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Increasing the Mission Capability of the Attack Submarine Force

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The Congress of the United States
Congressional Budget Office

NOTES

Unless otherwise indicated, all years referred to in this report are fiscal years and all costs are in 2002 dollars.

The cover shows (top) the Los Angeles class attack submarine *Jefferson City* (SSN-759) entering Apra Harbor in Guam and (bottom) the Trident ballistic missile submarine *Michigan* (SSBN-727), which was scheduled for retirement in 2003 but will now be converted into a guided-missle submarine. Photos courtesy of the U.S. Navy.

Preface

Today's U.S. Navy fleet includes 54 attack submarines (SSNs). In 1999, the Chairman of the Joint Chiefs of Staff released a study concluding that the Navy would need 68 SSNs by 2015 and 76 by 2025 to carry out critical peacetime missions. In public statements and testimony to the Congress, Navy officials have endorsed those numbers. However, reaching those force goals by building more submarines would require a substantial investment, which would compete with many other demands for defense dollars. Are there alternative ways to operate the currently planned force of 55 SSNs and four SSGNs (converted Trident ballistic missile submarines) that would meet those goals without increasing the number of attack submarines?

This Congressional Budget Office (CBO) study—prepared at the request of the Subcommittee on Seapower of the Senate Committee on Armed Services—examines that question. It looks at the missions and modernization plans of the SSN fleet and analyzes the budgetary implications both of maintaining that fleet at 55 and of achieving the force goals in the 1999 study by building additional submarines. The analysis also evaluates three options to increase the mission capability of the attack submarine force through changes in such things as operating concepts and basing locations. Those options would enable a force of 55 SSNs to provide the same number of mission days by 2015 and 2025 that 68 or 76 attack submarines, respectively, would provide under current policies—at substantially lower cost than building more submarines.

Eric J. Labs of CBO's National Security Division wrote this study under the general supervision of J. Michael Gilmore and R. William Thomas. Raymond Hall of CBO's Budget Analysis Division prepared the cost estimates under the general supervision of Jo Ann Vines. Russ Beland helped review the manuscript for factual accuracy before publication. Barry Anderson, David Austin, Debbie Clay-Mendez, Arlene Holen, and David Moore of CBO provided thoughtful comments on an earlier draft of the study, as did independent naval analyst Norman Polmar. The author is especially grateful to numerous officials and analysts at the Department of the Navy who answered many requests for information and thereby improved this analysis. (The assistance of such external participants implies no responsibility for the final product, which rests solely with CBO.)

Christian Spoor edited the study, and Leah Mazade proofread it. Cindy Cleveland produced drafts of the manuscript, Kathryn Winstead prepared the study for publication, and Annette Kalicki prepared the electronic versions for CBO's Web site.

Dan L. Crippen
Director

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Summary

In 1999, the Chairman of the Joint Chiefs of Staff (CJCS) released a study concluding that the United States will need a force of 68 attack submarines (SSNs) by 2015 and a force of 76 by 2025 to fulfill critical missions during peacetime. The study added that if the number of attack submarines fell below 55 in 2015 or 62 in 2025, regional commanders in chief would not be able to respond to crucial demands without putting other national security needs at risk. (The study also stated that 55 SSNs were necessary to meet submarine requirements in wartime.) The Navy's military leadership endorsed the higher numbers in the CJCS study, arguing that today's fleet of 54 attack submarines is too small to perform all of its missions.

One factor driving those force goals is the fact that under current operating policies, attack submarines spend only about 10 percent of their service life carrying out required missions. Like other types of Navy ships, they spend most of their service life conducting training, making port calls, going to and from theaters of operation, and undergoing maintenance.

Building a larger submarine force would require the Navy to spend much more on attack submarines than it does today. Alternatively, the Navy could take various steps to get more mission days from its current force for less than the cost of building additional submarines. This Congressional Budget Office (CBO) study looks at three such options, which expand on ideas or practices that the Navy intends to pursue or that have been mentioned in policy debates. Those options are:

- Retaining four Trident ballistic missile submarines that are set to be retired and converting them to perform conventional rather than nuclear missions,

- Using two alternating crews (dual crewing) or three crews rotating between two submarines (multiple crewing) to operate some attack submarines more efficiently, and

- Basing more submarines in the Pacific island of Guam rather than in the United States.

