tons, which would make it roughly 50% larger than the Navy's current 9,000-ton Aegis cruisers and destroyers, and larger than any U.S. Navy destroyer or cruiser since the nuclear-powered cruiser Long Beach (CGN-9), which was procured in FY1957.[31]

Estimated DD(X) unit procurement costs have increased substantially since 2004:

- The Navy in 2004 estimated that the first DD(X) would cost about $2.8 billion to procure, including about $1 billion in detailed design and nonrecurring engineering costs (DD/NRE) for the class; it now estimates the cost at $3,291 million (an increase of about 18%), including $558 million in DD/NRE costs.

- The Navy in 2004 estimated that the second DD(X) would cost $2,053 million to procure; it now estimates the cost at $3,061 million (an increase of about 49%), including $219 million in DD/NRE costs.

- The Navy in 2004 estimated that subsequent DD(X)s would cost between $1.5 billion and $1.8 billion each to procure; it now estimates the cost at about $2.2 billion to $2.6 billion each (an increase of roughly 45%). This is much higher than the cost of Arleigh Burke (DDG-51) class Aegis destroyers procured in recent years. The three DDG-51s procured in FY2005, for example, were funded at a total cost of $3,491 million, or an average cost of about $1,164 million per ship.

The Cost Analysis Improvement Group (CAIG) within the Office of the Secretary of Defense (OSD) reportedly believes that DD(X) procurement costs may be 20% to 33% higher than the figures above.[32]

The Navy originally envisaged procuring a total of 16 to 24 DD(X)s, but Navy officials now state they have a requirement for eight to 12. The FY2005-FY2009

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[31] Over the last few decades, U.S. Navy cruisers have become smaller while U.S. Navy destroyers have become larger, with the result that there is now considerable overlap between U.S. Navy cruisers and destroyers in terms of size and capability. Remaining points of distinction between the two types of ships include the presence on all recent U.S. Navy cruiser classes but not all recent U.S. Navy destroyer classes of a high-capability area air-defense system, and the presence on cruisers but not destroyers of additional command facilities for accommodating senior officers who are directing operations on multiple ships.

[32] Tony Capaccio, "Destroyer May Cost 33% More Than Navy Budgeted, Pentagon Says," *Bloomberg.net*, May 4, 2005; Christopher P. Cavas, "Rising Costs of DD(X) Threaten U.S. Fleet Plans," *DefenseNews.com*, May 2, 2005; Christopher J. Castelli, "Pentagon Postpones DD(X) DAB Meeting To Resolve Cost Estimates," *Inside the Navy*, May 2, 2005.

FYDP submitted to Congress in February 2004 called for procuring the first DD(X) in FY2005, another two in FY2007, two more in FY2008, and three more in FY2009, for a total of eight ships through FY2009. The FY2006-FY2011 FYDP submitted to Congress in February 2005 reduces planned DD(X) procurement to one per year for FY2007-FY2011, for a total of five ships through FY2009. The FY2006-FY2011 FYDP also accelerates procurement of the first CG(X) from FY2018 to FY2011.

The decision to reduce DD(X) procurement to one per year in FY2007-FY2011, which appears to have been driven in large part by affordability considerations, suggests that, unless budget conditions change, the Navy may never be able to afford to procure more than one DD(X) or CG(X) per year. A one-per-year DD(X)/CG(X) procurement rate, if sustained for a period of many years, might not be enough to introduce the planned new DD(X)/CG(X) technologies into the fleet in sufficient numbers to meet operational needs. The prospect of a one-per-year rate might also raise questions about the potential cost effectiveness of the DD(X)/CG(X) effort when measured in terms of average unit acquisition cost, which is the average cost to develop and procure each ship. Given the $10 billion dollars in research and development funding programmed for the DD(X)/CG(X) effort, if DD(X)s or CG(X)s are procured at a rate of one per year, the average acquisition cost for each DD(X) or CG(X) could be more than $3 billion, using the Navy's cost estimates, or possibly closer to $4 billion, using the reported CAIG estimates.

Options for a reduced-cost surface combatant include a roughly 9,000-ton surface combatant, a roughly 6,000-ton frigate, and a low-cost gunfire support ship.

