Congressional Budget Office

Testimony

An Analysis of the Navy's Fiscal Year 2016 Shipbuilding Plan

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Committee on Armed Services
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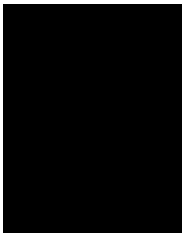
Notes

Unless otherwise indicated, all dollar amounts reflect budget authority in 2015 dollars, and all years are federal fiscal years, which run from October 1 to September 30 and are designated by the calendar year in which they end.



Chairman Forbes, Ranking Member Courtney, and Members of the Subcommittee, thank you for the opportunity to testify on the Navy's 2016 shipbuilding plan and the 2014 update to the service's 2012 force structure assessment. My submitted statement today reprises the Congressional Budget Office's report entitled *An Analysis of the Navy's Fiscal Year 2016 Shipbuilding Plan,* which was released on October 29, 2015. That report was required under the 2012 National Defense Authorization Act.

The Navy is required by law to submit a report to the Congress each year that projects the service's inventory goals, procurement plans, and cost estimates for its shipbuilding program over the coming 30 years. Since 2006, CBO has been performing an independent analysis of the Navy's latest shipbuilding plan. The CBO report on which I am testifying today analyzes the implications of the Navy's 2016 plan for its ability to meet inventory goals through 2045. The report also provides independent estimates of the cost of the Navy's shipbuilding program and compares those cost estimates with the funding levels that the Navy has received historically.

According to its most recent 30-year plan, the Navy envisions buying a total of 264 ships over 30 years at an average annual cost of $16.5 billion for new construction and $18.3 billion for total shipbuilding (including new-ship construction, refueling of nuclear-powered aircraft carriers, and other costs related to shipbuilding). By comparison, CBO's estimates of the costs of the Navy's plan are about $2 billion higher—an average of $18.4 billion per year for new construction or $20.2 billion per year for total shipbuilding. Those amounts are significantly greater than the amounts the Navy has received for shipbuilding annually over the past 30 years.

Contents

An Analysis of the Navy's Fiscal Year 2016 Shipbuilding Plan

Summary

The Department of Defense (DoD) submitted to the Congress the Navy's 2016 shipbuilding plan for fiscal years 2016 to 2045 in April 2015.[1] The total annual cost of carrying out the 2016 plan—an average of about $20 billion in 2015 dollars per year over the next 30 years, the Congressional Budget Office estimates—would be one-third more than the amount the Navy has received in Congressional appropriations for shipbuilding in recent decades. The Navy's 2016 shipbuilding plan is similar to its 2015 plan with respect to the goal for the total number of battle force ships, the number and types of ships the Navy would purchase, and the funding proposed to implement its plans.

The Navy Plans to Expand the Fleet to 308 Battle Force Ships

The Navy's 2016 shipbuilding plan states that the service's goal (in military parlance, its requirement) is to have 308 battle force ships, consisting of aircraft carriers, submarines, surface combatants, amphibious ships, combat logistics ships, and some support ships. The 2016 shipbuilding plan falls short of the goals for some types of ships in some years, although generally the shortfalls are smaller than they have been in previous years' plans. The fleet today numbers 273 ships.

Under the 2016 plan, the Navy would buy a total of 264 ships over the 2016–2045 period: 218 combat ships and 46 combat logistics and support ships (see Table 1). Given the rate at which the Navy plans to retire ships from the fleet, the 2016 plan would not meet the inventory goal of 308 ships until 2022, but it would allow the Navy to maintain its inventory at least at that level through 2031. After that, in most years through 2045, the fleet would fall below 308 ships.[2]

The size of the Navy does not depend on ship construction alone; the length of time that particular ships remain in the fleet affects the force structure as well. The Navy often shows flexibility in its approach to retiring ships: A ship may be retired before the end of its service life to save money or may be kept beyond that span to maintain a desired force level.[3] Generally, the Navy's estimates of expected service life align with historical experience. However, the Navy currently assumes a 35- or 40-year service life for its large surface combatants; in the past, few of those ships were in the fleet for longer than 30 years. (See Table 2 for the composition and the planned service life of major ship types in the fleet.)

CBO Estimates That Spending for New Ships in the Navy's Plan Would Average $18.4 Billion per Year

The Navy estimates that buying the new ships specified in the 2016 plan would cost $494 billion (in 2015 dollars) over 30 years—or an average of $16.5 billion per year—slightly less than the costs of the 2015 plan. Using its own models and assumptions, CBO estimates that the cost of new-ship construction in the Navy's 2016 plan would total $552 billion over 30 years, or an average of $18.4 billion per year.

1. Department of the Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2016* (March 2015), http://tinyurl.com/ocrqtfc.

2. Most new-ship construction occurs to replace older ships as they retire, although the Navy sometimes builds ships to fulfill a new mission or to satisfy a specific need. For example, the Navy proposes buying new ballistic missile submarines in the 2020s and 2030s to replace existing submarines that provide strategic deterrence, whereas several years ago, it canceled the DDG-1000 destroyer program and restarted its DDG-51 destroyer line because it had reassessed the need for one kind of ship over the other.

3. The Navy's budget request often reflects trade-offs between buying new ships and modernizing existing ships to serve longer in the fleet. Over the past several years, the Navy has proposed retiring rather than modernizing seven Ticonderoga class cruisers and spending that money on new ships or to meet other objectives. Instead, lawmakers directed the Navy to modernize the cruisers to keep them in the fleet. The Congress appropriated funds greater than the amounts requested in the President's recent budget proposals to pay for that modernization as well as for new ships.

Table 1.

The Navy's 2015 and 2016 Shipbuilding Plans

	2015 Plan (2015–2044)	2016 Plan (2016–2045)	Change From 2015 to 2016
	Number of Ships Purchased Over 30 Years		
Combat Ships			
Aircraft carriers	6	6	0
Ballistic missile submarines	12	12	0
Attack submarines	48	45	-3
Large surface combatants	65	65	0
Littoral combat ships and fast frigates	66	67 [a]	1
Amphibious warfare ships	21	23	2
Subtotal	218	218	0
Combat Logistics and Support Ships	46	46	0
Total	264	264	0
	Costs of New-Ship Construction[b] (Billions of 2015 dollars)		
Total Cost Over 30 Years			
Navy's estimate	515	494	-21
CBO's estimate	583	552	-31
Average Annual Cost			
Navy's estimate	17.2	16.5	-0.7
CBO's estimate	19.4	18.4	-1.0
Average Cost per Ship			
Navy's estimate	2.0	1.9	-0.1
CBO's estimate	2.2	2.1	-0.1
Memorandum:			
Average Annual Costs of All Activities Typically Funded From Budget Accounts for Ship Construction			
Navy's estimate	19.2	18.3	-0.9
CBO's estimate	21.3	20.2	-1.1

Source: Congressional Budget Office based on data from the Department of the Navy.

a. Under the 2016 plan, the Navy will have 32 littoral combat ships in service after 2029. However, because each of those ships is expected to be in service for 25 years, the Navy will begin buying replacements in 2030.

b. Costs exclude funds for refueling nuclear-powered aircraft carriers and for ship conversions, construction of ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items. Costs for the mission packages for littoral combat ships, which are not funded in the Navy's shipbuilding accounts, also are excluded.

CBO's estimates are higher because the Navy and CBO use different estimating methods and assumptions regarding future ships' design and capabilities and treat growth in the costs of labor and materials for building ships differently. CBO's constant-dollar estimate is 8 percent higher than the Navy's for the first 10 years of the plan, 12 percent higher for the following decade, and 17 percent higher for the final 10 years (see Figure 1). The difference widens over time in part because the Navy's method of developing constant-dollar estimates (which differs from CBO's method) does not account for the faster growth in the costs of labor and materials in the shipbuilding industry than in the economy as a

Table 2.

Navy Ship Inventory and Expected Service Life by Ship Type, as of August 2015

	Inventory	Service Life (Years)
Aircraft Carriers	10	50
Ballistic Missile Submarines	14	42
Guided Missile Submarines	4	42
Attack Submarines	54	33
Large Surface Combatants	84	35–40
Small Surface Combatants and Mine Countermeasures Ships	18	25–30
Amphibious Ships	30	40
Combat Logistics and Support Ships	59	30–45
Total	273	

Source: Congressional Budget Office based on data from the Department of the Navy.

whole and thus does not reflect the anticipated increase in inflation-adjusted costs of future purchases of ships with today's capabilities.

The Navy's shipbuilding plan reports only the costs of new-ship construction. Other activities typically funded from the Navy's budget accounts for ship construction—such as refueling nuclear-powered aircraft carriers or outfitting new ships with various small pieces of equipment after the ships are built and delivered—would add $1.7 billion to the Navy's average annual shipbuilding costs under the 2016 plan, by CBO's estimate. (Between 2010 and 2015, the cost of those other activities averaged $2.1 billion per year.) Including those extra costs would increase the average annual cost of the Navy's 2016 plan to $20.2 billion per year, CBO estimates. CBO's estimate of the total cost of the Navy's plan is 10 percent above the Navy's estimate.

The Navy's Shipbuilding Plan for the Next 30 Years Would Cost Almost One-Third More Than It Has Spent Over the Past 30 Years

If the Navy received the same amount of funding (in constant dollars) for new-ship construction in each of the next 30 years that it has received, on average, over the past three decades, the service would not be able to afford its 2016 plan. CBO's estimate of $18.4 billion per year for new-ship construction in the Navy's 2016 shipbuilding plan is 32 percent above the historical average annual funding of $13.9 billion (in 2015 dollars). And CBO's estimate of $20.2 billion per year for the full cost of the plan is 28 percent higher than the $15.8 billion the Navy has spent, on average, annually over the past 30 years for all items in its shipbuilding accounts. If funding were to continue at the average for the past 30 years, under one possible approach to ship construction, the Navy would be able to build about 70 fewer battle force ships than it currently plans, CBO estimates.

Implementing the Navy's Shipbuilding Plan Might Be Difficult Under Current Law

At least for 2016 through 2020, the Navy's shipbuilding plan incorporates the assumption that total discretionary funding for DoD will comport with the President's 2016 budget submission and the associated 2016 Future Years Defense Program (FYDP; a five-year funding plan that DoD updates annually). However, the funding proposed in the 2016 FYDP exceeds the amounts available to DoD under the Budget Control Act of 2011 (BCA), which placed caps on discretionary spending through 2021. (The BCA does not address specific budgetary accounts such as the one for shipbuilding.)

Under the BCA, if the Navy receives the same percentage of DoD's budget during the coming decade and devotes the same percentage of its budget to ship construction that it has historically, the annual shipbuilding budget would be 30 percent below CBO's estimate of the amount required to execute the Navy's 2016 plan over the 2016–2021 period. If all shipbuilding programs were cut proportionately, a reduction of that magnitude would require the Navy to purchase 16 fewer ships than the 57 it plans to purchase over that period. Consequently, under current law, policymakers face a choice between implementing the Navy's 2016 shipbuilding plan and cutting costs elsewhere in the Navy's budget (or in DoD's budget more broadly), scaling back the 2016 plan, or taking some combination of those actions.

As of this writing, the Congress was considering H.R. 1314, the Bipartisan Budget Act of 2015.* That bill, if enacted, would raise the budget caps for national defense for fiscal years 2016 and 2017. That change would allow the Navy to cut 15 ships rather than 16 ships from its 2016 plan, if all shipbuilding programs were cut proportionately.

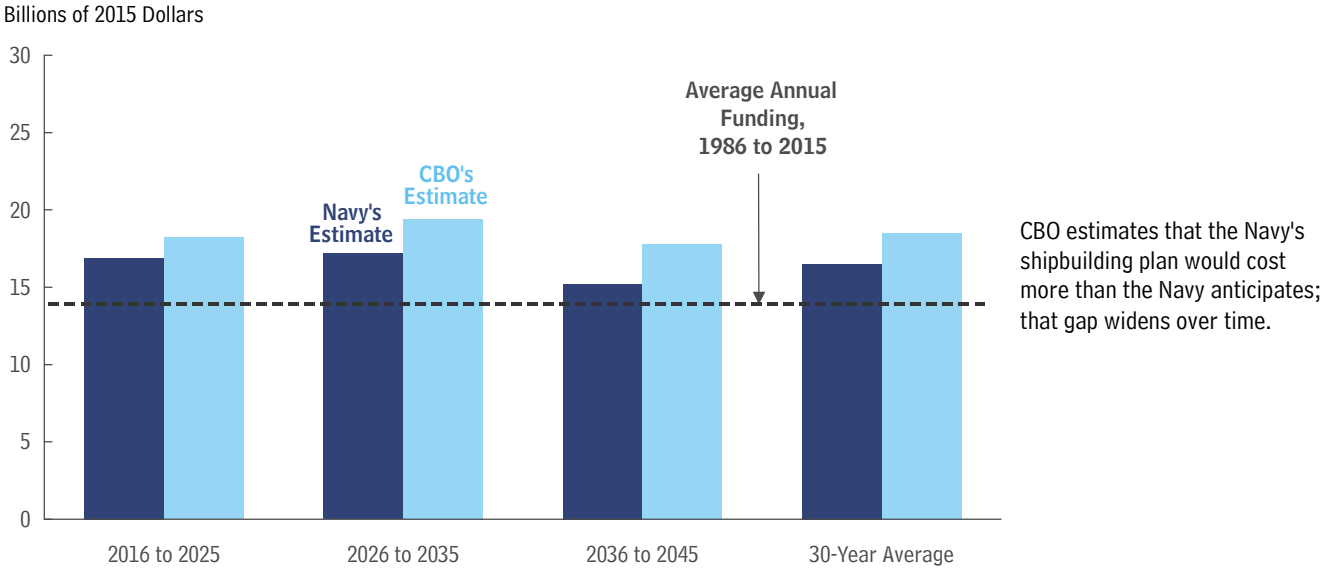
Ship Purchases and Inventories Under the 2016 Plan

The Navy's 2016 shipbuilding plan, submitted to the Congress by the Deputy Secretary of Defense on April 3, 2015, reflects the service's inventory goal of 308 battle

*The Bipartisan Budget Act of 2015 (Public Law 114-74) was enacted on November 2, 2015.

Figure 1.

Average Annual Costs of New-Ship Construction Under the Navy's 2016 Plan



Source: Congressional Budget Office based on data from the Department of the Navy.

Note: Costs exclude funds for refueling nuclear-powered aircraft carriers and for ship conversions, construction of ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items. Costs for the mission packages for littoral combat ships, which are not funded in the Navy's shipbuilding accounts, also are excluded.

force ships, an increase from the 306-ship goal established in the force structure assessment the Navy performed in 2012 (see Table 3).[4] For this report, CBO did not evaluate the validity of the Navy's goals or the fleet's ability to fulfill its missions in the national military strategy. Rather, this report presents CBO's assessment of the plan's costs, its effects on the force structure, and the extent to which it would satisfy the Navy's goals for major components of the U.S. fleet. (The major types of ships in the fleet and their basic missions are described in Box 1.)

Total Ship Purchases and Inventories

The Navy intends to buy 9 ships in 2016 and a total of 48 between 2016 and 2020—the period covered by DoD's 2016 FYDP (see Figure 2 on page 8 and Figure 3 on page 9). Thereafter through 2045, the Navy would buy an additional 216 ships, for a total of 264 ships over 30 years, or an average of about 9 per year. The pace of shipbuilding would be slightly faster, on average, in the near term than later on. The Navy plans to purchase an average of about 10 ships annually between 2016 and 2025, slightly fewer than 8 ships per year between 2026 and 2035, and 9 ships per year between 2036 and 2045.

With those purchases, the Navy projects that it will have 282 ships in the fleet at the end of 2016. Under the Navy's current ship-counting rules, the 2016 plan would not achieve the intended force of 308 ships until 2022. The service would meet its overall goal for 12 of the 30 years in the plan—and except in the 2016–2019 period—the shortfall would never be more than 6 ships (see the bottom panel of Figure 2). The Navy would achieve its force structure goal at about the same time under the 2016 plan that it would have under the 2015 plan, although under this year's plan, the Navy would meet its force goal for fewer years than it would have

4. Department of the Navy, *Report to Congress: Force Structure Assessment* (February 2015). A more extensive discussion of the history of the Navy's force structure goals is presented in Ronald O'Rourke, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress,* Report for Congress RL32665 (Congressional Research Service, September 21, 2015).

Table 3.

