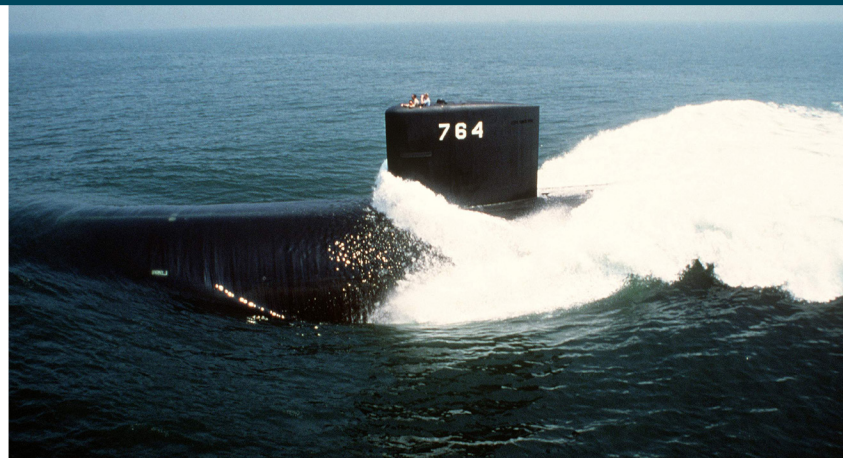




# The Capacity of the Navy's Shipyards to Maintain Its Submarines



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# At a Glance

The Navy's four shipyards have experienced significant delays in completing maintenance on its submarines (all of which are nuclear-powered). In this report, the Congressional Budget Office examines the capacity of those shipyards to maintain the submarines and suggests options to reduce or mitigate delays.

- Two factors have been the primary causes of delays in the Navy's shipyards: The amount of maintenance that shipyards must perform in each overhaul has increased, and the Navy has not hired enough new workers to keep pace with the workload.
- Delays affect operational readiness. They have reduced the number of submarines that the Navy can put to sea, idling expensive ships and their skilled crews.
- CBO's projections of the shipyards' workload and capacity indicate that the submarine fleet's size will exceed the yards' capacity to maintain it, not only over the next several years but in 25 of the next 30 years.
- More accurate maintenance schedules would enable the Navy to better plan deployments by minimizing the disruptive effects of those delays. Or maintenance delays could be reduced by hiring more workers, sending more submarines to private shipyards for maintenance, or cutting the size of the fleet.

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# Contents

<b>Summary</b>	1
What Causes Delays in Maintenance?	1
How Might the Navy Lessen the Effects of Delays or Reduce Delays?	2
What Are the Limitations of This Analysis?	3
<b>Background</b>	3
The Navy’s Policy on Maintenance at Nuclear Shipyards	4
Delays in Maintenance	6
Factors That Have Not Contributed to Delays	7
Plan for Increasing the Size of the Fleet	8
<b>Trends in the Maintenance of Nuclear Ships</b>	10
Virginia Class Submarines	11
Other Classes of Ships	14
<b>CBO’s Projections of Workload and Output</b>	15
CBO’s Projections of Future Maintenance Demand and Shipyards’ Capacity	15
CBO’s Approach	16
Uncertainty About Key Information Used in CBO’s Analysis	17
<b>Policy Options to Mitigate the Effects of Delays or Reduce Delays</b>	18
Option 1: Improve Forecasting	19
Options 2 and 3: Increase Capacity	19
Option 4: Reduce the Size of the Fleet	19
BOX 1. The Navy’s New Shipbuilding Plan	20
Uncertainty About Key Inputs in CBO’s Analysis of Options	20
<b>List of Tables and Figures</b>	22
<b>About This Document</b>	23

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# Notes

Unless this report indicates otherwise, all years referred to are federal fiscal years, which run from October 1 to September 30 and are designated by the calendar year in which they end.

Numbers in the text, tables, and figures may not add up to totals because of rounding.

All costs are expressed in 2020 dollars. To remove the effects of inflation, the Congressional Budget Office adjusted costs using the gross domestic product price index from the Bureau of Economic Analysis.

On the cover (clockwise from left): Navy ships during maintenance at Norfolk Naval Shipyard in Portsmouth, Virginia (photo courtesy of Norfolk Naval Shipyard); the USS *Boise* on sea trials in July 1991 (photo by Mike Dillard of Newport News Shipbuilding, courtesy of the Department of Defense); the USS *Boise* in dry dock at Newport News Shipbuilding, Newport News, Virginia, in August 2020 (photo by Matt Hildreth, courtesy of Huntington Ingalls Industries).

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# The Capacity of the Navy's Shipyards to Maintain Its Submarines

## Summary

The U.S. Navy's 70 submarines represent nearly one-quarter of its total fleet. Like all naval ships, those submarines require several periods of intensive maintenance during their service life. Navy policy dictates that most maintenance on nuclear-powered ships (all U.S. submarines are nuclear-powered) be performed by the four shipyards it owns and operates.

Those four public shipyards have experienced long delays—sometimes as long as several years—in performing maintenance on submarines. For example, after overhauls Virginia class submarines have returned to operations almost nine months later than expected, on average; Los Angeles class submarines have taken four and a half months longer than scheduled, on average, to return to the fleet. As a result, some submarines have missed deployments or had their deployments at sea shortened. The delays have reduced the number of submarines that the Navy can put to sea, idling expensive ships and their skilled crews. In response to those delays, the Navy has sent several submarines to private shipyards for maintenance in recent years, but still performs the vast majority of submarine maintenance at its own shipyards. It has also increased the number of workers at its shipyards and taken steps to improve productivity.

In this report, the Congressional Budget Office finds that maintenance delays will continue despite those changes. Barring other changes, required maintenance is projected to exceed the capacity of the Navy's shipyards in 25 of the next 30 years. This report examines some options for mitigating or reducing future delays.

## What Causes Delays in Maintenance?

Two factors have been the primary causes of delays in the Navy's shipyards: The amount of maintenance that shipyards must perform in each overhaul has increased, and the Navy has not hired enough new workers to keep pace with the workload. Those factors have increased the number of days nuclear ships spend in the shipyard and the number of days of labor that are required to

complete their overhauls. Overhauls have exceeded the number of days of labor scheduled for overhauls by 13 percent to 26 percent, depending on the ship's class (see Figure 1).

Maintenance delays have been most acute for attack submarines because those ships are a lower priority at the shipyards than ballistic missile submarines and aircraft carriers (like the Navy's submarines, all of its aircraft carriers are nuclear-powered). Over the past 12 years, overhauls of attack submarines have typically taken 20 percent to 40 percent longer than planned, both in terms of the number of days of labor required to complete the work and the length of time ships spend in the shipyard.

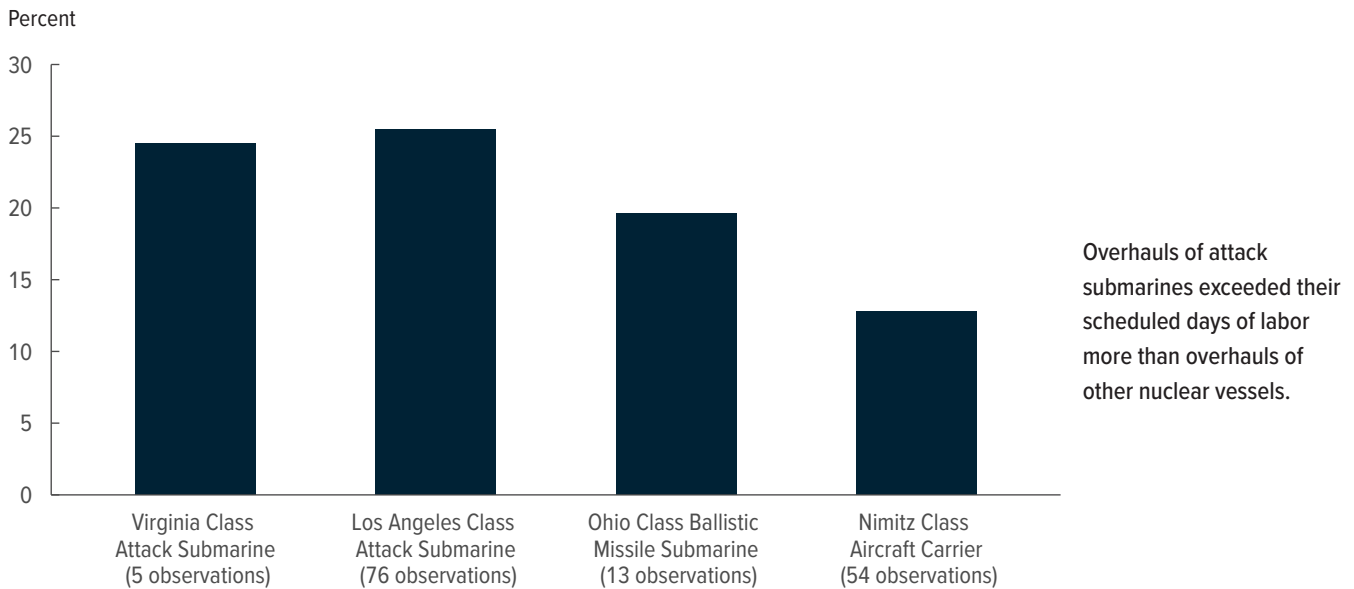
CBO staff visited all four of the Navy's shipyards and interviewed Navy officials regarding the delays. The shipyards and the Naval Sea Systems Command (NAVSEA) reported that a shortage of workers was the primary reason for past delays. A shortage of skilled labor has been a challenge for all shipyards, public and private. The hiring and training process at shipyards is slow: Obtaining security clearances for new workers takes time, and it can take several years to train and apprentice workers. The Navy has increased hiring in recent years, reaching its goal of having about 37,000 workers at the public shipyards. In addition, the Navy is taking steps to improve productivity, including repair and redesign of its shipyards.

Despite the increased number of shipyard workers and the anticipated improvements in productivity, CBO projects that the demand for maintenance over the next few decades will exceed the supply of labor in most years. That is because the Navy's submarines require more days of labor for overhauls than the Navy has planned. As a result, the shipyards will not be able to complete future overhauls on schedule. The 2020–2021 coronavirus pandemic has caused additional delays because it has affected productivity at the shipyards; CBO projects a 5 percent decrease in shipyard productivity in 2020 and 2021 as a result.



Figure 1.

### Average Days of Labor Exceeding the Scheduled Number for Nuclear Ships, 2008 to 2019



Data source: Congressional Budget Office, using data from Naval Sea Systems Command and Department of the Navy, *Budget Materials, Operation and Maintenance Navy (OMN) Volume II Data Book* (various years). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

#### How Might the Navy Lessen the Effects of Delays or Reduce Delays?

CBO examined four policy options that could diminish the effects of delays on the fleet or reduce the delays by better matching the size of the workload facing public shipyards to the supply of labor. Any or all of the options could be combined.

- **Option 1:** Keep the workforce at its current size, but improve the accuracy of maintenance projections and adjust ships' operation schedules accordingly.
- **Option 2:** Increase the workforce at public shipyards from about 37,000 to about 39,500.
- **Option 3:** Shift some maintenance of nuclear ships to private shipyards.
- **Option 4:** Reduce the size of the nuclear fleet.

Option 1 would not speed the completion of maintenance but would lessen the impact of delays by enabling operating forces to better plan deployments around maintenance. The operating forces have goals for the number of attack and ballistic submarines to be deployed at all times.<sup>1</sup> Those deployment goals could be prioritized

1. Details of deployment goals are classified and beyond the scope of this report.

and adjusted further in advance if the actual timing and duration of maintenance conformed more closely to deployment schedules.