Roughly 9,000-Ton Surface Combatant (SC(X)). One option for a lower-cost surface combatant would be a new-design ship about equal in size to the Navy's current 9,000-ton Aegis cruisers and destroyers. Such a ship, which might be called the SC(X) (meaning surface combatant, in development) could:

- be intended as a replacement for either the CG(X) program or both the DD(X) and CG(X) programs;

- incorporate many of the same technologies now being developed for the DD(X) and CG(X), including, for example, radar technologies, the Advanced Gun System (AGS), integrated electric-drive propulsion, and technologies permitting a reduced-sized crew;

- cost substantially less to procure than a DD(X) or CG(X), and perhaps about as much to procure as a DDG-51 class Aegis destroyer (which currently costs about $1,350 million per ship when procured at a rate of two per year);

- be similar to the DD(X) and CG(X) in terms of using a reduced-size crew to achieve annual operation and support costs that are considerably less than those of the current DDG-51 design;

- carry a payload — a combination of sensors, weapon launchers, weapons, related computers and displays, aircraft, and fuel — that is smaller than that of the DD(X) or CG(X), but comparable to that of current DDG-51s or Aegis cruisers.

A land-attack oriented version of the SC(X) might be able to carry one Advanced Gun System, or AGS (a new-design 155mm gun), as opposed to the two on the DD(X). An air- and missile-defense version of the SC(X) would have fewer missile tubes than CG(X), but still a fairly substantial number.

Roughly 6,000-Ton Frigate (FFG(X)). A second option for a smaller, less expensive, new-design ship that has been suggested by CBO would be a frigate intended as a replacement for both the DD(X)/CG(X) effort and the Littoral Combat Ship (LCS) program that is discussed later in this report. CBO estimated that such a ship, which it calls the FFG(X), might displace about 6,000 tons. CBO estimates that a 6,000-ton FFG(X) might have a unit procurement cost of about $800 million.

A 6,000-ton FFG(X) might be too small to be equipped with the AGS, in which case it could not provide the additional naval gunfire capability that would be provided by the DD(X). A 6,000-ton FFG(X) might, however, be capable of performing the non-gunfire missions that would be performed by both the DD(X) and the LCS. A 6,000-ton FFG(X) would could be viewed as a replacement in the surface combatant force structure for the Navy's Oliver Hazard Perry (FFG-7) class frigates and Spruance (DD-963) class destroyers. Since a 6,000-ton FFG(X) would be roughly midway in size between the 4,000-ton FFG-7 design and the 9,000-ton DD-963 design, it might be suitable for carrying more modern versions of the mission equipment currently carried by the FFG-7s and DD-963s.

Low-Cost Gunfire Support Ship. A third option for a smaller, less expensive, new-design ship would be a low-cost gunfire support ship — a relatively simple ship equipped with one or two AGSs and only such other equipment that is needed for basic ship operation. Other than the AGSs and perhaps some advanced technologies for reducing crew size and thus total life-cycle cost, such a ship could use existing rather than advanced technologies so as to minimize development time, development cost, and technical risk. Some of these ships might be forward-stationed at sites such as Guam or Diego Garcia, so as to be available for rapid crewing and movement to potential contingencies in the Western Pacific or Indian Ocean/Persian Gulf regions. The goal would be to procure specialized AGS-armed ships as a niche capability for the Navy, and then forward-station some of that capability so as to maximize the odds of being able to bring a desired number of AGSs to an overseas theater of operation in a timely manner on those occasions when it is needed.

A variant of this option that was suggested in the CSBA report would be to place one or two AGSs on the basic San Antonio (LPD-17) class amphibious ship hull design. LPD-17s currently under construction for supporting Marine operations are to displace about 25,000 tons, but a basic version of the LPD-17 hull equipped with one or two AGSs might have a different displacement.[33]

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[33] The Navy currently plans to procure a total of nine LPD-17 class ships, with the eighth (continued...)

Smaller Surface Combatants.

