

CBO

Costs of Submarine Maintenance at Public and Private Shipyards



APRIL 2019

At a Glance

To lessen delays at public shipyards, the Navy sent 29 submarines to private shipyards for overhauls between 1993 and 2017. This report compares the costs of submarine maintenance at public and private shipyards during that period. The analysis focuses on depot maintenance—specifically, Docking Selected Restricted Availability (DSRA) overhauls—for the Navy’s Los Angeles class attack submarines (SSN-688s).

- On average, overhauls at private shipyards have been 31 percent less expensive over the period analyzed.
- The average cost of DSRA—removing the effects of economywide inflation—has risen for all shipyards, climbing from about \$20 million in the mid-1990s to about \$30 million in the mid-2000s and to \$50 million in the mid-2010s.
- Since 2007, costs of overhauls at private and public shipyards have been about the same, although CBO’s data include only one overhaul at a private shipyard after 2010, which makes comparisons difficult.



Contents

Summary	1
What Did This Analysis Find?	1
How Do These Results Differ From CBO’s Earlier Analysis?	2
What Limitations Apply to This Analysis?	2
Background	3
Earlier Research on Cost Differences	4
Funding Mechanisms for Public Shipyards	5
Differences in Accounting Methods	7
Uniqueness of Ships and Overhauls	7
Limitations of the Available Data	7
Considerations Other Than Costs	8
Comparing Costs for Overhauls of Los Angeles Class Submarines	8
Adjusting Data for Missing Overhead Costs at Public Shipyards	8
Comparing 25-Year Average Costs	10
Trends in DSRA Overhauls	11
Comparing Costs by Funding Period	14
Comparing Costs by Maintenance Plan	15
Comparisons Using an Alternative Approach to Projecting Overhead Costs	17
Adjusting for Age and Maintenance Plan	18
Appendix A: Changes in the Maintenance Plans for Los Angeles Class Submarines	21
Appendix B: An Empirical Model of Overhaul Costs for Los Angeles Class Submarines	23
List of Tables and Figures	25
About This Document	26

Notes

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

All costs are expressed in 2018 dollars. They have been adjusted to remove the effects of inflation using the Bureau of Economic Analysis's gross domestic product price index.

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

The cover photograph shows the USS *Providence* undergoing depot maintenance at Norfolk Naval Shipyard in Portsmouth, Virginia. The photograph was provided courtesy of the Department of the Navy.



Costs of Submarine Maintenance at Public and Private Shipyards

Summary

Public shipyards conduct a large majority of all submarine maintenance. Those shipyards are Navy-owned and -operated, but the Navy has been experiencing long delays—sometimes as much as several years—to obtain maintenance on its submarines at those shipyards. As a result, some submarines have missed deployments or had shortened deployments. The Navy has sent several submarines to private shipyards for overhauls in recent years but could send more.

This report compares the costs of submarine maintenance at public and private shipyards. This analysis focuses on depot maintenance—specifically, Docking Selected Restricted Availability (DSRA) overhauls—for the Navy’s Los Angeles class attack submarines (SSN-688s). DSRA are medium-sized maintenance events that last several months and occur every four to six years over the 33-year lifetime of an SSN-688 submarine. They include maintenance, repairs, and upgrades; the submarine is put into a dry dock to enable work on the hull, propulsion, and systems (which would otherwise be underwater).

What Did This Analysis Find?

The Congressional Budget Office found that DSRA overhauls for Los Angeles class submarines cost less, on average, in private shipyards from 1993 to 2017 than in public shipyards, although that difference has narrowed—and perhaps disappeared—in recent years.

- On average, overhauls at private shipyards have been 31 percent less expensive over the entire period (see Table 1).
- After accounting for the age of the submarines and differences in maintenance plans, the gap was slightly larger: Overhauls at private shipyards were 35 percent less expensive, on average, than at public shipyards.

- From 1993 to 1998, when the Navy used working capital funding (WCF) at public shipyards, DSRA at private shipyards cost about half as much as those at public shipyards.¹
- From 1999 to 2006, during the Navy’s transition to mission funding, costs at private shipyards were 21 percent less than those at public shipyards.²
- Since 2007, when the switch to mission funding at public shipyards was complete, costs at private and public shipyards have been about the same (see Figure 1). However, CBO’s data include only one overhaul at a private shipyard after 2010, which makes a comparison of costs for overhauls after 2010 not meaningful.
- The average cost of overhauls at all shipyards has risen: It was about \$20 million in the mid-1990s, about \$30 million in the mid-2000s, and roughly \$50 million in the mid-2010s. In part, those rising costs reflect the aging of the submarines and the Navy’s shift to maintenance schedules that increased the time between, and the duration of, DSRA.

Those findings were derived from CBO’s examination of data on 146 DSRA (the most common type of overhaul) that occurred between 1993 and 2017. Of the DSRA overhauls that CBO examined, 29 were done at private shipyards and 117 were done at public shipyards.

-
1. Under working capital funding, the public shipyards charged the Navy for each job as it was performed, and prices were set to cover all the costs the shipyards incurred, including all overhead costs.
 2. Under mission funding, the Navy provides the shipyards with a certain amount of funding each year and then the shipyards perform as much maintenance as possible. That funding includes some overhead costs, but they are not identified as they were under working capital funding.

Table 1.

DSRA Overhauls of SSN-688s, by Period of Funding

	Private Shipyards	Public Shipyards	Difference (Percent)
Number of Overhauls			
1993–1998	17	44	n.a.
1999–2006	5	47	n.a.
2007–2017	7	26	n.a.
Total Number of Overhauls	29	117	n.a.
Adjusted Average Cost (Millions of 2018 dollars) ^a			
1993–1998	10.7	22.3	-52
1999–2006	26.1	32.9	-21
2007–2017	52.1	53.8	-3
Total Adjusted Average Cost	23.3	33.6	-31
Average Days in Shipyard			
1993–1998	72	88	n.a.
1999–2006	124	104	n.a.
2007–2017	206	171	n.a.
Total Average Days in Shipyard	113	113	n.a.

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

DSRA = Docking Selected Restricted Availability; n.a. = not applicable.

From 1993 to 1998, Navy shipyards used working capital funding, and from 2007 to 2017 they used mission funding. The years between were a period of transition between the two types of funding.

a. Costs were adjusted to include overhead activities that the Navy omitted from VAMOSC starting in 1999.

How Do These Results Differ From CBO's Earlier Analysis?

In September 2018, CBO released a preliminary analysis of the costs of DSRA for Los Angeles class submarines.³ The results of that analysis are very similar to those in this report: DSRA cost less at private shipyards, on average, from 1993 through 2016, and the gap in costs between public and private shipyards has narrowed over time. The primary difference between CBO's two analyses is the size of the gap in costs in recent years. The 2018 analysis showed that costs at private shipyards remained lower in recent years than costs at public

shipyards, whereas the gap has roughly disappeared in this analysis (for overhauls after 2007).

The reason for that change is that CBO received updated data from the Navy. In response to CBO's 2018 analysis, the Navy provided CBO with updated data for several of the recent DSRA conducted at private shipyards. Those data show higher costs for those DSRA than the costs listed in the Navy's official Congressionally mandated database. The Navy performed its own analyses as well: Originally, the Navy asserted that overhauls at public shipyards cost about 20 percent less than those at private shipyards.⁴ Following discussions with CBO, the Navy changed its analytical approach and now finds that the costs of overhauls at public and private shipyards are nearly the same, a result that is broadly consistent with CBO's analysis of recent DSRA.⁵

What Limitations Apply to This Analysis?

Several limitations apply to CBO's analysis. First, the Navy's database does not include the overhead costs at public shipyards for overhauls conducted using mission funding. (The public shipyards switched to mission funding between 1999 and 2007.) CBO used other Navy data to adjust for the missing overhead costs, but those other data omit some costs, which suggests that CBO's estimates of the costs of overhauls at public shipyards are too low. Second, the costs of overhauls in the Navy's database did not always agree with those from other sources. CBO corrected the data to the extent possible, but some inconsistencies may remain. Third, CBO only examined DSRA overhauls of Los Angeles class submarines. Analysis of other types of overhauls and other ship classes could yield different results. Finally, costs are not the only factor to consider when selecting where to conduct an overhaul: wait times, excess capacity, workforce issues, and the industrial base are also important.

4. See, for example, *Inside Defense*, "Navy Awards Huntington Ingalls Boise Overhaul Contract" (October 16, 2017).

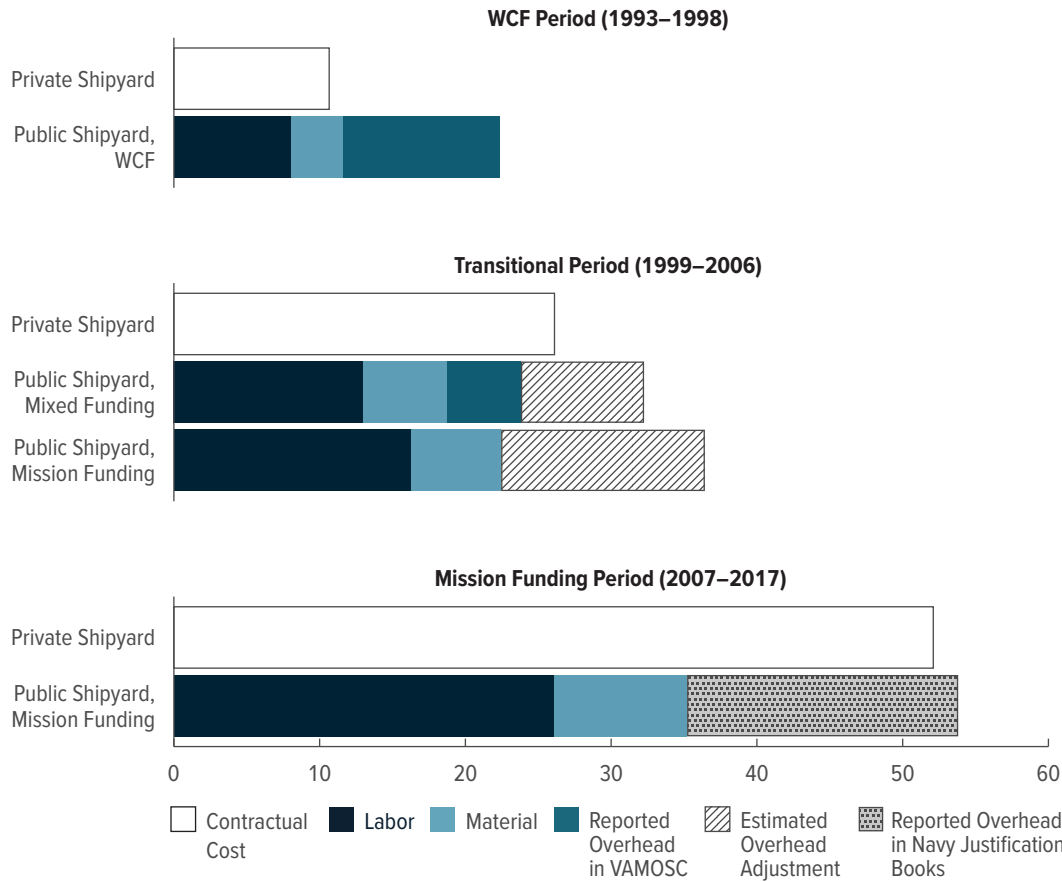
5. The Navy's analysis used a more recent but smaller sample of overhauls. That analysis determined that the costs at public and private shipyards were similar and that the results were sensitive to the sample selected. The Navy also used a different method than CBO did to determine costs and estimate overhead at public shipyards. See Naval Sea Systems Command, *Private & Public Shipyards Docking Selected Restricted Availabilities (DSRA) Study* (November 2018), which the Navy provided to CBO. See also Naval Sea Systems Command, *Private & Public Shipyards Docking Selected Restricted Availabilities (DSRA), SEA 05C Analysis* (March 2019), which the Navy provided to CBO.