The Navy's Goals for Its Force Structure

	Goals for a 313-Ship Fleet in the Navy's 2005 Force Structure Assessment	Goals for a 313-Ship Fleet in the Navy's 2010 Force Structure Assessment	Goals for a 306-Ship Fleet in the Navy's 2012 Force Structure Assessment	Goals for a 308-Ship Fleet in the Navy's 2014 Update of the 2012 Force Structure Assessment[a]
Aircraft Carriers	11	11	11	11
Submarines				
Ballistic missile	14	12	12	12
Attack	48	48	48	48
Guided missile	4	4	0	0
Large Surface Combatants	88	94	88	88
Small Surface Combatants and Mine Countermeasures Ships[b]	55	55	52	52
Amphibious Warfare Ships	31	33	33	34
Maritime Prepositioning Force (Future) Ships	12	0	0	0
Combat Logistics Ships	30	30	29	29
Support Ships				
Joint high-speed vessels	3	10	10	10
Other[c]	17	16	23	24
Total	**313**	**313**	**306**	**308**

Source: Congressional Budget Office based on data from the Department of the Navy.

a. The Navy's 2016 shipbuilding plan is based in part on achieving the goal for a 308-ship fleet.

b. Includes littoral combat ships, Oliver Hazard Perry FFG-7 frigates, fast frigates, and Avenger class mine countermeasures ships.

c. Includes command ships, salvage ships, ocean tugs, ocean surveillance ships, and tenders.

under the 2015 plan.[5] All together, the 2016 plan calls for the Navy to buy the same number of ships over 30 years that it would have under the 2015 plan. The number of purchases of combat ships and logistics and support vessels is the same under the 2015 and 2016 plans, although the composition of major ship types is slightly different in the 2016 plan.

Combat Ships

Under the 2016 plan, the Navy envisions buying 218 combat ships—aircraft carriers, submarines, large and small surface combatants, and amphibious warfare ships—over the 30 years, matching the total in its 2015 plan. Those purchases would leave the Navy short of its inventory objectives for ballistic missile submarines, attack submarines, and large surface combatants—but not for amphibious warfare ships—for significant segments of the 2016–2045 period (see Figure 4 on page 10).

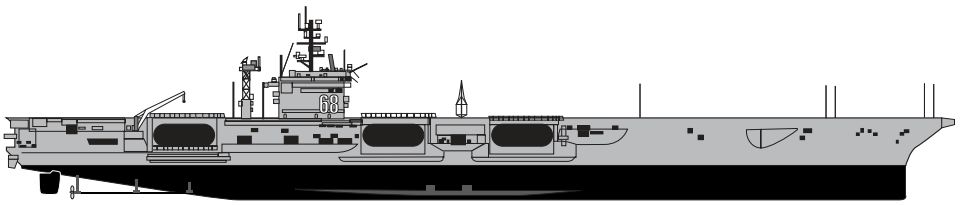
Aircraft Carriers. Under its 2016 shipbuilding plan, the Navy would purchase 6 aircraft carriers between 2016

5. Those numbers reflect the ship-counting rules specified in the Carl Levin and Howard P. "Buck" McKeon National Defense Authorization Act for Fiscal Year 2015, which required the Navy to revert in 2016 to the rules it had used for the 2014 plan but permitted the Navy to add one high-speed transport vessel to the battle force. For the 2015 shipbuilding plan, the Navy had adopted new counting rules involving a small number of ship classes designated as (very) small combatants or logistics and support ships; the Congress rejected the new rules. For a discussion of the Navy's ship-counting rules in 2015, see Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2015 Shipbuilding Plan* (December 2014), p. 8, www.cbo.gov/publication/49818.

Box 1.

Major Ship Types in the Navy's Fleet

Nimitz Class Aircraft Carrier



The Navy's 10 **aircraft carriers** are the heart of the battle force. Each carries an air wing of about 60 aircraft, which can attack hundreds of targets per day for up to a month before needing to rest. Carriers are the largest ships in the fleet, with a displacement of about 100,000 tons. All 10 current carriers belong to the Nimitz class.

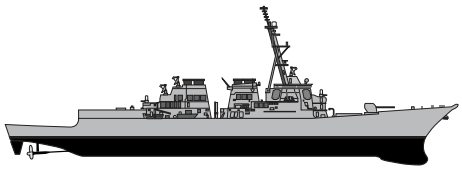
Ohio Class Ballistic Missile Submarine

Strategic ballistic missile submarines carry one of the major parts of the U.S. nuclear deterrent, up to 24 Trident missiles with one to eight nuclear warheads apiece. The Navy has 14 Ohio class ballistic missile submarines, each of which displaces about 19,000 tons when submerged. In addition, the Navy has converted 4 submarines of that class to a conventional guided missile (SSGN) configuration. Those SSGNs carry up to 154 Tomahawk missiles as well as special-operations forces.

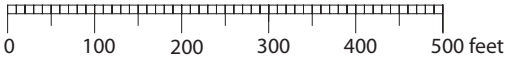
Los Angeles Class Attack Submarine

Attack submarines are the Navy's premier undersea warfare and antisubmarine weapons. Since the end of the Cold War, however, they have mainly been used for covert intelligence gathering. They also can launch Tomahawk missiles at inland targets in the early stages of a conflict. Forty-one of the Navy's 54 attack submarines belong to the Los Angeles class. At 7,000 tons, they are less than half the size of ballistic missile submarines.

Arleigh Burke Class Destroyer



Large surface combatants, which include cruisers and destroyers, are the workhorses of the fleet. They provide ballistic missile defense for the fleet and for regional areas overseas. They defend aircraft carriers and amphibious warfare ships against other surface ships, aircraft, and submarines, and they perform such day-to-day missions as patrolling sea lanes, providing an overseas presence, and conducting exercises with allies. They also can launch Tomahawk missiles to strike land targets. Most of the Navy's surface combatants displace about 9,000 to 10,000 tons.



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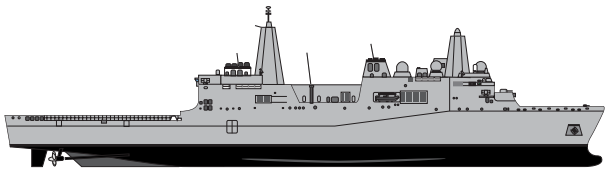
Box 1. **Continued**

Major Ship Types in the Navy's Fleet

Freedom Class Littoral Combat Ship*

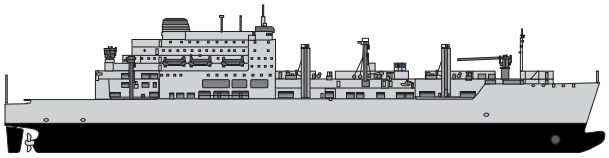
Small surface combatants include frigates and littoral combat ships. Frigates are used to perform many of the same day-to-day missions as large surface combatants. Littoral combat ships are intended to counter mines, small boats, and diesel electric submarines in the world's coastal regions. More routinely, they also patrol sea lanes, provide an overseas presence, and conduct exercises with allies. They range in size from 3,000 to 4,000 tons. The Navy retired all of its Oliver Hazard Perry frigates in 2015. [*Image corrected on October 30, 2015]

San Antonio Class Amphibious Transport Dock

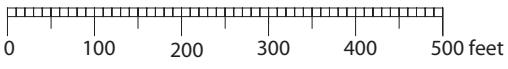


The Navy has five classes of **amphibious warfare ships**. Two classes, referred to as **amphibious assault ships** (also known as large-deck amphibious ships or helicopter carriers), are the second-largest types of ships in the fleet at 40,000 to 45,000 tons. They form the centerpiece of amphibious ready groups, and each can carry about half the troops and equipment of a Marine expeditionary unit. In addition, they can carry as many as 30 helicopters and 6 fixed-wing Harrier jump jets; alternatively, they can carry up to 20 Harriers or short takeoff and landing versions of the Joint Strike Fighter. The other three classes are divided into two types: **amphibious transport docks** and **dock landing ships.** Two of those ships together provide the remaining transport capacity for a Marine expeditionary unit in an amphibious ready group. They range in size from 16,000 to 25,000 tons.

Lewis and Clark Class Dry Cargo/Ammunition Ship*



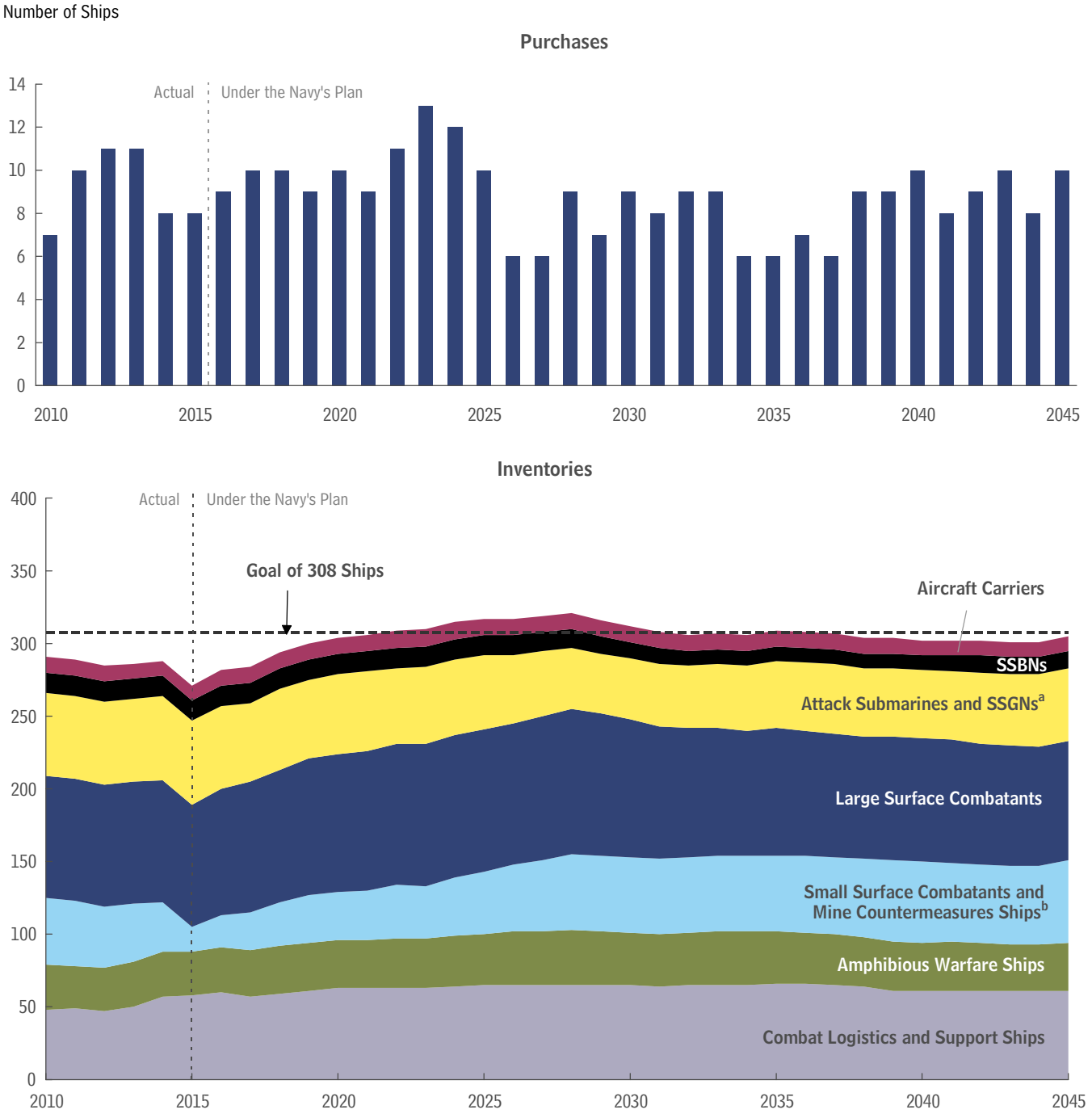
The many **combat logistics and support ships** in the Navy's fleet provide the means to resupply, repair, salvage, or tow combat ships. The most prominent of those vessels are fast combat support ships, which operate with carrier strike groups to resupply them with fuel, dry cargo (such as food), and ammunition. Logistics and support ships can be as small as 2,000 tons for an oceangoing tug or as large as 50,000 tons for a fully loaded fast combat support ship. [*Label corrected on October 30, 2015]



Source: Congressional Budget Office.

Figure 2.

Annual Ship Purchases and Inventories Under the Navy's 2016 Plan



Source: Congressional Budget Office based on data from the Department of the Navy.

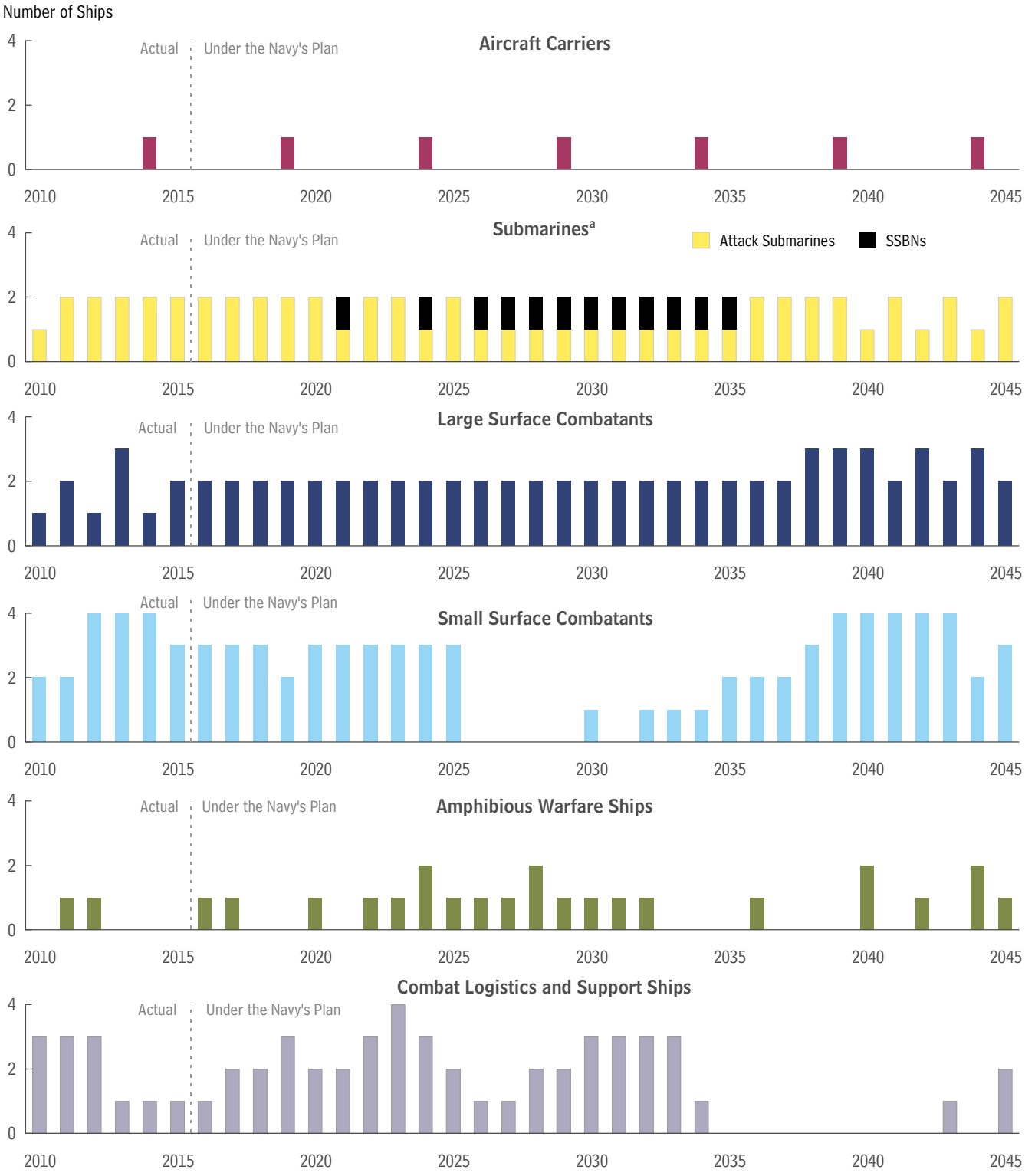
Note: SSBNs = ballistic missile submarines; SSGNs = guided missile submarines.

a. Although the Navy does not plan to build more SSGNs, 4 will be in service through the mid-2020s.

b. Includes littoral combat ships, Oliver Hazard Perry FFG-7 frigates, fast frigates, and Avenger class mine countermeasures ships.