Current design:
- *2,500- to 3,000-ton Littoral Combat Ship (LCS)*

Potential Lower-Cost Options
- *Roughly 1,000-ton surface combatant*
- *Roughly 100-ton surface combatant*

2,500- to 3,000-ton Littoral Combat Ship (LCS).[34] In addition to DD(X) destroyers and CG(X) cruisers, the Navy currently plans to procure Littoral Combat Ships (LCSs), which would be small (2,500- to 3,000-ton), fast surface combatants that would use modular "plug-and-fight" weapon systems. Congress for FY2005 provided $212.5 million to fully fund the first LCS "sea frame,"which is the term the Navy uses to refer to the basic ship, without any modular mission packages. For FY2006, the Navy has requested $613.3 million for the program, including $240.5 million in research and development funding to build the second LCS sea frame, $336.0 million in additional research and development funding, and $36.8 million in procurement funding for LCS mission modules.

A March 2005 Navy report to Congress on potential future Navy force levels suggests that the Navy wants to procure a total of 63 to 82 LCSs.[35] The Navy wants the procurement cost of each LCS sea frame to be no more than $220 million. Figures from the FY2006-FY2011 FYDP suggest that when the cost of the mission modules is added in, the LCS program might have an average ship procurement cost of about $387 million, and that a program of 63 to 82 LCSs might therefore have a total acquisition (i.e., research and development plus procurement) cost of about $25.3 billion to $32.7 billion.[36]

1,000-Ton Surface Combatant. Rather than procuring the LCS, the OFT report recommended procuring a 1,000-ton surface combatant. Like the LCS, this

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[33] (...continued)
and ninth ships to be procured in FY2006 and FY2007, respectively. The estimated procurement costs of the two final ships are $1,353 million and $1,584 million, respectively, but these figures may reflect costs associated with the winding down of LPD-17 production. The seventh LPD-17, procured in FY2005, has an estimated procurement cost of $1,193 million. An additional surface combatant option recommended in the OFT report is a large missile-and-rocket ship based on the same 57,000-ton commercial-like hull design that the report recommended using as the basis for a medium-sized aircraft carrier. Although this ship would be based on a commercial-like hull, the unit procurement cost of this ship would be higher than, not lower than, that of the DD(X).

[34] For more on the LCS program, see CRS Report RS21305, *Navy Littoral Combat Ship (LCS): Background and Issues for Congress*, by Ronald O'Rourke and CRS Report RL32109, op. cit.

[35] *An Interim Report To Congress on Annual Long-Range Plan For The Construction Of Naval Vessels For FY 2006*, op. cit.

[36] For a discussion, see CRS Report RS21305 and CRS Report RL32109, op. cit.

ship would have a maximum speed of 40 to 50 knots and standard interfaces for accepting various modular mission packages, and would self-deploy to the theater of operations. The ship would be supported in theater by one or more larger types of ships that were also recommended by OFT.

100-ton Surface Combatant. As an alternative to the 1,000-ton surface combatant, the OFT report recommended procuring a 100-ton surface combatant with a maximum speed of 60 knots and standard interfaces for accepting various modular mission packages. These ships would be transported to the theater by a "mother ship" based on the same 57,000-ton commercial-like hull used for OFT's proposed medium-sized aircraft carrier. The 100-ton surface combatants would be supported in theater by the mother ship and possibly another larger ship that was recommended by OFT.

Issues For Congress

The potential lower-cost ship designs outlined above can be assessed in terms of cost, capability, technical risk, homeporting arrangements, and potential impact on the shipbuilding industrial base.

Cost

Although the potential ship designs outlined in the previous section would have lower unit procurement costs than currently planned designs, a complete assessment of the cost implications of these options would take into account development and design cost, procurement cost, life-cycle operation and support cost (O&S), and end-of-life disposal costs. Each of these are discussed below.

Development And Design Cost. Developing and designing a large, complex Navy ship can cost billions of dollars. Consequently, if a currently planned ship has already been developed and designed, stopping that program in favor of a new, lower-cost design could incur substantial additional development and design costs, and consequently might save money over the long run (i.e., reach the financial break-even point compared to continuing with the current design) only if the lower-cost design is procured in large enough total numbers so that the cumulative procurement savings were greater than the additional up-front development and design costs. The earlier in the development and design process that an existing ship acquisition program is stopped, the earlier in the future it might be that a lower-cost alternative design might reach the break-even point. In addition, if a lower-cost ship could use many of the same technologies intended for the more-expensive ship, or technologies already developed for other ships, then the cost to develop the new design could be reduced, perhaps substantially.