3. See Congressional Budget Office, "Comparing the Costs of Submarine Maintenance at Public and Private Shipyards" (presentation, September 2018), www.cbo.gov/publication/54444.

Figure 1.

Average DSRA Costs for SSN-688s

Millions of 2018 Dollars



Private shipyards are less expensive, but the gap is narrowing. Meanwhile, the cost for overhauls has been increasing at all shipyards.

Source: Congressional Budget Office, using data from VAMOS and Department of the Navy, *Budget Materials, Operation and Maintenance, Navy (OMN) Volume II Data Book*, “Naval Shipyards” (February 2018 and previous years).

Between 1999 and 2007, the Navy was transitioning the funding mechanism for shipyards from WCF to mission funding; different shipyards made the transition in different years during that time. Mixed funding means that some costs were reported under WCF, and some were reported under mission funding.

DSRA = Docking Selected Restricted Availability; VAMOS = the Navy’s Visibility and Management of Operating and Support Costs system; WCF = working capital funding.

Background

Over the life of a naval ship, it must intermittently receive in-depth maintenance at specialized facilities away from where the ship is ordinarily stationed. Those maintenance events (sometimes called overhauls) involve a prescribed set of procedures (inspections, repairs, and replacement of parts) intended to keep the ship operating safely and effectively until the next maintenance event.⁶ For example, a Los Angeles class attack subma-

rine is expected to have an overhaul (such as a Docking Selected Restricted Availability) every four to six years over its 33-year lifetime; larger overhauls (involving major repairs or system upgrades) take the place of a DSRA about every third time.

The Navy can obtain ship maintenance from either public or private shipyards. All four public shipyards are owned and operated by the Navy: the Norfolk Naval Shipyard in Portsmouth, Virginia; the Portsmouth Naval Shipyard in Kittery, Maine; the Puget Sound Naval

6. The Navy also calls those maintenance events availabilities. They indicate that a ship is available for maintenance.

Shipyard in Bremerton, Washington; and the Pearl Harbor Naval Shipyard in Pearl Harbor, Hawaii. All of those shipyards can work on nuclear-powered submarines. (All U.S. submarines today are powered by nuclear reactors, as are all U.S. aircraft carriers.) Federal civilian employees perform most of the work at those shipyards.

Several private shipyards also have the capability to maintain the Navy's ships. Newport News Shipbuilding in Newport News, Virginia, and Electric Boat in Groton, Connecticut, primarily build nuclear-powered submarines but have the necessary skills and facilities to maintain them as well. In addition, Newport News Shipbuilding builds and maintains nuclear-powered aircraft carriers.

In addition to the several submarines the Navy has sent to private shipyards for overhauls in recent years, it could have sent several more. However, the Navy has stated that it prefers using public shipyards because it believes that they cost less.⁷

In conducting this analysis, CBO examined earlier research on the differences in costs between overhauls that were performed at public and private shipyards. CBO also took into account a number of other factors, such as these:

- The Navy changed the process used to fund maintenance in public shipyards from working capital funding to mission funding;
- Public and private shipyards used different accounting methods;

7. See, for example, *Inside Defense*, "Navy Awards Huntington Ingalls Boise Overhaul Contract" (October 16, 2017). The Navy also considers nuclear maintenance a core capability and satisfies the requirements of 10 U.S.C. 2464 and 10 U.S.C. 2466 by performing most nuclear maintenance work in Navy shipyards and most nonnuclear depot maintenance in private shipyards. See Jeffrey A. Drezner and others, *Measuring the Statutory and Regulatory Constraints on DoD Acquisition* (RAND, 2007). However, the Navy told CBO that modest expansion of nuclear maintenance in private shipyards would not violate those laws or the Department of Defense's policies. New submarine construction is no longer seen as a core capability, and that work is handled exclusively by private shipyards. Extensive repairs for collision damage are also typically made by private shipyards.

- The amount of planned work changed over time as new class maintenance plans were introduced,⁸ and
- The submarines aged over the sample period and thus required more maintenance.

CBO could not account for the uniqueness of each submarine—including its operating environment, past maintenance actions, and past modernization work—because of limitations of the available data.

Earlier Research on Cost Differences

Most previous studies that examined costs to maintain military equipment find that the private sector is less costly than the public sector in cases where similar products and services are produced and where competition in the private sector exists.⁹ Two studies specifically address submarine maintenance.

A 1981 Center for Naval Analyses (CNA) study examined 40 submarine overhauls conducted from 1972 to 1978 at nine shipyards (three private and six public). In general, that study found no difference in the quality and timeliness of work performed at public and private shipyards. However, individual differences between shipyards (in input prices and experience) accounted for average

- 8. The class maintenance plan specifies the expected number and type of maintenance events over the life of a ship. Those plans are adjusted on the basis of experience, maintenance philosophy, and changes in deployment schedules (see Appendix A). The original maintenance plan for Los Angeles class submarines called for six DSRA's over the life of the ship. The most recent plan calls for four DSRA's over that span, and the last two would take longer to accomplish the required maintenance. Even under the same maintenance plan for the same phase in the life cycle of a submarine, there can be large differences in duration and cost from one DSRA to another based on a ship's condition and available maintenance resources.
- 9. See, for example, Congressional Budget Office, *Public and Private Roles in Maintaining Military Equipment at the Depot Level* (July 1995), www.cbo.gov/publication/15000. Also see Susan M. Gates and Albert A. Robbert, *Personnel Savings in Competitively Sourced DoD Activities: Are They Real? Will They Last?* (RAND, 2000); Government Accountability Office, *Navy Maintenance: Assessment of the Public and Private Shipyard Competition Program* (June 1994); and John D. Keenan and others, *Issues Concerning Public and Private Provision of Depot Maintenance* (Center for Naval Analyses, April 1994).

estimated costs of overhauls that were 7 percent lower at the private shipyards.¹⁰

A 1994 CNA study looked at 259 public-private competitions for depot maintenance between 1985 and 1993, 76 of which were for submarines. CNA's analysis of ship repair data found savings ranging from 20 percent to 40 percent from increased competition, regardless of whether the private or public entity won. The study did not address particular differences in costs between public and private shipyards, however.¹¹

Funding Mechanisms for Public Shipyards

Over the period covered by the data that CBO analyzed—1993 to 2017—the Navy's four public shipyards operated under two different funding mechanisms: working capital funding and mission funding. Although each shipyard started with WCF and switched to mission funding in a particular year between 1999 and 2007, the funding for a single overhaul under WCF was sometimes staggered over several years, making the accounting changes more gradual. In a report issued in 2007, CBO did not find substantial differences in performance at public shipyards as they operated under the two types of funding.¹² In this analysis, however, CBO found some relationship between the accounting practices and the performance at public and private shipyards (discussed below).

Working Capital Funding. Before transitioning to mission funding, all naval shipyards operated under some type of revolving-fund financial system, supporting their continuing operations through income from the sale of goods and services (in this case, maintenance) to their customers (in this case, the Navy). The Navy Working Capital Fund (NWCF) consists of "activity groups" (which are similar to budget accounts) for depot maintenance, supply management, research and development,

base support, transportation, and information services. (Aircraft depots still operate under WCF.)

When the shipyards were financed through the NWCF, the Congress appropriated funds each year to the Atlantic and Pacific Fleets for ship maintenance and to the Naval Sea Systems Command (NAVSEA) for modifications and conversions.¹³ The income that each shipyard received for the work it performed paid for its operations, including labor, materials, local overhead, and capital depreciation. (Military construction is handled directly through separate military construction appropriations.)

Under the WCF approach, public shipyards set the rates they charged on the basis of their planned workloads and to cover all of their expected costs for performing that work, including labor and overhead. (Direct costs of materials were billed separately.) Naval customers obligated funds to the NWCF to cover a project order, fully funding a ship's maintenance costs before any work began. Any differences between expected and actual costs could cause the shipyard to experience a net profit or loss. Shipyards incorporated their annual net profits or losses into their next rate-setting cycle to try to make their future accumulated operating results equal to zero. Because shipyards' rates under the WCF approach were adjusted each year to account for gains and losses in previous years, they could change significantly from year to year, even if the work being performed stayed the same.

According to the Department of Defense (DoD), a primary purpose of working capital funds is to focus attention on the total costs of providing a good or service. Those revolving funds were designed to enable DoD's programs and activities to operate more like businesses, with customers and providers acutely aware of the full costs of what they bought and sold and how well they were allocating their resources. If rates were set correctly, customers would know the cost consequences of their

10. Marianne Bowes, *Overhaul Costs in Public and Private Shipyards: A Case Study* (Center for Naval Analyses, October 1981).

11. John D. Keenan and others, *Issues Concerning Public and Private Provision of Depot Maintenance* (Center for Naval Analyses, April 1994).

12. Congressional Budget Office, *Comparing Working-Capital Funding and Mission Funding for Naval Shipyards* (April 2007), www.cbo.gov/publication/18555.

13. A modification is the replacement of a weapon system or a mechanical system on a ship with a system that is better or more efficient. A conversion usually means changing the mission of a ship by installing different combat and auxiliary systems.

decisions about purchases and would allocate their funds in the most effective way to serve their needs.¹⁴

Mission Funding. Under mission funding, by contrast, the Navy provides the shipyards with a certain amount of funding each year regardless of the amount of work the shipyards perform. The Congress appropriates money to the Department of the Navy, a portion of which is earmarked (through line items) for operating mission-funded support units, such as shipyards. The budgets of those units are set to cover the amount of work that the unit is expected to perform.

Despite the potential advantages of WCF, the Navy switched public shipyards to mission funding.¹⁵ The Navy gave several reasons for requesting the transition, including the fact that mission funding allows the Navy to easily switch priorities within fiscal years. For example, the Navy can switch shipyard workers from one ship to another or from depot maintenance to less intensive intermediate maintenance, with no need to make budgetary adjustments (as would be necessary under WCF).¹⁶ Another reason was that under working capital

funding, the shipyards had difficulty achieving a net operating result of zero. In most years, they had either a profit or a loss, which led to price swings between fiscal years.¹⁷

Mission-funded shipyards provide maintenance services to the Atlantic and Pacific Fleets at no charge, but they receive reimbursement from NAVSEA for the cost of modifications and conversions. (Separate direct appropriations fund capital expenditures and military construction at mission-funded shipyards.) Most important for CBO's analysis, however, is that under mission funding, the Navy no longer reports overhead costs for overhaul work, which it was required to do under WCF. As a result, the costs reported to the Navy's ship maintenance cost-reporting system that CBO relied on for this analysis no longer include overhead costs. (Those overhead costs did not disappear, but they are no longer reported in the Navy's Visibility and Management of Operating and Support Costs, or VAMOSC, system.) Instead, each public shipyard tracks costs only for direct civilian labor and materials, a policy consistent with DoD's guidance on financial management regulations.¹⁸ By contrast, costs for work done at private shipyards include overhead, which makes them appear higher in VAMOSC than costs at public shipyards operating under mission funding.