Options 2 and 3 would add capacity so that the anticipated demand for maintenance would be equal to capacity, on average, over the next 30 years. Either option would cost about the same amount, CBO estimates.<sup>2</sup> The only difference between them is whether the work would be performed in public or private shipyards.

Option 4 would reduce demand by adjusting the size of the fleet to match the Navy's maintenance capacity. That could be accomplished by retiring older submarines ahead of the current schedule or by purchasing fewer new submarines. The magnitude of savings would depend on how the option was implemented. Savings in maintenance or procurement would be offset, in part, by increases in the costs of disposing of retired ships. Although the submarine fleet would be smaller, the same number of submarines might be available in peacetime because fewer submarines would be awaiting

2. The costs of overhauls at public and private shipyards have been similar in recent years. See Congressional Budget Office, *Costs of Submarine Maintenance at Public and Private Shipyards* (April 2019), [www.cbo.gov/publication/55032](http://www.cbo.gov/publication/55032).

maintenance. However, the Navy's ability to surge its submarine force during wartime would be reduced.

Option 1 should have a very small cost and could benefit the operational fleet's planning. Increasing capacity under Options 2 and 3 would cost about \$275 million per year. Option 4 could save between \$1.6 billion and \$16 billion in procurement costs over 30 years (depending on whether the Navy forgoes refueling existing submarines or purchasing new ones) and \$250 million to \$290 million per year in operating costs.

### What Are the Limitations of This Analysis?

CBO's analysis has several limitations. For example, CBO used recent historical values for the amount of work conducted by shipyard workers that was not part of large scheduled maintenance events, such as less intensive maintenance that could be performed by sailors or unusually large repairs necessitated by accidental or combat damage to ships. If such work in the future is out of line with recent historical values, maintenance delays would be different from those estimated in CBO's analysis. The results of CBO's analysis are also sensitive to a number of factors, including the amount of overtime and the extent of efficiency improvements at the shipyards, the number of days required for overhauls, and the future size of the submarine fleet.

Although CBO estimated the short-term effects of the coronavirus pandemic on shipyards' workers, the estimates are highly uncertain, and the long-term impact on workers' productivity (from prolonged social distancing, for example) and hiring (perhaps from having a larger pool of available workers in a weaker economy) are unknown.<sup>3</sup>

In addition, CBO could not account for the effect of any parts shortages or delays associated with planned dry dock repairs or upgrades. Although the shipyards indicated that the planned dry dock maintenance would not affect their schedules, some of the upgrades require dry docks to be closed for more than a year. Finally, CBO did not account for each submarine's unique operating environment, maintenance history, and

past modernization work because such data were not available.

### Background

The Navy's current fleet consists of 81 nuclear-powered ships (aircraft carriers and submarines) and 219 conventionally powered ships (surface combatants, amphibious ships, combat logistics force, mine warfare ships, and support ships).<sup>4</sup> During their service lives, naval ships require several periods of intensive maintenance. The Navy refers to those large maintenance events as overhauls or availabilities.<sup>5</sup> Overhauls are usually performed at specialized facilities away from where the ships are ordinarily stationed. They involve a prescribed set of procedures (inspections, repairs, and replacement of parts) to keep ships operating safely and effectively until the next maintenance event.

For example, a Los Angeles class attack submarine is expected to undergo significant maintenance (such as a docking selected restricted availability, or DSRA) every four to six years over its 33-year service life; more substantial maintenance (involving major repairs or system upgrades) replaces DSRA about every third time. The Navy expects each DSRA to consume 20,000 to 60,000 days of labor and take several months to complete (actual DSRA often take much longer). The replacement ship for the Los Angeles class, the new Virginia class attack submarine, is expected to undergo a more extensive overhaul known as an extended docking selected restricted availability (EDSRA) about every six years. The Navy estimates that EDSRAs will require 200,000 days of labor (in practice, however, EDSRAs have taken much longer).

3. See Paul McLeary, "Navy Rushes 'Unprecedented' 1,600 Reservists to Shipyards as COVID Guts Workforce," *Breaking Defense* (June 16, 2020), <https://tinyurl.com/y26ulfrj>; and Ronald O'Rourke, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, Report RL32665, version 333 (Congressional Research Service, March 18, 2021), <https://go.usa.gov/xAtj>.

4. See Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (October 2019), [www.cbo.gov/publication/55685](http://www.cbo.gov/publication/55685); and Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2021: Appendix* (February 2020), [www.govinfo.gov/app/collection/budget](http://www.govinfo.gov/app/collection/budget). CBO's analysis was completed before the Navy released a new 30-year shipbuilding plan dated December 9, 2020, that calls for building a much larger attack submarine force than called for in the Navy's fiscal year 2020 plan. The new plan is not formally associated with a fiscal year, although the document implies it is for fiscal year 2022. The new Administration has not yet released its own shipbuilding plan.

5. When used in reference to a maintenance event, the Navy's term *availability* indicates that a ship is available for extended maintenance, not that it is available for use. In fact, a ship undergoing an availability is by definition not operationally available because it could not be used to perform a military mission.

The Navy's policy is to conduct all of the maintenance for its nuclear-powered ships at Navy shipyards using a labor force that works directly for the Navy. The total demand for maintenance at the Navy's shipyards depends upon the size of the fleet as well as the amount of maintenance each ship requires. Meeting that demand requires adequate maintenance budgets and a workforce that is large enough to perform the work in a timely fashion.

Delays occur for a variety of reasons, but primarily they occur when the demand for maintenance exceeds the supply of labor or the capacity of the shipyard infrastructure. Despite a fleet of nuclear ships that has been nearly constant in size for more than a decade, the Navy's shipyards have experienced some significant delays in large part because overhauls have consumed more labor than planned. To meet the growing maintenance demand, the Navy has increased hiring at its shipyards in the past several years but not fast enough to meet demand. CBO found that maintenance budgets have grown in recent years, though apparently not sufficiently to keep pace with increased workload at the shipyards.<sup>6</sup> Despite a larger workforce and larger maintenance budgets, delays at the shipyards persist, and the Navy does not plan to increase the size of the workforce at its shipyards any further.

The Navy's shipyards will face more challenges with delays over the next few decades. The size of the nuclear-powered fleet is expected to grow in the future after falling for the next several years. The number of nuclear-powered ships would shrink from 79 today to 67 in the late 2020s and then grow to 90 by 2050, under the Navy's fiscal year 2020 plan.

### The Navy's Policy on Maintenance at Nuclear Shipyards

All public shipyards and some private shipyards are capable of maintaining the Navy's nuclear-powered fleet. The Navy owns and operates four public shipyards: Norfolk Naval Shipyard in Portsmouth, Virginia; Portsmouth Naval Shipyard in Kittery, Maine; Puget Sound Naval Shipyard in Bremerton, Washington; and Pearl Harbor

Naval Shipyard in Pearl Harbor, Hawaii. Federal civilian employees perform most of the work at those shipyards.

The two private shipyards that build nuclear-powered submarines are also capable of maintaining them: Newport News Shipbuilding in Newport News, Virginia; and General Dynamics-owned Electric Boat in Groton, Connecticut. Newport News Shipbuilding also builds nuclear-powered aircraft carriers.

The total workforce at public shipyards shrank from about 62,000 in 1991 to about 21,000 in 2001 after the Navy reduced the number of public shipyards from eight to four as part of the Base Realignment and Closure process in the 1990s (see Figure 2). The move reflected the fact that a smaller fleet emerged from the defense draw-down of the 1990s at the end of the Cold War.<sup>7</sup> Since then, the workforce has grown, recently reaching the Navy's new goal of about 37,000 employees, a number the Navy plans to maintain.<sup>8</sup> By CBO's estimate, workers in public shipyards account for about 5.5 million days of direct labor (work on a particular ship or component) annually.<sup>9</sup>

The ratio of days of labor to the number of workers rose in the 1990s and has been slowly falling since 2005. The decline could be one reason that delays have increased. However, CBO could not determine what caused the changes in the ratio from the available data. Many factors—some positive and some negative—may influence that ratio. For example, if the shipyard uses more overtime, the ratio will increase (enabling more work to be done but possibly putting more stress on workers). The ratio will also increase if new workers take longer than average to complete a job; in that case, each job will require more hours. If severe weather prevents workers from performing tasks on an overhaul or requires workers to switch from overhauling ships to repairing dry docks, the ratio will decrease.

6. See Bradley Martin and others, *A Strategic Assessment of the Future of U.S. Navy Ship Maintenance: Challenges and Opportunities*, RR-1951 (RAND Corporation, 2017), <https://tinyurl.com/d5jwxrug> (PDF, 3 MB).

7. See Lorna S. Jaffe, *The Development of the Base Force 1989–1992*, Joint History Office, Office of the Chairman of the Joint Chiefs of Staff (July 1993), <https://go.usa.gov/xA3ZH> (PDF, 334 KB).

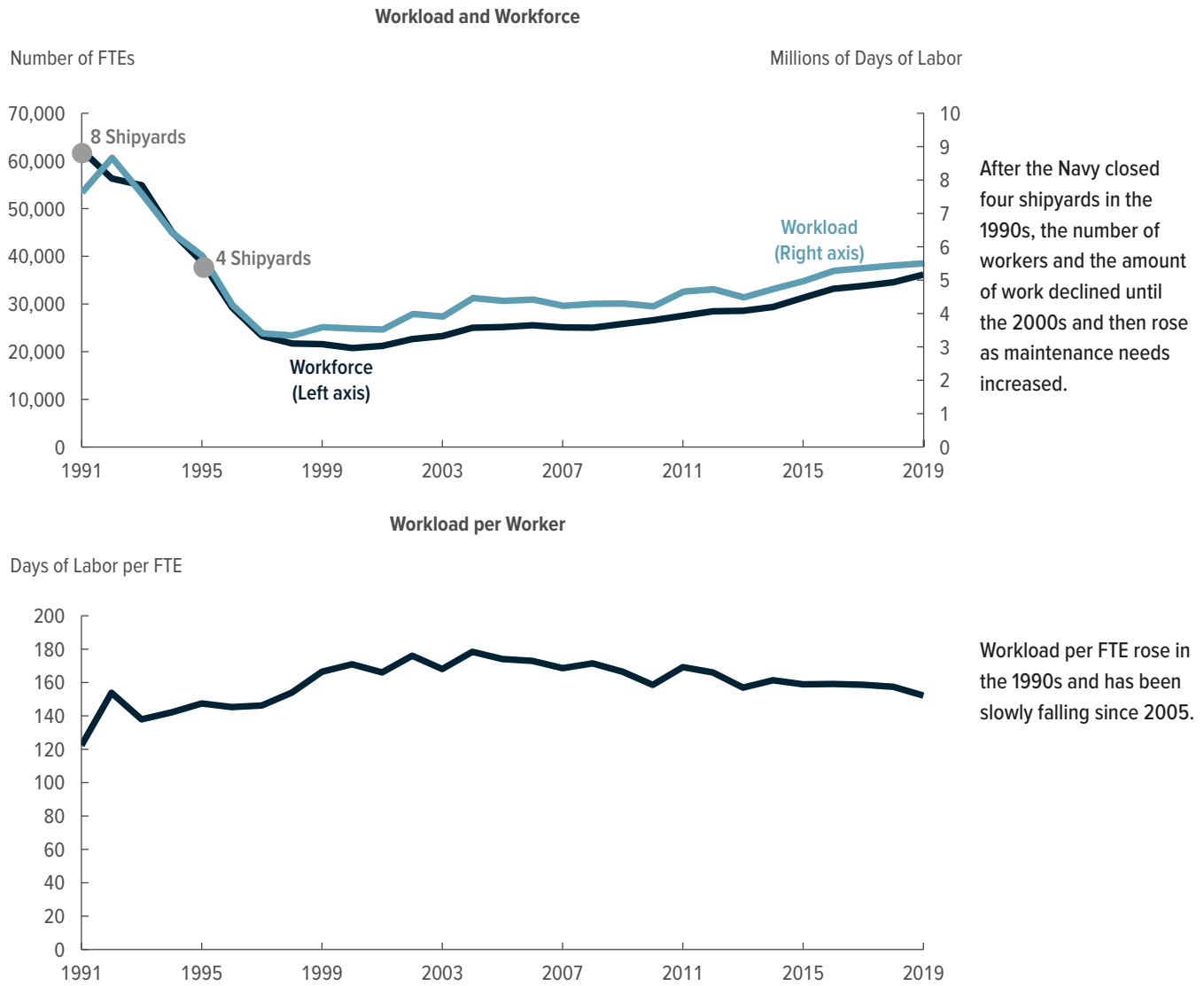
8. Staff of Naval Sea Systems Command, briefing to CBO staff (March 2020).