Converting four Trident submarines to perform conventional missions cited in the CJCS study (using a so-called SSGN configuration) would provide a cost-effective way to increase the mission capability of the attack submarine force until those subs were retired by the mid-2020s.[1] After that, basing 11 submarines in Guam or using dual or multiple crews for some attack submarines would enable a force of 55 SSNs to provide the same number of mission days as a 76-submarine force operating under today's policies. (Of course, the Navy would not have to wait until the mid-2020s to make those two changes.) Overall, basing submarines in Guam represents the most cost-effective option of the three that CBO examined.

1. In the Navy's designations, SSN refers to a nuclear-powered attack submarine and SSGN to a nuclear-powered guided-missile submarine. Trident subs are SSBNs, nuclear-powered ballistic missile submarines.

To keep its analysis impartial, CBO used assumptions and methods to evaluate cost-effectiveness that did not favor either submarine construction or the alternatives to it. On average, CBO estimated that the Navy's new Virginia class submarines would cost about $2.1 billion to produce and that an SSGN would cost the same amount to operate per year as a Trident ballistic missile submarine. CBO estimated that a dual- or multiple-crewed attack submarine would have higher operating costs than a single-crewed attack submarine would, though not as high as those of an SSGN or a ballistic missile submarine (both of which are dual crewed, have larger crews than an attack submarine's, follow a more stringent and costly maintenance program, and are used more intensively than a dual- or multiple-crewed SSN would be in this analysis).

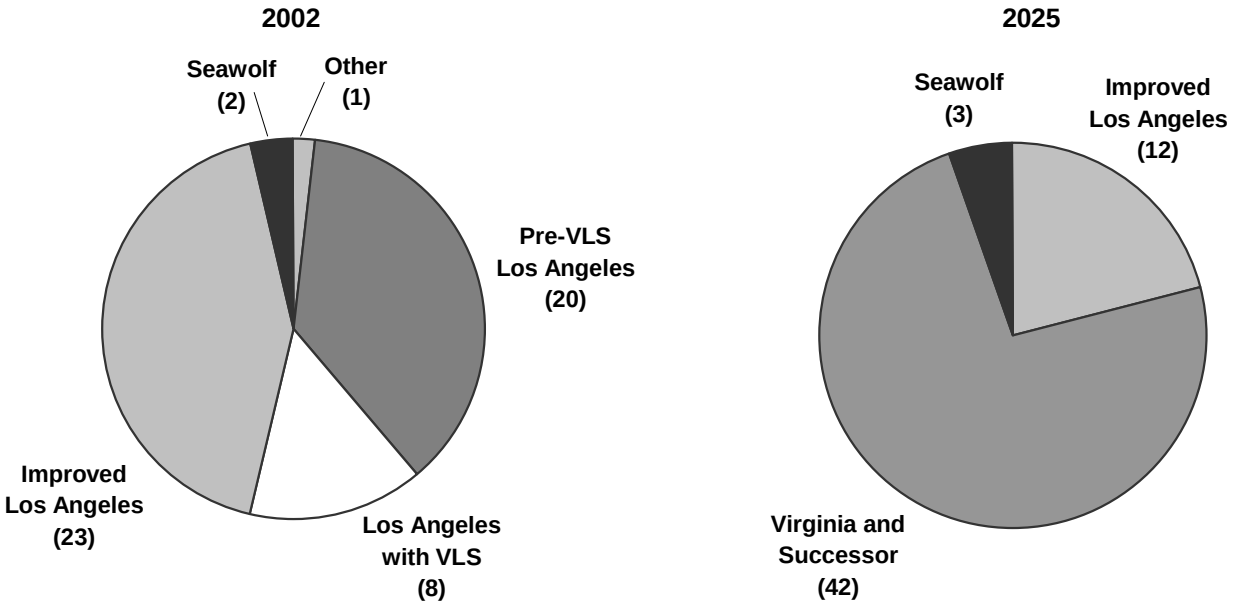
In addition, because the attack submarines with dual or multiple crews and those based in Guam are assumed to operate more intensively than single-crewed attack submarines do, they would have a shorter service life. That shorter life is incorporated into CBO's analysis of cost-effectiveness.