Another reason that overhauls at private shipyards appear to cost more than those at public shipyards is that they are funded on the margin—in other words, work at private shipyards must be budgeted for separately and in addition to the shipyards' annual budgets. For that reason, work that was expected to be done in public shipyards is often seen as costing more if it was instead sent to a private shipyard because the Navy has to find that money while it continues to fully fund the public shipyards. Nevertheless, the budget that funds come from affects neither the benefits nor the full costs incurred by the Navy.¹⁹

14. One criticism of working capital funding has been that, in an effort to focus attention on total costs, shipyards under such systems set rates for their services by using expected-average-cost pricing rather than marginal-cost pricing. The rates shipyards charged customers under working capital funding were based on total projected costs—including the accumulated profits and losses of prior years—and projected workloads for a given year. Total costs thus included fixed and sunk costs that were independent of the amount of work the shipyards performed, as well as costs that varied according to shipyards' workloads. Consequently, the prices that shipyards charged customers for a specific task exceeded the marginal (additional) cost of the work performed. If customers viewed those rates as too high, they might have reduced the scope of work they wanted performed at the shipyard, deferred maintenance, or (if possible) shifted to a new maintenance provider (such as an intermediate-level maintenance facility) that operated under mission funding and thus did not include fixed costs in its prices. For additional explanation, see Congressional Budget Office, *Comparing Working-Capital Funding and Mission Funding for Naval Shipyards* (April 2007), www.cbo.gov/publication/18555.

15. Congressional Budget Office, *Comparing Working-Capital Funding and Mission Funding for Naval Shipyards: An Interim Report* (attachment to a letter to the Honorable Joel Hefley, December 1, 2005), www.cbo.gov/publication/17506.

16. Although the fleets that operate the shipyards can switch the priorities of the shipyard within a fiscal year, adjusting how much funding in total goes to the shipyard must be done in the regular budgeting process.

17. See R. Derek Trunkey and Jino Choi, *The Defense Business Operations Fund (DBOF), Problems and Possible Solutions* (Center for Naval Analyses, March 1996).

18. See Department of Defense, Under Secretary of Defense (Comptroller), *Financial Management Regulation*, DoD 7000.14-R, vol. 11A, Chapter 1 (March 1997).

19. When considering a onetime short-term decision about whether to perform an individual overhaul at a Navy shipyard or at a private shipyard, it may be appropriate to compare only the

Differences in Accounting Methods

To make the costs of overhauls at private and public shipyards more comparable, CBO adjusted for important differences in their methods of accounting. In particular, CBO adjusted for each shipyard's overhead costs, which were included in the costs of overhauls at public shipyards when they were operating under working capital funding but not when they switched to mission funding. To account for that change, CBO estimated overhead by year (using the overhead rates observed under WCF and those reported in the Navy's budget justification materials for mission-funded shipyards) and then applied those estimates to the costs per overhaul under mission funding and the shipyards transitioning to mission funding. The details of that adjustment are explained below.²⁰

For private shipyards, the winning bid includes some portion of all costs incurred by the company, including those for overhead, security, construction, capital improvements, and profit. The profit that those shipyards include in their costs billed to the Navy tends to make their overhauls more costly. Because those profits are reflected in VAMOSOC's total costs, CBO did not need to adjust for them. CBO could not adjust for some costs that the Navy incurs for managing the work at private shipyards, such as contract management at NAVSEA, because they are not identified separately.²¹

marginal costs (excluding fixed costs, such as overhead) of each option. However, all costs that can be adjusted over time are relevant for long-term decisions about the appropriate mix of capacity at public and private shipyards (such as those for overhead and facilities). See R. Derek Trunkey and Jino Choi, *The Defense Business Operations Fund (DBOF), Problems and Possible Solutions* (Center for Naval Analyses, March 1996).

20. The Navy performed public-private competitions in the early 1990s (before the period examined in this analysis), when specific rules were used to adjust for differences in cost accounting between private and public shipyards. See Congressional Budget Office, *Public and Private Roles in Maintaining Military Equipment at the Depot Level* (July 1995), www.cbo.gov/publication/15000; and John D. Keenan and others, *Issues Concerning Public and Private Provision of Depot Maintenance* (Center for Naval Analyses, April 1994). CBO could not recreate those calculations using the available data and adjust for all of those cost-accounting differences, but it used the overhead reported under WCF and in the Navy's budget justification materials for mission-funded shipyards to estimate overhead per overhaul under mission funding.
21. CBO estimates that costs for the Navy-wide contract management workforce (contract officers and technical representatives) make up less than 1 percent of the value of all Navy contracts. However, that estimate does not include costs

Uniqueness of Ships and Overhauls

Each ship in the Navy's fleet needs maintenance and modernization throughout its life. For each class of ship, the Navy has a maintenance plan that gives the expected type and number of overhauls (see Appendix A). Some overhauls emphasize maintenance and others emphasize modernization, but most include a mix of the two. Each Navy ship is unique, so each overhaul is tailored to that ship's specific needs. Factors that determine each ship's needs are the year in which the ship was built, the yard where it was built, past maintenance actions, past modernization work, and the conditions under which the ship was operated. According to Navy officials, those individual differences do not factor into decisions about whether to send a ship to a public or private shipyard for an overhaul, so the individual differences in overhauls should average out in the shipyard comparisons.

Limitations of the Available Data

For this analysis, CBO relied on data from the Navy's VAMOSOC system. That database reports operating and support costs (including maintenance costs) for the Navy's ships and covers overhauls completed between 1993 and 2017.²² For each overhaul, VAMOSOC records the name of the ship, the type of overhaul, whether the shipyard that undertook the maintenance was public or private, the dates of maintenance (entrance into and exit from the shipyard), and the total cost.

Those data have several fundamental limitations:

- After 2006 (once all of the public shipyards had transitioned to mission funding), overhead costs were no longer reported.
- There is no standardized way to measure a ship's condition or the amount of work it needs.
- There is no way to assess the quality of the maintenance performed using the available data.

for other headquarters management and oversight for which the positions are not designated specifically for contract oversight.

22. Military departments are required to collect data on the operating and support costs for major weapon systems and to make such data available to the Congress. See National Defense Authorization Act for Fiscal Year 2012 (Public Law 112-81), section 832.

If the Navy systematically assigns ships in worse (or better) condition to public shipyards, then a comparison of average costs or average days in the shipyard would not provide meaningful insight as to which approach is less costly or more expeditious. The observed data would reflect differences in the shipyards' costs as well as differences in the difficulty and complexity of the work assigned to the shipyards. When CBO asked various Navy officials if there was any systematic difference in the assignment of work, they indicated that there was not.²³ In addition, although the data do not contain any measure for the quality of the maintenance performed, the Navy indicated that quality was consistent across shipyards.

Considerations Other Than Costs

When deciding whether to conduct a particular overhaul at a private shipyard (because of anticipated delays at public shipyards), the Navy and the Congress must consider factors other than costs. One factor is the actual time saved by outsourcing the DSRA. Private shipyards have also had long delays for some overhauls. Some of those delays have resulted from unexpected damage that the shipyard discovered once work began and presumably would have caused delays in public shipyards as well. Other delays might arise because of a shortage of qualified labor at private shipyards or because the shipyard was devoting its efforts to new construction instead. An outsourced DSRA that encounters such delays might still be quicker than waiting for the backlog to clear at the public shipyards—or it might not. A second factor is the effect that a particular overhaul will have in supporting the industrial base, either at the public shipyards (which the Navy relies on for most of its overhauls of nuclear-powered ships) or at private shipyards (which the Navy relies on for all of its production of new nuclear-powered ships). A goal for the Navy is to have ready access to the skills and facilities used to build and maintain its ships.

Comparing Costs for Overhauls of Los Angeles Class Submarines

CBO's analysis, which primarily used data from VAMOSC, examined 146 Los Angeles class submarine

23. Navy officials indicated that there is no systematic assignment of ship maintenance between public and private shipyards. There is, however, systematic distribution between the two private shipyards: Electric Boat (in Connecticut) and Newport News (in Virginia) have tended to mostly overhaul submarines that are stationed near their respective locations, whereas ships from the Pacific could be assigned to either shipyard.

DSRAs between 1993 and 2017, 29 of which were conducted in private shipyards and 117 of which were conducted in public shipyards (see Table 1 on page 2).²⁴ On average, the duration of the overhauls was the same in both types of shipyards—113 days—but individual overhauls varied substantially in duration across both types of shipyards.

CBO found that overhauls conducted at private shipyards between 1993 and 2017 cost 31 percent less, on average, than those conducted at public shipyards—after adjusting for the overhead costs of mission-funded overhauls at public shipyards that are missing from the VAMOSC database. Without those adjustments, the reported data understate the cost of overhauls at public shipyards starting in 1999, making overhauls at private shipyards thereafter appear relatively more expensive. CBO also found that the gap in costs between public and private shipyards has narrowed considerably in recent years, even after adjusting for missing overhead costs. CBO examined those effects and, to make its comparisons as complete as possible, used a model to account for a submarine's age and the maintenance plan in effect when it entered the shipyard for an overhaul.

Adjusting Data for Missing Overhead Costs at Public Shipyards

To make more accurate comparisons between the costs of overhauls at public and private shipyards, CBO adjusted the data that the Navy reports in VAMOSC for mission-funded overhauls to include as many of the missing overhead costs as possible.

Under working capital funding, public shipyards reported costs in three categories: labor, material, and overhead. Overhead costs made up 48 percent of the total cost, on average. After switching to mission funding, each public shipyard stopped reporting its overhead costs. (Pearl Harbor switched to mission funding in 1999, Puget Sound in 2004, and Portsmouth and Norfolk in 2007.)²⁵ For overhauls that

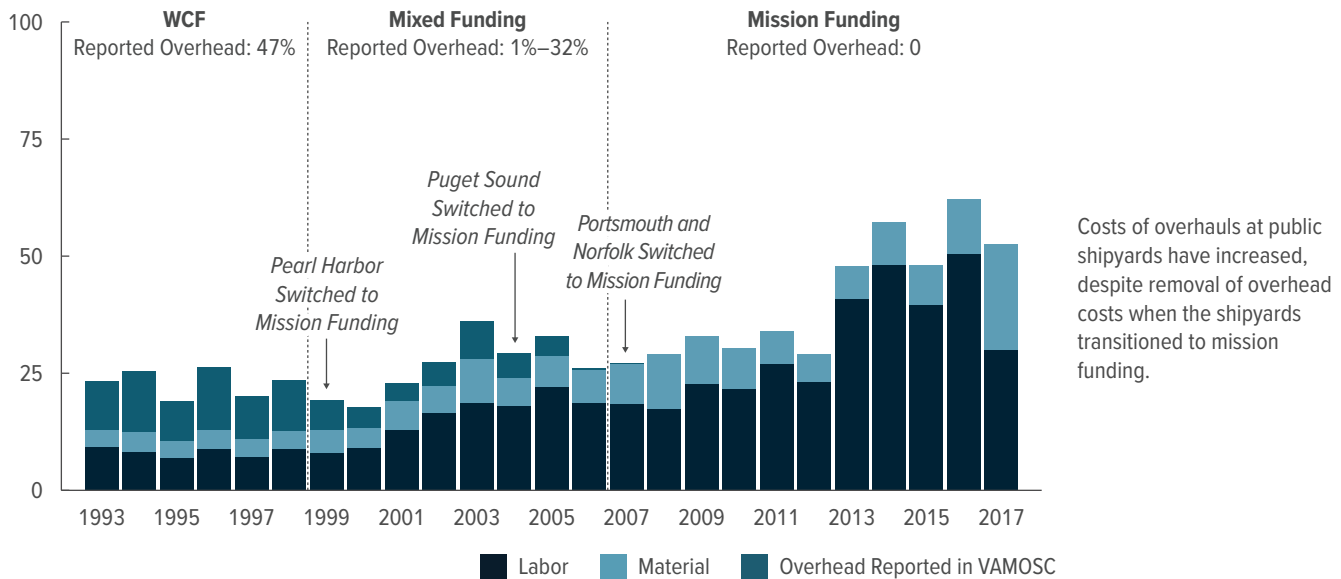
24. Five observations were dropped because they were incomplete, 12 observations were updated using additional information provided by the Navy's Center for Cost Analysis and Naval Sea Systems Command (in May and June of 2018, respectively), and four observations regarding private shipyards were updated with additional information provided by Naval Sea Systems Command in November 2018.