Procurement Cost. Through a process common to many manufacturing activities called moving down the learning curve, the number of shipyard labor hours required to build a ship design decreases as a shipyard builds more ships to that design and shipyard workers become increasingly familiar with the design.[37] Consequently, if some number of ships have already been built to a currently planned design, the difference in cost between that design and the first units of a lower-cost alternative design might be less than if the currently planned design had not yet entered production, and the break-even point for the lower-cost design will be further into the production run than if the currently planned design had not yet entered production. On the other hand, if the lower-cost design can be procured at a greater annual rate than the currently planned design (e.g., two ships per year for the lower-cost design vs. one ship per year for the currently planned design), then the lower-cost design could move down the learning curve more quickly and achieve the cost-reducing benefits of the learning curve more fully than the currently planned design.

Life-Cycle Operation and Support (O&S) Cost. Navy ships are expensive to operate and support, and can remain in service for many years — 20 or more years for a small combatant, 30 or more years for an attack submarine or larger surface combatant, and up to 50 years for an aircraft carrier. Consequently, although ship procurement costs are often more visible in the budget than ship O&S costs, a ship's life-cycle O&S cost can contribute as much as, or even more than, its procurement cost to total long-term Navy expenditures.

Reducing a ship's life-cycle O&S cost can sometimes involve including design features that increase its procurement cost. Personnel costs are a major component of ship O&S costs, and reducing crew size can involve fitting the ship with technology for automating functions that were previously performed by people, including damage control, which is a function that traditionally has contributed to a need for larger crews. If the cost of added technology is greater than the avoided expense of building extra crew-related spaces into the ship, then adding the technology will increase the ship's procurement cost. Maintenance costs are another major component of ship O&S costs, and reducing maintenance costs might require building certain parts of the ship with more-durable but more-expensive materials, or increasing the size (and thus construction cost) of certain spaces on the ship, so as to provide room for easier access during maintenance.

In light of these considerations, it is possible for an alternative ship design to have a lower procurement cost in part because it incorporates features that give it a higher life-cycle O&S cost. If so, then procuring this ship rather than the currently planned design might not reduce total Navy expenditures over the long run as much as might be expected by looking only at ship procurement costs.

End-Of-Life Disposal Cost. Other things held equal, nuclear-powered ships have higher end-of-life disposal costs than conventionally powered ships because of the need to defuel, cut out, and seal up the reactor compartment and transport it to the permanent Navy reactor-plant storage area at the Hanford nuclear reservation in Washington state. For a nuclear-powered submarine, this work might cost about $30

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[37] For more on learning-curve effects in Navy shipbuilding, see CRS Report 96-785 F, *Navy Major Shipbuilding Programs and Shipbuilders: Issues and Options for Congress*, by Ronald O'Rourke, pp. 59, 95-110. (Out of print; available directly from the author.)

million to $35 million, while for a nuclear-powered carrier, which has a much larger nuclear propulsion plant, it might cost roughly $570 million.[38]

Capability

As mentioned earlier, lower-cost ship designs in most cases will be individually less capable than their higher-cost counterparts. One exception to this might be the reduced-cost Tango Bravo SSN, which might be equal in capability to the Virginia-class design due to its use of the more advanced technologies being pursued under the Navy-DARPA Tango Bravo program.

Aspects of capability that may be considered include ship payload, ship detectability and survivability, ship mobility, and the value of ship numbers in naval operations.

Payload. As the size of a Navy combat ship decreases, its total payload — the weight and volume of the ship's sensors, weapon launchers, weapons, related computers and displays, aircraft, and fuel — tends to decrease. Indeed, due to certain factors relating to ship design, as ship size decreases, payload can often decrease more quickly, making the smaller ship not just less capable than the larger ship, but proportionately less capable. One factor contributing to this effect relates to propulsion: As ship size increases, the amount of horsepower needed to move a ton of the ship's weight through the water at a certain speed tends to decrease. As a result, as ship size increases, the size of the propulsion plant increases less than proportionately, leaving proportionately more room for payload.[39]

Consequently, for example, as the size of an aircraft carrier is reduced, the total weight of the aircraft that can be embarked on the carrier can decline even more quickly. A 40,000-ton LHA(R)-based medium-sized carrier, for example, is about 40% as large as a 100,000 ton carrier, but its potential air wing of about two dozen aircraft might have a total weight equivalent to less than 40% of the 75 aircraft on the 100,000-ton carrier.