The Attack Submarine Force and Its Missions

Today's SSN force consists of 51 Los Angeles class submarines, two new Seawolf class submarines, and one submarine equipped to perform special operations and high-value intelligence missions. The Navy is also developing and beginning to build Virginia class submarines. Under the Navy's long-term shipbuilding plan, by 2025 the SSN force will comprise 42 Virginia class submarines and their successors, three Seawolf class submarines, and 12 Los Angeles class submarines (see Summary Figure 1).

Although the Virginia will be technologically more sophisticated than the Los Angeles and thus may be able to conduct SSN missions more effec tively, it will not necessarily perform those missions more efficiently. Thus, the introduction of a new class of submarine may not reduce the number of submarines required. In fact, new capabilities could lead to new missions and thus to greater requirements.

Summary Figure 1.
Composition of the Attack Submarine Force, by Class, in 2002 and 2025 (By number of submarines)



SOURCE: Congressional Budget Office based on data from the Navy.

NOTE: VLS = vertical launch system.

Traditionally, the missions of attack submarines included performing covert intelligence gathering, surveillance, and reconnaissance; conducting covert special operations; attacking targets on land with Tomahawk missiles; and engaging in mine warfare, antisubmarine warfare, and anti-surface-ship warfare. Those missions are still part of the SSN repertoire, although in recent years the focus on antisubmarine warfare has declined and the emphasis on intelligence gathering has grown. The CJCS study expects that the need for intelligence missions will continue to increase substantially.

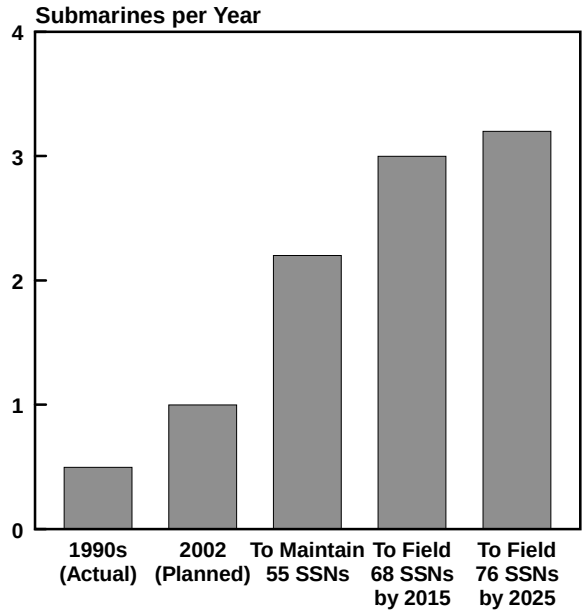
The Resource Implications of Building a Larger SSN Force

Fielding a force of 68 attack submarines in 2015 and 76 in 2025 would necessitate a higher construction rate than is now planned or funded. The Navy currently intends to buy six attack submarines between 2002 and 2007, an average of one per year—twice the production rate of the 1990s (see Summary Figure 2). To meet the 2015 goal, the service would have to build 24 submarines between 2002 and 2009, an average of three per year. (Typically, six years elapse between an attack submarine's authorization by the Congress and its commissioning in the Navy.) To meet the 2025 goal, the Navy would need to order 58 submarines between 2002 and 2019, an average of 3.2 per year.

Reaching and sustaining the 2025 force goal would require the Navy to spend an average of $6.1 billion per year on submarine construction between 2002 and 2025, CBO estimates. That level of funding represents about 58 percent of the average annual shipbuilding budget for the next five years envisioned in the 2003 Future Years Defense Program (FYDP). By comparison, the Navy devoted 14 percent of its shipbuilding budget to attack submarines in the 1990s and 24 percent in 2002 (see Summary Figure 3).