25. Under mission funding, the total workforce budget is set by the amount appropriated, and any spending over that amount would

Figure 2.

Average DSRA Costs for SSN-688s at Public Shipyards, Without Adjusting for Missing Overhead Costs

Millions of 2018 Dollars



Source: Congressional Budget Office, using data from the Navy’s Visibility and Management of Operating and Support Costs (VAMOSC) system.

DSRA = Docking Selected Restricted Availability; WCF = working capital funding.

Between 1999 and 2007, the Navy was transitioning the funding mechanism for shipyards from WCF to mission funding; different shipyards made the transition in different years during that time. Mixed funding means that some costs were reported under WCF, and some were reported under mission funding.

straddled the switch from WCF to mission funding, shipyards reported some, but not all, overhead costs.²⁶ Notwithstanding the accounting change that reduced the costs that the Navy reported for overhauls at public shipyards, the average costs of DSRA that the Navy reported tended to increase from 1999 to 2017 (see Figure 2).

Even though overhead costs for each overhaul were no longer reported in VAMOSC after the transition to mission funding, the Navy—at Congressional direction—started reporting overhead costs by shipyard in the budget justification materials provided with the President’s budget starting in 2007. From 2007 to

2017, those overhead costs ranged from 32 percent to 39 percent when averaged across the shipyards for each year and averaged 34 percent during the entire period. However, those overhead costs are missing some of the costs that were reported under WCF, so the rates reported in the Navy’s budget materials since 2007 probably understate overhead costs of overhauls conducted under mission funding. (The Navy could not provide sufficient information for CBO to determine how much larger overhead costs might be if the Navy accounted for them fully.)

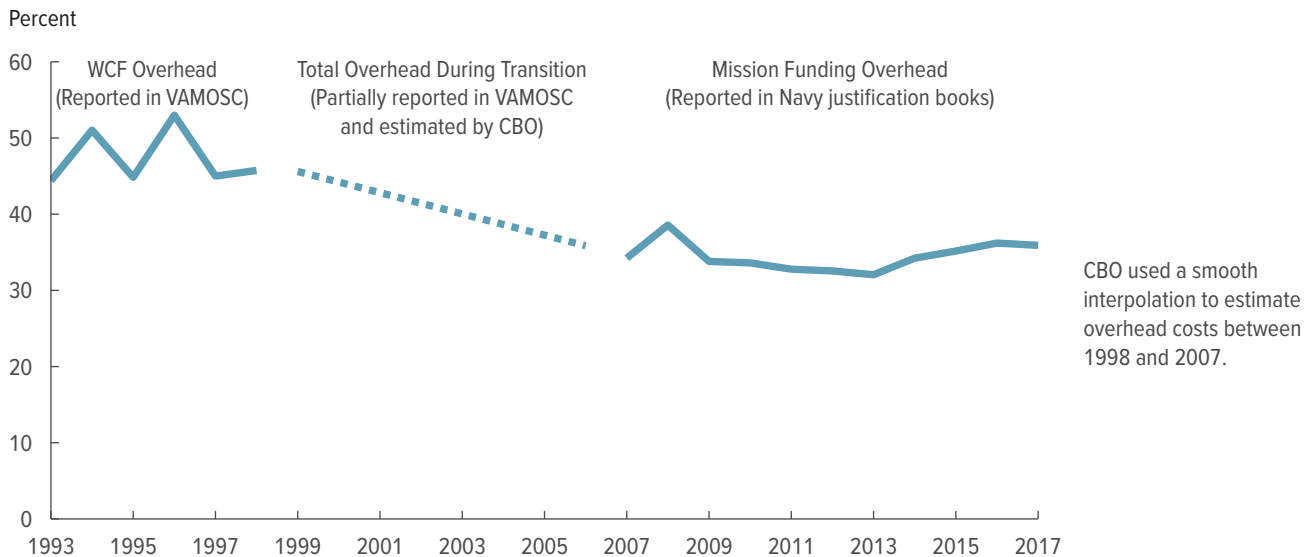
During the transition to mission funding from 1999 to 2006, the data in VAMOSC only reflected overhead costs at shipyards that were still funded by WCF. In the absence of more complete data, CBO’s analysis used a smooth transition from an average of 47 percent overhead until 1998, when all shipyards were under WCF, to an average of 35 percent beginning in 2007, when all shipyards were under mission funding (see Figure 3). In other words, overhead costs at public shipyards fell by an average of about 1.4 percentage points per year from

lead to a violation of the Antideficiency Act, 31 U.S.C. §1341(a) (1)(A). That total workforce budget is then divided between direct work and overhead.

26. Costs in VAMOSC are reported over multiple years, even if an overhaul is completed in one fiscal year. For that reason, some overhauls that were completed at a shipyard under WCF had costs that were later reported under the mission funding rules and thus did not include overhead costs.

Figure 3.

Overhead Costs for Shipyards Transitioning From Working Capital Funding to Mission Funding



Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSOC) system and Department of the Navy, *Budget Materials, Operation and Maintenance, Navy (OMN) Volume II Data Book, "Naval Shipyards"* (February 2018 and previous years).

WCF = working capital funding.

1999 to 2007. For data after 2007, CBO adjusted the costs of each overhaul reported in VAMOSOC by applying the average overhead costs for the shipyards reported in the budget justification materials for that year.

When the estimated overhead is added to overhauls performed in mission-funded shipyards (during the transition years and afterward), the upward trend in costs per DSRA observed in the unadjusted VAMOSOC data is accentuated (compare Figure 4 with Figure 2 on page 9). Actual overhead costs may be larger or smaller under mission funding than they were under WCF, but they are probably higher than the Navy reports in its budget justification materials after 2006 and are certainly greater than the overhead costs of zero that the Navy reports in VAMOSOC. (The overhead costs reported in the budget justification materials are the most complete data available from the Navy.)²⁷

27. Department of the Navy, *Budget Materials, Operation and Maintenance, Navy (OMN) Volume II Data Book, Naval Shipyards* (February 2018), <https://go.usa.gov/xPsEr>. See also Congressional Budget Office, *Review of Proposed Congressional Budget Exhibits for the Navy's Mission-Funded Shipyards* (attachment to a letter to the Honorable Duncan Hunter, April 14, 2006), www.cbo.gov/publication/17725.

Comparing 25-Year Average Costs

After adjusting the Navy's data for missing overhead costs, CBO determined that the 146 DSRA overhauls conducted between 1993 and 2017 cost the Navy \$31.6 million each, on average.²⁸ But the costs varied by type of shipyard. The 117 overhauls performed at public shipyards averaged \$33.6 million each, and the 29 overhauls performed at private shipyards averaged \$23.3 million each—or 31 percent less (see Table 1 on page 2).

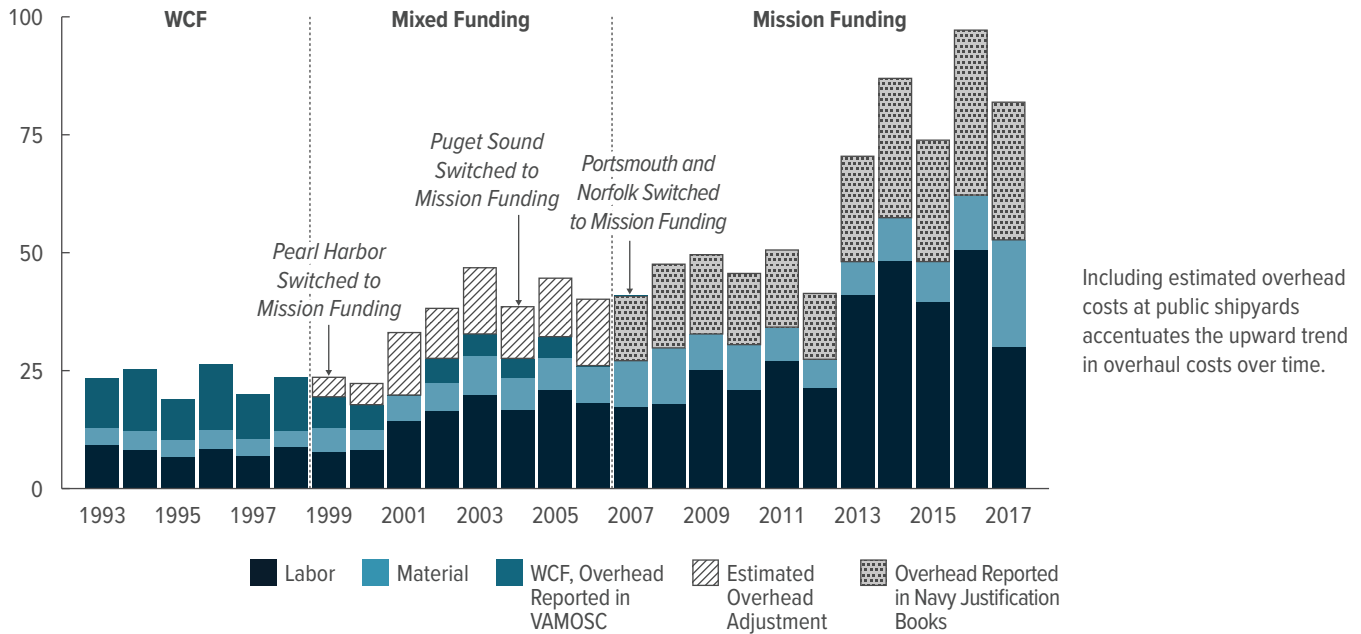
Those 25-year averages obscure some important changes that occurred over the 1993–2017 period. For example, both types of shipyards experienced rising costs over the period, in part because of the aging of the submarines and because of changes to the maintenance plans. Other factors, such as when the overhauls were performed, also affected the comparison. Private shipyards conducted relatively more of their overhauls in the 1990s, when overhauls cost less, skewing their average cost downward. In contrast, public shipyards conducted most of their overhauls since 1999, when costs have been higher, which skewed their costs upward in the latter part of the period.

28. All costs in this analysis are expressed in 2018 dollars and adjusted to remove the effects of inflation (using the Bureau of Economic Analysis's gross domestic product price index).

Figure 4.

Average DSRA Costs for SSN-688s at Public Shipyards

Millions of 2018 Dollars



Source: Congressional Budget Office, using data from the Navy’s VAMOSOC system.

DSRA = Docking Selected Restricted Availability; VAMOSOC = the Navy’s Visibility and Management of Operating and Support Costs system; WCF = working capital funding.

Trends in DSRA Overhauls

The adjusted costs reveal some important trends in costs, days of labor, and duration of overhauls for Los Angeles class submarines.

Costs at Private Shipyards Have Been Lower, Especially Early On. Private shipyards completed most of their 29 DSRA’s in the 1990s and early 2000s, at an average cost that was much lower than the cost at public shipyards in the same time frame (see Figure 5). One explanation for that difference is that the Navy had just finished its public-private ship maintenance initiative, which drove down costs because of increased competition.²⁹ A second explanation is that the private shipyards had more experience maintaining submarines in the early 1990s and thus could perform the overhauls more quickly and efficiently.