Figure 3.

Annual Ship Purchases, by Category, Under the Navy's 2016 Plan



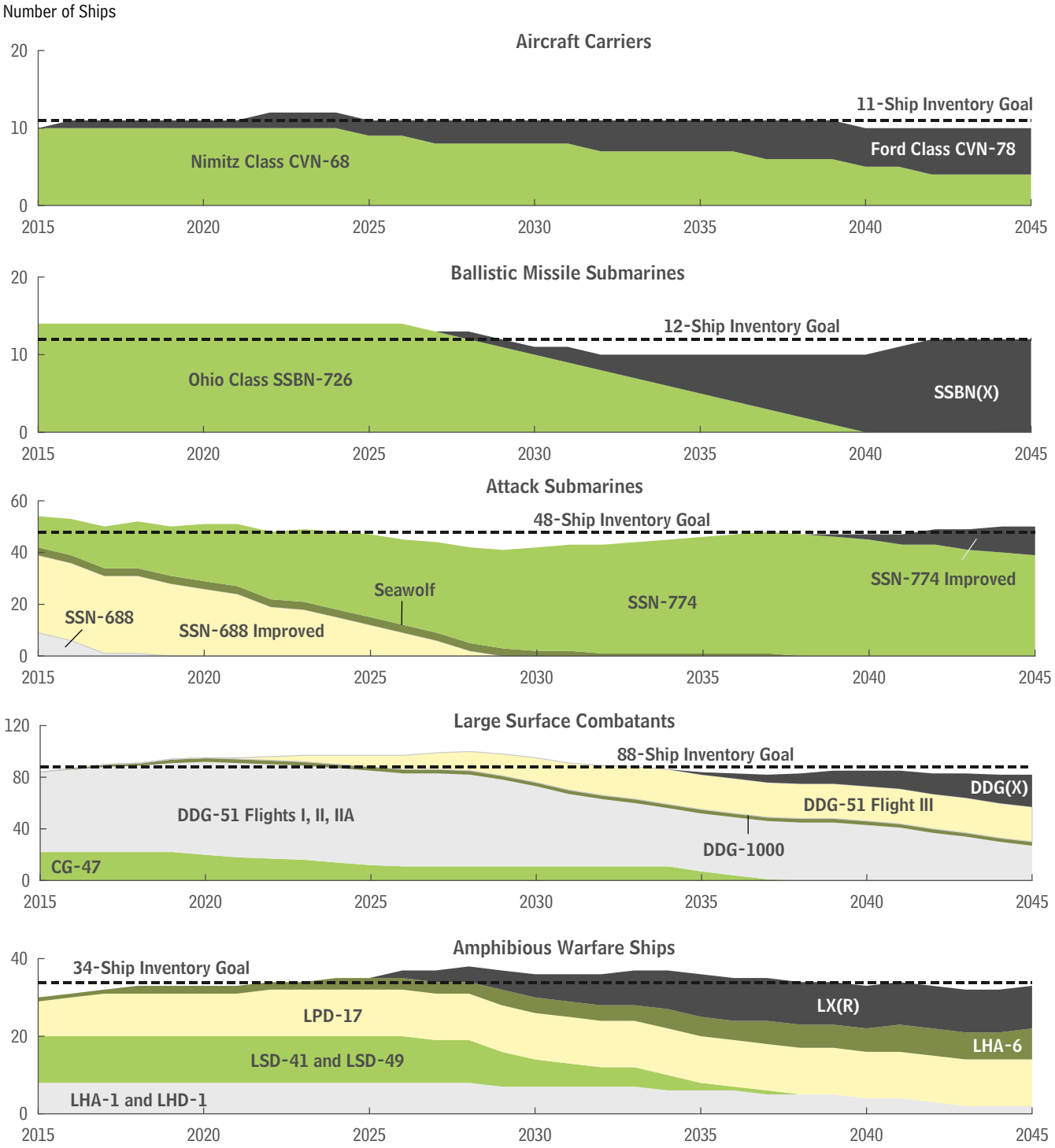
Source: Congressional Budget Office based on data from the Department of the Navy.

Note: SSBNs = ballistic missile submarines.

a. Although guided missile submarines are included in the Navy's inventory, the service does not plan to build more of them.

Figure 4.

Annual Inventories Versus Goals for Selected Categories of Ships Under the Navy's 2016 Plan



Source: Congressional Budget Office.

Note: CG = guided missile cruiser; CVN = nuclear-powered aircraft carrier; DDG and DDG(X) = guided missile destroyer; LHA and LHD = amphibious assault ship; LPD = amphibious transport dock; LSD = dock landing ship; LX(R) = dock landing ship replacement; SSBN and SSBN(X) = ballistic missile submarine; SSN = attack submarine.

and 2045, at a rate of one every five years. That plan would be sufficient to maintain a force of 11 aircraft carriers through 2039. However, with a 50-year expected service life, the force would fall to 10 carriers in 2040 and beyond.

Ballistic Missile Submarines. The 2016 shipbuilding plan calls for buying the first replacement for the Ohio class ballistic missile submarine in 2021 and for purchasing 12 such submarines, also known as SSBN(X)s, that would begin to enter the fleet in 2028. (The Navy estimates that the lead submarine will take about seven years to build and that two to three years after that will be needed for testing before it is placed into regular operation.) However, because the Ohio class submarines are retired at the end of their 42-year service life, the Navy's inventory of SSBNs would fall below the goal of 12 by 1 or 2 ships between 2030 and 2041. In particular, between 2032 and 2040, the Navy would have 10 SSBNs.

Attack Submarines. Under the 2016 plan, the Navy would purchase 45 attack submarines (SSNs) through 2045. That number is 3 fewer than under the 2015 plan, and it would not be enough to keep the force at the goal of 48 for all of the next 30 years. The number of attack submarines would decline from 48 in 2024 to a low of 41 in 2029 and then increase to 48 or more after 2042. The decline is the result of the retirement, beginning in 2014, of Los Angeles class attack submarines (SSN-688s). Those ships are reaching the end of their 33-year service life, having generally been built at a rate of 3 or 4 per year during the 1970s and 1980s. The Navy would replace those submarines with Virginia class attack submarines (SSN-774s) and their successors, at a rate of 1 or 2 per year.

Large Surface Combatants. The 2016 shipbuilding plan calls for buying 65 destroyers—the same number as in the 2015 plan—based on the existing Arleigh Burke class destroyer (DDG-51) design. Those purchases and the Navy's plan to modernize its cruiser force would allow the Navy to meet or exceed the goal of 88 large surface combatants through 2034 (with the exception of 2016) and then decline by 6 destroyers, to 82 ships, by 2044.

The Navy's assumptions about the service life of large surface combatants have not changed for several years: All 34 Arleigh Burke class destroyers commissioned after 2000 are assumed to have a service life of 40 years and the 28 destroyers commissioned earlier would remain in the fleet for 35 years. Historically, very few cruisers or destroyers have served longer than 30 years.[6] If the Navy's large surface combatants serve for 30 years instead of their longer intended life, and if the Navy's acquisition of such ships matches the pace of the 2016 plan, their number in the fleet will fall substantially short of the Navy's goal of 88 large surface combatants.[7]

Small Surface Combatants. For small surface combatants, the Navy plans to replace its retired Oliver Hazard Perry frigates and mine countermeasures ships with littoral combat ships (LCSs) and improved LCSs, which are to be designated as frigates. The service would not reach its objective of having 52 small surface combatants in the fleet until 2028, the same as under the 2015 plan.

Amphibious Warfare Ships. The Navy's current plan calls for buying 23 amphibious warfare ships through 2045—2 more than specified in the 2015 plan—and increasing the amphibious force from 30 ships today to 34 by 2022. The force would stay at that size or increase through 2039 and then fall 1 or 2 ships short of the goal in the 2040s. The Navy assumes that it will keep its LHD class amphibious assault ships in the fleet for 43 to 45 years, although their expected service life is just 40 years.

Combat Logistics and Support Ships

Under the 2016 plan, the Navy envisions buying 46 combat logistics and support ships in the next three decades—the same number included in the 2015 plan. Combat logistics ships include T-AKE dry cargo ships, T-AO oilers, and AOE fast combat support ships; they operate with or directly resupply combat ships that are on deployment. The plan includes the purchase of 17 new oilers (which provide fuel and a few other supplies to ships at sea) at a rate of 1 per year through the 2020s, concluding in 2033. The plan also includes the purchase of 3 replacement T-AKE dry cargo and ammunition ships in 2043 and 2045. Other support ship purchases in the Navy's plan include 10 joint high-speed vessels (JHSVs), 4 salvage ships, 5 surveillance ships, 2 tenders,

6. See Congressional Budget Office, *Resource Implications of the Navy's Fiscal Year 2009 Shipbuilding Plan* (attachment to a letter to the Honorable Gene Taylor, June 9, 2008), p. 25, www.cbo.gov/publication/41703.

7. See Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2014 Shipbuilding Plan* (October 2013), p. 26, www.cbo.gov/publication/44655.

4 fleet tugs, and 1 new afloat forward staging base (a variant of the Navy's mobile landing platform ship).[8]

One notable change in this category in the 2016 shipbuilding plan is the removal of the proposed purchase of 2 command ship replacements; the existing command ships are still slated to be retired in 2039.[9] Another change is a delay, from 2016 to 2017, in the slated retirement of 2 salvage ships and 2 fleet tugs. Those retirements had been moved up as a cost-saving measure by nine and four years, respectively, under the 2015 plan. That would leave the Navy with 2 fleet tugs and 2 salvage ships in its inventory until 2019 and 2023, respectively, when replacements are scheduled to enter the fleet. The decision to retire the ships early (even though they are less expensive to operate than many other ship types), and the consequent gaps in the inventory raise the question of whether the Navy needs 4 ships of each type to support fleet operations. In the 2015 plan, the Navy stated that it would use leased vessels "if [the] mission workload requires additional ships."[10]

Shipbuilding Costs Under the 2016 Plan

According to the Navy's estimates, its planned purchases of new ships would cost an average of $16.5 billion per year (in 2015 dollars) through 2045 (see Table 4)—3 percent less than the $17.2 billion average shown in its 2015 plan (see Figure 5). In making its estimates, the Navy divided the time frame of the 2016 plan into three periods: the near term (2016 to 2025), the midterm (2026 to 2035), and the far term (2036 to 2045).

CBO also estimated the costs of the Navy's 2016 plan; it used its own cost models and assumptions, which are explained in detail later in this report, to price the ships. All together, CBO's estimates for new-ship construction are nearly $2 billion per year (or 12 percent) higher than the Navy's for the 30-year period, but the differences increase over time: They are smallest for the near term and largest for the far term. If other items that the Navy would need to fund from its budget accounts for ship construction are included, the Navy's estimates and those of CBO are $1.7 billion higher per year.[11]

The Navy's Estimates

The Navy's 2016 report is a relatively brief update to the 2015 report—the 2016 version regularly refers to the language in the earlier document. The 2015 report offers a frank discussion of the difficulties in estimating the capabilities that the Navy will want ships to have—and thus the cost of those ships—over the three planning periods. For the near term, the report explains, "projections in the period are based on our most accurate understanding of required combat capabilities, future defense budget toplines, and shipbuilding costs based on actual procurements in progress. The cost estimates for this period are the most accurate of the three planning periods." For the midterm, "the accuracy of the plan cost estimates diminishes." And for the far term, "Since the strategic environment and state of technology 20–30 years hence are both sure to be much different than they are today, the precision and accuracy of the ship types required and cost projections in this period are much more speculative."[12]

New-Ship Construction Costs. According to the Navy's estimates for its 2016 plan, over the near term, new-ship construction will cost an average of $16.9 billion per year. That amount excludes about $600 million in cost overruns and cuts made as a result of the automatic spending reductions (called sequestration) in 2013 that need to be restored to complete the construction of ships funded before 2016; that sum would be paid out from 2016 through 2018. The Navy projects that about a quarter of the funding for the construction of the Ohio Replacement class ballistic missile submarines will be spent in the next 10 years—mostly between 2021 and 2025. According to the Navy's estimates, the average budget for

8. The afloat forward staging base is a ship designed to remain on station overseas for long periods to provide support to other naval forces, such as special operations units, patrol craft, or minesweepers.

9. Since the 2005 publication of the Navy's interim report on shipbuilding, command ships have been removed from or added to Navy shipbuilding plans four times.

10. Department of the Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for FY2015* (June 2014), p. 13, http://go.usa.gov/FYZR (PDF, 3.4 MB).

11. The Navy has funded shipbuilding through two accounts: Shipbuilding and Conversion, Navy (commonly called the SCN account); and the National Defense Sealift Fund (NDSF), which includes funding for the procurement of some types of logistics ships. With the 2015 budget, the Navy proposed terminating the NDSF and funding all ships through the SCN account.

12. Department of the Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for FY2015* (June 2014), p. 10, http://go.usa.gov/FYZR (PDF, 3.4 MB).

Table 4.

Average Annual Shipbuilding Costs Under the Navy's 2016 Plan, by Decade

	Near Term (2016–2025)	Midterm (2026–2035)	Far Term (2036–2045)	All Three Decades (2016–2045)
		Navy's Estimates (Billions of 2015 dollars)		
New-Ship Construction	16.9	17.2	15.2	16.5
New-Ship Construction and Refueling of Nuclear-Powered Aircraft Carriers[a]	18.3	18.2	15.9	17.5
New-Ship Construction, Refueling of Nuclear-Powered Aircraft Carriers, and Other Items[b]	19.5	18.8	16.5	18.3
		CBO's Estimates (Billions of 2015 dollars)		
New-Ship Construction	18.2	19.2	17.8	18.4
New-Ship Construction and Refueling of Nuclear-Powered Aircraft Carriers	19.6	20.2	18.4	19.4
New-Ship Construction, Refueling of Nuclear-Powered Aircraft Carriers, and Other Items	20.7	20.8	19.0	20.2
		Percentage Difference Between the Navy's and CBO's Estimates		
New-Ship Construction	8	12	17	12
New-Ship Construction and Refueling of Nuclear-Powered Aircraft Carriers	7	11	16	11
New-Ship Construction, Refueling of Nuclear-Powered Aircraft Carriers, and Other Items	6	11	16	10
Memorandum (Billions of 2015 dollars):				
CBO's Estimate of the Costs of New-Ship Construction Needed to Meet Nearly All Inventory Goals in Each Year	20.6	20.8	16.5	19.3
Costs of Mission Packages for Littoral Combat Ships	0.3	0.1	0.3	0.3

Source: Congressional Budget Office based on data from the Department of the Navy.

Note: Costs for other items include funds for ship conversions and for ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items. Actual costs for the Navy's shipbuilding accounts over the past 30 years averaged about $16 billion per year for all items.

a. These figures are the Navy's estimates for new-ship construction and CBO's estimates for the refueling of nuclear-powered aircraft carriers.

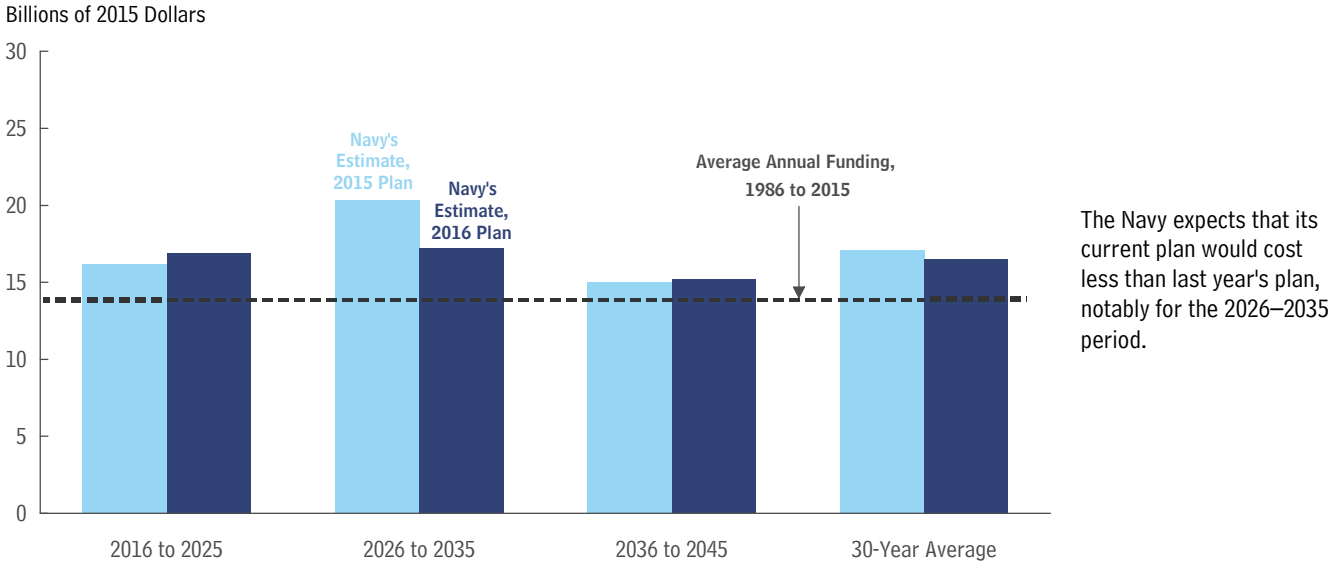
b. These figures are the Navy's estimates both for new-ship construction and for the cost to complete for ships purchased in prior years and CBO's estimates for the refueling of nuclear-powered aircraft carriers and for other items.

new-ship construction rises from $14.9 billion per year between 2016 and 2020 to $18.9 billion per year for 2021 to 2025 (see Figure 6).