If the Navy indefinitely extended the currently planned production rate of one submarine per year, it could sustain the minimum CJCS force level of 55 SSNs through 2015.[2] After that, however, the force would decline rapidly (see Summary Figure 4). It would shrink to 36 attack submarines by 2025 and 28 by 2030 as many Los Angeles class submarines (which were built at rates of three or four a year during the 1970s and 1980s) reached the end of their service life. The Navy's long-term building plan envisions constructing an average of 2.2 submarines per year until 2020, which would maintain the SSN force at about 55 through 2030. That plan would cost an average of $4.5 billion per year for procurement between 2002 and 2025, CBO estimates—or about 43 percent of the average shipbuilding budget in the 2003 FYDP.[3]

Summary Figure 2.
Average Annual Production Rate for Attack Submarines



SOURCE: Congressional Budget Office.

NOTE: SSN = nuclear-powered attack submarine.

2. That statement assumes that all of the current Los Angeles class submarines remain in the fleet for the duration of their service life (30 to 33 years).

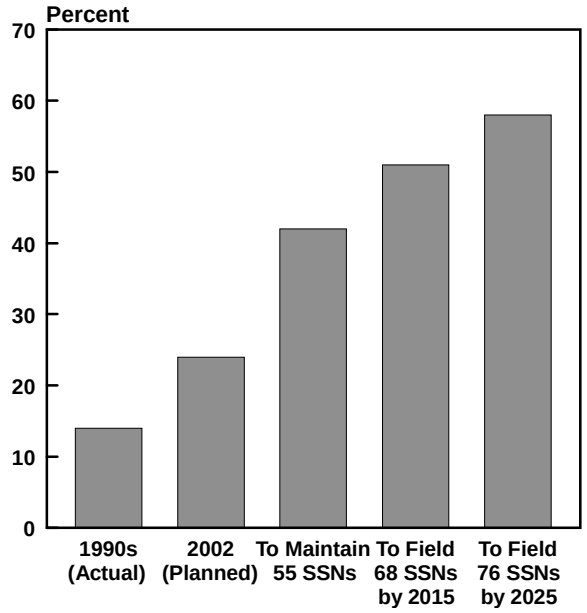
3. As proposed by the President in February, the 2003 FYDP includes the conversion of all four retiring Trident submarines to SSGNs. For the purposes of this analysis, however, the Navy's long-term plan is not assumed to include those SSGN conversions.

The gap between the Navy's long-term procurement plan and its current funding and construction levels is especially important because attack submarines represent the largest shortfall in the Navy's shipbuilding account. By the end of the year, the Navy expects to have devoted 22 percent of its ship construction budget between 1998 and 2002 to SSNs, or an average of $1.9 billion out of $8.8 billion annually. If those numbers were held constant (a steady state), the Navy could buy 30 attack submarines at an average price of $2.1 billion apiece (using CBO's estimate)—well below the minimum force goal of 55. In dollar terms, that shortfall amounts to about $1.6 billion a year. Although other shipbuilding programs face similar problems, their shortfalls are not nearly as great as the one for SSNs.

To boost the number of mission days provided by the current SSN force, the Navy has decided to base three attack submarines in Guam by the end of 2003. The Navy's operating concept for Guam-based submarines would allow them to provide 88 to 123 mission days per year, as opposed to 36 mission days per year for U.S.-based subs.

The reason for the difference is that whereas an SSN based in the United States goes on a six-month deployment every two years, one based in Guam will spend a total of six months at sea each year (although every deployment will last no more than 56 days). That operating tempo complies with the Navy's policies about how much time a submarine's crew may spend away from its home port—policies that the Navy considers crucial to recruit and retain personnel. On the basis of the different operating concept and the fact that Guam is closer than the United States to likely theaters of operation, CBO calculated that an attack submarine in Guam would provide an average of 106 mission days per year (with the rest of its time at sea spent on other tasks, such as training).