9. That figure excludes indirect workload (work that is not associated with a specific ship or project) and overhead (management of the shipyard).



Figure 2.

## Workforce and Workload at the Navy's Shipyards



Data source: Congressional Budget Office, using data from Naval Sea Systems Command. See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

The workload is the total number of days of labor required for maintenance events. It excludes indirect work (work that is not associated with a specific ship or project) and overhead (management of the shipyard).

FTE = full-time-equivalent position.

The Navy's policy has been to undertake most maintenance of nuclear-powered ships at its public shipyards and to have private shipyards maintain conventionally powered ships.<sup>10</sup> However, because of delays at the public

shipyards, the Navy has made a few exceptions recently, including for the USS *Boise*, which had been scheduled for work at Norfolk Naval Shipyard in October 2015. Norfolk did not have the capacity to perform that maintenance, so the Navy contracted for it with Newport News Shipbuilding. As a result of the initial delays at

10. Aircraft carriers are an exception to that policy. Although their maintenance work is performed at public shipyards, many private contractors are employed for the portion of the overhaul that does not involve nuclear propulsion. In addition, refuelings of the carriers (refueling is a large, complex maintenance event) are conducted at Newport News Shipbuilding, which is owned by

Huntington Ingalls Industries. For information about submarine maintenance conducted at private shipyards, see Congressional Budget Office, *Costs of Submarine Maintenance at Public and Private Shipyards* (April 2019), [www.cbo.gov/publication/55032](http://www.cbo.gov/publication/55032).



Norfolk and the decision to change yards, the start of maintenance on the *Boise* was delayed by more than three years or about 10 percent of the submarine's service life.<sup>11</sup> One consequence of moving the *Boise* to a private shipyard is that the data available to CBO about the submarine are less detailed and updated less often than for submarine overhauls at Navy shipyards.<sup>12</sup>

### Delays in Maintenance

Delays in maintenance among the Navy's submarine fleets have resulted in the delay or cancellation of some scheduled deployments. Overages as a percentage of the scheduled days and as a percentage of required maintenance hours have been more severe for attack submarines. (One day of overage means that a submarine spent one more day in maintenance than planned and was therefore not available for operations or training.) Submarine Force Atlantic, the command in charge of operating submarines on the East Coast, told CBO this reflects attack submarines' lower priority at the shipyards. If an attack submarine and a ballistic missile submarine need the same workers, the ballistic missile submarine usually receives priority, Navy officials told CBO. The data suggest that maintenance delays have been trending upwards for both types of submarines in recent years (see Figure 3).

Delays have grown despite additional hiring by the shipyards in recent years, indicating that the additional hiring has not yet been adequate. To be sure, some time lag is to be expected because the training process for new workers takes several years. The Navy indicates that

timeliness is improving as a result of new hires and that delays will be shorter in 2021 and beyond. However, CBO has not yet observed such improvements in the Navy's data.<sup>13</sup> The coronavirus pandemic is likely to worsen the situation by reducing the productivity of the workforce in the short term.

**Plans for Infrastructure Improvements.** Although officials from the public shipyards and NAVSEA identified workforce shortages as the primary cause of delays, they also indicated that the condition and capacity of dry docks will be an issue in the future.<sup>14</sup> Some dry docks in poor condition need repair; others need to be enlarged to accommodate new ships such as the Virginia class and Columbia class submarines.

The Navy has created the Shipyard Infrastructure Optimization Program (SIOP) to address the problems with dry docks and other needs associated with public shipyards.<sup>15</sup> The Navy said that SIOP, which will cost about \$21 billion over 20 years (in current dollars), will move some facilities closer to the dry docks as well as add walls and covers to the dry docks to protect ships and allow work to continue in inclement weather.

The Navy expects the improvements made through SIOP to result in a savings of about 328,000 days of labor per year, or about 5 percent (meaning that 5 percent fewer hours of labor will be needed). In projecting shipyard capacity, CBO assumed that SIOP would be implemented and that the Navy's expected efficiency gains would be realized.<sup>16</sup>

**Shortages of Submarine Parts.** The public shipyards also noted that there have been shortages of some parts; such shortages can cause delays and disrupt workflow.

11. The effect on a submarine's service life of significantly delayed overhauls and missed deployments depends on circumstances and may not be known for many years. The Navy typically conducts an engineering analysis toward the end of a ship's service life to determine whether its service can be extended. The loss of service life might therefore be less than the total amount of maintenance delay; thus, the USS *Boise*, for example, may eventually recapture some of the time it has spent waiting for its overhaul to be completed.

12. The Navy publishes data on submarine overhauls by public shipyards in its budget justification books but does not include data for work done at private yards. As a result, data on overhauls by private yards were not available to CBO for this analysis. If the Navy were to increase its reliance on private shipyards, including the cost of such overhauls in future justification books could improve oversight. (Similarly, the Navy does not publish data about overhauls of surface ships by private yards, even though those yards conduct most such overhauls.) See Department of the Navy, *Budget Materials, Operation and Maintenance Navy (OMN) Volume II Data Book* (various years), <https://go.usa.gov/x7wzK>.

13. See David B. Larter, "Is the U.S. Navy Winning the War on Maintenance Delays?" *Defense News* (September 19, 2020), <https://tinyurl.com/y5jaxstt>.

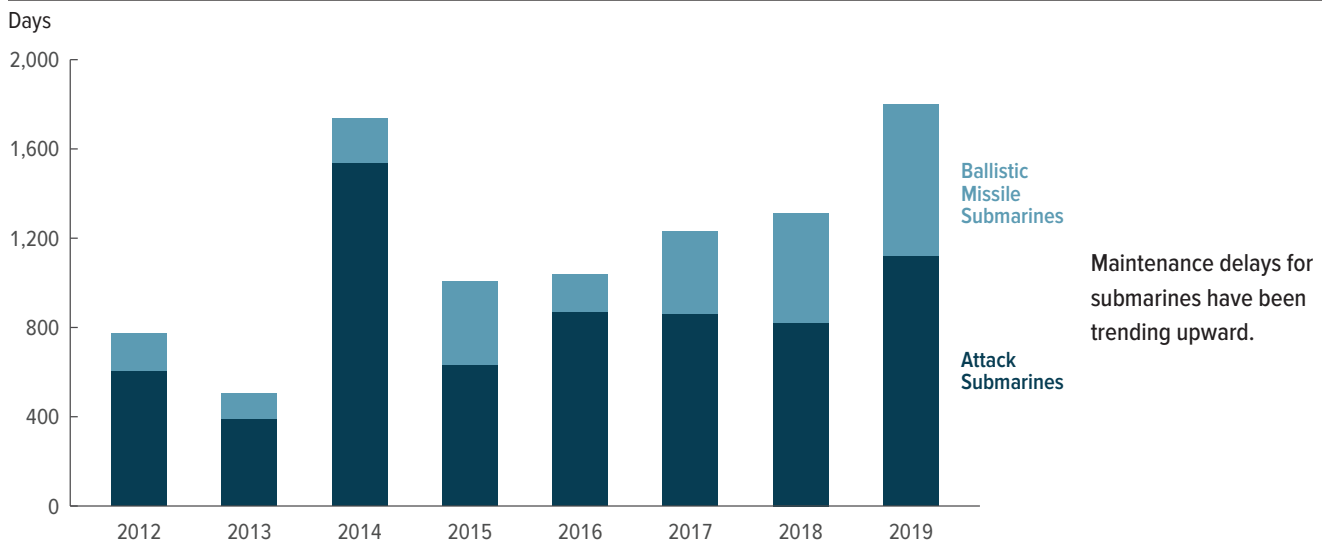
14. See Aidan Quigley, "Wittman Calls for Navy to Act Faster to Address Shipyard Issues," *Inside Defense* (September 30, 2020), <https://tinyurl.com/yy16u2m6>.

15. See Naval Sea Systems Command, "Shipyard Infrastructure Optimization Program" (accessed February 2018), <https://go.usa.gov/x7QKA>.

16. Some experts believe that greater productivity increases are possible as a result of additional investment in shipyard capital, but CBO did not include those possible increases because they are not part of the Navy's plan.

Figure 3.

### Total Length of Maintenance Delays by Type of Submarine



Data source: Submarine Force Atlantic. See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

Maintenance delays for cruise missile submarines are not shown because data on them were not available.

CBO did not have data on the shortages or their effects on maintenance schedules.

If a part is not available, the shipyard can sometimes borrow, or “cannibalize,” a part from another submarine to mitigate the effects of delays. Administrative data from NAVSEA suggest that cannibalization associated with submarine maintenance has increased over the past two years (see Figure 4). Cannibalization typically occurs if one submarine’s maintenance is nearly complete and another submarine has recently entered the shipyard. The shipyard removes the part from the arriving ship and installs it on the departing ship. Cannibalization allows the shipyard to complete maintenance on a ship without having to wait for a part.

A disadvantage of cannibalization is that it increases the workload because extra steps are required to make a spare part available: removal of the part from the donor ship and later installation of a new part for that ship. (Installation of the part on the recipient ship occurs whether or not a spare part is available or cannibalization is required.) There is also a risk that a part might be damaged during the extra steps. The effect of cannibalization is to increase the number of days of labor required, though CBO could not estimate the amount of such an increase.

### Factors That Have Not Contributed to Delays

CBO examined two other factors that might have contributed to delays in maintenance: the Navy’s maintenance budget and its fleet size. The agency found that neither increases in fleet size nor decreases in budgets caused the increasing delays.

Maintenance budgets have actually grown in recent years, although possibly they did not grow enough to keep pace with the growing workload (see Figure 5, upper line in the lower panel). The Navy expects that maintenance funding will continue to increase.<sup>17</sup> The growth in maintenance funding can also be observed for attack submarines, which are already more expensive to maintain than other ships (see Figure 5, lower line in the lower panel). Attack submarines make up about 17 percent of the fleet but receive about one-third of the maintenance budget (that is, they are more costly to maintain than a typical Navy ship).