Costs Have Risen at Both Public and Private Shipyards. In the mid-2000s, the Navy altered its policy toward

overhauls, giving work to the private shipyards only when the public shipyards were full. Thus, the private shipyards after that time had less experience maintaining submarines, and the public shipyards had less competition. Meanwhile, submarines were getting older, and maintenance plans were adding more planned hours of labor per DSRA (see Appendix A). As a result, the costs for all shipyards started rising through the 2000s and 2010s, from about \$20 million per DSRA, on average, in the 1990s to more than \$50 million after the Navy switched to mission funding in 2007. (That increase occurred even though public shipyards excluded overhead from their reported costs after they switched to mission funding.)

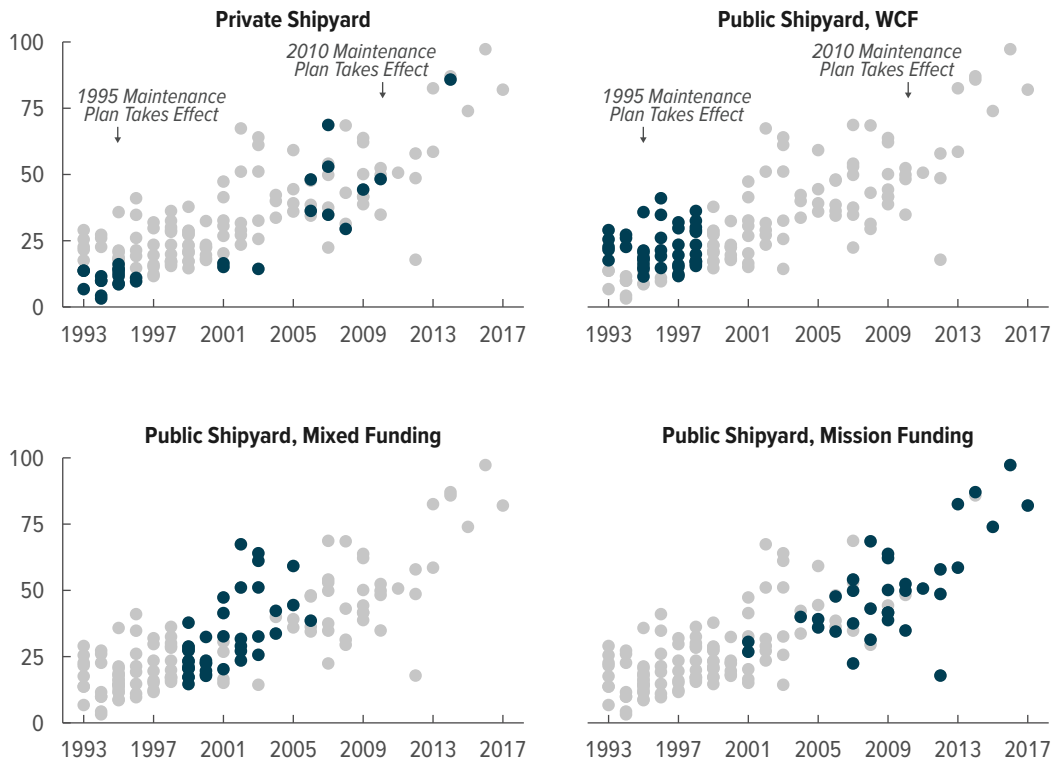
Costs From One Overhaul to Another Can Vary Widely. That can occur even for overhauls performed in the same year and at the same shipyard. That cost variation results mainly from two factors: the material condition of the submarines (because of either different operating conditions or deferred maintenance) and

29. John D. Keenan and others, *Issues Concerning Public and Private Provision of Depot Maintenance* (Center for Naval Analyses, April 1994).

Figure 5.

DSRA Costs for SSN-688s, by Type of Shipyard and Funding

Millions of 2018 Dollars



Costs to overhaul submarines have increased for all types of shipyards over time.

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

Between 1999 and 2007, the Navy was transitioning the funding mechanism for shipyards from WCF to mission funding; different shipyards made the transition in different years during that time. Mixed funding means that some costs were reported under WCF and some were reported under mission funding.

Costs were adjusted to include overhead activities.

DSRA = Docking Selected Restricted Availability; WCF = working capital funding.

the amount of modernization that the Navy decides to incorporate into a particular DSRA.

For example, the Navy's 1995 maintenance plan extended the time between maintenance events over the life of a submarine but increased the expected days of labor per DSRA. CBO adjusted for those changes to the maintenance plans by using an empirical model of costs (discussed in more detail below and in Appendix B).

The Days of Labor Spent on Each Overhaul at Public Shipyards Have Increased. In the public shipyards, average days of labor increased from about 20,000 per overhaul in the early 1990s to more than 60,000 in the 2010s, reflecting the change in maintenance plans (see

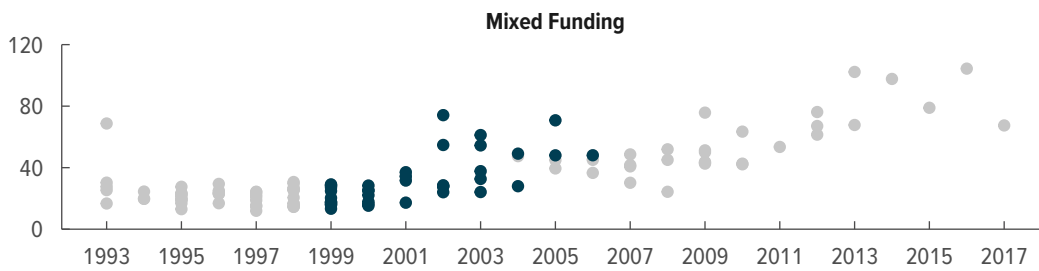
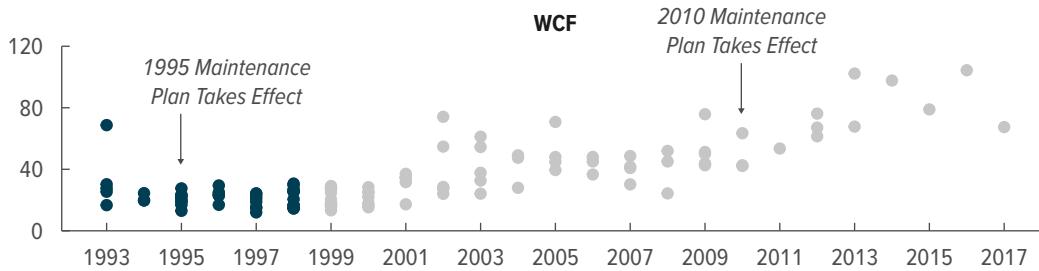
Figure 6).³⁰ Both of those values exceeded the expected days of labor stipulated in the maintenance plans in place for those time periods, which were 18,000 and 57,000, respectively (see Appendix A). Thus, cost increases at public shipyards coincided with increases in the number of days of labor, although costs grew more slowly than the growth in days of labor would suggest (compare Figure 5 with Figure 6).

30. Comparable data for private shipyards were not available consistently. Although VAMOSC does not include data on days of labor at private shipyards, the Navy provided that information separately for some of the overhauls at those shipyards. CBO chose not to include those data, however, because they were incomplete and because the missing values were concentrated in one of the shipyards and thus could bias the results.

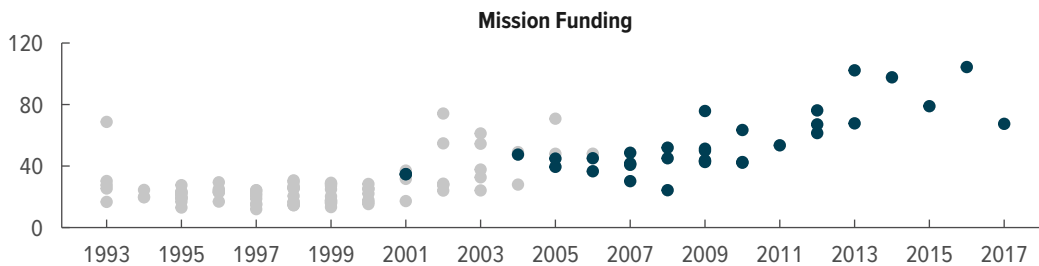
Figure 6.

Number of Days of Labor Spent on DSRA Overhauls for SSN-688s at Public Shipyards

Days of Labor, in Thousands



The number of days of labor per DSRA has trended upward at public shipyards.



Source: Congressional Budget Office, using data from the Navy’s Visibility and Management of Operating and Support Costs (VAMOSOC) system.

Between 1999 and 2007, the Navy was transitioning the funding mechanism for shipyards from WCF to mission funding; different shipyards made the transition in different years during that time. Mixed funding means that some costs were reported under WCF and some were reported under mission funding.

DSRA = Docking Selected Restricted Availability; WCF = working capital funding.

The Duration of Overhauls Also Increased. That trend is another indication of the effects of aging on the fleet. At both public and private shipyards, overhauls of Los Angeles class submarines took longer, even when the maintenance plan remained the same (see, for example, the period from 1995 to 2010 in Figure 7).³¹

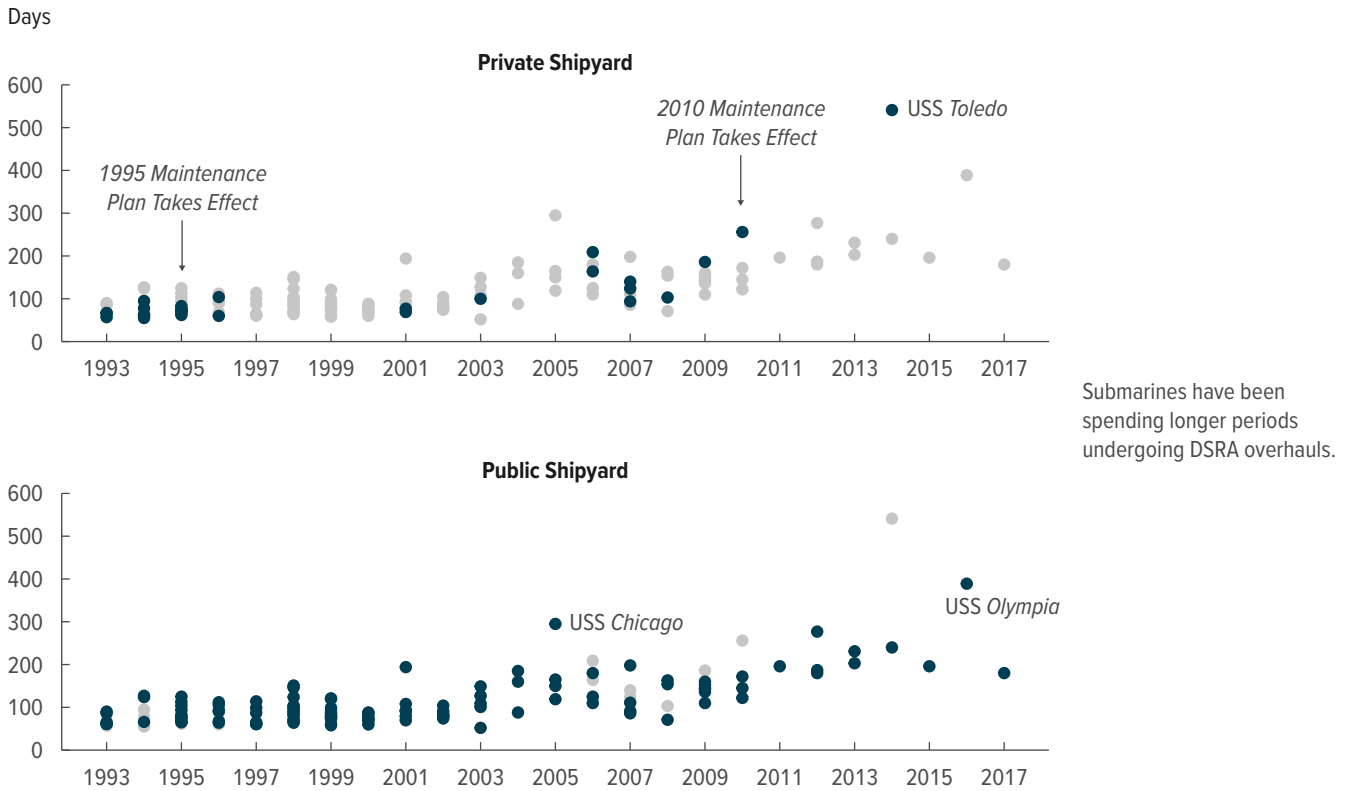
A DSRA that requires more work will be more expensive, for two reasons. First, the additional work requires more days of labor. Second, the overhaul will incur expenses—such as providing utilities to the submarine and accommodations for the crew—even if no work is being performed, perhaps because of a shortage of

31. The notable outlier is the DSRA associated with the USS *Toledo* (see the point on the upper right-hand side of Figure 7), which lasted more than 500 days. According to Electric Boat, its maintenance personnel discovered sizable damage to the *Toledo* during its DSRA that began in November 2012, delaying

completion until May 2014. The *Toledo* represents one of the very few DSRA’s conducted at a private shipyard in recent years, which makes comparisons with costs at public shipyards difficult after 2010.