Moreover, if a medium-sized carrier's air wing is transferred to a larger carrier, the larger carrier may be able to use that air wing to generate more sorties (i.e.,

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[38] Source: Telephone consultation with the office of the Navy Nuclear Propulsion Program, Apr. 28, 2005. The office stated that the total cost to inactivate, dismantle, and dispose of a retired nuclear-powered submarine is currently about $64 million, and that work related to the reactor compartment accounts for roughly half of this total. The office stated that the currently estimated cost to inactivate the nuclear-powered carrier Enterprise (CVN-65) in 2013 is about $1.1 billion in then-year dollars, which equates to about $830 million in FY2005 dollars, and that work related to the reactor compartment accounts for about $570 million of this $830-million figure.

[39] The Navy's 100,000-ton carriers, for example, are about 11 times as large as the Navy's 9,000-ton DDG-51 class destroyers, and both types of ships have a maximum sustained speed of more than 30 knots. In terms of shaft horsepower, however, the carriers' propulsion plant is less than three times as powerful as the DDG-51-class propulsion plant (about 280,000 shaft horsepower vs. about 100,000 shaft horsepower, respectively).

flights) per day because of its larger flight deck and greater fuel and ordnance capacities. According to one study, for example, a carrier capable of embarking 75 aircraft, can, with a 55-aircraft air wing, generate 40% more strike sorties per day than a medium-sized carrier that is sized for that same 55-aircraft air wing.[40]

Reducing ship size can, in addition to reducing total payload, make it difficult or impossible for a ship to be equipped with certain desired systems. A carrier smaller than a certain size, for example, would not be able to operate CTOL aircraft, while a surface combatant smaller than a certain size could not be equipped with certain large radars, sonars, missile-launching tubes, or guns.

A principal implication of payload decreasing more rapidly than ship size is that the total cost to put a certain collection of combat-related equipment to sea can go up as the size of the ships used to put the equipment to sea goes down. If total fleet payload is held constant, in other words, then reducing *unit* procurement costs by shifting to smaller ships can lead to a fleet design with a higher *total* procurement cost. In addition, if crew size and fuel consumption does not go down proportionately with ship size, then a similar effect could occur with regard to total fleet operation and support (O&S) costs.

The OFT report counters some of these points by arguing that using new technologies would permit the payload fraction of its recommended 1,000- and 100-ton surface combatants to be greater than what would have been possible in the past. Another counter-argument is that improvements in precision-guidance technology for weapons is permitting weapon size to be reduced because a smaller warhead that lands precisely on a target can do the same amount of damage to the target as a larger warhead that lands less precisely. As a result, it could be argued, payload related to weapons and weapon launchers can be reduced without reducing the ship's capability. Any improvements in technology that would permit a reduction in the weight and volume of sensors (e.g., radars or sonars) could lead to a similar argument relating to the sensor portion of a ship's payload.

Detectability and Survivability. Supporters of larger ships could argue that with careful design and construction, a large ship can be made no more susceptible to detection by enemy sensors (e.g., radars, sonars, or infrared sensors) than a much smaller ship. They could also argue that other things held equal, larger ships and ships built to military survivability standards are better able to withstand a hit from a weapon of a given size than a smaller ship or a ship built with an equal-sized commercial-like hull. A larger ship or a ship built to military survivability standards, they could argue, might be able to continue operations to some degree after being hit, or would at least would not be sunk, whereas a smaller ship or a ship built with a commercial-like hull is more likely to be sunk or rendered completely operable.