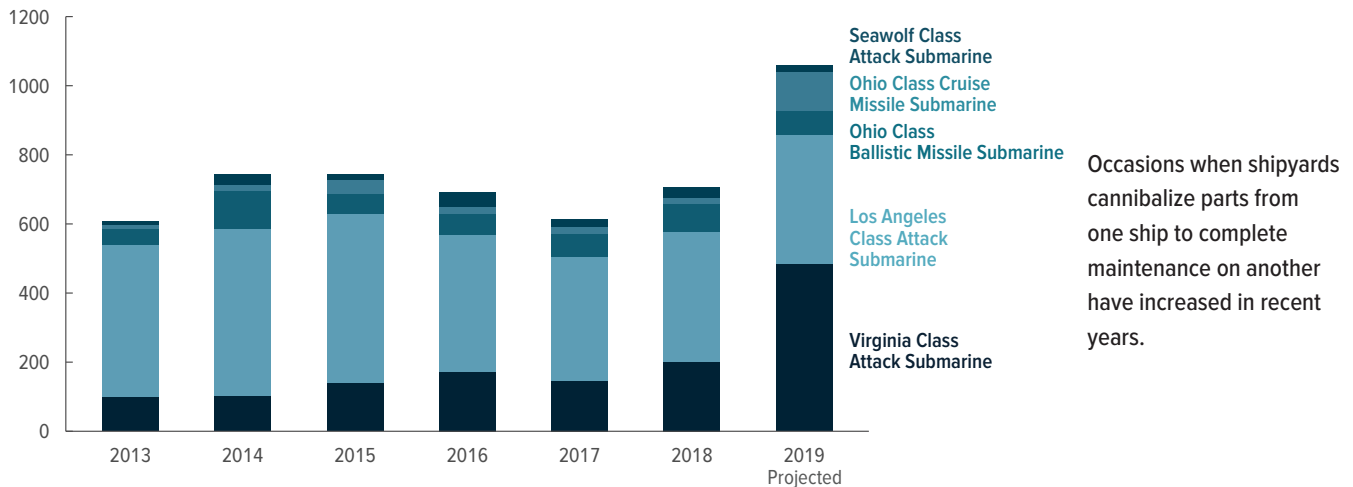
Maintenance delays in recent years were also not caused by a growing submarine fleet. The attack submarine fleet

17. See Naval Sea Systems Command, *Report to Congress on the Long-Range Plan for Maintenance and Modernization of Naval Vessels for Fiscal Year 2020* (March 29, 2019), <https://go.usa.gov/x7PJJa> (PDF, 486 KB).

Figure 4.

## Cannibalization of Parts by Class of Submarine

Number of Parts Cannibalized



Occurrences when shipyards cannibalize parts from one ship to complete maintenance on another have increased in recent years.

Data source: Congressional Budget Office, using data from Naval Sea Systems Command. See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

has become slightly smaller since 2015 (see Figure 5, upper panel).

### Plan for Increasing the Size of the Fleet

The Navy plans to increase the size of its fleet over the next several decades. The submarine force is projected to start to grow again in the late 2020s as more new submarines enter the fleet. Because the demand for maintenance is driven primarily by the size of the fleet, a growing submarine force would increase the demand for maintenance. However, the effect on maintenance in the public shipyards would be limited in the near future, because changes in the size of the submarine force would take many years to achieve.<sup>18</sup>

In the fiscal year 2020 shipbuilding plan, the Navy stated that its goal is to increase the size of its fleet to at least 355 ships from today's 300 ships. In CBO's projections of that plan (and CBO's adjustments to that plan as a result of the Navy's 2021 budget submission), the fleet grows by about 30 ships over the next 30 years (reaching 332 ships in 2050), or 10 percent.

18. See Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (October 2019), [www.cbo.gov/publication/55685](http://www.cbo.gov/publication/55685), and *Costs of Building a 355-Ship Navy* (April 2017), [www.cbo.gov/publication/52632](http://www.cbo.gov/publication/52632); also see Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2021: Appendix* (February 2020), [www.govinfo.gov/app/details/BUDGET-2021-APP/](http://www.govinfo.gov/app/details/BUDGET-2021-APP/).

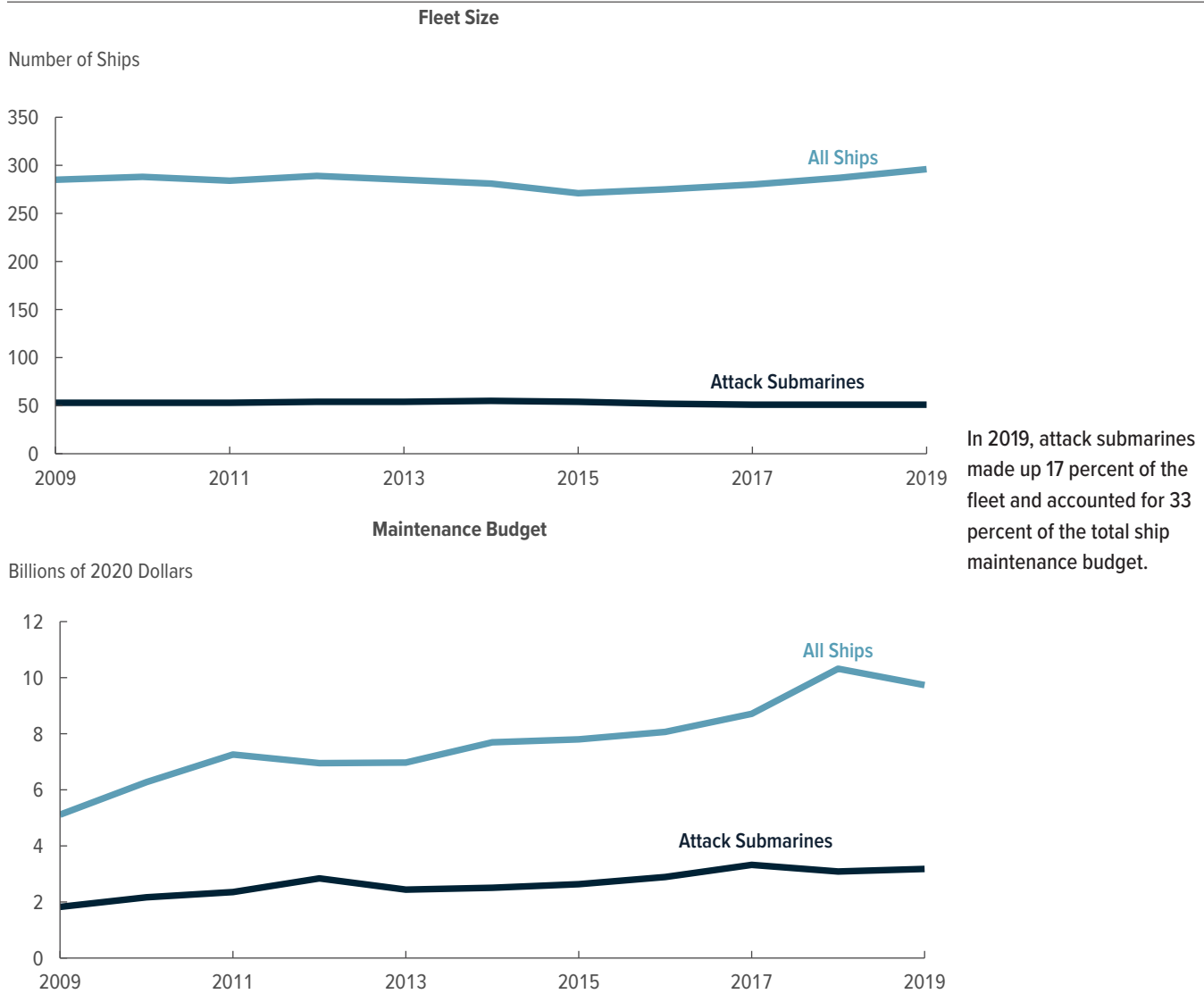
Most of that growth would be in the number of conventionally powered surface combatants (see Figure 6). That growth would thus have little impact on the Navy's shipyards because they only maintain the nuclear portion of the fleet (see Figure 7 on page 11), which under the 2020 plan would decline in size in the 2020s and grow in the 2030s and 2040s. The number of aircraft carriers and ballistic submarines would be about the same in 2050 as today under that plan, but the attack submarine fleet would be about 20 percent larger (see Figure 7 on page 11).

After CBO completed its analysis for this report using the Navy's fiscal year 2020 shipbuilding plan (making adjustments to reflect the 2021 budget submission), the Navy released a new shipbuilding plan on December 9, 2020, in the waning days of the Trump Administration. The new plan aims to expand the fleet to 405 ships by 2050 instead of the 332 ships envisioned in the fiscal year 2020 plan. The number of nuclear-powered aircraft carriers and ballistic missile submarines is about the same in both plans, but the attack submarine force is larger: 80 ships in the new plan compared with 65 in the fiscal year 2020 plan.

Not only would submarine production increase substantially under the new plan, but the Navy would extend the service life of many existing attack submarines, refueling the nuclear reactors of a total of seven ships and

Figure 5.

### Fleet Sizes and Maintenance Budgets



Data sources: Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (October 2019), [www.cbo.gov/publication/55685](http://www.cbo.gov/publication/55685); Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2021: Appendix* (February 2020), [www.govinfo.gov/app/collection/budget](http://www.govinfo.gov/app/collection/budget). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

assuming that the service life of others is longer than the Navy had anticipated. As a result, there would be 50 or more attack submarines throughout the 2020s, leading to higher long-term maintenance needs for the submarine fleet. The additional ships could spend years waiting for maintenance rather than being deployed unless the shipyards' capacity was increased to accommodate the larger fleet. The December 2020 plan is not associated with a specific budget request and would be challenging to execute.

The Navy also plans to increase maintenance budgets in the future, though perhaps not enough to meet growing demand. Most of the Navy's projected increase in maintenance budgets for submarines is for the new Virginia class and Columbia class submarines. The Navy also plans to refuel the nuclear reactors on at least five Los Angeles class submarines at Portsmouth Naval Shipyard to increase their service life instead of retiring them. Those refuelings will increase the workload at the shipyard: Previously, such refuelings have consumed about 320,000 days of labor each (but some have

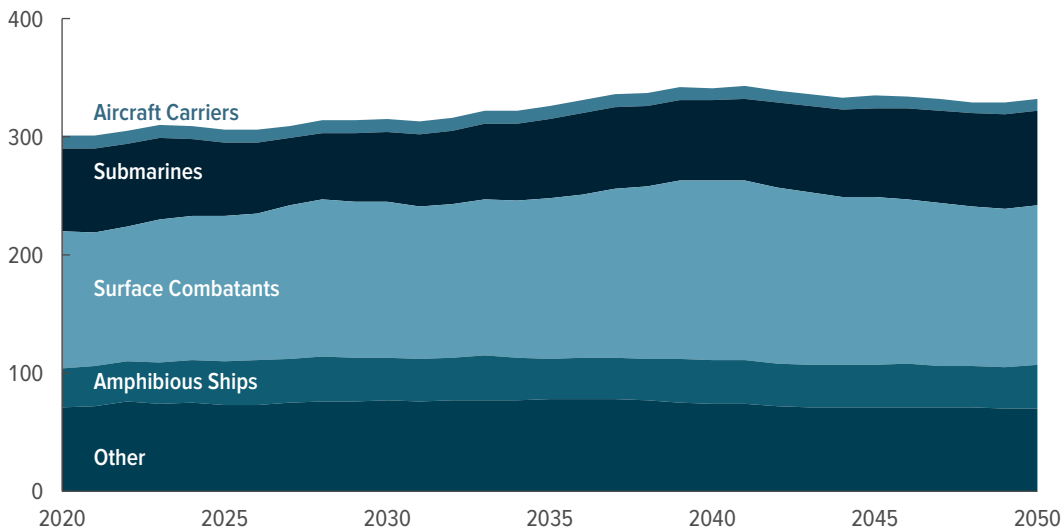




Figure 6.