Figure 7.

Number of Days in Shipyard for DSRA Overhauls of SSN-688s



Source: Congressional Budget Office, using data from the Navy’s Visibility and Management of Operating and Support Costs (VAMOSOC) system.
 DSRA = Docking Selected Restricted Availability.

workers or a shift in priorities. Delays from waiting for workers have occurred at Navy shipyards because, by Navy policy, work on Los Angeles class submarines has a lower priority than work on other nuclear-powered ships, such as strategic ballistic missile submarines and aircraft carriers. Delays have also occurred at private shipyards when additional damage was found and a new contract had to be written. The extent to which such delays have driven up costs at both types of shipyards is unknown. But costs have increased for DSRA overhauls at all types of shipyards as submarines have aged (see Figure 8). And although overhaul costs among submarines of the same age have varied widely, they have generally trended upward.³²

32. Changes in the submarine’s design over time may account for some of the increase in costs, although that effect appears to be small. Improved Los Angeles Class submarines (SSN 751-773s), which have retractable bow planes and vertical launch tubes, require additional maintenance. DSRA’s performed on those submarines were about 4 percent more expensive than overhauls

Comparing Costs by Funding Period

Average costs do not fully account for trends in the costs of submarine maintenance at public and private shipyards over the 25-year period examined here. To account for those trends, CBO examined overhauls over different periods: those marked by changes in the funding mechanism at public shipyards (examined in this section) and those marked by changes in maintenance plans (discussed in the next section).

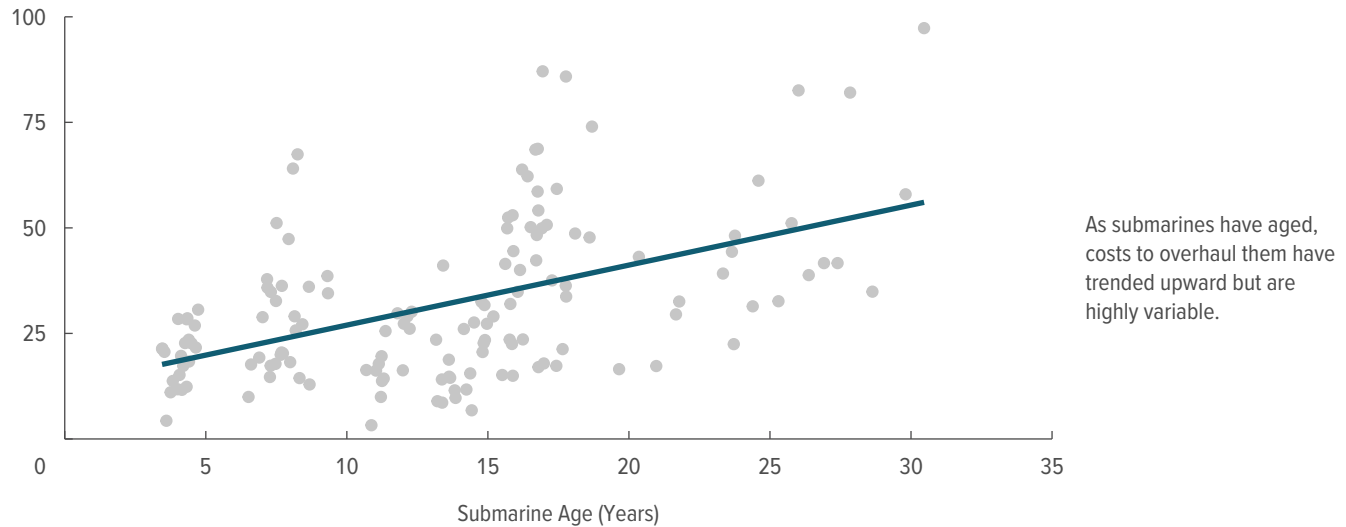
Using the periods defined by the type of funding at public shipyards, CBO found that costs rose over time at both public and private shipyards and that the gap between the costs at the two types of shipyards narrowed. For public shipyards, the adjusted average cost per overhaul rose from \$22 million during working capital funding (before 1999) to \$32 million during the transition from WCF to mission funding (1999 to 2006) and

performed on SSN-688s, but the difference was not statistically significant.

Figure 8.

DSRA Costs for SSN-688s, by Age of Submarine

Millions of 2018 Dollars



Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

Costs were adjusted to include overhead activities.

DSRA = Docking Selected Restricted Availability.

to \$50 million during mission funding (after 2006; see Table 2, which also shows the unadjusted costs for each time period).³³

Comparing the adjusted costs at public shipyards with the costs at private shipyards reveals that the gap between the shipyards has narrowed considerably. Private shipyards were 52 percent less expensive, on average, than public shipyards before 1999. That gap shrank to an average of 21 percent between 1999 and 2006 and almost disappeared from 2007 to 2017 (see Table 1 on page 2). The gap could be slightly wider in that last period than the adjusted data indicate, however, because the Navy's budget justification materials (and CBO's adjustments based on those data) still omit some overhead costs. (CBO examines the effects of a higher overhead rate below.)

The adjusted data also reveal some interesting trends. For example, if the estimated overhead rate is applied to all overhauls at public shipyards, the total cost per

day of labor in those shipyards can be compared over the whole period; such a comparison allows analysts to determine whether costs per overhaul are rising because more work is required or because the cost per day of labor is increasing. (Private shipyards do not provide labor hours to VAMOSC, so CBO could not examine those data for similar trends.) Comparisons show that overhaul costs per day of labor in public shipyards have not increased since 1993, so the main reason for rising costs over time has been the growing workload per overhaul from the aging of the submarines and the changing of maintenance plans (see Figure 9). The omission of overhead costs from the Navy's budget justification materials has lowered the estimated costs per day of labor under mission funding, but CBO could not estimate the magnitude of those missing costs.

Comparing Costs by Maintenance Plan

CBO also examined how costs have changed as the Navy has updated its maintenance plans. Costs per DSRA have been trending upward, and larger increases followed the introduction of new maintenance plans in 1995 and 2010 (see Figure 5 on page 12). Tabulating overhaul costs by maintenance plan is a simple way to control for those changes.

33. The difference between unadjusted and adjusted average costs was largest for the period during mission funding because the unadjusted data exclude overhead costs; including overhead raises the average cost from \$33 million to \$50 million.

Table 2.

DSRA Overhauls of SSN-688s, by Type of Funding

	Public Shipyards					
	Private Shipyards	Working Capital Funding	Transitional Funding		Mission Funding	
			Unadjusted With Some Overhead	Adjusted for Estimated Overhead ^a	Unadjusted	Adjusted for Estimated Overhead ^a
Number of Overhauls	29	44	40	40	33	33
Average Cost (Millions of 2018 dollars)	23.3	22.3	23.8	32.3	32.5	50.1
Average Days in Shipyard	113	88	98	98	164	164

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

From 1993 to 1998, Navy shipyards used working capital funding, and from 2007 to 2017 they used mission funding. The years between were a period of transition between the two types of funding.

DSRA = Docking Selected Restricted Availability.

a. CBO adjusted costs to include estimated overhead costs that the Navy omitted from VAMOSC starting in 1999.

Under the 1989 maintenance plan, public and private shipyards performed eight overhauls each. The average cost of those overhauls was \$24 million at public shipyards and \$9 million (or less than half) at private shipyards (see the first two columns of Table 3).

Under the 1995 maintenance plan, private shipyards completed 20 overhauls (at a cost of \$26 million each), and public shipyards completed 96 overhauls. Of the overhauls done at public shipyards, the 36 completed under WCF were the least costly, at \$22 million each, on average. The 40 overhauls done at public shipyards during their transition from WCF to mission funding cost \$32 million each, on average, after CBO adjusted the data. The 20 overhauls done at public shipyards under mission funding cost \$43 million each, after CBO adjusted the data. In total, compared with overhauls at public shipyards under the 1995 maintenance plan, those conducted at private shipyards cost about 18 percent more under WCF, 20 percent less under transitional funding, and 40 percent less under mission funding.

Available data are insufficient to compare overhauls done at public and private shipyards under the 2010 maintenance plan. Only one overhaul has been completed at a private shipyard since then (for the USS *Toledo*), the cost of which was higher than expected because of damage discovered during the overhaul. Although 13 overhauls have been conducted at public shipyards, the Navy had unexpected problems with some of them, such as the overhaul of the USS *Louisville*, which also cost more than

expected.³⁴ Those problems may be occurring more frequently as the Los Angeles class submarines are nearing the end of their expected life, but comprehensive data on specific reasons for cost overruns were not available. Because of the small number of overhauls performed under the 2010 plan, comparisons of costs across shipyards under that plan are not statistically meaningful.

Overall, after adjusting for overhead costs, CBO found that overhauls performed at private shipyards were less costly than those done at public shipyards—62 percent less, on average, under the 1989 maintenance plan and 16 percent less under the 1995 maintenance plan (see the average costs listed in the second and third columns of Table 4 on page 19). Costs were substantially higher for the one overhaul done at a private shipyard under the 2010 maintenance plan than for the 13 overhauls performed at public shipyards, but with only one observation it is not possible to assess whether overhauls at private shipyards have been more expensive under that plan.