The Navy's shipbuilding plan suggests that the midterm will be fiscally challenging as well: At $17.2 billion per year, the average total cost of new-ship construction is close to the average the service estimates for the first 10 years. The Navy projects that building the new submarines will cost $5.4 billion per year in the middle decade of the plan. In the far term, with Ohio Replacement submarines completed, the Navy's estimate for new-ship construction declines to an average of $15.2 billion per year.

Figure 5.

The Navy's Estimates of the Average Annual Costs of New-Ship Construction Under Its 2015 and 2016 Plans



Source: Congressional Budget Office based on data from the Department of the Navy.

Note: Costs exclude funds for refueling nuclear-powered aircraft carriers and for ship conversions, construction of ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items. Costs for the mission packages for littoral combat ships, which are not funded in the Navy's shipbuilding accounts, also are excluded.

Total Shipbuilding Costs. As in previous shipbuilding plans, the Navy's latest estimates exclude some costs that it would need to cover out of its budget accounts for ship construction:

- The cost of refueling nuclear-powered aircraft carriers midway through the ships' 50-year service life would increase the Navy's estimate for the 2016 shipbuilding plan by $1 billion per year, to an average of $17.5 billion a year through 2045,[13] and
- The costs of ship conversions, construction of ships that are not part of the Navy's battle force (oceanographic survey ships, for instance), moored training ships, outfitting and postdelivery (including the purchase of many smaller tools and pieces of equipment that are needed to operate a ship but that are not necessarily provided by the shipyard when the ship is built), and smaller items.

Adding those costs, plus the $600 million in cost-to-complete funding that will be spent from 2016 through 2018, to the estimated new-ship construction costs would boost the Navy's estimate for the full cost of the 2016 shipbuilding plan to $18.3 billion per year, or $1.8 billion more than its estimate for new-ship construction alone. That figure is 16 percent higher than the average funding of $15.8 billion per year that the Navy has received for total shipbuilding costs over the past three decades.

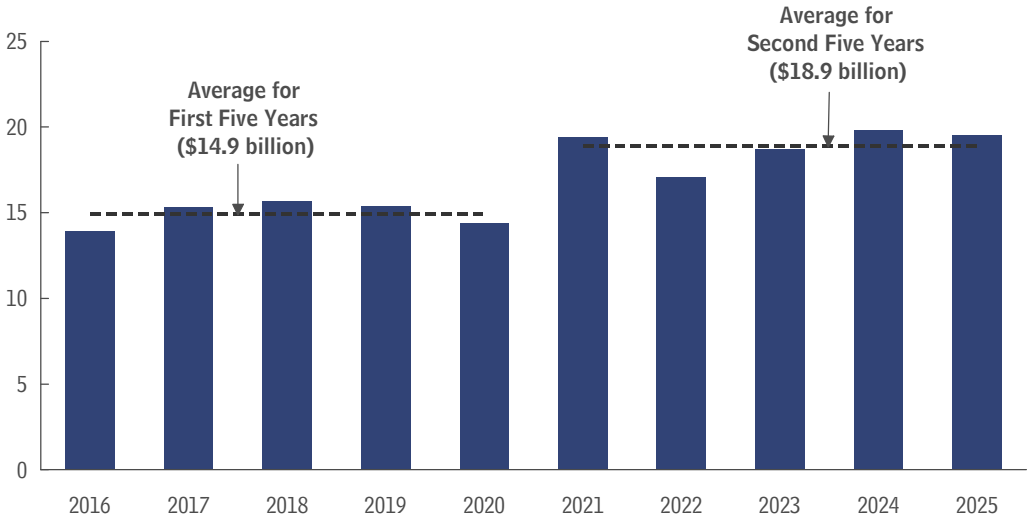
CBO's Estimates

In CBO's estimation, the full cost of the 2016 shipbuilding plan (including construction, refueling of nuclear-powered aircraft carriers, and other items) would average $20.2 billion per year over the 2016–2045 period (see Table 4 on page 13). That amount is 28 percent above the average annual funding the Navy

13. In 2010, the Navy transferred funding for refueling nuclear-powered submarines to other Navy accounts (Other Procurement, Operation and Maintenance, and Weapons Procurement) that are not used to purchase ships. Therefore, CBO did not include the refueling costs for submarines in its estimates of future shipbuilding costs.

Figure 6.

The Navy's Estimates of the Costs of New-Ship Construction, 2016 to 2025



Source: Congressional Budget Office based on data from the Department of the Navy.

Note: Costs exclude funds for refueling nuclear-powered aircraft carriers and for ship conversions, construction of ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items. Costs for the mission packages for littoral combat ships, which are not funded in the Navy's shipbuilding accounts, also are excluded.

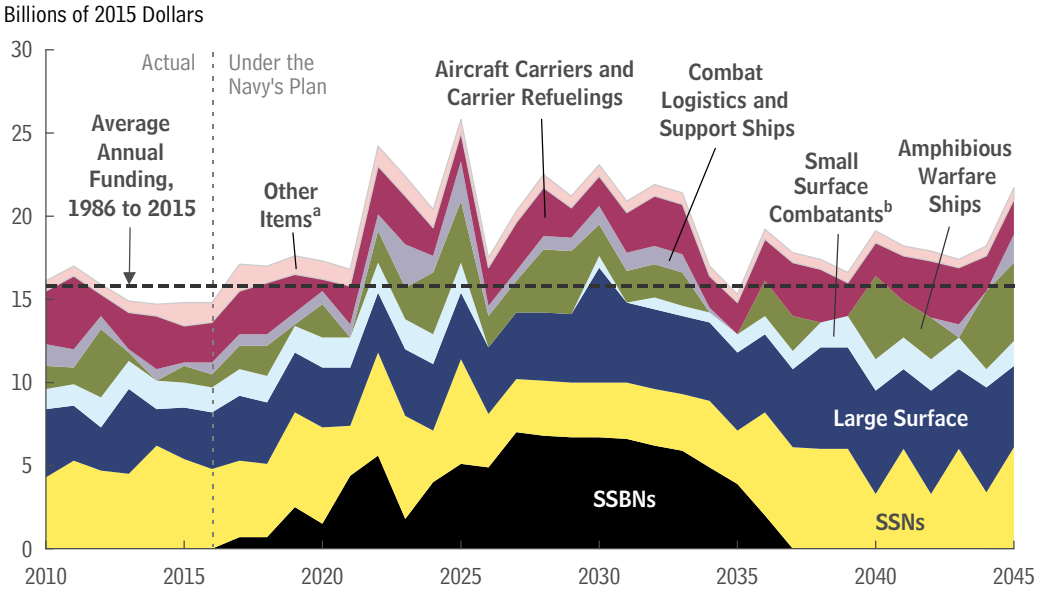
has received over the past three decades. The estimated costs have a fair amount of yearly variation but are on an upward trend for the first two decades of the plan (see Figure 7). CBO makes the following estimates for the 30-year period as a whole:

- New-ship construction would average $18.4 billion per year, 12 percent more than the Navy's figure of $16.5 billion;
- New-ship construction plus refueling of nuclear-powered aircraft carriers would cost an average of $19.4 billion per year, 11 percent more than the Navy's figure of $17.5 billion; and
- All other items would add annual costs of about $800 million, raising CBO's estimate to an average of $20.2 billion per year through 2045, 10 percent more than the Navy's figure of $18.3 billion.

CBO's estimates of the full cost of the plan are only 6 percent higher than the Navy's for the first 10 years but 16 percent higher for the final 10 years. The two sets of estimates are similar for the near term because most of the ships that the Navy plans to buy are already under construction and their costs are reasonably well known. But CBO and the Navy made different assumptions about the size and capabilities of future ships that contributed to different cost estimates for the midterm and far term. Generally, CBO estimates the cost of a future ship on the basis of the relationship between the weight and cost of analogous existing ships. The resulting amount is then adjusted for factors such as production efficiencies that occur as more ships of the same type are built simultaneously at a given shipyard and additional efficiencies that occur as more ships are built over the duration of a production run. CBO also incorporated into its estimates (which are in constant 2015 dollars) a projection that, as they have for the past several decades, labor and materials costs would probably continue to grow faster in the shipbuilding industry than in the economy as a whole. The Navy's constant-dollar estimates do not reflect that faster growth (see Box 2 on page 18). That difference in estimates is much more pronounced in the final decade of the plan, after 20 or more years of compounded cost growth, than in the early years. (For more information on CBO's methods for estimating the cost of new ships, see Appendix A.)

Figure 7.

CBO's Estimates of Annual Shipbuilding Costs Under the Navy's 2016 Plan



Over the next two decades, CBO estimates, the new SSBN program will push the Navy's annual shipbuilding costs above the historical average.

Source: Congressional Budget Office based on data from the Department of the Navy.

Note: SSBNs = ballistic missile submarines; SSNs = attack submarines.

a. Includes ship conversions, ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items.

b. Costs for the mission packages for littoral combat ships, which are not funded in the Navy's shipbuilding accounts, are not included.

Costs of Meeting Nearly All Inventory Goals in Each Year

Under its 2016 shipbuilding plan, the Navy would not build enough ships at the right times to meet the service's inventory goal of 308 battle force ships until 2022. In particular, the plan would lead to temporary shortfalls relative to the Navy's goals for ballistic missile submarines, attack submarines, large surface combatants, and, in the far term, for aircraft carriers as well. However, there would be only small and short-lived shortfalls for amphibious warfare ships (see Figure 4 on page 10).

The Navy does not believe that it can prevent the shortfall in ballistic missile submarines. Because of specific characteristics of the design and operations, the service of existing Ohio class submarines cannot be extended.[14] And building the new class of ballistic missile submarines faster, the Navy argues, would introduce technical risks that would outweigh the risk of having 10—rather than the preferred 12—SSBNs that are deployable for a decade.

Other shortfalls, however, could be avoided or reduced by accelerating or increasing ship purchases relative to those specified in the 2016 shipbuilding plan. To meet most of its existing goals, the Navy could make the following changes to the current shipbuilding plan:

- To prevent the force from falling below the inventory goal of 48 attack submarines, the Navy could accelerate the purchase of 7 submarines to the period from 2017 through 2023, thus increasing the production rate to 3 submarines per year for most of those years. In that case, the Navy could buy 7 fewer attack submarines between 2025 and 2034 than is called for under the 2016 plan and still maintain the

14. Among the many factors that determine the service life of a submarine are the two primary ones: the condition of its hull and the energy in its reactor. The number of times a submarine can "cycle"—submerge and surface—before it must be retired is limited, as is the reactor's capacity to produce energy. Some nuclear submarines can be refueled if their hulls have life remaining, but those with "life of the ship" reactor plants cannot be refueled.

desired inventory. However, doing so under the Navy's 2016 plan would reduce attack submarine construction to an average of 1 every other year for the 2026–2035 period.

- To prevent the carrier force from declining to 10 ships in the 2040s, 1 short of its inventory goal of 11, the Navy could accelerate purchases after 2018 to 1 every four years, rather than 1 every five years.

- To meet its goal of 88 large surface combatants in the last years of the plan, the Navy could purchase 6 additional destroyers between 2028 and 2037, increasing the production rate to 3 ships per year for six more years.

- To prevent small shortfalls in later years of the plan, the Navy could purchase 2 additional amphibious warfare ships by 2038 to meet its inventory goal of 34 ships in each year after 2022. However, the Navy cannot prevent a shortfall in amphibious warfare ships relative to its goal in the next few years because such ships take four to five years to build.

According to CBO's estimates, incorporating the changes described above into the Navy's 2016 plan would raise costs significantly in the first two decades of the plan but reduce them in the third decade. The annual cost of new-ship construction would average $20.6 billion between 2016 and 2025 (instead of the $18.2 billion in CBO's estimate of the Navy's plan), $20.8 billion between 2026 and 2035 (instead of $19.2 billion), and $16.5 billion between 2036 and 2045 (instead of $17.8 billion). Over the entire 30-year period, new-ship construction would average $19.3 billion per year, compared with CBO's estimate of $18.4 billion per year for the Navy's plan.

Other approaches to preventing the Navy from falling short of its goals could have different costs. For example, if the Navy was able to extend the service life of some existing ships, it would need fewer new ones, thus reducing procurement costs but possibly increasing operation and maintenance costs because older ships tend to be more expensive to operate than newer ships of the same class. Such an approach would not be effective in preventing a shortfall of all types of ships, however. In particular, the Navy's plan already reflects an assumption that most destroyers will be in service for 40 years, although historically very few have served longer than 30 years. Consequently, CBO does not expect that those ships could serve for an even longer period to prevent the shortfall in large surface combatants. By contrast, extending service life for amphibious warfare ships seems more plausible because those ships are already serving for 40 years and the Navy is planning to keep some beyond that length of service. Thus, the Navy could prevent the minor shortfalls in amphibious warfare ships after 2040 by not retiring existing ships and, in several cases, by extending their service life by a few years.

Shipbuilding With Historical Average Funding

CBO's estimate of $20.2 billion per year for the full cost of the Navy's 2016 shipbuilding plan is 28 percent higher than the $15.8 billion (in 2015 dollars) the Navy has spent on average per year over the past 30 years for all items in its shipbuilding accounts. If the Navy's future funding for shipbuilding is in line with the past, the Navy will need to substantially reduce its new-ship purchases relative to the number called for in its 2016 plan.[15]

To illustrate how much smaller the fleet of battle force ships might be under that scenario, CBO constructed an alternative shipbuilding plan to meet two criteria: First, the purchase of specific types of ships, with the exception of ballistic missile submarines and aircraft carriers, would be reduced in rough proportion to the 2016 plan. The Navy's most senior officials have described replacing the current Ohio class submarines as the service's top priority; CBO assumed, therefore, that the Navy would purchase all 12 submarines included in its 2016 plan. The Congress has mandated in law that the Navy maintain a fleet of 11 aircraft carriers, so in this illustrative scenario, CBO did not make cuts to that category.

With the nearly proportionate reduction in purchases of other types of ships, the composition of the fleet in 2045 would be about the same as that specified in the 2016 plan, although the number of ships of each type would be smaller.

15. For a broader discussion of historical cost trends in Navy shipbuilding, see the testimony of Eric J. Labs, Senior Analyst for Naval Forces and Weapons, Congressional Budget Office, before the Subcommittee on Seapower and Expeditionary Forces of the House Committee on Armed Services, *The Long-Term Outlook for the U.S. Navy's Fleet* (January 20, 2010), www.cbo.gov/publication/41886.

Box 2.

Inflation in the Cost of Shipbuilding

The costs of building future ships will depend not just on their size and capabilities but also on the evolution of production costs. The differences between the Navy's and the Congressional Budget Office's estimates of the cost of the Navy's shipbuilding plans arise in part from their different methods for measuring the value—in constant 2015 dollars (that is, removing the effects of inflation)—of production costs that will be incurred years or decades from now.

For the same ship with the same capabilities, the Navy reports the future cost of capabilities purchased as being the same as the cost today. By contrast, CBO projects the cost to build the same ship in the future but accounting for the rising cost of shipbuilding labor and materials relative to that for other goods and services in the economy. CBO regards that difference between shipbuilding inflation and overall inflation as growth in the constant-dollar cost of budgetary resources for building naval ships. The agency's constant-dollar estimates incorporate the increased costs of a future ship of any given size and capability relative to the average increase in costs for other goods and services that might be purchased with the same amount of discretionary funding.