## Projected Size of the Navy's Fleet

Number of Ships



The Navy projects that the number of ships in its fleet will increase gradually through the early 2040s. The growth is primarily because of an increase in the number of surface combatants.

Data sources: Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (October 2019), [www.cbo.gov/publication/55685](http://www.cbo.gov/publication/55685); Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2021: Appendix* (February 2020), [www.govinfo.gov/app/collection/budget](http://www.govinfo.gov/app/collection/budget). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

required more than 400,000 days of labor). Each of the refueled submarines will then require additional periodic maintenance.

### Trends in the Maintenance of Nuclear Ships

CBO analyzed the Navy's plans and schedules for maintenance of nuclear ships to better understand the trends in maintenance at the public yards. Each class of ship in the Navy has a class maintenance plan, or class plan, that specifies the expected number and type of maintenance events over the life of a ship and estimates the amount of time and labor that each event will require.<sup>19</sup> The class plan is created as a class is being designed. The plan may be changed a few times over the service life of the class, but those changes are infrequent; the plan might not be revised even if some maintenance events take longer than the plan called for. The class plan is for the class as a whole, not for specific ships within the class.

Once a ship joins the fleet, the Navy creates a schedule tailored specifically for that ship and its maintenance

events. As part of that schedule, the Navy develops an itemized package for each maintenance event. The package may contain upgrades and additional maintenance items that were not anticipated in the class plan, or it may include additional adjustments that are based on the condition of that ship or on the experience of maintaining other ships in the class. During a maintenance event, additional maintenance needs may be discovered, possibly requiring more work and causing delays. Workforce shortages, adverse weather, and unavailable parts can also cause delays. Thus, before a ship enters a shipyard, more days of labor and time in the shipyard may be scheduled than were estimated in the class plan.<sup>20</sup> In addition, once work begins there may be overages in both time and labor.

CBO compared the time the shipyards actually spent to maintain individual ships with the time allotted for that maintenance by each ship's schedule and class plan. The agency also examined 12 years of historical data on the maintenance events and workload at public shipyards. CBO found that nuclear ships experienced delays getting

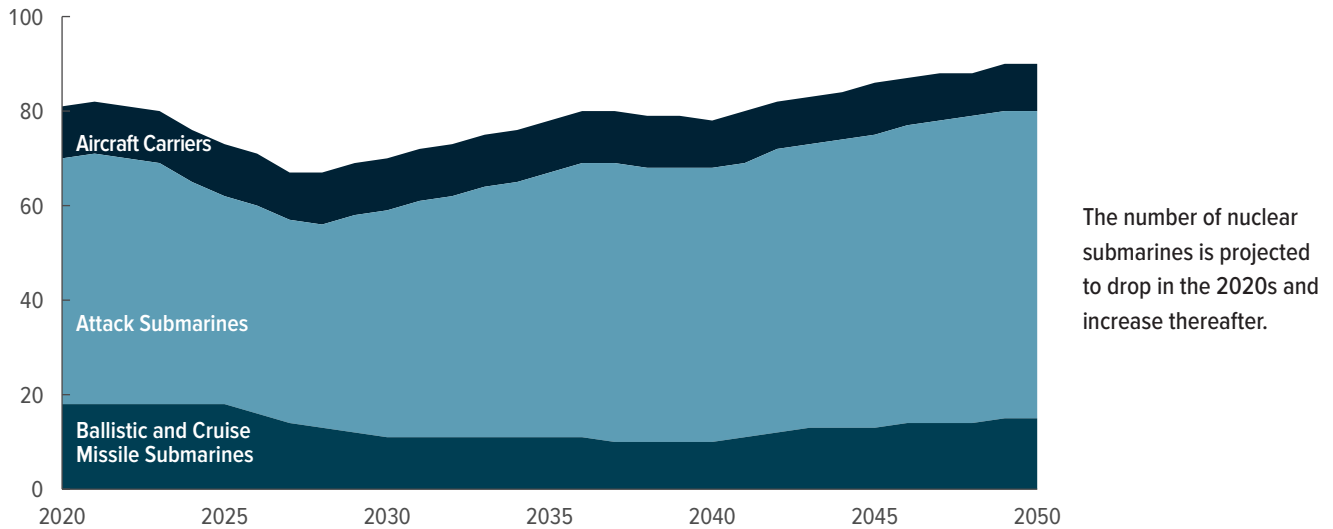
19. See Congressional Budget Office, *Costs of Submarine Maintenance at Public and Private Shipyards* (April 2019), Appendix A, pp. 21–22, [www.cbo.gov/publication/55032](http://www.cbo.gov/publication/55032).

20. See Bradley Martin and others, *A Strategic Assessment of the Future of U.S. Navy Ship Maintenance: Challenges and Opportunities*, RR-1951 (RAND Corporation, 2017), p. 21, <https://tinyurl.com/d5jwxrug> (PDF, 3 MB).

Figure 7.

### Projected Size of the Nuclear Fleet

Number of Ships



Data sources: Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (October 2019), [www.cbo.gov/publication/55685](http://www.cbo.gov/publication/55685); Naval Sea Systems Command; Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2021: Appendix* (February 2020), [www.govinfo.gov/app/collection/budget](http://www.govinfo.gov/app/collection/budget). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

into shipyards and that maintenance took longer and required more labor than expected, on average, once ships entered the shipyards. Those overages have been more pronounced for attack submarines, particularly Virginia class submarines.

#### Virginia Class Submarines

CBO examined five overhauls of Virginia class submarines—the newest attack submarines, which first entered the fleet in 2004. The agency found that those overhauls took longer and that most required more labor than the class plan estimated for each ship. Maintenance took longer than expected in part because some parts had to be replaced earlier than expected and in part because the shipyard took longer than planned on various tasks.

Because the Virginia class is new, the Navy's experience with its overhauls has been limited. To date, shipyards have completed overhauls (EDSRAs) of five Virginia class ships.<sup>21</sup> The initial class plan for 10 submarines (hull numbers SSN-774 through SSN-783) estimated that each EDSRA would require 203,000 days of labor

and that each ship would spend 450 days in the shipyard (see Table 1).<sup>22</sup>

The Navy's schedules for individual ships extended the time frame that was envisioned in the class plan. They called for an average of about 238,000 days of labor for each EDSRA (17 percent more than forecast in the class plan) and 547 days in the shipyard (22 percent more than forecast).

Those schedules in turn underestimated the amount of time that the first five Virginia class ships actually spent in the shipyard and the amount of labor required for each EDSRA. Ships spent an average of 760 days in the yards, an overage of 40 percent, and required about 290,000 days of labor, 25 percent more than the scheduled amount (see Figure 8). In addition, the overhauls began 47 days late, on average. The total delay (the 47-day late start plus the additional 213 calendar days of maintenance) meant that Virginia class submarines returned to operations almost nine months later than expected, on average.

21. More specifically, the Navy has provided CBO with data on five completed EDSRAs for the Virginia class. The Navy expected to complete overhauls of additional Virginia class submarines in 2020, but those data were not available to CBO.

22. The first four submarines in the class are called Block I because they have the same design. The next six submarines, called Block II, have a slightly revised design. Nevertheless, all 10 submarines have the same class plan.



Table 1.

## Number of Days of Labor and Number of Days in Shipyard Compared With Initial Class Plan and Schedule for Virginia Class Submarines

	USS <i>Virginia</i> (SSN-774)	USS <i>Texas</i> (SSN-775)	USS <i>Hawaii</i> (SSN-776)	USS <i>North Carolina</i> (SSN-777)	USS <i>New Hampshire</i> (SSN-778)	Average
<b>Class Plan</b>						
Days in shipyard	450	450	450	450	450	450
Days of labor	203,000	203,000	203,000	203,000	203,000	203,000
Ship's age (Years)	5.6	5.6	7.7	7.7	7.7	6.9
<b>Schedule</b>						
Start date	10/1/10	6/29/12	5/5/15	6/21/16	1/10/17	n.a.
End date	4/1/12	9/30/13	12/7/16	12/6/17	9/17/18	n.a.
Days in shipyard	548	458	582	533	615	547
Days of labor	288,952	221,301	246,496	229,083	202,429	237,652
<b>Actual</b>						
Start date	10/1/10	5/31/12	6/2/15	12/13/16	3/13/17	n.a.
End date	5/5/12	7/31/14	10/2/17	12/1/18	7/19/19	n.a.
Start delay (Days)	0	-29	28	175	62	47
Days in shipyard	582	791	853	718	858	760
Days of labor	262,982	261,924	307,109	294,371	323,952	290,068
Ship's age (Years)	5.9	5.7	8.1	8.6	8.4	7.4
<b>Comparison With Class Plan</b>						
Overage in days in shipyard						
Days	132	341	403	268	408	310
Percent	29	76	90	60	91	69
Overage in days of labor						
Days	59,982	58,924	104,109	91,371	120,952	87,067
Percent	30	29	51	45	60	43
<b>Comparison With Schedule</b>						
Overage in days in shipyard						
Days	34	333	271	185	243	213
Percent	6	73	47	35	40	40
Total days including start delay	34	304	299	360	305	260
Overage in days of labor						
Days	-25,970	40,623	60,613	65,288	121,523	52,415
Percent	-9	18	25	29	60	25

Data sources: Congressional Budget Office, using data from Naval Sea Systems Command and Department of the Navy, *Budget Materials, Operation and Maintenance Navy (OMN) Volume II Data Book* (various years). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

CBO compared the number of days of labor and number of days in shipyard for extended docking selected restricted availabilities (EDSRAs), which are large maintenance events that generally last many months and occur every six years. EDSRAs include maintenance, repairs, and upgrades. The submarine is put into dry dock to enable work on the hull, propulsion, and other systems.

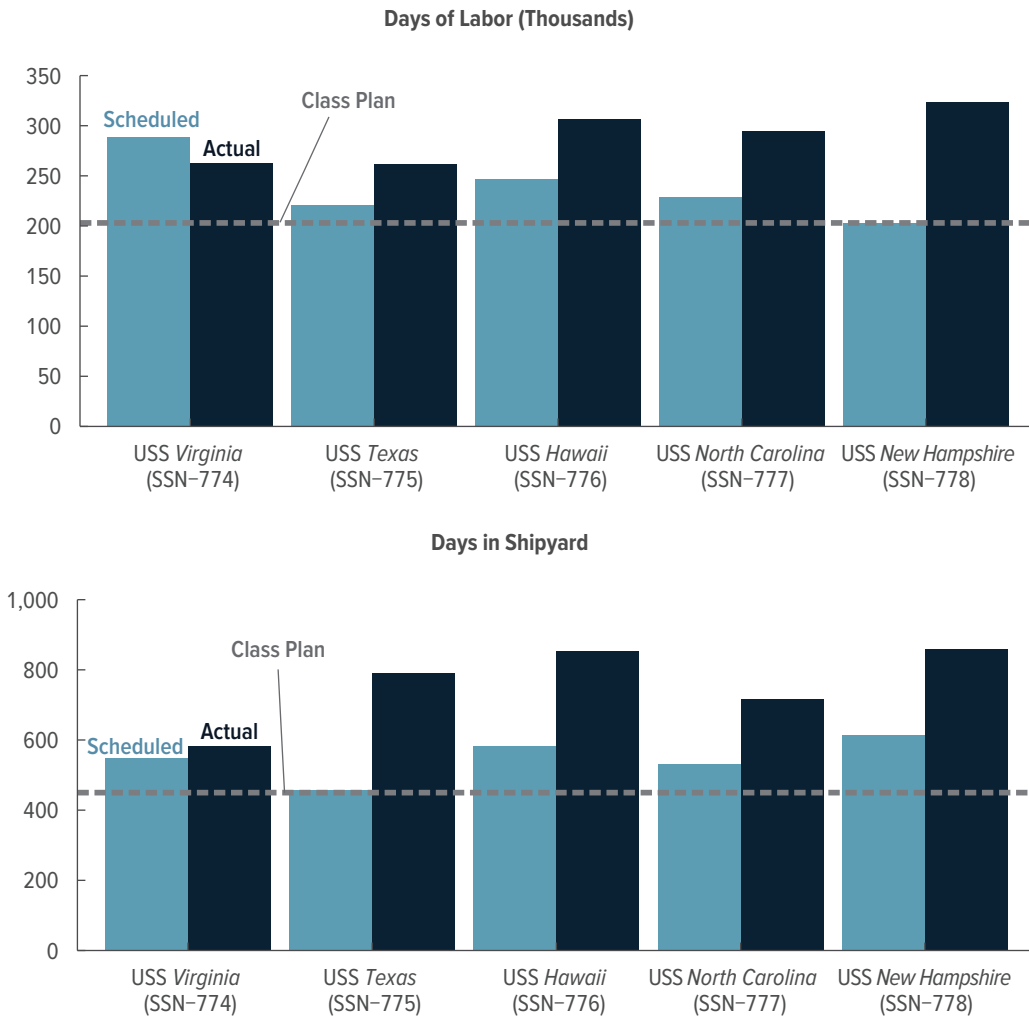
Start delay is the time ships spend waiting to be admitted to a shipyard for maintenance work after the scheduled start date for the work. Overage is the Navy's term for the delay ships experience after they enter a shipyard.