Summary Figure 3.
Share of the Navy's Annual Shipbuilding Budget Devoted to Attack Submarines

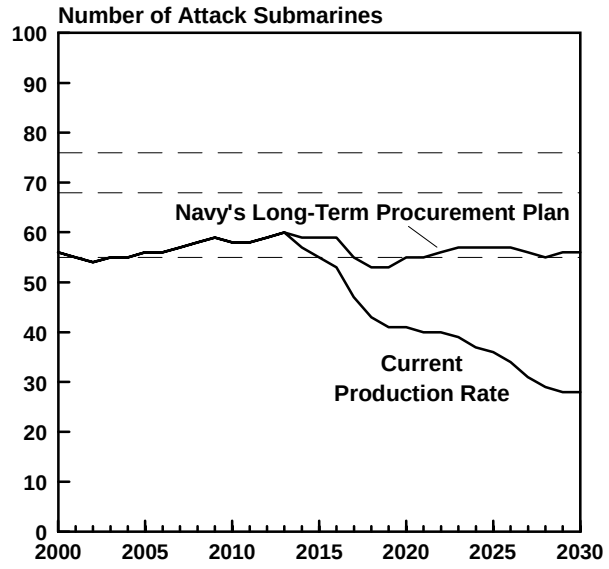


SOURCE: Congressional Budget Office.

NOTES: This figure assumes a future shipbuilding budget of $10.5 billion per year (adjusted for inflation)—the average under the 2003 Future Years Defense Program.

SSN = nuclear-powered attack submarine.

Summary Figure 4.
Number of Attack Submarines Through 2030 Under the Navy's Plan and the Current Production Rate



SOURCE: Congressional Budget Office.

NOTES: The Navy's long-term plan assumes an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, it assumes a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

The Navy's decision to base three submarines in Guam has the effect of reducing the number of SSNs needed to meet the CJCS requirements. With respect to mission days, a force of 62 attack submarines, assuming that three are stationed in Guam, is equivalent to 68 U.S.-based SSNs operated under current policies. Similarly, a force of 70 submarines with three based in Guam is equivalent to 76 SSNs. Stationing three subs in Guam and building those smaller forces would cost about $600 million less each year through 2025 in procurement and operating costs than building the full force of 68 or 76 submarines (see Summary Table 1). Moreover, it would lower the cost per mission day of the SSN force from $2.7 million to about $2.5 million (see Summary Table 2).

Options for Increasing the Mission Capability of the SSN Force

The Navy could take several other steps to use attack submarines more efficiently and further increase the number of mission days provided by the SSN force.

Summary Table 1.
Average Annual Costs of Different Options for the Attack Submarine Force (In millions of dollars)

	Procurement Costs	Operation and Support Costs	Other Costs[a]	Total Costs
Average Annual Costs Through 2007				
Navy's Current Plan[b]	2,870	1,840	0	4,710
Costs in Addition to the Navy's Current Plan				
Build 68 SSNs by 2015	3,500	0	0	3,500
Build 68 SSN equivalents by 2015[c]	1,540	0	0	1,540
Build 76 SSNs by 2025	2,510	0	0	2,510
Build 76 SSN equivalents by 2025[c]	1,440	0	0	1,440
Option I: Convert four Trident subs to SSGNs	550	60	0	610
Option IIA: Use dual crews on some SSNs	0	0	0	0
Option IIB: Use three crews to operate two SSNs	0	0	0	0
Option III: Base more SSNs in Guam	0	0	0	0
Average Annual Costs Through 2025				
Navy's Current Plan[b]	4,480	1,870	0	6,350
Costs in Addition to the Navy's Current Plan				
Build 68 SSNs by 2015	880	260	20	1,160
Build 68 SSN equivalents by 2015[c]	530	140	10	680
Build 76 SSNs by 2025	1,640	230	30	1,900
Build 76 SSN equivalents by 2025[c]	1,130	170	20	1,320
Option I: Convert four Trident subs to SSGNs	170	190	10	370
Option IIA: Use dual crews on some SSNs	0	110	20	130
Option IIB: Use three crews to operate two SSNs	0	60	10	70
Option III: Base more SSNs in Guam	0	10	10	20

SOURCE: Congressional Budget Office.