The Navy provided CBO with a shipbuilding cost index that measures growth in the costs of labor and materials for the period from 1960 to 2014. To project increases for 2015 through 2019, the Navy constructed a shipbuilding cost index by extrapolating from the historical cost data and incorporating other information—derived from advance-pricing agreements, vendor surveys, and forecasts of the labor market—into its projections. For the 2015–2019 period, the Navy projects, shipbuilding costs will rise at an average annual rate of 2.9 percent.

The Navy incorporated that projection into its budget request for 2016 and into the associated Future Years Defense Program; both documents express costs in nominal dollars. In projecting the constant-dollar costs for its 2016 shipbuilding plan, the Navy converted nominal dollars to constant 2015 dollars by discounting the nominal dollar amounts, using the same shipbuilding cost index the service used to construct the future-year estimates.[1] Thus, the Navy's constant-dollar estimates are essentially a measure of the amount of ship capability purchased: If a ship costs $2.5 billion to build in 2015, the cost (in 2015 dollars) of building an identical ship in 2035 will be the same amount—$2.5 billion.

In contrast, CBO used the gross domestic product (GDP) price index, which measures the prices of all final goods and services produced in the economy, to convert shipbuilding costs from nominal to constant dollars. CBO anticipates an average annual rate of increase in that measure of 1.9 percent for the 2015–2019 period. CBO's estimates of the cost of building a given ship (as projected from the Navy's shipbuilding cost index) show a rate of increase over the period that is 1.0 percentage point faster per year, on average, than the rate of inflation it projects for the overall

1. Department of the Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2016* (March 2015), http://tinyurl.com/ocrqtfc.

Continued

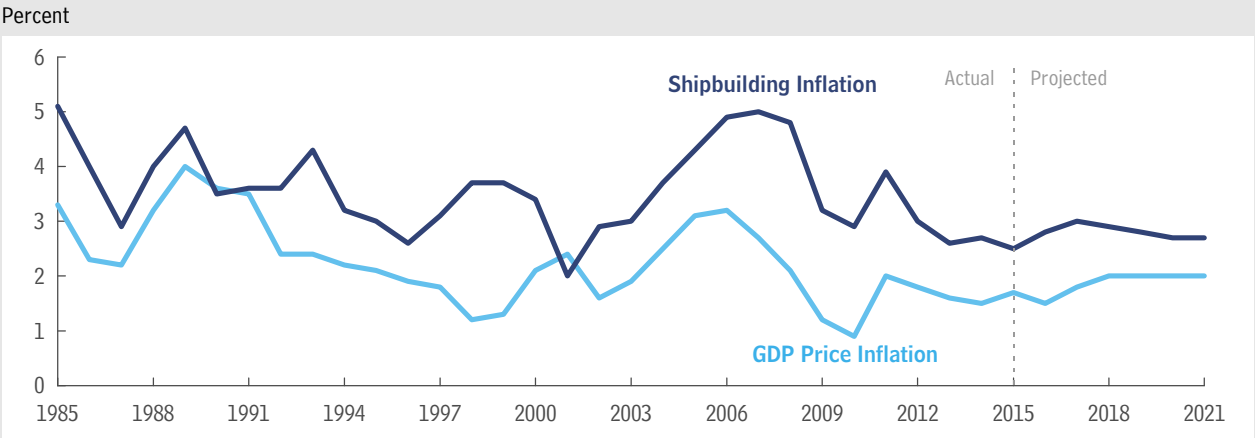
The second criterion underlying the alternative plan is to keep spending fairly similar (in inflation-adjusted, or real, dollars) during the near-term, midterm, and far-term periods. The alternative plan is not a recommendation by CBO but simply an illustration of the possible consequences of continuing funding for shipbuilding at its historical average amount rather than increasing it, as would be required under the Navy's 2016 plan.[16]

16. In a report accompanying the 2014 National Defense Authorization Act, the House Committee on Armed Services directed the Navy to provide to the Congress a similar illustration of a shipbuilding plan (starting in 2015) that conforms to historical funding levels. The Navy has not responded to that Congressional directive.

Box 2. **Continued**

Inflation in the Cost of Shipbuilding

Annual Rates of Shipbuilding Inflation and GDP Price Inflation



Sources: Congressional Budget Office; Department of the Navy.

Note: GDP = gross domestic product.

economy. CBO identified the same 1.0 percentage-point real annual growth in its analysis of the Navy's 2015 plan.

Since 1985, the average difference between the rate of increase in the Navy's shipbuilding cost index and that in the GDP price index has been about 1.3 percentage points per year (see the figure). Cost growth in the shipbuilding industry has exceeded general inflation for most of the past three decades, and CBO lacks an analytical basis for determining when or to what extent the difference between the two growth rates might narrow. Therefore, CBO projects that shipbuilding inflation will outpace GDP price inflation by 1.0 percentage point per year between 2015 and 2019 and by about 1.3 percentage points per year—matching the 30-year historical average—thereafter.[1] The result is that CBO estimates that a ship that costs $2.5 billion to build in 2015 will cost $3.2 billion (in 2015 dollars) in 2035. (Shipbuilding costs cannot continue indefinitely to grow faster than the costs of goods and services in the economy as a whole. If that occurred, the price of ships eventually would outstrip the Navy's ability to pay for even a small number of them.)

1. In its report, the Navy estimates shipbuilding costs in nominal dollars for the 2016–2025 period (it does not provide estimates beyond those years) totaling between $190 billion and $201 billion. The lower figure uses inflation assumptions determined by the Office of the Secretary of Defense; the higher figure uses shipbuilding inflation. CBO's nominal-dollar estimates for the 2016–2025 period total $204 billion.

Under that illustrative 30-year plan, the Navy would purchase 192 ships (versus 264 in the Navy's 2016 plan) as follows:

- 6 aircraft carriers (the Navy's plan also has 6),
- 12 ballistic missile submarines (the Navy's plan also has 12),
- 34 attack submarines (the Navy's plan has 45),
- 46 destroyers (the Navy's plan has 65),
- 44 littoral combat ships and fast frigates (the Navy's plan has 67),
- 15 amphibious ships (the Navy's plan has 23), and
- 35 combat logistics and support ships (the Navy's plan has 46).

Under this plan, the battle force fleet in 2023 would be about the same size as in the Navy's plan but by 2045 would number 237 ships, as opposed to the 305 in the Navy's plan. The inventory in 2045 would consist of the following ships:

- 10 aircraft carriers (the Navy's plan has 10),
- 12 ballistic missile submarines (the Navy's plan has 12),
- 37 attack submarines (the Navy's plan has 50),
- 64 destroyers (the Navy's plan has 82),
- 34 littoral combat ships and fast frigates (the Navy's plan has 57),
- 27 amphibious ships (the Navy's plan has 33), and
- 53 combat logistics and support ships (the Navy's plan has 61).[17]

Other approaches to staying within historical funding would produce different results. If the Navy reduced the number of larger and more expensive ships more sharply than in the plan described above, the fleet would be larger overall. Conversely, if it preserved the programs of more expensive ships, the fleet would be smaller overall. Ultimately, decisions about which ships to build would depend on policymakers' priorities for certain naval missions relative to others.[18]

Shipbuilding Under the Budget Control Act of 2011

The Budget Control Act of 2011, as amended by the American Taxpayer Relief Act of 2012 and the Bipartisan Budget Agreement of 2013, established caps on discretionary defense funding that will continue from 2016 through 2021. Those caps apply to DoD's base budget but exclude the costs of overseas contingency operations, which consist of U.S. involvement in the war in Afghanistan, Iraq, Syria, and other nonroutine military activities elsewhere. The caps set funding, in real terms, substantially below the amount DoD received in 2010, when its base budget reached its peak.

In the first three years of the BCA, the Congress has increased funding for shipbuilding above the President's requests, which roughly aligned with the historical shares the service would have expected to receive under the law. (During the past 15 years, the Department of the Navy has received about 30 percent of DoD's base budget and has devoted about 10 percent of its funding to shipbuilding.) Between 2013 and 2015, the President's budget requests included an average of about $14.1 billion per year in nominal dollars for shipbuilding. The Congress appropriated about 10 percent more, an average of $15.5 billion per year (see Figure 8). Nevertheless, the Navy bought substantially fewer ships between 2013 and 2015 than it had planned before the BCA took effect. In all, the 2012 shipbuilding plan called for the purchase of 36 ships over those three years. In his 2013, 2014, and 2015 budgets, the President proposed to purchase a total of 25 ships, and the Congress added funding for 2 additional ships along with partial funding for several more.

In 2015, DoD's real base budget fell to about the same amount that it received in 2007, and as a result of the BCA's caps, funding (in real terms) will remain essentially at that level through 2021. Consequently, under current law, policymakers face a choice between implementing the Navy's 2016 shipbuilding plan and cutting costs elsewhere in the Navy's budget (or in DoD's budget more broadly), scaling back the 2016 shipbuilding plan, or taking some combination of those actions.

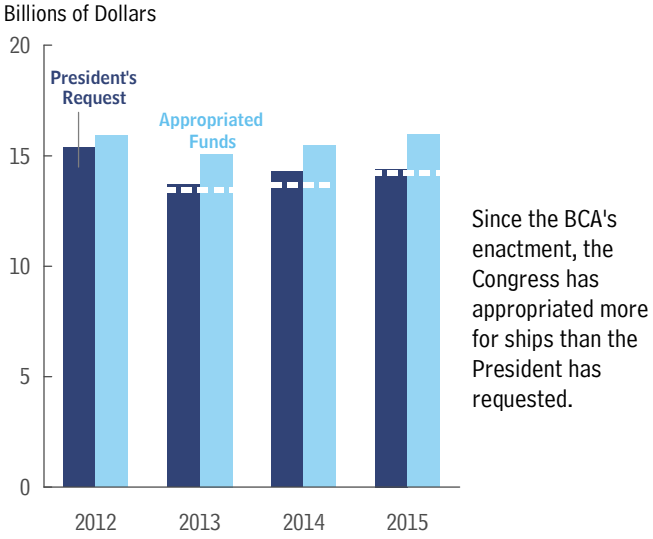
Specifically, if the Navy receives the same percentage of DoD's base budget during the coming decade and devotes the same percentage of its budget to ship construction that it has historically, the annual shipbuilding budget would be about $14 billion (in 2015 dollars) from 2016 through 2021. In comparison, the Navy's 2016 plan would require spending a little more than $19 billion per year on all shipbuilding over the same period, CBO estimates. The $14 billion amount would be about $5.5 billion per year—or 30 percent below CBO's estimate of the amount required to execute the Navy's 2016 plan over the 2016–2021 period. If all shipbuilding programs were cut proportionately, a reduction of that magnitude would require the Navy to purchase 16 fewer ships than the 57 it plans to purchase over that period, a reduction of about 30 percent.

17. The alternative plan also would fund the refueling of 1 aircraft carrier fewer than called for under the Navy's current plan.

18. For an illustration of such an analysis, see Congressional Budget Office, *Options for the Navy's Future Fleet* (May 2006), www.cbo.gov/publication/17802.

Figure 8.

Requested and Appropriated Shipbuilding Budgets Under the Budget Control Act



Source: Congressional Budget Office based on various volumes of the Department of the Navy's *Highlights of the Department of the Navy Budget*.

Notes: The dashed line indicates the estimated shipbuilding budget, calculated as the historical share of the Department of Defense's base budget under the BCA, as that act stood at the time of each year's budget submission.

BCA = Budget Control Act of 2011.

As of this writing, the Congress was considering H.R. 1314, the Bipartisan Budget Act of 2015.* That bill, if enacted, would raise the budget caps for national defense for fiscal years 2016 and 2017. That change would allow the Navy to cut 15 ships rather than 16 ships from its 2016 plan, if all shipbuilding programs were cut proportionately.

Outlook for Specific Ship Programs

To estimate the costs of implementing the Navy's 2016 shipbuilding plan, CBO calculated the cost of each of the 264 ships that the Navy intends to purchase between 2016 and 2045 (see Appendix A). For ships under construction, the estimates were based in part on data for actual costs from the Navy. For ships yet to be built, the estimates were based primarily on information about the cost per unit weight of similar ships from the past. Specifically, CBO used the cost per thousand tons of lightship displacement—which is the weight of the water the ship displaces without its crew, stores, weapons, fuel, or other liquids. CBO then adjusted its estimates to incorporate the effects of *rate* (the reduction in average overhead costs that occurs when a shipyard builds more than one of the same type of ship at a time) and *learning* (the efficiencies that shipyards gain as they produce additional units of a given type of ship). The effects of rate and learning were applied to the estimated cost of the first ship of a class (the lead ship) to determine the estimated costs for all subsequent ships of that class. Thus, CBO's estimate of the cost of the lead ship in a class drove its estimate of the costs of subsequent ships of that class. CBO had to make assumptions about the size and capabilities of ships for which the Navy has yet to develop even expected designs. All estimates exclude outfitting and postdelivery costs, which typically add at least 3 percent to a ship's cost.

Aircraft Carriers

The 2016 shipbuilding plan states that the Navy's goal is to have 11 aircraft carriers—a number also mandated by the Congress. The Navy intends to buy 6 CVN-78 Gerald R. Ford class aircraft carriers over the 2016–2045 period (see Table 5). Building 1 carrier every five years (referred to as five-year centers) would allow the Navy to have a force of at least 11 carriers through 2039, after which the force would drop to 10. (To maintain a force of 11 carriers that serve in the fleet for 50 years would require purchasing 1 ship every 4½ years rather than 1 every 5 years as is called for under the Navy's current plan.)

The Navy's current estimate of the total cost of the lead ship of the CVN-78 class is $12.9 billion in nominal dollars for the period from 2001 to 2016, an amount that is equal to the cost cap set in law.[19] CBO used the Navy's inflation index for naval shipbuilding to convert that figure to $14.7 billion in 2015 dollars, or 23 percent more than the amount requested in the President's budget proposal when the ship was first authorized in 2008. The Navy's estimate does not include $4.7 billion in research and development costs that apply to the entire class.

Because construction is nearly finished and no major problems have arisen in the test program (which is about half completed), CBO used the Navy's estimate for the lead ship to estimate the cost of successive ships in the class.

19. In its 2016 budget request, the Navy asked for an extra $124 million in nominal dollars in 2016 to cover cost growth and additional tooling and vendor services. That amount was anticipated in the 2014 and 2015 budget requests and it completes a total of $1.4 billion in additional funding requested in the past two budgets. The amount is included in the Navy's estimate of the total cost to complete the ship.

*The Bipartisan Budget Act of 2015 (Public Law 114-74) was enacted on November 2, 2015.

Table 5.

Comparison of the Navy's and CBO's Estimates for the Construction of Major New Ships Under the Navy's 2016 Plan

Billions of 2015 Dollars

	Number of New Ships Purchased Under the 2016 Plan	Total Costs per Class Over the 2016–2045 Period		Average Costs per Ship Over the 2016–2045 Period		Memorandum: Average Costs per Ship Under the 2015 Plan	
		Navy's Estimates	CBO's Estimates	Navy's Estimates	CBO's Estimates	Navy's Estimates	CBO's Estimates
CVN-78 Gerald R. Ford Class Aircraft Carriers	6	68 [a]	73 [a]	11.3 [a]	12.3 [a]	12.9	13.2
Ohio Replacement Ballistic Missile Submarines	12	75	88	6.2	7.3	6.8	7.9
Virginia Class Attack Submarines	26	74	76	2.9	3.0	2.9	3.0
Improved Virginia Class Attack Submarines (Replacements for Virginia class)	19	58	59	3.1	3.1	3.0	3.3
DDG-51 Flight III Arleigh Burke Class Destroyers	27	45	52	1.7	1.9	1.7	1.9
DDG(X) Destroyers (Replacements for Arleigh Burke class)	37	68	85	1.8	2.3	1.9	2.6
Littoral Combat Ships	9	4	5	0.5 [b]	0.5	0.5	0.5
Fast Frigates (Modified LCSs)	20	12	12	0.6	0.6	n.a.	0.6
LCS(X)s (Replacements for LCSs)	38	17	20	0.4 [b]	0.5	0.5	0.5
LHA-6 Amphibious Assault Ships	7	26	28	3.7	3.9	3.8	4.1
LX(R)s (Replacements for amphibious dock landing ships)	11	17	21	1.5	1.9	1.5	1.9
LPD-17 Replacements	4	8	11	2.1	2.6	2.3	2.7
T-AO(X) Oilers	17	8	10	0.5	0.5	0.5	0.6

Source: Congressional Budget Office based on data from the Department of the Navy.