The class plan, or class maintenance plan, specifies the expected number and type of maintenance events over the life of a ship. Separately, the Navy creates a schedule for maintenance events that is tailored to each ship and may include upgrades and additional maintenance that was not anticipated in the class plan. In its analysis, CBO relied on the original Virginia class plan created in 2004.

n.a. = not applicable.

Figure 8.

**Number of Days of Labor and Number of Days in Shipyard for Virginia Class Submarines**



The Navy has taken longer and put in more work than expected to complete overhauls of the first five Virginia class submarines.

Data sources: Congressional Budget Office, using data from Naval Sea Systems Command and Department of the Navy, *Budget Materials, Operation and Maintenance Navy (OMN) Volume II Data Book* (various years). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

CBO compared the number of days of labor and number of days in shipyard for extended docking selected restricted availabilities (EDSRAs), which are large maintenance events that generally last many months and occur every six years. EDSRAs include maintenance, repairs, and upgrades. The submarine is put into dry dock to enable work on the hull, propulsion, and other systems.

The class plan, or class maintenance plan, specifies the expected number and type of maintenance events over the life of a ship. Separately, the Navy creates a schedule for maintenance events that is tailored to each ship and may include upgrades and additional maintenance items that were not anticipated in the class plan. For its analysis, CBO used the original Virginia class plan, which was created in 2004.

The delays were caused by labor shortages (a problem that was exacerbated for the Virginia class because it is an attack submarine and labor is prioritized for aircraft carriers and ballistic missile submarines) and the fact that maintenance took more days of labor than anticipated.<sup>23</sup>

The unexpected increase in the number of days of labor meant that the submarines spent longer at the shipyards. Parts shortages and bad weather also contributed to delays, although separating those effects was beyond the scope of this project.

23. See David B. Larter, "The Hapless Attack Sub Boise Could Return to the Fleet in 2023 After 8 Years Sidelined," *Defense News* (September 22, 2020), <https://tinyurl.com/y4ezs6zg>.

The first ship of a class will usually take longer than anticipated because the shipyards are learning how to



perform maintenance on the new class, learning that increases their efficiency on future ships. Indeed, the Navy's schedules for the first five Virginia class ships anticipated that the ships after the first one (the USS *Virginia*) would require 22 percent fewer days of labor, on average, for their overhauls. However, the Navy's data show that the number of actual days of labor tended to increase over time rather than decrease. There was no evidence of a favorable learning curve (the efficiency gained from working on the same type of equipment repeatedly) in completing the succeeding overhauls. In fact, the three most recent overhauls required an average of about 308,000 days of labor, whereas the first two required about 262,000; the most recent EDSRA overhaul, which was completed in July 2019, required more days of labor than any of the earlier overhauls.

Perhaps because of that experience, in May 2019, the Navy revised the class plan for the first 10 Virginia class submarines (with hull numbers SSN-774 through SSN-783), increasing the expected duration of an EDSRA from 15 months to 19.7 months (450 days to 590 days) and the number of expected days of labor from 203,000 to 247,000. Despite the increases, the new class plan still anticipates fewer days of labor and time in the shipyard than the Navy experienced with the first five submarines of the class. (In its analysis, CBO used the original class plan for comparison, which was in place during the first five EDSRAs of the class.)

Officials at the shipyards said that using actual data from completed overhauls of the Virginia class would be a more accurate guide for projecting future overhauls than relying on projections from the class plan or schedules.

In CBO's projections, future EDSRAs for the Virginia class will each require about 290,000 days of labor—the average amount of labor required for past overhauls. That average is 43 percent more than the initial class plan. The next large maintenance event for the Virginia class, a depot maintenance period, is more extensive than an EDSRA. CBO projects those events to also take 43 percent more time to complete than the class plan anticipates.

CBO's finding is noteworthy because the Virginia class was designed to require less maintenance than the Los Angeles class, in part because the Virginia class featured more parts that were designed to last the life of the ship. At this early stage in the class's life cycle, the reverse has been the case, though that could change as the shipyards gain more experience with the class.

### Other Classes of Ships

CBO found that the other submarine classes and aircraft carriers that make up the nuclear fleet also experienced delays at the public shipyards. For every class, the average number of days of labor and the average amount of time ships spent in the yards exceeded the amounts in the class plans and schedules (see Table 2). CBO did not analyze the data for other ship classes at the individual level, as it did for the Virginia class and the Ohio class, because the other classes have received more types of maintenance and their class plans have changed more over time. Those changes meant that it was not always possible to match particular maintenance events with the class plan. However, CBO could compare the average amount of time and labor required for a class's overhaul with the schedules for each ship.<sup>24</sup>

In addition to the fact that maintenance took more time than the Navy expected, work began later than anticipated. For example, maintenance on Los Angeles class submarines began, on average, 55 days late; once ships entered the yard, the duration overage was 82 days, on average. In total, therefore, Los Angeles class submarines took 137 days longer than scheduled, on average, to return to the fleet. The overage in the number of days of labor was 26 percent.

Those averages show that ballistic missile submarines and aircraft carriers experienced shorter delays in maintenance as a percentage of their schedule, consistent with the fact that they are given priority over attack submarines. Both ballistic missile submarines and aircraft carriers spent less time waiting for work to begin and experienced smaller percentage overages in the amount of time spent in the shipyard.

CBO's findings are consistent with a recent report by the Government Accountability Office (GAO), which examined 51 overhauls for aircraft carriers and submarines that were completed between 2015 and 2019.<sup>25</sup> GAO found that aircraft carriers returned to the fleet 113 days late, on average, and submarines returned 225 days late, on average. GAO observed that unscheduled work

24. For an explanation of the complexity of identifying maintenance events in the class plan, see Congressional Budget Office, *Costs of Submarine Maintenance at Public and Private Shipyards* (April 2019), pp. 15–16 and 23, [www.cbo.gov/publication/55032](http://www.cbo.gov/publication/55032).

25. See Government Accountability Office, *Navy Shipyards: Actions Needed to Address the Main Factors Causing Maintenance Delays for Aircraft Carriers and Submarines*, GAO-20-588 (August 20, 2020), [www.gao.gov/products/GAO-20-588](http://www.gao.gov/products/GAO-20-588).



Table 2.

**Average Number of Days of Labor and Average Number of Days in Shipyard Compared With Class Plan and Schedule for Selected Nuclear Ships, 2008 to 2019**

Class	Number of Observations	Start Delay (Days)	Comparison With Schedule			Comparison With Class Plan (Percentage overage in days of labor)
			Overage (Days in shipyard)		Overage (Days of labor)	
			Days	Percent	Percent	
Virginia class attack submarine	5	47	213	40	25	69
Los Angeles class attack submarine	76	55	82	22	26	n.a.
Ohio class ballistic missile submarine	13	18	124	15	20	24
Nimitz class aircraft carrier	54	30	25	16	13	n.a.

Data source: Congressional Budget Office, using data from Naval Sea Systems Command and Department of the Navy, *Budget Materials, Operation and Maintenance Navy (OMN) Volume II Data Book* (various years). See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

CBO compared the average number of days of labor and average number of days in shipyard for overhauls for classes for which data were available. Some overhauls took much longer than others. For example, of the 13 Ohio class ballistic missile submarine overhauls, 3 had much larger duration overages than the other 10. Those 3 overhauls averaged 356 days (43 percent) more than the scheduled duration. The other 10 had an average duration overage of 53 days (6 percent).

Start delay is the time ships spend waiting to be admitted to a shipyard for maintenance work after the scheduled start date for the work. Overage is the Navy's term for the delay ships experience after they enter a shipyard.

The class plan, or class maintenance plan, specifies the expected number and type of maintenance events over the life of a ship. Separately, the Navy creates a schedule for each maintenance event that is tailored to each ship and may include upgrades and additional maintenance items that were not anticipated in the class plan. In its analysis, CBO relied on the original Virginia class plan created in 2004.

n.a. = not available.

(work that was not anticipated at the beginning of the overhaul) and workforce shortages were about equally responsible for delays.

**CBO's Projections of Workload and Output**

Using the shipyards' historical experience with start delays, the amount of time ships spent in the yards, the number of days of labor required for each class of ship, and the schedule for future maintenance, CBO projected the future workload and output of the Navy's shipyards. CBO's projection incorporated estimates of the shipyards' use of overtime, productivity increases that the Navy expects to achieve, and the effects of retiring a large number of submarines over the next several years.

**CBO's Projections of Future Maintenance Demand and Shipyards' Capacity**

CBO projects that the Navy will experience maintenance delays throughout the next 30 years because the demand for labor will exceed the shipyards' supply of it in 25

of the next 30 years (see Figure 9). CBO projects a 4.6 percent annual shortage in labor, on average—that is, the Navy will need 295,000 more days of labor than the shipyards can supply. That amount is roughly equivalent to falling behind each year by the number of days of labor required to complete an EDSRA for a Virginia class submarine.