NOTE: SSN = nuclear-powered attack submarine; SSGN = nuclear-powered guided-missile submarine.

a. These costs, which include such things as infrastructure improvements, would occur between 2008 and about 2015.

b. Does not include the cost of converting four Trident submarines to SSGNs.

c. This alternative includes the basing of three submarines in Guam, which reduces the total number of attack submarines required under the Chairman of the Joint Chiefs of Staff's submarine study to 62 by 2015 and 70 by 2025.

Summary Table 2.
Cost-Effectiveness of Different Options for the Attack Submarine Force (In millions of dollars)

	Total Cost per Mission Day Provided by the SSN Force
Navy's Current Plan	2.5
Build 68 SSNs by 2015	2.7
Build 68 SSN Equivalents by 2015[a]	2.5
Build 76 SSNs by 2025	2.7
Build 76 SSN Equivalents by 2025[a]	2.5
Option I: Convert Four Trident Subs to SSGNs	2.2
Option IIA: Use Dual Crews on Some SSNs	2.2
Option IIB: Use Three Crews to Operate Two SSNs	2.2
Option III: Base More SSNs in Guam	2.0

SOURCE: Congressional Budget Office.

NOTES: Cost per mission day is calculated using steady-state estimates of procurement and operation and support costs. Other costs, such as changes in infrastructure, are also included.

SSN = nuclear-powered attack submarine; SSGN = nuclear-powered guided-missile submarine.

a. This alternative includes the basing of three submarines in Guam, which reduces the total number of attack submarines required under the Chairman of the Joint Chiefs of Staff's submarine study to 62 by 2015 and 70 by 2025.

For example, it could convert Trident ballistic missile submarines to perform missions specified in the CJCS study, use more than one crew per submarine, or base more than three SSNs in Guam. CBO compared the mission days that each of those options could provide with the force goals of the CJCS study. To show the results in graphic form, CBO converted the mission-day analysis to equivalent force levels. In other words, if an attack submarine could provide an average of 72 mission days per year by adopting a more efficient crewing concept, it was counted as two submarines. CBO also compared the cost of the options with the cost of achieving the same capability by building new submarines. (Each of the options assumes that the Navy will base three attack submarines in Guam indefinitely.)

Option I: Convert Four Trident Submarines to Perform Conventional Missions

In this alternative, the Navy would maintain 55 attack submarines and convert four Trident ballistic missile submarines to perform nonnuclear missions—changing them to an SSGN configuration. With the Cold War over and the United States planning to reduce its arsenal of strategic nuclear warheads, the Navy intends to decrease the Trident fleet from 18 submarines to 14, retiring two subs in 2003 and two in 2004. If, instead, their nuclear reactors were refueled, those submarines would have about 20 years of useful service life left. In this option, the SSGNs would retain the dual-crew system that Trident submarines use now.

Most of the past discussion about turning Trident submarines into SSGNs has focused on having them available to perform land-attack or special-operations missions. Land attack, however, was not mentioned in the CJCS study as one of the required missions of attack submarines. For purposes of this analysis, CBO assumed that the SSGNs would be used as much as practicable to perform missions identified in the CJCS study. Whether or not they should be used that way is an important policy decision.

In any event, SSGNs would not be equipped to carry out all of the missions of attack submarines. On the basis of information provided by the Navy, CBO calculated that SSGNs could perform 17 percent of the mission days identified in the CJCS study. Thus, although each SSGN could provide a raw average of 142 mission days per year (assuming some of that time was not needed for at-sea training and certifications), the four SSGNs would be equivalent to about 12 attack submarines with respect to the total number of mission days identified in the CJCS

Summary Table 3.
Actual and Equivalent Force Levels in 2015 and 2025 Under Various Options

	2015		2025	
	Actual Force Level[a]	Equivalent Force Level	Actual Force Level[a]	Equivalent Force Level
Option I: Convert Four Trident Subs to SSGNs	63	76	58	66
Option IIA: Use Dual Crews on Some SSNs	59	72	57	78
Option IIB: Use Three Crews to Operate Two SSNs	59	73	57	78
Option III: Base More SSNs in Guam	59	73	57	79
Memorandum:				
Force Goal in 1999 CJCS Study	n.a.	68	n.a.	76

SOURCE: Congressional Budget Office.