Notes: The costs in this table exclude funding for research and development.

Unlike Table 1, this table excludes 1 DDG-51 Flight IIA destroyer, 1 LPD-17 amphibious ship, and 29 support ships of various types.

CVN = nuclear-powered aircraft carrier; DDG and DDG(X) = guided missile destroyer; LCS = littoral combat ship; LHA = amphibious assault ship; LPD = amphibious transport dock; LX(R) = dock landing ship replacement; T-AO(X) = oiler; n.a. = not applicable.

a. In CBO's and the Navy's estimates for aircraft carriers, total costs per class include remaining funding for the CVN-78 and CVN-79 but exclude some funding for the carrier the Navy plans to purchase in 2043 because that money would not be budgeted until 2046 or later. CBO's and the Navy's estimates of the average cost per ship exclude the remaining funding for the CVN-78 and CVN-79 but include all funding for the 2043 carrier.

b. The Navy's estimate for the LCSs is $463 million per ship; its estimate for the LCS(X) is $441 million each. Those costs exclude the cost of LCS mission packages, which CBO also excluded from its estimates.

That does not mean that all of the cost risk has been eliminated, but CBO estimates that the remaining risk of cost growth would be less than $100 million for the ship. (CBO thus no longer expects the $500 million in cost growth it had estimated for last year's report.)

The next carrier after the CVN-78 will be the CVN-79, the *John F. Kennedy*. Funding for that ship began in 2007, the Congress officially authorized its construction in 2013, and appropriations for it are expected to be complete by 2018. The Navy estimates that the ship will cost $11.5 billion in nominal dollars and $10.6 billion in 2015 dollars. The Navy's selected acquisition report on the CVN-79 states that "the Navy and shipbuilder have made fundamental changes in the manner in which the CVN 79 will be built to incorporate lessons learned from CVN 78 and eliminate key contributors to cost performance challenges realized in the construction of

CVN 78."[20] Although CBO expects the Navy to achieve a considerable cost reduction in the CVN-79 compared with the CVN-78, CBO's estimates are somewhat higher than the Navy's. Specifically, CBO estimates that the cost of the ship will be $11.9 billion in nominal dollars and $11.3 billion in 2015 dollars, about 4 percent more than the Navy's estimate.

The Navy estimates an average cost of $11.3 billion for the 6 carriers in the 2016 shipbuilding plan, the CVN-80 through CVN-85. CBO's estimate is $12.3 billion per ship. Both estimates are substantially lower for the 2016 plan than they were for 2015. The Navy's current estimate incorporates the effects of efforts to reduce costs for the CVN-79 and successive ships in the class. CBO's estimate is based on the Navy's estimate for the final cost of the CVN-78, which reduced the estimated cost of succeeding ships in the class. CBO's estimate is still above the Navy's, however, because CBO projects smaller reductions in price than the Navy predicts and because CBO anticipates real cost growth in the naval shipbuilding industry.

Submarines

Under the 2016 shipbuilding plan, submarines would consume the lion's share of shipbuilding funds over the next 20 years (see Table 6). The Navy currently operates 14 Ohio class ballistic missile submarines (SSBNs), 4 Ohio class guided missile submarines (SSGNs) modified from the SSBN version, and 54 attack submarines (SSNs) of several classes. Over the next three decades, the Navy plans to buy 12 new SSBNs, starting in 2021. It also plans to buy 45 new SSNs, including 26 Virginia class submarines (mostly at an average rate of 1.5 per year through 2033) and 19 submarines that are based on a redesigned and improved Virginia class (production is set to begin in 2034). The Navy does not plan to replace the 4 SSGNs it will retire in the mid-to-late 2020s.

Ohio Replacement Ballistic Missile Submarines. SSBNs, which carry Trident ballistic missiles, constitute the sea-based leg of the United States' strategic triad for nuclear deterrence. (The other two legs are land-based intercontinental ballistic missiles and manned strategic bombers.) The design, cost, and capabilities of the 12 Ohio Replacement submarines in the 2016 shipbuilding plan are among the most significant uncertainties in the Navy's and CBO's analyses of the cost of future shipbuilding. Under the 2016 plan, the first Ohio Replacement submarine—sometimes called the SSBN(X)—would be purchased in 2021, although advance procurement funding would be needed starting in 2017 for items with long lead times. A second submarine would be purchased in 2024, followed by 1 per year from 2026 to 2035 (see Figure 3 on page 9).[21]

The Navy currently estimates the cost of the first Ohio Replacement submarine at $12.1 billion in 2015 dollars, and it estimates an average cost for follow-on ships of $5.7 billion (the Navy has stated an objective of reducing that cost to $5.6 billion).[22] The implied total cost for the 12 submarines is $75 billion, or an average individual cost of $6.2 billion (see Table 5).

The Navy's estimate represents a 12 percent reduction in the cost per thousand tons for the first Ohio Replacement submarine compared with the first Virginia class submarine—an improvement that would affect costs for the entire new class of ballistic missile submarines. The main reason for those purported improved costs by weight for the Ohio Replacement is that the Navy will recycle, to the extent possible, the design, technology, and components used for the Virginia class. Furthermore, because ballistic missile submarines (such as the Ohio Replacement) tend to be larger and less densely built ships than attack submarines (like the Virginia class), they will be easier to build and therefore less expensive per thousand tons, the Navy asserts.

However, the historical record for the lead ships of new classes of submarines in the 1970s and 1980s provides little evidence that ballistic missile submarines are cheaper by weight to build than attack submarines (see Figure 9).

20. Defense Acquisition Management Information Retrieval, *Selected Acquisition Report: CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier, as of FY 2016 President's Budget* (Department of the Navy, December 2014), p. 29.

21. More information appears in Ronald O'Rourke, *Navy SSBN(X) Ballistic Missile Submarine Program: Background and Issues for Congress,* Report for Congress R41129 (Congressional Research Service, July 31, 2014). See also the testimony of Eric J. Labs, Senior Analyst for Naval Forces and Weapons, Congressional Budget Office, before the Subcommittee on Seapower and Expeditionary Forces of the House Committee on Armed Services, *The Long-Term Outlook for the U.S. Navy's Fleet* (January 20, 2010), www.cbo.gov/publication/41886.

22. That figure was stated in a briefing by the Navy to the staff of the House Committee on Armed Services, CBO, and the Congressional Research Service (February 28, 2011). The Navy's estimates, expressed in 2010 dollars, were $5.6 billion for the average follow-on submarine, with an objective of reducing that cost to $4.9 billion.

Table 6.

Total Shipbuilding Costs, by Major Category, 1986 to 2045

	Historical				CBO's Estimates Under the Navy's 2016 Plan			
	1986-1995	1996-2005	2006-2015	1986-2015	2016-2025	2026-2035	2036-2045	2016-2045
	Average Annual Costs (Billions of 2015 dollars)							
New-Ship Construction								
Aircraft carriers	2.4	1.1	2.0	1.8	2.3	2.4	2.7	2.4
Submarines	5.2	3.0	4.4	4.2	7.7	9.2	5.4	7.5
Surface combatants	7.1	4.8	4.2	5.4	5.4	5.0	7.1	5.8
Amphibious ships	1.3	1.7	1.6	1.6	1.7	1.9	2.3	2.0
Logistics and support ships	1.5	0.5	0.7	0.9	1.1	0.7	0.3	0.7
Subtotal	17.6	11.1	12.9	13.9	18.2	19.2	17.8	18.4
Refueling of Nuclear-Powered Carriers and Submarines[a]	0.4	1.0	1.3	0.9	1.4	1.0	0.7	1.0
Other Items	1.1	1.2	0.7	1.0	1.2	0.6	0.6	0.8
Total	**19.1**	**13.2**	**15.0**	**15.8**	**20.7**	**20.8**	**19.0**	**20.2**
	Percentage of Average Annual Costs							
New-Ship Construction								
Aircraft carriers	13	8	13	11	11	11	14	12
Submarines	27	23	29	27	37	44	29	37
Surface combatants	37	36	28	34	26	24	37	29
Amphibious ships	7	13	11	10	8	9	12	10
Logistics and support ships	8	4	5	6	6	4	1	4
Subtotal	92	84	86	88	88	92	93	91
Refueling of Nuclear-Powered Carriers and Submarines[a]	2	8	9	6	7	5	4	5
Other Items	6	9	5	6	5	3	3	4
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Congressional Budget Office.

Note: Costs exclude funds for refueling nuclear-powered aircraft carriers and for ship conversions, construction of ships that are not part of the Navy's battle force (such as oceanographic survey ships) and training ships, outfitting and postdelivery (including the purchase of smaller tools and pieces of equipment that are needed to operate a ship but not necessarily provided by the manufacturing shipyard as part of ship construction), and smaller items. Costs for the mission packages for littoral combat ships, which are not funded in the Navy's shipbuilding accounts, also are excluded.

a. CBO's estimates under the Navy's 2016 plan reflect only the costs of refueling aircraft carriers. Historically, the refueling of nuclear-powered submarines also was included in the Navy's shipbuilding accounts, but in 2010, the Navy transferred that funding to other accounts.

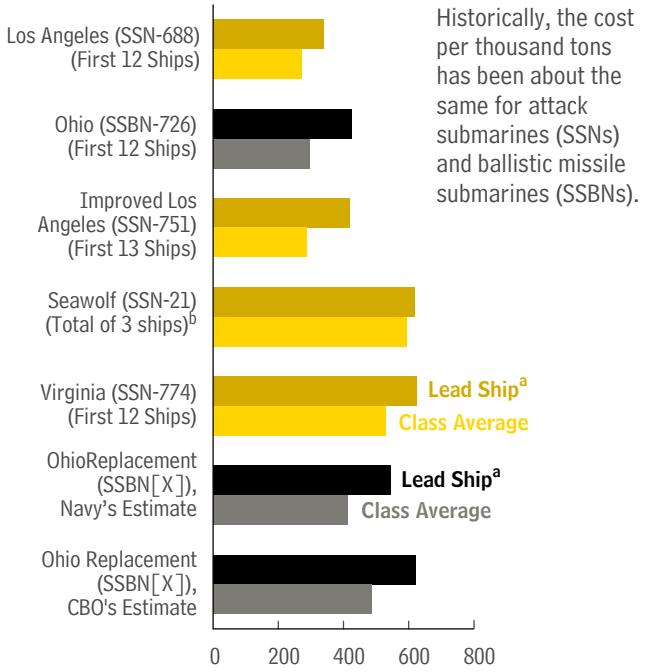
The first Ohio class submarine was more expensive than the lead ships of the two classes of attack submarines built during the same period—the Los Angeles and the Improved Los Angeles. (The design of the Improved Los Angeles included the addition of 12 vertical launch system cells.) In addition, the average cost by weight of the first 12 or 13 ships of the Ohio, Los Angeles, and Improved Los Angeles classes was virtually identical. By the 1990s, the cost of lead ships for submarines had grown substantially. The first Virginia class submarine, which was ordered in 1998, cost about the same per thousand tons as the first Seawolf submarine, even though the Seawolf is 20 percent larger and was built nine years earlier.

Using data from the Virginia class submarine program, CBO estimates that the first Ohio Replacement submarine will cost $13.2 billion in 2015 dollars. Estimating

Figure 9.

Cost per Thousand Tons for Various Classes of Submarine, Lead Ship and Class Average

Millions of 2015 Dollars



Source: Congressional Budget Office based on data from the Department of the Navy.

Notes: Cost per thousand tons of Condition A-1 weight, which is analogous to lightship displacement (the weight of the ship without its crew, materiel, weapons, fuel, or other liquids) for surface ships.

SSBN = ballistic missile submarine; SSN = attack submarine.

a. Data exclude costs for plans, which include nonrecurring engineering and detail design.

b. Although 29 Seawolf class submarines were planned, only 3 were built.

the cost of the first submarine of a class with an entirely new design is particularly difficult because of uncertainty about how much the Navy will spend on nonrecurring engineering and detail design. All told, 12 Ohio Replacement submarines would cost $88 billion, in CBO's estimation, or an average of $7.3 billion each—$1.1 billion more per submarine than the Navy's estimate. That average includes the $13.2 billion estimated cost of the lead submarine and a $6.8 billion average estimated cost for the 2nd through 12th submarines. Research and development would cost between $10 billion and $15 billion, for a total program cost of $98 billion to $103 billion, CBO estimates.

Overall, the Navy expects a 22 percent improvement in the cost-to-weight relationship of the Ohio Replacement class compared with the first 12 submarines in the Virginia class. Given the history of submarine construction, however, CBO is less optimistic that the Navy will realize as large an improvement in the cost-to-weight relationship of the Ohio Replacement class compared with the Virginia class. CBO estimates a 9 percent improvement, based in part on projected savings attributable to the concurrent production of the Ohio Replacement and Virginia class submarines.

As the Navy develops its acquisition strategy, costs for the Ohio Replacement could decline. For example, if lawmakers authorized and the Navy used a block-buy strategy to purchase a group of submarines over a specified period (effectively promising a steady stream of work for the shipyard to achieve better prices for those submarines, as it does for some other ship types)—and if that action also authorized the Navy to purchase submarines' components and materials in batches—the savings could be considerable.[23] Similarly, if the Congress funded the purchase of the Ohio Replacement submarines through the National Sea-Based Deterrence Fund, which was established in the fiscal year 2015 National Defense Authorization Act, the Navy could potentially save several hundred million dollars per submarine by purchasing components and materials for several submarines at the same time.[24] A disadvantage of that acquisition strategy is that if the Congress decided not to build all of the submarines for which the Navy purchased some materials, those materials might go unused.

Attack Submarines. The 2016 shipbuilding plan calls for the Navy to buy 26 Virginia class attack submarines. Between 2016 and 2033, those purchases would occur at a rate of 1 or 2 per year. In 2034, the Navy would switch to an improved Virginia class submarine but continue to build at the same rate. With such a procurement

23. More information on block-buy and multiyear procurement authority acquisition strategies is in Ronald O'Rourke and Moshe Schwartz, *Multiyear Procurement (MYP) and Block Buy Contracting in Defense Acquisition: Background and Issues for Congress,* Report to Congress R41909 (Congressional Research Service, September 24, 2015).

24. That fund, like the National Sealift Defense Fund, would probably operate outside of many of DoD's acquisition regulations but it would allow the Navy to make a single purchase of components and materials for a group of submarines. The potential cost savings are not included in either the Navy's or CBO's estimates.

schedule, the attack submarine force would remain at or above the Navy's goal of 48 submarines through 2024 but would then fall to 41 to 47 submarines for the 2025–2041 period before reaching or exceeding 48 submarines again beginning in 2042—seven years later than under the 2015 plan (see Figure 4 on page 10).

For the entirety of the Virginia class under the 2016 shipbuilding plan, the Navy's and CBO's estimates are quite similar: The Navy estimates that the total cost of purchasing 26 of the submarines between 2016 and 2033 would be about $74 billion; CBO estimates that cost to be $76 billion.

The Navy expects to begin purchasing the Improved Virginia class submarine in 2034. The service's recent shipbuilding plans call for continuous changes to the current design to create a new class of submarine that incorporates significant technological upgrades in systems and capabilities. CBO assumed as well that the Improved Virginias would incorporate changes that were sufficient to make the submarines a new class, although not with a wholly new design. On the basis of that assumption, both CBO and the Navy estimate that the average Improved Virginia class attack submarine would cost $3.1 billion.

Although the Navy's plan does not include submarines to replace the 4 existing Ohio class guided missile submarines when they are retired in the 2020s, the service expects to lengthen the hull of future Virginia class submarines to insert the Virginia payload module (VPM). The VPM would contain four large-diameter payload tubes, each of which could carry seven Tomahawk missiles. That change would increase the submerged displacement of the submarine—the weight of the water it displaces—by nearly 30 percent and would increase the number of the Virginia class submarine's vertical-launch weapons from 12 to 40 (in addition to the approximately 25 weapons in the torpedo room). The Navy estimates that 20 Virginia class submarines equipped with the additional payload modules would provide a "near equivalent" to the strike capability of the existing force of 4 SSGNs. In his 2016 budget, the President proposed spending $700 million between 2015 and 2019 for research and development on the VPM and for modifying the design of the Virginia class submarine. The Navy's 2016 plan calls for building only 15 Virginias with the VPM, beginning in 2019. (The 2015 plan had 20 Virginias with the VPM.) Both the Navy's and CBO's estimates of costs reflect that change. Neither the Navy nor CBO assumes that the Improved Virginia class will include the missile module.