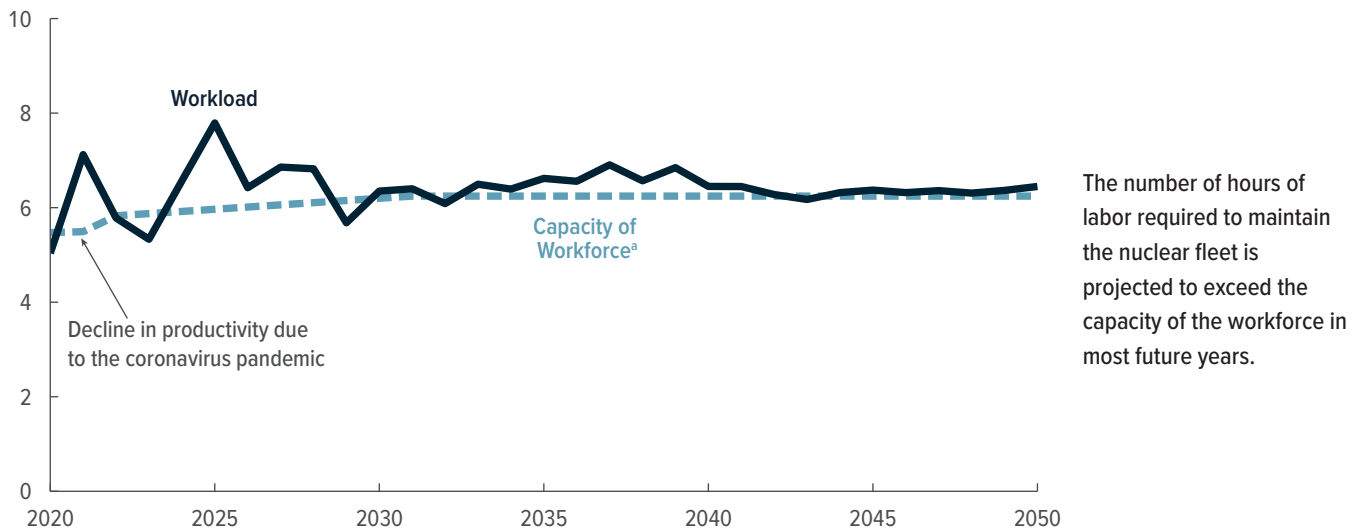
For the first half of the 2030s, CBO projects shipyards will have adequate capacity for the expected workload because the number of submarines will temporarily decline in the late 2020s. The need for maintenance is projected to rise later in the 2030s after the Navy purchases new submarines. (At that time, the number of submarines will exceed the number in the fleet today, and the new submarines will begin receiving overhauls.) In the early 2040s, the capacity and required workload will again be close to balancing because, although the overall nuclear fleet is expected to grow, there will be fewer ballistic missile submarines and aircraft



Figure 9.

## Projections of Workforce and Workload for Nuclear Ships

Millions of Days of Labor



Data source: Congressional Budget Office. See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

The workload is the total number of days of labor required for maintenance events.

a. The Navy created the Shipyard Infrastructure and Optimization Plan to repair and upgrade dry docks and facilities in public shipyards. The Navy expects those investments to result in a 5 percent increase in efficiency, meaning that 5 percent fewer hours of labor will be needed to accomplish a specific task. CBO projects that shipyards' efficiency would also increase by 3 percent over the next decade as a result of increased automation such as computer-aided design of replacement parts. The agency also expects that shipyards would continue to use overtime at a rate of 19 percent of the total number of days of labor (work on a specific ship or component).

carriers, which require more maintenance than attack submarines.<sup>26</sup>

### CBO's Approach

CBO projected the workload at the public shipyards over the next 30 years by applying the historical average of the number of days of labor for each type of maintenance event, using NAVSEA's schedule for maintenance events over the next decade. The sum of those averages generated an estimate of the shipyards' total workload.<sup>27</sup>

26. Ballistic submarines receive some maintenance at Trident Refit Facilities (TRFs) that have dry docks. Some of the Navy shipyards' workers travel to the TRFs for those events. Navy shipyards perform some large maintenance events for ballistic submarines, including refueling. With refueling complete for the Ohio class, the current class of ballistic submarine, the Navy plans to perform less ballistic submarine maintenance at its shipyards in the future. CBO projected that ballistic submarines would continue to be supported at TRFs and shipyards, with one exception: no refuelings are planned for the Columbia class of ballistic submarines.

27. Other parts of shipyards' workload, such as less intensive maintenance events and repairs that are not associated with a

After 2030, NAVSEA's schedule was incomplete, so CBO modeled the yards' workload for overhauls in later decades on the basis of the projected size of the Navy's fleet of nuclear-powered ships and the maintenance schedules in each class plan.

CBO modeled the supply of labor in the shipyards as a function of the number of workers and their expected productivity levels, including improvements that the Navy expects to achieve.

**Days of Labor and Use of Overtime.** Historical data suggest that the number of days of labor supplied by the shipyards will increase in proportion to the number of full-time-equivalent positions that are added. However, the amount of overtime also affects the number of days of labor per worker, and that amount has differed each year. CBO accounted for annual differences in overtime to better explain some of the annual variation in the

particular ship, are included in total workload. CBO projected that workload using historical averages.

number of days of labor compared with the size of the workforce.

The shipyards and NAVSEA aim to have overtime account for about 15 percent or less of the total number of hours of direct labor. The shipyards' average has been about 19 percent in recent years. CBO projected that the yards would continue to use overtime at that higher rate.

**Improvements in Productivity.** CBO's projection includes anticipated improvements in productivity. Automation is expected to lead to a onetime 3 percent increase in productivity—that is, tasks will take 3 percent less time, on average. For example, the design and manufacture of replacement parts is being automated in ways including computer-aided design and automated cutting of sheet metal. Because some tasks are more difficult to automate than others, the amount of time saved per task will vary greatly. The agency also projected that shipyards would realize the 5 percent efficiency gain that the Navy anticipates from the infrastructure improvements made under SIOP. CBO projected that both increases in efficiency would phase in from 2022 to 2031 (see Figure 10).

**Effects of the Coronavirus Pandemic.** The coronavirus is affecting shipyard workers as it is the rest of the American workforce.<sup>28</sup> Some shipyards are reporting higher absenteeism among employees. The Navy could not quantify that effect for CBO, but other estimates indicate that the shipyards supply about 10 percent fewer days of labor when cases of infection are high, which has occurred in fiscal years 2020 and 2021.<sup>29</sup> CBO estimates that, on average, productivity at the Navy's shipyards will be lower by 5 percent in fiscal years 2020 and 2021 as a result.

CBO did not estimate the long-term effects of the pandemic. On the one hand, social distancing and other safety measures could slow output for many years if their use continues after fiscal year 2021. On the other hand, the greater supply of labor in a weakened economy could make it easier for the shipyards to hire workers.

28. See Paul McLeary, "Navy Rushes 'Unprecedented' 1,600 Reservists to Shipyards as COVID Guts Workforce," *Breaking Defense* (June 16, 2020), <https://tinyurl.com/y26ulfrj>.

29. See Paul McLeary, "DoD Details \$11B for COVID Costs, Warns 'at Least One' Shipyard May Close," *Breaking Defense* (August 10, 2020), <https://tinyurl.com/y5at24pd>.

**Inactivation and Disposal of Reactors.** CBO's projection of future workload includes the inactivation and disposal of nuclear reactors. When the Navy retires a submarine, the vessel undergoes a procedure known as inactivation to make its nuclear reactor safe, so that the crew can leave, the vessel can be dismantled, and the reactor can be disposed of.

CBO took several factors into account in projecting the amount of time required for inactivation and disposal. For a Los Angeles class submarine, inactivation generally requires about 90,000 days of labor, but a few submarines in that class have required much more work. Therefore, CBO projected an average of 105,000 days of labor for such an inactivation. Disposal of the nuclear reactor takes an additional 60,000 days of labor. Inactivation usually occurs within a year of a submarine's ceasing to operate, but disposal of the reactor has been delayed by up to 15 years after a submarine has been inactivated.

CBO's projection also incorporates the effect of the Navy's new process for inactivation. Some submarines have had to wait years for inactivation, and the delays have meant that their crews have stayed with nonoperational submarines. To minimize such occurrences, the Navy has begun breaking inactivation into two parts: layup, in which the ship is made safe for short-term storage before it is put in dry dock; and decommissioning of its propulsion plant, which occurs in dry dock. Another change in the process means that shipyards now work on more than one dry-docked ship simultaneously.<sup>30</sup> An advantage of the new process is that most of the crew can be released after the first part of the inactivation. A disadvantage is that the two steps of the new process together require more days of labor than the old process. CBO's projection incorporates the new approach, increasing days of labor to 128,000 from 105,000.

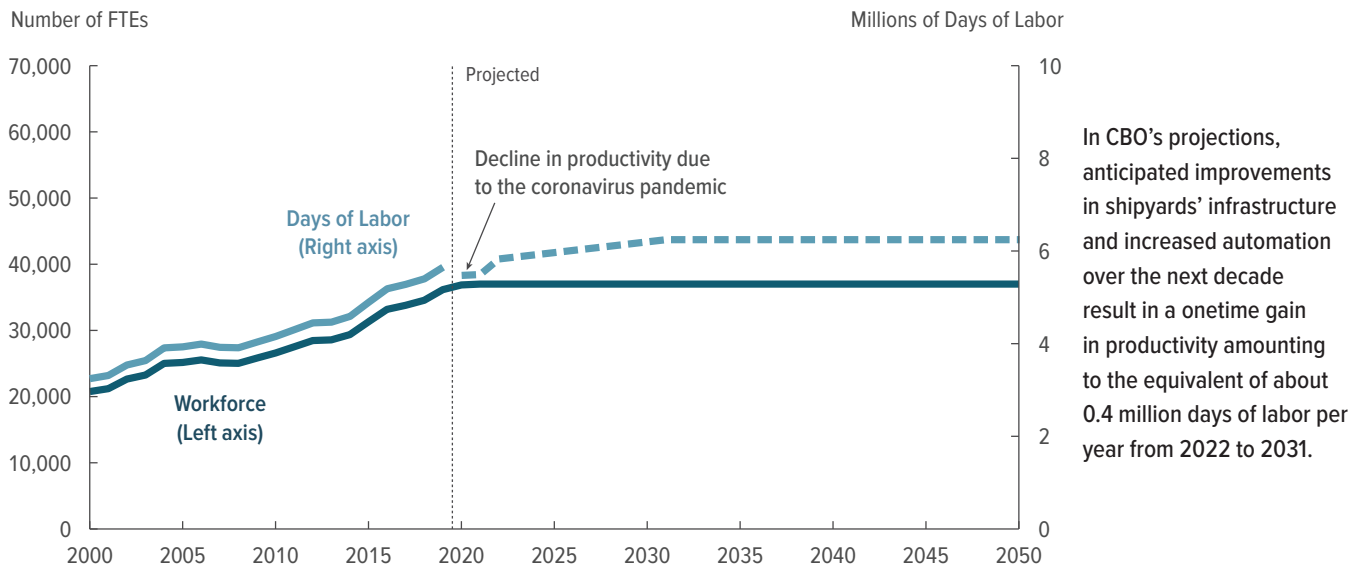
### Uncertainty About Key Information Used in CBO's Analysis

The actual values of key data may differ from CBO's projections, which would affect the agency's analysis. Shipyards might have a greater workload than anticipated, which would increase delays. For example, CBO did not include unusual repairs, such as severe accidental or combat damage to a ship, that would exceed the

30. See "Two Submarines Share Dry Dock for Simultaneous Inactivations," *Marine Log* (July 10, 2020), <https://tinyurl.com/yyp1349>.

Figure 10.

## Projected Number of Days of Labor for Nuclear Ships After Improvements in Productivity



Data source: Congressional Budget Office, using data from Naval Sea Systems Command. See [www.cbo.gov/publication/57026#data](http://www.cbo.gov/publication/57026#data).

The Navy created the Shipyard Infrastructure and Optimization Plan to repair and upgrade dry docks and facilities in public shipyards. The Navy expects those investments to result in a 5 percent increase in efficiency, meaning that 5 percent fewer hours of labor will be needed to accomplish a specific task. CBO projects that shipyards' efficiency would also increase by 3 percent over the next decade as a result of increased automation, such as the computer-aided design of replacement parts.