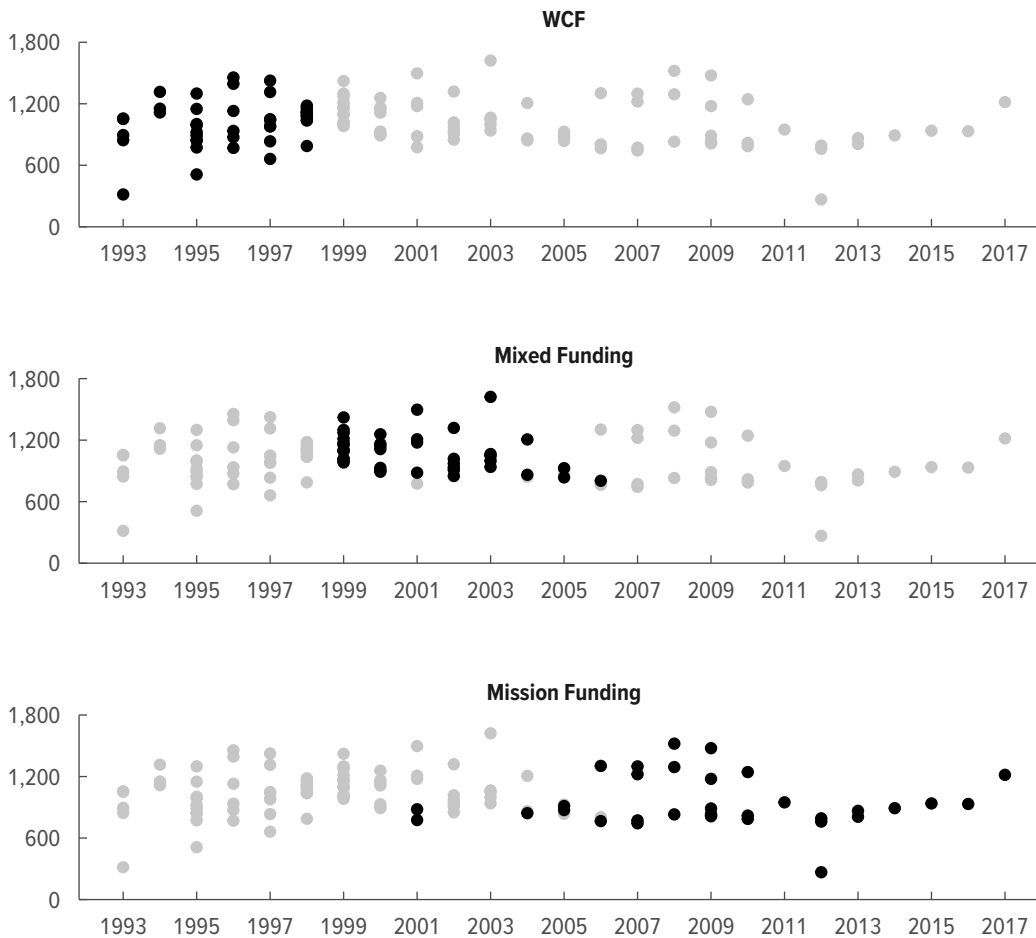
The average age of the submarines at the time of each overhaul was slightly lower at the private shipyards (12.9 years compared with 13.4 years at the public shipyards), but that factor accounts for only a small part of the difference in costs (as discussed below).

34. See Naval Sea Systems Command, *Private & Public Shipyards Docking Selected Restricted Availabilities (DSRA) Study* (December 2018), which the Navy provided to CBO. Data in VAMOSC do not reflect the higher cost for the USS *Louisville*.

Figure 9.

DSRA Costs per Day of Labor for SSN-688s at Public Shipyards

Costs per Day of Labor, in 2018 Dollars



Source: Congressional Budget Office, using data from the Navy’s Visibility and Management of Operating and Support Costs (VAMOSC) system and Department of the Navy, *Budget Materials, Operation and Maintenance, Navy (OMN) Volume II Data Book, “Naval Shipyards”* (February 2018 and previous years).

Between 1999 and 2007, the Navy was transitioning the funding mechanism for shipyards from WCF to mission funding; different shipyards made the transition in different years during that time. Mixed funding means that some costs were reported under WCF and some were reported under mission funding.

Costs calculated on the basis of data from VAMOSC do not match those calculated on the basis of data reported in the Navy’s budget justification materials.

DSRA = Docking Selected Restricted Availability; WCF = working capital funding.

Comparisons Using an Alternative Approach to Projecting Overhead Costs

In this analysis, CBO adjusted costs at public shipyards by adding overhead for each mission-funded overhaul at the average rate for all shipyards reported for each year in the Navy’s budget justification materials. That rate varied each year but averaged 35 percent between 2007 and 2017 (see Figure 3 on page 10).

If, instead, CBO used the rate that the Navy experienced under working capital funding—48 percent—the difference in adjusted costs across overhauls would be larger. Under that alternative assumption, overhauls at private shipyards over the 25-year period would cost 36 percent less (not 31 percent less) than at public shipyards, on average. Using those historical overhead rates would also increase the cost difference during the transitional

Table 3.

DSRA Overhauls of SSN-688s, by Maintenance Plan and Type of Funding

	Private Shipyards	Public Shipyards		
		Working Capital Funding	Transitional Funding	Mission Funding
Number of Overhauls				
1989 maintenance plan	8	8	n.a.	n.a.
1995 maintenance plan	20	36	40	20
2010 maintenance plan	1	n.a.	n.a.	13
Total Number of Overhauls	29	44	40	33
Average Cost (Millions of 2018 dollars)				
1989 maintenance plan	9.2	24.1	n.a.	n.a.
1995 maintenance plan	25.9	22.0	32.3 ^a	43.0 ^a
2010 maintenance plan	85.9	n.a.	n.a.	61.1 ^a
Total Average Cost	23.3	22.3	32.3^a	50.1^a
Average Days in Shipyard				
1989 maintenance plan	68	85	n.a.	n.a.
1995 maintenance plan	110	89	98	134
2010 maintenance plan	541	n.a.	n.a.	209
Total Average Days in Shipyard	113	88	98	164

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

From 1993 to 1998, Navy shipyards used working capital funding, and from 2007 to 2017 they used mission funding. The years between were a period of transition between the two types of funding.

DSRA = Docking Selected Restricted Availability; n.a. = not applicable.

a. CBO adjusted costs to include estimated overhead costs that the Navy omitted from VAMOSC starting in 1999.

funding period (25 percent less rather than 21 percent) and during the mission funding period (14 percent less rather than 3 percent), which suggests that the gap in costs may still persist.

One reason to expect that overhead costs could be the same under mission funding and under WCF is that some categories of overhead costs that the Navy reported under WCF are no longer captured by the accounting system—and it is not clear that the Navy can track them anymore.³⁵ That alternative assumption alters the size of the difference in costs but does not change the basic finding: Overhauls at private shipyards were less expensive, on average, for most of the 1993–2017 period, and that difference has narrowed in recent years (but may not have vanished).

35. Congressional Budget Office, *Comparing Working-Capital Funding and Mission Funding for Naval Shipyards* (April 2007), www.cbo.gov/publication/18555.

Adjusting for Age and Maintenance Plan

In this analysis, CBO used simple comparisons of adjusted data for each time period or maintenance plan. To examine the individual contribution of each factor, CBO used a regression model. That model enabled CBO to estimate the difference between costs of overhauls at public and private shipyards after making adjustments for overhead costs and accounting for differences in the age of the submarine and the maintenance plan in effect when the submarine entered the shipyard (see Appendix A).

That regression analysis confirms the results of the simple comparisons: Overhauls at private shipyards were 35 percent less expensive, on average, than at public shipyards from 1993 to 2017, after controlling for age and maintenance plan.

Because a submarine's age and the year increase together, distinguishing the effects of time from the effects of age can be difficult. Using the regression model, CBO found that the cost of a DSRA rises by about 3.5 percent for each year that a submarine ages, after controlling for the type of shipyard and the changes in maintenance plans. (That cost increase attributed to age could also reflect time trends unrelated to age.)

That aging coefficient can be used to refine the comparisons of maintenance plans to account for the differences in the ages of submarines when they were overhauled. According to the model, about 6 percentage points of the difference in costs (of a total difference of 52 percent) under the 1989 maintenance plan stemmed from the fact that the submarines receiving their overhauls at private shipyards were about two years younger than those at public shipyards. If the submarines had been the same age in both private and public shipyards, private shipyards would have been 56 percent less expensive (rather than 62 percent, as shown in Table 4).

Under the 1995 maintenance plan, public shipyards conducted DSRA on submarines that were about two years younger, so the correction goes in the other direction—making the difference larger. Instead of the 23 percent lower cost at private shipyards, the difference would have been 28 percent if the submarines' ages had been the same. (A reliable estimate of the cost differences for the 2010 plan is not possible because of the small sample size.)

The early 1990s represented a time when private shipyards were doing multiple overhauls per year; because of that volume, they were prepared for and experienced in undertaking that type of work. The cost differences between public and private shipyards might be smaller today, but CBO is not aware of any evidence showing that private shipyards are more expensive than public shipyards after adjustments for overhead are taken into account.

Table 4.

DSRA Overhauls of SSN-688s, by Maintenance Plan

	Private Shipyards	Public Shipyards ^a	Difference (Percent)
Number of Overhauls			
1989 maintenance plan	8	8	n.a.
1995 maintenance plan	20	96	n.a.
2010 maintenance plan	1	13	n.a.
Total Number of Overhauls	29	117	n.a.
Adjusted Average Cost (Millions of 2018 dollars)^b			
1989 maintenance plan	9.2	24.1	-62
1995 maintenance plan	25.9	30.6	-16
2010 maintenance plan	85.9 ^c	61.1	c
Total Adjusted Average Cost	23.3	33.6	-31
Average Days in Shipyard			
1989 maintenance plan	68	85	-20
1995 maintenance plan	110	102	7
2010 maintenance plan	541 ^c	209	c
Total Average Days in Shipyard	113	113	0
Average Age of Submarine			
1989 maintenance plan	8.2	10.0	-18
1995 maintenance plan	14.5	12.5	16
2010 maintenance plan	17.8 ^c	21.5	c
Total Average Age of Submarine	12.9	13.4	-3

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSOC) system.

DSRA = Docking Selected Restricted Availability; n.a. = not applicable.

- Includes all types of funding: working capital, transitional, and mission.
- Costs were adjusted to include overhead activities that the Navy omitted from VAMOSOC starting in 1999.
- Insufficient sample size to have confidence in the comparison.

Changes in the Maintenance Plans for Los Angeles Class Submarines

Life-cycle maintenance plans display the expected duration and frequency of depot maintenance over the life of submarines. For Los Angeles class (SSN-688) submarines, those plans have evolved over time as the Navy has accumulated more experience with the class (see Figure A-1). The original 1974 maintenance plan included eight of the most common type of overhaul, the Docking Selected Restricted Availability (DSRA). Over the submarines' expected 30-year lifetime, one DSRA overhaul occurred about every three years, and more intensive overhauls (such as regular overhauls, or ROHs, and refueling overhauls, or RFOs), took the place of DSRA three times.

The 1989 maintenance plan made several changes. In place of the two regular overhauls, it introduced a depot modernization period (DMP) and a pre-inactivation overhaul—a small overhaul that was intended to do only what was required for the remaining life of the ship. In addition, the 1989 plan eliminated two of the DSRA. The net effect was to reduce the lifetime days of labor required for DSRA maintenance—from about 1 million to about 600,000—and to boost the expected number of deployments from 12 to 13 over the life of the submarine.¹

1. The plans do not account for the days of labor associated with the Post Shakedown Availabilities that occur at private shipyards or the inactivations at the end of a submarine's life that usually occur at public shipyards.

The 1995 maintenance plan made additional changes. It extended the life of each submarine from 30 years to 33 years and eliminated the midlife refueling. (That refueling was no longer required with the reactors that were built into Improved Los Angeles class submarines.) As a result, the submarines were able to complete 15 deployments. Under the 1995 plan, the number of DSRA was the same, but each one was increased in duration and days of labor.