Supporters of smaller ships or ships built with commercial-like hulls could argue that making larger ships less detectable adds to their cost, and that a fleet composed of a large number of small ships could, by presenting the enemy with a

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[40] David A. Perin, "Are Big Decks Still the Answer?" *U.S. Naval Institute Proceedings*, June 2001, pp. 30-33.

large number of targets, overwhelm the enemy's target-tracking capabilities.[41] They could also argue that even large ships built to military survivability standards can be sunk or put out of operation, and that a fleet consisting of a relatively small number of such ships concentrates too large a fraction of the fleet's total capability and replacement value in each individual platform. They could argue that the most important measure of survivability is not individual-ship survivability but overall fleet survivability, and that a fleet consisting of a larger number of smaller ships can have superior overall fleet survivability. They could also argue that U.S. leaders might be averse to using expensive, highly capable Navy ships in certain high-threat situations because they would not want to risk one or more of them being heavily damaged or sunk, in which case the effective utility of these ships would be reduced.

Mobility.

Nuclear Power. Since nuclear propulsion plants do not require access to the atmosphere to generate power, equipping a submarine with a nuclear propulsion plant produces a fundamental change in ship mobility and consequently in the kinds of operations for which the submarine may be suitable. Some observers, particularly supporters of nuclear-powered submarines, have stated that without nuclear power, ships referred to as submarines are simply submersibles — ships that occasionally and for limited periods of time operate below the surface — and that it is the addition of nuclear power that creates a true submarine — a ship whose primary operating environment is below the surface.

As mentioned earlier, an AIP system such as a fuel-cell or closed-cycle diesel engine extends the stationary or low-speed submerged endurance of a non-nuclear-powered submarine. A conventional diesel-electric submarine has a stationary or low-speed submerged endurance of a few days, while an AIP-equipped submarine may have a stationary or low-speed submerged endurance of up to two or three weeks.

An AIP system does not, however, significantly increase the high-speed submerged endurance of a non-nuclear-powered submarine. A non-nuclear-powered submarine, whether equipped with a conventional diesel-electric propulsion system or an AIP system, has a high-speed submerged endurance of perhaps 1 to 3 hours, a performance limited by the electrical storage capacity of the submarine's batteries, which are exhausted quickly at high speed.

In contrast, a nuclear-powered submarine's submerged endurance, at any speed, tends to be limited by the amount of food that it can carry. In practice, this means that a nuclear-powered submarine can remain submerged for weeks or months at a time, operating at high speeds whenever needed.

As a consequence of their very limited high-speed submerged endurance, non-nuclear-powered submarines, even those equipped with AIP systems, are not well suited for submarine missions that require:

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[41] The OFT report makes the second argument.

- long, completely stealthy transits from home port to the theater of operation,

- submerged periods in the theater of operation lasting more than two or three weeks, or

- submerged periods in the theater of operation lasting more than a few hours or days that involve moving the submarine at something more than low speed.

With regard to the first of the three points above, the OFT report proposes transporting the AIP submarines into the overseas theater of operations aboard a transport ship.[42] In doing so, the OFT report accepts that the presence of a certain number of U.S. AIP submarines in the theater of operations will become known to others. A potential force-multiplying attribute of having an SSN in a carrier strike group, in contrast, is that the SSN can be detached from the strike group, and redirected to a different theater to perform some other mission, without alerting others to this fact. Opposing forces in the strike group's theater of operations could not be sure that the SSN was not in their own area, and could therefore continue to devote resources to detecting and countering it. This would permit the SSN to achieve military effects in two theaters of operation at the same time — the strike group's theater of operations, and the other theater to which it is sent.

With regard to the second and third points above, the effectiveness of an AIP submarine would depend on what kinds of operations the submarine might need to perform on a day-to-day basis or in conflict situations while operating as part of a forward-deployed carrier strike group.

For aircraft carriers, the effects of adding nuclear power are less dramatic than they are for submarines, but still significant. Nuclear-powered carriers can make high-speed transits over long distances to respond to urgent crises without need for stopping or slowing down to refuel along the way. They do not need to be refueled upon arriving at the area of operations, permitting them to commence combat operations immediately upon arrival. And since they do not need large fuel tanks to store fossil fuel for their own propulsion plant, they can devote more of their internal volume to the storage of aircraft fuel and ammunition, which permits them to sustain combat operations for longer periods of time before they need to be resupplied.

Maximum Speed. Proponents of higher-speed ships like the LCS, the 13,500-ton carrier recommended in the OFT report, or the 1,000- or 100-ton surface combatants recommended in the OFT report, argue that the higher maximum speeds of these ships increases their capability by enabling them to shift locations more rapidly and making them more difficult for the enemy to track and target. Skeptics could argue that the advantages of ship speeds much higher than about 30 knots are unproven or overrated.