Large Surface Combatants

The Navy's 2016 plan incorporates the purchase of the same types of destroyers as the 2015 plan. The service restarted production of DDG-51 Flight IIA destroyers in 2010 and purchased 10 ships through 2015 (in addition to the 62 ships that had already been purchased when production ceased in 2005). The Navy plans to purchase 1 more DDG-51 Flight IIA in 2016. Beginning in 2016 and continuing through 2029, the Navy plans to purchase 27 DDG-51s with an upgraded design, a configuration known as Flight III (see Table 5 on page 22). In 2030, the Navy would start buying 37 DDG(X)s, a not-yet-designed destroyer intended to replace the DDG-51 class.

The Navy also is pursuing two other strategies to boost its inventory of large surface combatants. One is to modernize 11 of its 22 Ticonderoga class cruisers and thereby extend their service in the fleet through 2038. (The other 11 would remain in the fleet through the end of their service life but would not require as much modernization to remain effective.) If the Navy does not modernize those ships, all of its cruisers would be retired by 2028. The other critical strategy is to keep all DDG-51 Flight IIAs and subsequent destroyers serving in the fleet for 40 years. The class originally was designed to serve for 30 years, but the Navy has gradually increased the planned service life—first to 35 years and then, in the 2009 shipbuilding plan, to 40 years—of Flight IIA and Flight III ships. However, 12 of the last 13 classes of destroyers and cruisers have been retired after serving for 30 years or less. Indeed, in recent years, Spruance class destroyers and some Ticonderoga class cruisers have been retired after serving 25 years or less. The Navy retired all of those ships for various reasons: They had reached the end of their useful service life, they became too expensive to maintain toward the end of their service life, or they no longer had the combat capabilities needed to meet existing threats and modernization was not considered cost-effective.[25] If the DDG-51 class met the same fate, additional ship purchases would be needed to achieve the Navy's inventory goal.

Taken together, the intended ship purchases, cruiser modernization, and extended service life for destroyers would allow the Navy to meet or exceed its inventory

25. See the testimony of Eric J. Labs, Senior Analyst, Congressional Budget Office, before the Subcommittee on Seapower and Expeditionary Forces of the House Committee on Armed Services, *The Navy's Surface Combatant Programs* (July 31, 2008), www.cbo.gov/publication/20065.

goal of 88 large surface combatants through 2033; although it would fall 6 ships short in the following decade (see Figure 4 on page 10).

DDG-51 Flight IIA Destroyers. The Navy's existing force of 62 DDG-51 destroyers was built in three primary configurations. The first 28 ships, designated Flight I or II, did not include hangars for embarking helicopters, which are important in countering enemy submarines and attacks by small boats, along with other missions. The next 34, designated Flight IIA, were equipped with hangars that could carry two helicopters or several ship-launched unmanned aerial vehicles.[26] In the Navy's 2016 plan, 1 new DDG-51, purchased in 2016 (in addition to 10 that were purchased between 2010 and 2015 but that are not yet in the fleet), would use the Flight IIA configuration but also incorporate the latest ballistic missile defense capabilities.[27]

DDG-51 Flight III Destroyers. The Navy's strategy for meeting the combatant commanders' goal that future ballistic missile defense capabilities exceed those provided by existing DDG-51s—and for replacing 11 Ticonderoga class cruisers when they are retired in the 2020s—is to substantially modify the design of the DDG-51 Flight IIA destroyer, creating a Flight III configuration.[28] That change would incorporate the new Air and Missile Defense Radar (AMDR), now under development, which will be larger and more capable than the radar on current DDG-51s. The effective operation of the AMDR in the new Flight III configuration, however, will require an increase in the ships' capacity to generate electrical power and their ability to cool major systems.[29]

With those changes and associated increases in the ships' displacement, CBO expects that the average cost per ship over the entire production run would be $1.9 billion in 2015 dollars, or about 15 percent more than the Navy's estimate of $1.7 billion. Costs could be higher or lower than CBO's estimate, however, depending on the eventual cost and complexity of the AMDR and the associated changes in the ship's design to integrate the new radar.

DDG(X) Future Guided Missile Destroyers. Like the Navy's 2015 shipbuilding plan, the current plan includes a future class of destroyers that is intended to replace the DDG-51 Flight I and II ships when they are retired in the late 2020s and 2030s.[30] The Navy's 2016 plan described the ship as a "mid-sized future surface combatant," but it does not provide further specification.[31] CBO has adopted a generic DDG(X) designation, implying an unknown design.

Under the 2016 plan, production of the DDG(X) would start in 2030, which would make that ship a successor to the DDG-51 Flight III. The Navy says that it would buy 37 DDG(X)s at an average cost of $1.8 billion, or about $100 million more than the cost of DDG-51 Flight III ships. Those estimates imply that the DDG(X)'s capabilities would represent a modest improvement over the DDG-51 Flight III or, if capabilities were significantly improved, that the DDG(X) would be smaller than the DDG-51 Flight III.

CBO expects that the DDG(X) will have a largely new design but will be about the same size as the DDG-51 Flight III, which would be consistent with the concept of

26. For a detailed discussion of the differences between the DDG-51 flights, see Norman Polmar, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet,* 19th ed. (Naval Institute Press, 2013), pp. 140–145.

27. The Navy has announced that eventually all existing DDG-51s will have improved ballistic missile defense capabilities. As of the end of fiscal year 2015, those improvements were funded for up to 35 destroyers. More discussion is in Ronald O'Rourke, *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress,* Report for Congress RL32109 (Congressional Research Service, September 22, 2015).

28. Combatant commanders—the four-star generals or admirals who head the regional commands—oversee all U.S. military operations within their areas of geographic responsibility.

29. More information is in Ronald O'Rourke, *Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress,* Report for Congress RL33745 (Congressional Research Service, September 25, 2015), and *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress,* Report for Congress RL32109 (Congressional Research Service, September 22, 2015). Press reports indicate that some Navy officials do not agree with the DDG-51 Flight III strategy and would prefer to build Flight IIAs a little longer while designing an entirely new destroyer that would allow for new, more capable, potentially larger weapons and increased capabilities in the future. See Christopher P. Cavas, "U.S. Navy Weighs Halving LCS Order," *Defense News* (March 17, 2013), http://tinyurl.com/kbey7qp.

30. Those retirement dates are based on the Navy's assumption that all DDG-51 Flight IIAs will be modernized midway through their 40-year service life.

31. Department of the Navy, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2016* (March 2015), http://tinyurl.com/ocrqtfc.This description did not appear in previous shipbuilding plans.

a large surface combatant. CBO projects the average cost of the DDG(X) at $2.3 billion, roughly 30 percent more than the Navy's projection. Over the 2016–2045 period, CBO estimates, the Navy would have to spend $85 billion for the DDG(X) portion of the shipbuilding program—$17 billion more than the Navy's estimate of $68 billion. That amount represents almost one-third of the overall difference of $58 billion between the Navy's and CBO's estimates of the cost of the 2016 shipbuilding plan as a whole (see Appendix B). The great uncertainty about the ultimate size and capabilities of the DDG(X) suggests that the true cost could be substantially different from either the Navy's or CBO's estimate.

Littoral Combat Ships and Fast Frigates

Under the 2016 plan, the Navy envisions building a force of 52 small surface combatants consisting of littoral combat ships and improved LCSs—the latter designated as fast frigates—by 2025. The first LCS was authorized in 2005, and the Navy already has 23 either in its fleet or under construction—split nearly evenly between the two designs built by two contractors. Because those ships are assumed to have a service life of 25 years, the Navy would need to begin procuring their replacements in 2030. Therefore, the Navy plans to purchase 9 more LCSs through 2018 and then 20 fast frigates between 2019 and 2025 to complete its initial force of 52 ships. In 2030, the Navy would begin purchasing 38 next-generation ships, called LCS(X)s, to replace the first-generation LCSs as they retire. The Navy's plan does not indicate a replacement for the fast frigate, although the purchase schedule for the first generation suggests that the last 6 of those LCS(X)s should be replacements for the fast frigates.

The LCS differs from past and present U.S. warships in that its production program is divided into two components—the sea frame (the ship itself) and mission packages (the main combat systems). The sea frame is being designed and built so that mission packages can be switched onto or off of a given ship over time as the ship's mission changes. Currently, the Navy expects to use three types of mission package—one each for countering mines, submarines, and fast-moving small boats. It also expects that the LCS will be able to perform maritime security operations (such as sanctions enforcement, counterpiracy operations, and engagement with friendly navies) while equipped with any of those mission packages. In all, by 2025 the service plans to buy 64 mission packages for the 52 ships.[32] The Navy has not announced the anticipated effects of restructuring the program into its LCS and fast frigate components on the number or type of mission packages that it plans to purchase. In time, the Navy may also develop and purchase other types of mission packages.[33]

In the 2016 FYDP, the Navy estimates an average cost of about $437 million (in 2015 dollars) per LCS over the next three years. That figure is well below the cost cap of $515 million per ship (adjusted for inflation to 2015 dollars) that the Congress set for the LCS program.[34] The Navy estimates the average cost of the fast frigates at $590 million each, although the ships' final design and capabilities have not been determined. CBO estimates the cost of the fast frigates at $610 million per ship.

Under the 2016 plan, the Navy also would purchase 38 LCS(X)s beginning in 2030. Both the Navy and CBO assumed that the LCS(X)s would have a design similar to that of the LCSs being built today rather than that of the improved LCSs that are designated as fast frigates. The Navy's cost estimate for an LCS(X) is $441 million, essentially the same as the current cost of LCSs. CBO estimates that the average cost of the LCS(X) would be higher, about $516 million per ship, largely reflecting the real cost growth in the shipbuilding industry. However, if the LCS(X) was built to meet or exceed the capabilities of the fast frigate, it would cost more than either the Navy or CBO now estimate.

Amphibious Warfare Ships

The Navy's inventory goal for amphibious warfare ships is 34. That proposed force would consist of 11 LHA or LHD amphibious assault ships, 12 LPD amphibious transport docks, and 11 replacements for the Navy's LSD dock landing ships. The 2016 plan calls for buying 7 LHA-6s, at a rate of 1 every four or seven years, to

32. The Navy presumably will reduce the number of mission modules it purchases for the LCS, but it had not done so by the time of the President's 2016 budget submission.

33. More detail is in Ronald O'Rourke, *Navy Littoral Combat Ship (LCS)/Frigate Program: Background and Issues for Congress*, Report for Congress RL33741 (Congressional Research Service, September 23, 2015).

34. The 2010 National Defense Authorization Act, which set the LCS cost cap for ships purchased in or after fiscal year 2010, permits the Secretary of the Navy to waive compliance with the cap if doing so is considered in "the best interest of the United States," if the ship is "affordable, within the context of the annual naval vessel construction plan," or in other specific circumstances.

replace LHD-1 class amphibious assault ships as they are retired.[35] The plan calls for the purchase of 11 LX(R)s (the replacement for LSDs), the first in 2020, and then 1 per year between 2022 and 2031 to replace existing dock landing ships in the LSD-41 and LSD-49 classes. Under the 2016 plan, the LX(R) would be completed three years earlier than under the 2015 plan. Under the 2016 plan, the Navy also would start replacing the LPD-17 class with a new class, buying 4 ships between 2040 and 2045.

The Navy intends to keep the existing class of LHD-1 amphibious assault ships in service for 43 to 45 years. That expectation, which was stated in the three most recent shipbuilding plans, differs from the 40-year service life identified in the 2012 plan, which is the expected service life the Navy uses for amphibious warfare ships generally. With the procurement schedule and service life as described in the 2016 plan, the number of amphibious warfare ships would be at or above the goal of 34 for about two-thirds of the 30-year period covered by the plan (see Figure 4 on page 10). After 2016, the number of such ships would never fall short of the goal by more than 2 ships.

The Navy estimates that the LHA-6 class amphibious assault ships will cost $3.7 billion each. CBO's estimate is slightly higher at $3.9 billion. Both CBO and the Navy assumed that the LHA-6 class ship authorized for 2017 and all subsequent amphibious assault ships would include well decks—necessitating some redesign of the LHA-6 class and therefore additional costs. (A well deck is a large floodable area in the stern of an amphibious warfare ship that allows direct launching of amphibious vehicles and craft.) The costs are included in the estimates both of the Navy and of CBO.

35. There is a seven-year gap between a purchase in 2017 and the next one, in 2024. After that, however, ships in the LHA class are to be purchased at the rate of 1 every four years.

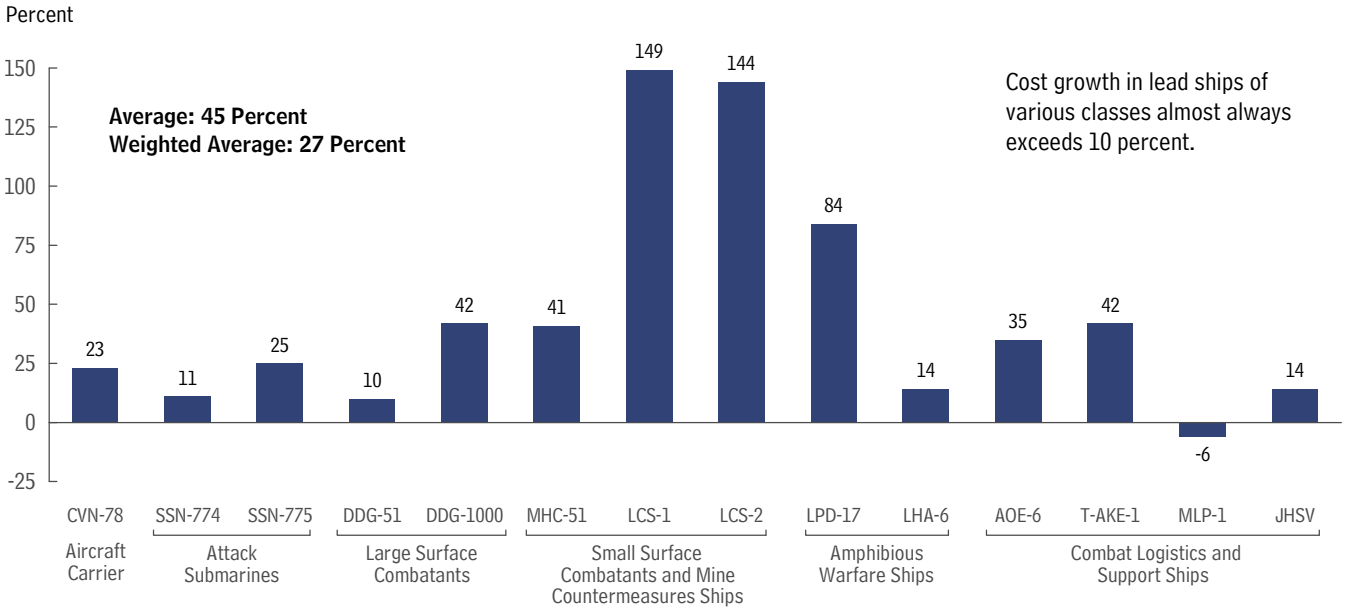
The Navy estimates an average cost of $1.5 billion per ship for the LX(R); the first of the class is expected to cost about $1.6 billion. The design of the LX(R) is to be based on the hull of the LPD-17, which is much larger than existing LSDs. An LPD-17 ordered today would cost about $2.1 billion. Thus, the Navy's estimate for the first ship of the class appears optimistic in light of cost growth in lead ships over the past 30 years (see Figure 10). To achieve its cost goal for the LX(R), the Navy plans to alter the design of those ships and change the manner in which it buys them. First, the LX(R) variant of the LPD-17 would need to have substantially less capability than the LPD-17 class. Second, the Navy plans to use a competitive process for procurement, which would probably include asking the Congress to give it multiyear authority or block-buy authority to purchase ships—or at least their materials—in batches of 5 to 10.[36] Such authority would be similar to that provided for the Arleigh Burke class destroyers, Virginia class attack submarines, and LCSs. The shipyards competing to build the LX(R) would almost certainly incorporate the benefits of such contracts into their bids.

On the basis of the limited information available, CBO estimates the cost of the LX(R) at $1.9 billion per ship, on average. The agency used the existing LPD-17 hull as the starting point for its estimate and then adjusted the ship's size to reflect the reduced capability it expects for the LX(R). CBO's estimate also accounts for the use of multiyear or block-buy procurement authority in a potentially competitive environment.