FTE = full-time-equivalent positions.

typical workload for unanticipated (emergent) repairs. When the USS *San Francisco* struck an undersea mountain in 2005, for example, it required 865 days in the shipyard and 294,000 days of labor.<sup>31</sup>

If the amount of overtime is less than CBO projected or efficiency improvements that the agency projected do not occur, delays in maintenance may be greater than estimated. For example, if the Navy achieves its goal of keeping overtime hours to about 15 percent (rather than 19 percent) of total labor hours, the gap between demand and capacity would roughly double, and the number of total hours of labor required would increase by about 4 percent or 260,000 days per year. Similarly, if over the next decade the Navy fails to increase efficiency by 5 percent through infrastructure improvements and 3 percent through automation, the gap between demand and supply could increase by as much as 8 percent. Conversely, efficiency improvements might be greater

than CBO projects. Shipyards have sometimes achieved larger gains in efficiency for specific tasks than have been projected.

### Policy Options to Mitigate the Effects of Delays or Reduce Delays

CBO examined four policy options for overhauls of nuclear ships that might alleviate or reduce delays. Option 1 would help reduce the disruptive effects of delays on the operations of the fleet but would not affect the delays themselves. Options 2 and 3 would increase the supply of labor. Option 4 would reduce the size of the workload.

Even if one or more of the options are pursued, CBO projects that maintenance delays will continue, through the 2020s for Options 2 and 3 because it takes several years to hire and train workers at shipyards, and through the 2020s or 2030s for Option 4, depending on whether the Navy reduces fleet size sooner by retiring old submarines or later by building fewer new submarines. In

31. See Kyle Mizokami, "15 Years Ago, a U.S. Navy Submarine Ran Into a Mountain," *Popular Mechanics* (January 9, 2020), <https://tinyurl.com/y8gmr9m9>.

the meantime, delays will continue, pushing a wave of unfinished work into the future.

- **Option 1:** Improve the accuracy of maintenance projections and adjust ships' operating schedules accordingly.
- **Option 2:** Increase the shipyards' workforce from about 37,000 to about 39,500.
- **Option 3:** Shift additional maintenance of the nuclear fleet to private shipyards.
- **Option 4:** Reduce the size of the nuclear fleet.

Any or all of the four options could be combined. For example, the Navy might choose to increase capacity and reduce the size of the fleet. Combining options would mean that changes would be smaller: For example, fewer ships would need to be retired under Option 4 if the workforce increased by 1,000 workers.

### **Option 1: Improve Forecasting**

Under Option 1, maintenance delays would not be reduced, but fleets would be better able to plan deployments around maintenance events. One way to improve forecasting would be to update class plans to more accurately reflect the actual duration of maintenance events.<sup>32</sup> Deployment goals could be met or readjusted if the duration of maintenance events was closer to the planned duration.

### **Options 2 and 3: Increase Capacity**

Options 2 and 3 would effectively add about 2,500 workers to boost maintenance capacity. Under Option 2, the Navy would hire those workers directly; under Option 3, it would send an equivalent amount of work to private yards. Either option would better balance supply and demand over the next 30 years; the demand for maintenance would exceed the supply of labor in just 8 of those years rather than in 25 of them. The cost of the two options is about the same, \$275 million per year, CBO estimates. Hiring and training workers at shipyards takes several years (about five years from when the authorization is given to hire more workers to when the new workers can be hired, get security clearances, and receive enough training to start to be productive), but if started

soon, it could be accomplished before the nuclear fleet started to grow in the 2030s and 2040s.

### **Option 4: Reduce the Size of the Fleet**

Option 4 would reduce the size of the fleet by approximately five attack submarines to match the public shipyards' maintenance capacity. That could be accomplished by retiring older submarines ahead of the current schedule or by purchasing fewer new submarines. Although the size of the fleet would be smaller, the same number of submarines might be available in peacetime as under the Navy's plan because fewer submarines would be awaiting maintenance. However, the Navy's ability to surge its submarine force during wartime would be reduced.

For example, the Navy could cancel its planned refueling of five Los Angeles class submarines (as called for by its 2020 shipbuilding plan, as modified by CBO for this analysis to reflect the Navy's 2021 budget request) and retire the ships instead. The retired submarines would have to be inactivated, which would increase the workload in the Navy's shipyards for several years before leading to a smaller workload starting in about 2030. Retiring five Los Angeles class submarines would save \$1.6 billion in refueling costs and \$250 million annually in operation and support costs. The long-term savings in maintenance costs would be partially offset by short-term increases in disposal costs.

If the Navy chose instead to purchase fewer new submarines, it could buy fewer of them in the 2030s and 2040s than it had planned. Buying fewer submarines would not reduce the shipyards' workload as quickly as retiring old Los Angeles class submarines because it takes many years for a new submarine to enter the fleet and years of service before it enters a shipyard for maintenance. By CBO's estimate, the workload under the second approach would not fall until late in the 2030s. Buying five fewer Virginia class submarines would save about \$16 billion in procurement costs and \$290 million annually in operation and support costs, CBO estimates. Those procurement savings might be partially offset by increases in unit procurement costs (because the purchase of fewer submarines might increase the cost per submarine).

A third alternative might be to procure different ships that require less maintenance. Procuring different types of ships, however, could have significant effects on other parts of the Navy's budget.

32. For some possible changes, see R. Leon Lary IV, "Analysis of SSN 688 Class Submarine Maintenance Delays" (thesis, Naval Postgraduate School, June 2017), <https://calhoun.nps.edu/handle/10945/55640>.



## Box 1.

**The Navy's New Shipbuilding Plan**

On December 9, 2020, the Department of Defense released a 30-year shipbuilding plan for the years 2022 to 2051.<sup>1</sup> That new plan differs substantially from the Navy's modified shipbuilding plan for fiscal year 2020. (The Navy did not release a shipbuilding plan for fiscal year 2021 when it submitted that year's budget request; for this analysis, the Congressional Budget Office modified the fiscal year 2020 plan to account for changes that arose from the service's 2021 budget request.) Under the December 2020 plan, the Navy's fleet buildup would be larger than in the previous plan, from about 300 warships today to more than 400 by 2051. The number of nuclear-powered aircraft carriers and ballistic missile submarines would be about the same under both plans, but the attack submarine force would increase substantially under the new plan.

Under the Navy's fiscal year 2020 plan (as modified by the 2021 budget request), the Navy would purchase 61 attack submarines over the next 30 years. It would extend the service life of 5 Los Angeles class attack submarines by about 10

years. The inventory would decrease from about 53 attack submarines today to 46 by 2030, then increase to 59 by 2040, and finally to 65 by 2050.

By contrast, under the December 2020 plan, the Navy would purchase 77 attack submarines over a 30-year period and extend the service life of 7 Los Angeles class attack submarines by about 10 years each. Other Los Angeles class submarines would have several years added to their planned service life; as a result, 22 ships of that class would be retired after 35 years, compared with 7 under the prior plan.<sup>2</sup> The resulting inventory would be 54 attack submarines by 2030, 64 by 2040, and 80 by 2051.

A larger attack submarine force would require more maintenance and thus impose a larger workload on the shipyards. The increased workload would stem from both extending the service life of submarines now in service and performing routine maintenance on a larger force. If the December 2020 shipbuilding plan was adopted, it would increase shipyards' workload by about 10 percent and require about 4,000 more workers than the 2,500 that would be added in Options 2 and 3.

1. See Department of the Navy, *Report to Congress on the Annual Long-Range Plan for the Construction of Naval Vessels* (December 2020), <https://tinyurl.com/y7aox3gs>; and Eric J. Labs, Senior Analyst for Naval Forces and Weapons, National Security Division, Congressional Budget Office, "Navy Shipbuilding: Prospects for Building a Larger Fleet" (presentation at the Surface Navy Association's 33rd Annual Symposium, January 15, 2021), [www.cbo.gov/publication/56956](http://www.cbo.gov/publication/56956).

2. It is unclear whether extending the service life of some Los Angeles class submarines is feasible. Many of the older submarines in the fleet today are experiencing maintenance delays and missing deployments.

**Uncertainty About Key Inputs in CBO's Analysis of Options**

The uncertainty about some key projections contributes to uncertainty in CBO's analysis of the four options. For example, if the Navy achieves its goal of limiting overtime to about 15 percent of labor hours but cannot achieve any of its planned efficiency gains, Option 2 and Option 3 would cost more because the Navy would need more labor.

In addition to those variables, the maintenance workload could exceed CBO's projections if, for example, the number of days of labor that are required to overhaul a Virginia class submarine continues to grow. CBO's projection incorporates the assumption that overhauls of Virginia class submarines will take about the same amount of work in the future as in the past. If future overhauls take more work, the number of workers would

need to be increased (Options 2 and 3) or the number of ships reduced (Option 4).<sup>33</sup> If instead, the Navy increases efficiency by more than it has estimated, maintenance delays would be shorter and capacity would not need to be increased as much as CBO projects for Options 2 and 3. For Option 4, fleet size would not need to shrink as much as CBO projects.

A final uncertainty is the future size of the Navy's submarine force. Under the new shipbuilding plan released on December 9, 2020, the Navy would substantially increase the production of attack submarines (see Box 1). The number of attack submarines would grow to 80 in 2050 instead of 65 in the present analysis. The cost for

33. CBO found that the cost of overhauls for Los Angeles class submarines increased as the submarines aged. See Congressional Budget Office, *Costs of Submarine Maintenance at Public and Private Shipyards* (April 2019), [www.cbo.gov/publication/55032](http://www.cbo.gov/publication/55032).

refueling and procurement would increase under the new plan; in addition, about 4,000 more shipyard workers would be needed to handle the larger submarine fleet (in addition to the 2,500 that would be added if Option 2

were adopted) and the cost would be \$440 million more per year (in addition to the \$275 million that would be added under Option 2) to match shipyards' capacity with the maintenance needs of the larger fleet.

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# List of Tables and Figures

## Tables

- |  |    |
|--|----|
| 1. Number of Days of Labor and Number of Days in Shipyard Compared With Initial Class Plan and Schedule for Virginia Class Submarines                    | 12 |
| 2. Average Number of Days of Labor and Average Number of Days in Shipyard Compared With Class Plan and Schedule for Selected Nuclear Ships, 2008 to 2019 | 15 |

## Figures

- |  |    |
|--|----|
| 1. Average Days of Labor Exceeding the Scheduled Number for Nuclear Ships, 2008 to 2019    | 2  |
| 2. Workforce and Workload at the Navy's Shipyards  | 5  |
| 3. Total Length of Maintenance Delays by Type of Submarine                                 | 7  |
| 4. Cannibalization of Parts by Class of Submarine  | 8  |
| 5. Fleet Sizes and Maintenance Budgets   | 9  |
| 6. Projected Size of the Navy's Fleet  | 10 |
| 7. Projected Size of the Nuclear Fleet   | 11 |
| 8. Number of Days of Labor and Number of Days in Shipyard for Virginia Class Submarines    | 13 |
| 9. Projections of Workforce and Workload for Nuclear Ships                                 | 16 |
| 10. Projected Number of Days of Labor for Nuclear Ships After Improvements in Productivity | 18 |

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# About This Document

This Congressional Budget Office report was prepared at the request of the Chairman and Ranking Member of the Subcommittee on Readiness and the Chairman and Ranking Member of the Subcommittee on Seapower and Projection Forces of the House Committee on Armed Services in the 115th Congress. In accordance with CBO's mandate to provide objective, impartial analysis, the report makes no recommendations.

R. Derek Trunkey prepared the report, with assistance from Eric J. Labs and guidance from David Mosher and Edward G. Keating. Scott Laughery provided useful comments.

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CBO continually seeks feedback to make its work as useful as possible. Please send any feedback to [communications@cbo.gov](mailto:communications@cbo.gov).



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