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[42] The strategy of transporting the AIP submarines to the theater using transport ships is not mentioned in the report but was explained at a Feb. 18, 2005 meeting between CRS and analysts who contributed to the OFT report.

Ship Numbers In Naval Operations. Advocates of a fleet with a larger number of ships, which is something that might be facilitated by shifting to lower-cost ship designs, argue that a ship cannot be in two places at the same time, and consequently that a fleet with a larger number of ships would be better able to maintain a day-to-day presence in multiple locations around the world or be better able to respond to simultaneous crises or conflicts in multiple locations. A fleet consisting of a larger number of less-capable ships, they could argue, might offer more flexibility for responding to situations with an appropriate amount of naval capability, as opposed to being forced to deploy a naval force with more capability than needed at a high daily O&S cost.[43] Advocates of a fleet with a larger number of ships could also argue that under the theory of network-centric warfare, the capability of the force grows as a function of the number of nodes (e.g., ships, aircraft, unmanned vehicles, and distributed sensors) that make up the network, and that increasing the number of ship nodes will consequently increase the total capability of the force.[44] Advocates who make this last argument in some cases might argue that in light of networking and other advanced technologies, U.S. military forces in general should shift to less concentrated and more highly distributed force designs.

Defenders of a fleet consisting of a smaller number of more-expensive ships could argue that being able to deploy ships to a greater number of locations around the world might be of limited value if those ships are less-capable designs that are not capable of performing required missions. They could also argue that the Navy has taken steps in recent years to increase the fraction of the fleet that is deployed, or ready to be deployed, at any given time, mitigating the effects of having a relatively limited total number of ships in the fleet.[45] They could argue that current ship designs already provide adequate flexibility for creating naval formations with appropriate amounts of capability for responding to various situations. They could also argue that when numbers of aircraft, unmanned vehicles, and distributed sensors are taken into account, a fleet consisting of a smaller number of more-expensive ships would still have an adequate number of nodes for engaging in network-centric warfare.

Technical Risk

Of the lower-cost options outlined earlier, those that might pose some technical risk for the Navy include the AIP-equipped non-nuclear-powered submarine (because a non-nuclear-powered submarine has not been designed and built for the U.S. Navy

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[43] The OFT report makes this point from a budgetary perspective as well, arguing that a fleet consisting of lower-cost ships can be adjusted in size more smoothly to adapt to changes in available funding levels.

[44] For more on network-centric warfare, see CRS Report RL32411, *Network Centric Warfare: Background and Oversight Issues for Congress,* by Clay Wilson and CRS Report RL20557, *Navy Network-Centric Warfare Concept: Key Programs and Issues for Congress*, by Ronald O'Rourke.

[45] For additional discussion of this point, see CRS Report RS21338, *Navy Ship Deployments: New Approaches — Background and Issues for Congress*, by Ronald O'Rourke.

since the 1950s), the Tango Bravo nuclear-powered submarine (because of the need to mature the Tango Bravo technologies), the 13,500-ton high-speed carrier (because of its fairly large SES/catamaran hull design), and perhaps the 1,000- and 100-ton surface combatants (because of the new technologies that are intended to increase their payload fractions).

Homeporting Arrangements

Smaller ships might offer a wider range of homeporting possibilities because some ports might not have large enough berthing spaces or deep enough waters to accommodate ships of more than a certain size.

Homeporting a nuclear-powered carrier or submarine can be a more complex undertaking than homeporting a conventionally powered ship due to requirements that are unique to nuclear-powered ships, such as having access in the home port to a nuclear-certified maintenance shop. In addition, gaining permission to forward-homeport a Navy ship in a foreign country can be politically more difficult if the ship in question is nuclear-powered and there are substantial anti-nuclear sentiments in the intended host country.[46]

Impact On Shipbuilding Industrial Base

Lower-cost ship designs could affect the shipbuilding industrial base by changing the total volume of Navy shipbuilding work or the distribution of that work among various shipyards.