36. Although multiyear procurement and block-buy authority are broadly similar as acquisition strategies, block-buy authority is not regulated in statute, is more flexible in that there is less oversight by the Congress, and is less likely to carry cancellation penalties. Multiyear procurement authority allows the Navy to buy materials in large quantities for the ships covered under a given contract. Block-buy authority would require separate authorization to purchase materials for more than one ship at a time. That authority is called authorizing economic order quantity.

Figure 10.

Cost Growth in Lead Ships, 1985 to 2015



Source: Congressional Budget Office based on data from the Department of the Navy.

Notes: For most ships, CBO calculated cost growth using the first and last mentions of a ship in the books that accompany each year's budget: *Justification of Estimates, Shipbuilding and Conversion, Navy.* For AOE-6, MHC-51, JHSV, and DDG-51, CBO relied on Navy information papers provided to CBO for the final estimates and the Budget Appendixes for the years those ships were authorized.

AOE = fast combat support ship; CVN = nuclear-powered aircraft carrier; DDG = guided missile destroyer; JHSV = joint high speed vessel; LCS = littoral combat ship; LHA = amphibious assault ship; LPD = amphibious transport dock; MHC = coastal mine hunter; MLP = mobile landing platform; SSN = attack submarine; T-AKE = ammunition cargo ship.

Appendix A: How CBO Estimates the Cost of New Ships

For this report, the Congressional Budget Office projected the costs of the Navy's proposed new-ship purchases by first analyzing the cost per thousand tons for analogous, previously built ships. The resulting figures were then adjusted to account for the percentage of the cost attributable to *rate*, the production efficiencies that are made possible when several ships of the same type are built at a given shipyard, and those that arise from *learning*, the gains in efficiency that accrue over the duration of a ship's production as shipyard workers gain familiarity with a particular ship model. CBO also accounted for the effect of the Navy's acquisition strategy for purchasing new ships, specifically, whether the service can reduce spending by purchasing in quantity. Last, CBO's estimates (all in constant 2015 dollars) incorporated the assumption that growth in the costs of labor and materials for the shipbuilding industry would continue to outpace that in the economy as a whole, as has been the case for the past several decades.

Projecting the Size of Future Ships

To estimate the cost of a future ship, CBO first uses data from the Navy to estimate the ship's size, which traditionally is measured as displacement—the weight of the water it displaces. At this step, CBO determines the size by *full-load displacement* for surface ships and by *submerged displacement* for submarines; that is, the weight displaced by the ships with their contents—crew, stores, ammunition, fuel, and other liquids. If such data are not available (perhaps because the ship is projected to be built in 20 years and the Navy does not specify ship designs that far in advance), CBO makes its estimate based on the sizes of existing ships of the same type that perform the same missions.

For example, the Navy has described the DDG(X), a guided missile destroyer, as a future "midsized" surface combatant, although it has not yet designed the ship. The Navy estimates that the cost of a DDG(X) will be close to that of a large surface combatant—in this case, a modified version of the DDG-51 Flight III destroyer. A fully loaded midsized surface combatant displaces between 6,000 and 9,000 tons; a large surface combatant in the Navy today displaces 9,000 to 10,000 tons. (The new Zumwalt class DDG-1000 destroyers will displace 15,000 tons once completed.) CBO's estimate of the cost of the DDG(X) incorporates an assumption that, like current the DDG-51 Flight III, the new ship would displace 10,000 tons. Once the full size of the ship is determined, CBO estimates the *lightship displacement* for surface ships or the *A-1 weight* for submarines—both reasonable measures of the weight of the mostly empty vessel—without a crew, stores, ammunition, fuel, or other liquids.

The Relationship Between Weight and Cost

After estimating a ship's size, CBO calculates the cost per thousand tons, using historical data from an analogous class of ship (see Table A-1). A primary advantage of CBO's use of analogous ships and cost-to-weight comparisons in the development of estimates is that doing so is more straightforward than projecting costs on the basis of supposition; similar ships have already been built and their cost-to-weight ratios are already documented. The primary disadvantage of this approach is that, because the data are historical, they will not capture potential improvements in manufacturing or other efficiencies that come with new approaches to manufacturing or changes in technology that could lower a ship's cost per ton. (However, that disadvantage may not have much practical effect: CBO has not identified any examples of new-generation ships that proved to be less expensive per ton than earlier ships of the same type.) Another disadvantage

Table A-1.

Ship Analogues for Estimating Cost-to-Weight Relationships

	Ship Class
Aircraft Carriers	Ford (CVN-78)
Ballistic Missile Submarines	Virginia (SSN-774)
Attack Submarines	Virginia (SSN-774)
Large Surface Combatants	Arleigh Burke (DDG-51)
Small Surface Combatants	Freedom (LCS-1) Independence (LCS-2)
Large Amphibious Ships	America (LHA-6)
Small Amphibious Ships	San Antonio (LPD-17)

Source: Congressional Budget Office.

is that sometimes there is no good historical analogue, recent or distant, to use as the basis of a cost projection for a new ship with an innovative design. In rare instances, CBO may start with the Navy's estimate and then apply a more generic factor for the likely increase in cost above the amount in the Navy's current plan. The object is to track cost growth as the shipbuilding program evolves; such factors are derived empirically from historical data.[1]

As a rule, CBO tries to find the most comparable recent ship as a model for its cost-to-weight estimates. It would not be appropriate or useful to use an aircraft carrier as the analogue for a submarine: They are different vessels with different missions and designs, and so their cost-to-weight ratios are not comparable.

1. Several researchers have examined the historical cost growth of weapon systems. See, for example, David L. McNicol and Linda Wu, *Evidence on the Effect of DoD Acquisition Policy and Process on Cost Growth of Major Defense Acquisition Programs*, IDA Paper P-5126 (Institute for Defense Analyses, 2014), www.acq.osd.mil/parca/docs/ida-p5126.pdf (826 KB); Obaid Younossi and others, *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of Completed and Ongoing Programs* (prepared by the RAND Corporation for the United States Air Force, 2007), www.rand.org/pubs/monographs/MG588.html; and Mark V. Arena and others, *Historical Cost Growth of Completed Weapon System Programs* (prepared by the RAND Corporation for the United States Air Force, 2006), www.rand.org/pubs/technical_reports/TR343.html.

For example, CBO identified the current Virginia class submarine as the most logical analogue for a new ballistic missile submarine. Specifically, CBO used the cost per thousand tons of A-1 weight of the Virginia class submarine to estimate the cost of the SSBN(X)—also often called the Ohio Replacement submarine—as though it would be built in 2015. On the basis of the Navy's estimate that the new submarine would be about two and a half times the size of the current Virginia class submarine, CBO estimated that the total cost of the new vessel would be about two and half times that of a Virginia at this point in the cost-estimating process. The agency did not use the historical cost of the original Ohio class submarine as the basis of its estimate because the Ohio was first built in the 1970s, too long ago to be useful. Even if adjusted for inflation, that basis would yield a cost for the SSBN(X) that is only slightly higher than the Virginia today, despite the large difference in size.

Adjusting for Rate, Learning, and Acquisition Strategy

After establishing its preliminary estimate of how much a new ship would cost in 2015, CBO applied factors associated with rate, learning, and, as appropriate, the Navy's acquisition strategy to the entire proposed shipbuilding program. Although described here separately, those factors are applied simultaneously in the cost-estimating process. The result was an estimate of the cost of building new ships, before accounting for future economic conditions in the industry.

When more than one ship is purchased in a given year, the cost per ship is less than it would be for a single ship, largely because the fixed overhead costs of ship construction at a shipyard would be shared by more ships. That difference is the rate effect: It is less expensive per ship to produce two ships than to build one, and four ships are less expensive to build per ship than two—as long as the shipyard has the production facilities and workforce to accommodate the larger volume of work. Historically, the rate effect varies by ship type. For example, building two attack submarines rather than one in a year reduces the cost of both by 10 percent; for surface combatants, the rate effect is closer to 20 percent.

At the same time, as more ships of the same type are built in sequence, the shipyard learns how to build those ships

more and more efficiently. The cost of the second ship in a production run is less than the first, the fifth ship more so, and the ninth ship is cheaper to build than the fifth. That effect represents the learning curve in production and, based on historical evidence, the slope of that learning curve varies by ship type. In addition, unlike the rate effect, which always provides a reduction in cost when more than one ship is built in the same shipyard, the reduction in cost that comes from learning levels off as more and more ships are built; eventually, learning becomes effectively exhausted. Generally, the effects of the learning curve have the smallest influence of all factors in CBO's methods for estimating shipbuilding costs.

CBO's cost estimates also incorporate the effects of the ship acquisition strategy, when applicable. For example, DDG-51 Arleigh Burke class destroyers are usually purchased under a multiyear procurement contract. Such a contract commits the government to purchase a certain number of ships in exchange for a price that is less than if those ships were purchased under a series of individual contracts because the shipyard can better plan its labor force and its purchases of inputs over a longer period. If the government does not purchase the agreed number of ships in the multiyear contract, it pays a substantial penalty to the shipbuilder.

Adjusting for Cost Growth in the Shipbuilding Industry

In the final step of the process, CBO adjusts the estimate to account for the consistently faster growth in prices paid for labor and materials in the shipbuilding industry than in the rest of the U.S. economy. The earlier part of the process established how much a ship would cost to build today, given current economic conditions and including adjustments for rate, learning, and acquisition strategy. But because the ship will be built in the future, CBO adjusts its constant-dollar estimates for new ships by means of a factor that is derived from the difference between historical inflation in the shipbuilding industry and general inflation in the economy as a whole. CBO regards that difference as real cost growth in the shipbuilding industry. (For more discussion, see Box 2 in the main text.)

An Example: Projecting the Cost of Virginia Class Attack Submarines

Between 2016 and 2033, the Navy plans to purchase 26 Virginia class attack submarines at a rate of 2 per year in most years through 2025 and then 1 per year for the rest of the period. Using the methods described above, CBO estimated a total cost (in 2015 dollars) of $76 billion, or about $3.0 billion per submarine. (The Navy's estimate was slightly lower: $74 billion, or about $2.9 billion each.)

The Virginia class is the closest analogue to the future submarines included in the Navy's current shipbuilding report. The Navy has a lengthy history of Virginia purchases: Production began in 1998; 12 Virginia submarines currently serve in the fleet and 10 more are in various stages of construction. To arrive at its cost projections, CBO started with the actual cost of $6.0 billion for the first Virginia class submarine. CBO then subtracted from that total the $2.3 billion that the Navy spent for nonrecurring engineering and detailed design, because those onetime costs are reflected solely in the expense of building the first submarine; they do not carry over to subsequent vessels.

On the basis of cost data for that lead ship plus another 21 submarines that have been completed or authorized thus far, CBO estimated a learning effect of 95 percent: As successive ships are built, the cost of a ship twice as far in the production sequence is 95 percent that of the ship to which it is being compared. So, for example, costs drop by 5 percent from the second ship to the fourth, by another 5 percent from the fourth to the eighth, and so on. Learning tends to level out because the distance to the next doubling increases; 8 more ships must be built to reach the 16th ship and thus to achieve an additional 5 percent decline in costs. CBO applied the 95 percent learning effect going forward from the 22nd submarine (the one most recently authorized) so that the next 5 percent reduction would occur at the 22nd submarine in the Navy's plan—the 44th in the Virginia class. CBO estimated the cost of that submarine to be $2.9 billion, before applying the rate effect.

At the same time CBO applied the learning effect to the Virginia class estimates, it applied the rate effect where appropriate. When submarines are purchased at a rate of two per year (a practice that began in 2011 and that is anticipated to continue in most years through 2025 under the Navy's plan), the cost per submarine is

reduced by the 10 percent; that reduction is added to the reduction attributable to the learning effect.

In addition, in 2019 the Navy will start including what is called the Virginia payload module in most of its new Virginia class submarines. To account for the cost of redesign, CBO added 10 percent, starting in 2019, to the estimate of the cost for most submarines. The two planned for 2025 would be the 39th and 40th in the class and both would include the new payload module. The position in the production sequence from the 22nd to the 40th is not quite double, so the learning effect was set at 4.3 percent rather than a full 5 percent.[2] Applying both a 4.3 percent learning effect and a 10 percent rate effect to the 40th submarine, CBO arrived at an estimate of $2.8 billion in constant 2015 dollars for that ship.

In the final step, CBO applied a factor to account for the difference between general inflation in the U.S. economy and inflation specific to the shipbuilding industry. That real growth would increase by 13 percent the cost of submarines purchased in 2025. With all of those adjustments, CBO estimates the cost of the 40th submarine to be $3.2 billion.

2. For more discussion on procedures for estimating and applying learning curves see Matthew S. Goldberg and Anduin E. Touw, *Statistical Methods for Learning Curves and Cost Analysis* (Institute for Operations Research and the Management Sciences, 2003).

Appendix B: The Difference Between the Navy's and CBO's Estimates for the Cost of New Ships

Each year, the Navy provides estimates of the costs of building each class of ship in its 30-year shipbuilding plan. The Congressional Budget Office also produces annual estimates. Table B-1 compares the two sets of figures for the five most recent 30-year plans.

Table B-1.

Percentage Difference in the Navy's and CBO's Estimates of Shipbuilding Costs, by Program

Percentage of Total Cost Difference

	2012 Plan	2013 Plan	2014 Plan	2015 Plan	2016 Plan
CVN-78 Gerald R. Ford Class Aircraft Carriers	18	13	3	3	9
Ohio Replacement Ballistic Missile Submarines	15	13	12	20	22
Virginia Class Attack Submarines	1	1	-1	3	3
Improved Virginia Class Attack Submarines (Replacements for Virginia class)	3	4	-3	8	2
DDG-51 Arleigh Burke Class Destroyers					
Flight IIA	3	0	0	0	0
Flight III	-7	11	7	11	12
DDG(X) Destroyers (Replacements for Arleigh Burke class)	41	34	58	38	29
Littoral Combat Ships	1	3	4	5	2
Fast Frigates (Modified LCSs)	n.a.	n.a.	n.a.	n.a.	0
LCS(X)s (Replacements for LCSs)	5	4	7	0	5
LHA-6 Amphibious Assault Ships	7	5	5	3	3
LX(R)s (Replacements for amphibious dock landing ships)	5	4	4	5	3
LPD-17 Replacements	n.a.	n.a.	n.a.	n.a.	5
T-AO(X) Oilers	0	0	1	1	3
Other	8	7	4	4	2
Total	**100**	**100**	**100**	**100**	**100**
Memorandum:					
Difference in Billions of Dollars[a]	74	94	76	66	58

Source: Congressional Budget Office.

Notes: Numbers reflect the percentage that each ship program contributes to the total cost difference between CBO's and the Navy's estimates for each plan: Positive values indicate instances in which CBO's estimate is higher; negative values, instances in which the Navy's is higher.

CVN = nuclear-powered aircraft carrier; DDG and DDG(X) = guided missile destroyer; LCS = littoral combat ship; LHA = amphibious assault ship; LPD = amphibious transport dock; LX(R) = dock landing ship replacement; T-AO(X) = oiler; n.a. = not applicable.

a. For each plan, the difference is expressed as a percentage in constant dollars from the preceding year: The value for the 2012 plan is calculated in 2011 dollars; the value for the 2016 plan is calculated in 2015 dollars.

List of Tables and Figures

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About This Document

This testimony reprises the Congressional Budget Office's report, *An Analysis of the Navy's Fiscal Year 2016 Shipbuilding Plan*, which was released on October 29, 2015, and prepared as required by the National Defense Authorization Act for Fiscal Year 2012 (Public Law 112-81). In accordance with CBO's mandate to provide objective, impartial analysis, the report makes no recommendations.

Eric J. Labs of CBO's National Security Division prepared the report with guidance from Matthew Goldberg and David Mosher. Raymond Hall of CBO's Budget Analysis Division produced the cost estimates with guidance from Sarah Jennings. Bernard Kempinski of CBO provided comments on the report, as did independent naval analyst Norman Polmar. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Keith Hall, Jeffrey Kling, John Skeen, and Robert Sunshine reviewed the report; Kate Kelly edited it; Jeanine Rees prepared it for publication; and Bernard Kempinski produced the ship illustrations.

Electronic versions of this testimony and the report are available on CBO's Web site (www.cbo.gov/publication/50981 and www.cbo.gov/publication/50926, respectively).