NOTE: SSGN = nuclear-powered guided-missile submarine; SSN = nuclear-powered attack submarine; CJCS = Chairman of the Joint Chiefs of Staff; n.a. = not applicable.

a. The actual number of submarines tends to vary from year to year according to retirement and commissioning schedules. As it happens, 2015 is one of the peak years for attack submarines under the Navy's current plan.

study.[4] In terms of equivalent force levels, the currently planned force of attack submarines (including the three in Guam), augmented by four SSGNs, would achieve even the 76-SSN force goal in 2015. However, by 2025, it would fall well below that goal (see Summary Table 3).

Option I would have relatively high costs in the near term but would be more cost-effective over the longer term. To refuel, convert, and arm four SSGNs would cost a total of $4 billion. For the next six years, costs to convert and operate the subs would average $610 million per year more than the Navy's plan. Over the 2002-2025 period, Option I would cost an average of $370 million more per year than the Navy's plan, but it would reduce the SSN fleet's cost per mission day from $2.7 million to $2.2 million. (Option I is the only alternative examined by CBO that would involve significant start-up costs.)

4. To provide the exact number of mission days SSGNs could perform and, therefore, how that calculation was made would reveal information that is currently classified.

   If four SSGNs were equivalent to 12 attack submarines with respect to the total number of mission days identified in the CJCS study, each SSGN would have a little more than 35 days a year, on average, to perform other missions or to conduct at-sea training.

Option II: Use Dual- or Multiple-Crewed Submarines

Another approach would be for the Navy to maintain 55 attack submarines but operate some of them using either two alternating crews (as it does with Trident submarines) or three crews rotating between two submarines. In either case, the 55-SSN force would provide the same number of missions days as would a larger force built to meet the CJCS goals, but much more cost-effectively.

Option IIA: Adapt the Trident Blue/Gold Crewing Model to SSNs. Under this variant, the Navy would use a dual-crew operating concept for its new Virginia class submarines, beginning with the one

due to be authorized in 2003 and commissioned in 2009. By 2015, nine Virginia class submarines would have dual crews, and by 2025, 19 would have them. A dual-crewed submarine, as envisioned in this option, would spend an average of 65 days per year conducting missions—80 percent more than an SSN today. As a result, the Navy could perform the same number of mission days provided by a 68-submarine force using 55 SSNs.

This option would cost an average of $130 million more per year than the Navy's current plan through 2025, mostly to pay for the additional crews. However, the total cost per mission day of the SSN fleet would decline to $2.2 million.

The Navy has raised several concerns about using dual crews on attack submarines. Those concerns focus on maintaining the submarines, developing the new crews, and keeping the crews proficient between deployments. Navy officials point out that ballistic missile submarines, which use dual crews, are very different from Los Angeles class attack submarines, which do not. Specifically, some of the physical features of today's ballistic missile submarines were designed with a dual-crew concept in mind.

In addition, the two types of submarines have distinct operating cycles. Tridents deploy for two and one-half months and then return to port for a short, intensive maintenance period lasting a little more than a month. That cycle repeats for many years, with each crew alternating the deployment. In contrast, attack submarines and their crews spend about 18 months resting, training, and maintaining equipment, followed by a six-month deployment. As a result of those cycles, the maintenance and training procedures for ballistic missile and attack submarines are quite different and cannot be easily substituted for one another.

This option was designed to address the Navy's concerns. Rather than adopt the concept used by ballistic missile submarines, it would compress the planned operating cycle of the new Virginia class attack submarine using two crews. Both crews would assist in maintaining the submarine before its deployment. The operating schedule in this option would allow about the same ratio of maintenance time to at-sea time that today's SSNs have. Moreover, the first dual-crewed Virginia would not be commissioned until 2009, giving the Navy time to develop the new crews.

In terms of training, this option envisions an expanded shore-based training infrastructure, as well as opportunities for both crews to train at sea before a submarine goes on deployment. The crew deploying with the sub would receive its normal at-sea training before departure. During that period, the other crew would also be able to spend some time at sea so that it was not completely dependent on shore-based training to maintain its skills between deployments.