Total Volume Of Work. The total volume of Navy shipbuilding work is to a large degree a function of the total amount of funding available for Navy ship procurement. Consequently, the effect that shifting to lower-cost designs might have on the total volume of shipbuilding work would depend to a large degree on whether the shift somehow affects the total amount of funding available for Navy ship procurement. At least three scenarios are possible:

- One possibility is that shifting to lower-cost designs does not substantially affect the total amount of funding available for Navy ship procurement, in which case the total volume of Navy shipbuilding work might not change substantially.

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[46] The Navy may face this second issue at some point with regard to the continuation of its carrier homeporting arrangement with Japan. A Navy carrier has been homeported in Japan since the early 1970s, and the three carriers that have been homeported there over the years have all been conventionally powered. Of the Navy's 12 carriers, only two — the Kitty Hawk (CV-63) and the John F. Kennedy (CV-67) — are conventionally powered, and these two ships are among the oldest carriers in the fleet. The Kitty Hawk is scheduled for retirement in 2008, and the Navy has proposed retiring the Kennedy in FY2006. For further discussion, see CRS Report RL32731, *Navy Aircraft Carriers: Proposed Retirement of USS John F. Kennedy — Issues and Options for Congress,* by Ronald O'Rourke.

- A second possibility is that the shift to lower-cost designs is used to reduce the total cost of building the same total number of ships as previously planned, in which case the total volume of Navy shipbuilding work would be reduced.

- A third possibility is that the shift to lower-cost designs makes Navy ships appear more cost-effective compared to competing Navy or DOD programs, in which case the total amount of funding available for Navy ship procurement might be increased, enabling an increase in the total volume of Navy shipbuilding work.

Distribution Of Work Among Shipyards. The lower-cost ship designs in this report could affect the distribution of shipbuilding work among various shipyards in one or more of the following ways:

- **Attack submarines.** A Tango Bravo nuclear-powered submarine would be designed and built by one or both of the country's two current nuclear-submarine construction shipyards — General Dynamics' Electric Boat (GD/EB) of Groton, CT, and Quonset Point, RI, and Northrop Grumman Newport News (NGNN) of Newport News, VA. If both GD/EB and NGNN are involved in the program, the division of work between the two yards could be different than the current, roughly even, division of work the two yards have for building Virginia-class submarines. An AIP-equipped non-nuclear powered submarine could be designed and built by GD/EB or NGNN, or by a non-nuclear shipyard, such as the Ingalls shipyard at Pascagoula, MS, that forms part of Northrop Grumman Ship Systems (NGSS). Ingalls has been associated with past proposals for building non-nuclear-powered submarines for export to foreign countries.

- **Aircraft carriers.** NGNN is the only U.S. yard that can build large nuclear-powered carriers (and the only yard that could readily build large conventionally powered carriers). A medium-sized, conventionally powered carrier based on the LHA(R) design could be built by NGNN or by another yard, such as Ingalls, the builder of previous ships similar to the LHA(R). A medium-sized, conventionally powered carrier based on a merchant-like hull could be built by NGNN, Ingalls, or other shipyards, particularly those with experience building merchant-like hulls, such as the Avondale shipyard near New Orleans that also forms part of NGSS or General Dynamics' National Steel and Shipbuilding Company (GD/NASSCO) of San Diego, CA. A small, high-speed carrier using an SES/catamaran hull design might be built at a number of yards, particularly any that might have experience building SES/catamaran hulls.

- **Larger surface combatants.** DD(X) destroyers are to be built at NGSS (particularly Ingalls) and General Dynamics' Bath Iron Works (GD/BIW) of Bath, ME. A 9,000-ton SC(X), a 6,000-ton FFG(X), or a low-cost gunfire support ship would likely be built at one or both of the same yards, but could also be built at other yards, such as Avondale or NGNN. If built at both NGSS and GD/BIW, the division of work between the two yards might not be the same as would occur under the DD(X) program.

- **Smaller surface combatants.** One version of the LCS is to be built at Marinette Marine of Marinette, WI, and Bollinger Shipyards of Louisiana and Texas. The other version is to be built at the Austal USA shipyard at Mobile, AL. A 1000- or 100-ton surface combatant could be built at either of these yards or at other yards, particularly yards that focus on building smaller ships