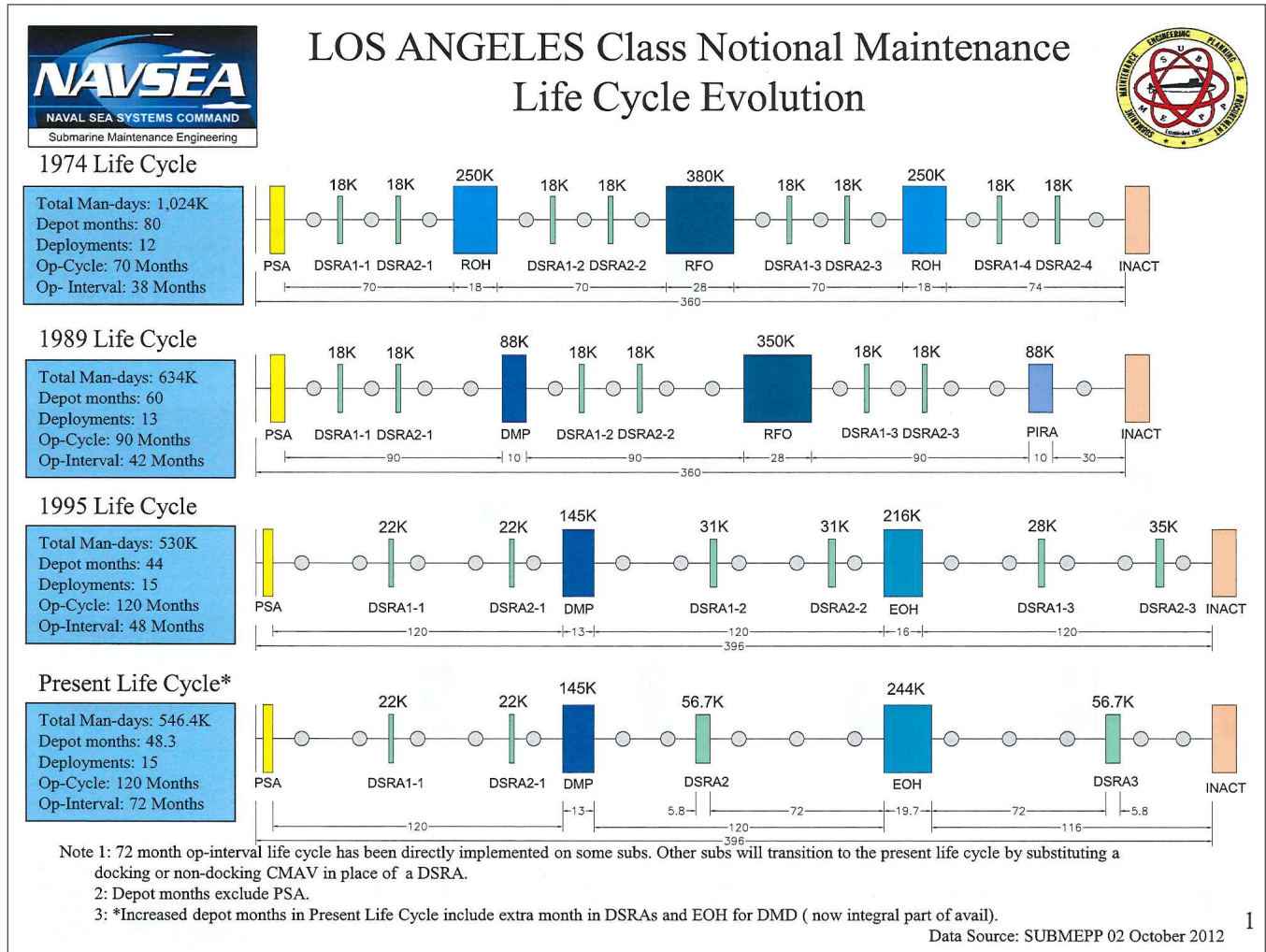
The most recent maintenance plan is from 2010. That plan eliminated two more DSRA but more than doubled (relative to the 1989 plan) the days of labor required for the last two DSRA.

All of the maintenance plans are just that—plans. The actual maintenance on submarines occurs on a less predictable schedule and often takes longer than the plan anticipates in terms of time in the shipyard and days of labor expended. Nevertheless, the four plans reflect changes in expected workload and maintenance philosophy that have evolved over the years.

Figure A-1.

Evolution of Life-Cycle Maintenance Plans for Los Angeles Class Submarines

The Los Angeles class's maintenance plans have evolved toward having fewer overhauls, which allows for more ship deployments.



Source: Naval Sea Systems Command (NAVSEA).

This image is a reproduction. NAVSEA provided additional information indicating that the "Present Life Cycle" maintenance plan took effect in fiscal year 2010.

An Empirical Model of Overhaul Costs for Los Angeles Class Submarines

To examine the results of the Congressional Budget Office’s primary analysis from another perspective, the agency used a linear regression model to estimate the association between the costs of an overhaul—specifically, a Docking Selected Restricted Availability, or DSRA—for a Los Angeles class (SSN-688) submarine and other explanatory factors. Each coefficient shows the association between cost and one factor, holding the other factors constant. For example, the estimates show the difference between the costs of maintenance in public and private shipyards for submarines of the same age and class maintenance plan.

The model is represented by the following equation:

$$\ln(\text{Adjusted Cost}) = \alpha + \rho \times \text{Private} + \beta \times \text{Age} + \gamma \times \text{1995 maintenance plan (22,000 days of labor)} + \tau \times \text{1995 maintenance plan (28,000 to 31,000 days of labor)} + \delta \times \text{2010 maintenance plan}$$

Adjusted cost is the cost of an overhaul, including adjustments to impute overhead costs from historical data when those costs were not reported. *Private* is an indicator variable equal to zero for a public shipyard and one for a private shipyard. *Age* is the age of a submarine, in years. The variable *1995 maintenance plan (22,000 days of labor)* is an indicator that the 1995 maintenance plan was in effect when the submarine’s overhaul was completed and that the DSRA was one of the first two DSRA in that submarine’s life cycle (see Appendix A for the evolution of the SSN-688’s maintenance plans). The variable *1995 maintenance plan (28,000 to 31,000 days of labor)* is an indicator that the 1995 maintenance plan was in effect when the submarine’s overhaul was completed and that the DSRA was one of the last four DSRA in that submarine’s life cycle. The last

variable, *2010 maintenance plan*, is an indicator that the 2010 maintenance plan was in effect when the overhaul was completed.¹

The coefficient ρ shows the difference in costs between conducting maintenance at a private shipyard or a public shipyard (see Table B-1). The coefficient of -0.428 in that table indicates that conducting maintenance at a private shipyard is associated with a 35 percent decrease in costs—calculated as $\exp(-.428) - 1$. That coefficient, combined with its standard error of 0.101, implies that the probability of observing an association that large by chance is less than one-half of 1 percent.

One of the uses of those results (the coefficient estimate and the standard error) is to calculate a range of estimates of the difference in costs between public and private shipyards. Doing so yields a 95 percent confidence interval for ρ that is between -0.23 (corresponding to a 20 percent decrease in price) and -0.63 (corresponding to a 47 percent decrease in price). In other words, that interval would contain the true value of the parameter 95 percent of the time in repeated samples from the same underlying population. (Those numbers are based on the data in Table B-1 but are not shown.)

1. Under the 1995 class maintenance plan, the last DSRA in a submarine’s life cycle is expected to take 35,000 days of labor to complete, but no submarines in the Navy’s Visibility and Management of Operating and Support Costs (VAMOSOC) database received a DSRA in that part of their life cycle. Under the 2010 plan, the first two DSRA in the life cycle are expected to take 22,000 days each, but no submarines in the VAMOSOC database received a DSRA in that part of their life cycle. Portions of the class maintenance plans discussed in Appendix A do not apply to the available VAMOSOC data (1993 through 2017), and CBO only accounted for class maintenance plans observed in the data.

Table B-1.

Regression Results for DSRA Overhauls of SSN-688s

Variable	Coefficient	Standard Error	P Value ^a
Intercept	16.348	0.159	< 0.005
Private Shipyards	-0.428	0.101	< 0.005
Age	0.035	0.010	< 0.005
1995 Maintenance Plan With 22,000 Expected Days of Labor	0.410	0.140	< 0.005
1995 Maintenance Plan With 28,000 to 31,000 Expected Days of Labor	0.326	0.156	0.038
2010 Maintenance Plan	0.814	0.212	< 0.005

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

a. The p value is the probability of observing a coefficient at least as large as the one listed in the table if the true coefficient is zero (assuming that all of the model's other conditions are met).

The data set includes 146 observations. The dependent variable is $\ln(\text{adjusted cost})$. The adjusted R squared is 0.422.

DSRA = Docking Selected Restricted Availability.

In the above equation, α is the coefficient on a constant, and β shows how the costs of an overhaul increase as a submarine ages. In this case, the β coefficient's estimate of 0.035 indicates that an increase of one year in the age of a submarine is associated with roughly a 3.6 percent increase in the cost of a DSRA overhaul (computed as $\exp(0.035) - 1$).

The coefficients γ and τ estimate the increase in costs, respectively, associated with implementation of the 1995 maintenance plan (when the DSRA was one of the

first two in its lifetime) compared with costs under the previous (1989) maintenance plan. The 1995 maintenance plan increased the expected hours needed to complete each DSRA. The coefficient estimates of 0.410 and 0.326 indicate that the 1995 plan is associated with costs that are 51 percent higher (computed as $\exp(0.410) - 1$) and 39 percent higher (computed as $\exp(0.326) - 1$) than costs in the 1989 plan, depending on where the submarine is in its life cycle. The coefficient δ shows the increase in costs associated with the 2010 maintenance plan; those costs are 126 percent higher (computed as $\exp(0.814) - 1$) than costs in the 1989 plan.



List of Tables and Figures

Tables

1.	DSRA Overhauls of SSN-688s, by Period of Funding	2
2.	DSRA Overhauls of SSN-688s, by Type of Funding	16
3.	DSRA Overhauls of SSN-688s, by Maintenance Plan and Type of Funding	18
4.	DSRA Overhauls of SSN-688s, by Maintenance Plan	19
B-1.	Regression Results for DSRA Overhauls of SSN-688s	24

Figures

1.	Average DSRA Costs for SSN-688s	3
2.	Average DSRA Costs for SSN-688s at Public Shipyards, Without Adjusting for Missing Overhead Costs	9
3.	Overhead Costs for Shipyards Transitioning From Working Capital Funding to Mission Funding	10
4.	Average DSRA Costs for SSN-688s at Public Shipyards	11
5.	DSRA Costs for SSN-688s, by Type of Shipyard and Funding	12
6.	Number of Days of Labor Spent on DSRA Overhauls for SSN-688s at Public Shipyards	13
7.	Number of Days in Shipyard for DSRA Overhauls of SSN-688s	14
8.	DSRA Costs for SSN-688s, by Age of Submarine	15
9.	DSRA Costs per Day of Labor for SSN-688s at Public Shipyards	17
10.	Evolution of Life-Cycle Maintenance Plans for Los Angeles Class Submarines	22



About This Document

This Congressional Budget Office report was prepared at the request of the Chairmen and Ranking Members of the Subcommittee on Readiness and 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. Justin Falk provided helpful comments.

Karl Hasslinger of the Telemus Group and William Hilarides of Hilarides Partners provided comments on the draft, as did Jessie Riposo of the RAND Corporation and Robert Trost of the Center for Naval Analyses. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Jeffrey Kling, John Skeen, and Robert Sunshine reviewed the report. Christine Bogusz edited it, and Casey Labrack prepared it for publication. An electronic version is available on CBO's website (www.cbo.gov/publication/55032).

CBO continually seeks feedback to make its work as useful as possible. Please send any feedback to communications@cbo.gov.

Keith Hall
Director
April 2019