Option IIB: Use Three Crews to Operate Two Submarines. This alternative would operate two Virginia class SSNs with three crews, which would rotate every 90 days to a submarine on a nine-month deployment. Under this concept, eight Virginia class submarines would operate with multiple crews by 2015 and 14 by 2025. Those submarines would spend an average of 73 days per year conducting missions over the course of their service life—double what SSNs perform today.

This option would meet the CJCS force goals in 2015 and 2025 with the same number of submarines that the Navy hopes to buy under its current plan. The annual cost would be $70 million more than the Navy's plan through 2025, but the total cost per mission day of this force would be $300,000 lower ($2.2 million).

The principal disadvantage of this option is that it would represent a radical departure from the way the Navy operates attack (or ballistic missile) submarines today. Each relief crew would be flown out to a forward location to take over from the crew operating a submarine, rather than waiting for the submarine to return to its home port. The Navy has not used that technique with attack submarines, although it did so with some ballistic missile submarines during the Cold War.

This alternative would pose other challenges as well. To make sure the two SSNs that three crews shared were as similar as possible, the Navy might need to design and build attack submarines in pairs. In addition, this option would keep attack submarines at sea three months longer than SSNs are now, which could make it harder to keep them in working order.

Option III: Base More Attack Submarines in Guam

Under this option, the Navy would permanently base four more SSNs in Guam by 2015 and eight more by 2025 (besides the three that it already plans to station there by the end of 2003). Because those submarines would use a different operating concept and spend less time in transit than ones based in the United States, having additional submarines in Guam would allow a force of 55 SSNs to provide the same number of mission days as at least 68 subs in 2015 and 76 in 2025.

The principal disadvantage of this option is that it would require substantially greater infrastructure in Guam, at a total cost of about $200 million, CBO estimates. Overall, however, the SSN fleet's cost per mission day would fall to $2.0 million—the lowest cost of all the options that CBO examined.

Force Levels If the Production Rate Does Not Increase

The options analyzed in this study assume that the Navy will implement its long-term procurement plan to keep the attack submarine force at 55. At the same time, this analysis shows that carrying out that plan could be difficult because of its cost.

If the production rate remains at the current level of one submarine per year, for how long could the approaches represented in these options maintain an SSN force equivalent to 55? Option I would sustain that level until 2023. However, because of the six-year interval between authorizing a submarine and fielding it, the production rate would need to increase to two or more SSNs per year in 2017. Under Options IIA and IIB, that rate would have to increase in 2013 or 2021, respectively, to maintain a force equivalent to 55 SSNs—assuming that *all* new Virginia class submarines after the fourth ship were dual or multiple crewed rather than the smaller numbers envisioned in the options. Finally, if the Navy put as many as 12 SSNs in Guam—probably the largest number it might reasonably want to base there—the production rate would not have to rise until 2022. Under all of those scenarios, however, the SSN force would fall below 55 actual submarines (as opposed to their equivalent in mission days), which is the wartime requirement stated in the CJCS study.

Overall Cost-Effectiveness of the Options

All of the options examined by CBO would exceed the CJCS study's force goal in 2015 with respect to equivalent force levels and mission days provided (see Summary Table 3). In 2025, Options IIA, IIB, and III would exceed the study's goal for that year. Option I would not, however, largely because three of the four SSGNs would have been retired by then.

Those alternatives would meet the force goals at a much lower incremental cost than buying new submarines would. (A discussion of how CBO made that calculation is contained in Appendix B.) Transferring a submarine to Guam would cost $0.2 million for each additional mission day it provided, making it the most cost-effective of the options (see Summary Table 4). Converting a Trident into an SSGN or using more than one crew to operate a Virginia class

Summary Table 4.
Relative Costs of Different Ways to Add Mission Days to the Attack Submarine Force (In millions of dollars)

	Cost per Additional Mission Day Provided
Build a New Submarine	2.7
Convert a Trident Sub to an SSGN	0.8
Operate an SSN with Two Crews	1.2
Operate an SSN with Three Crews per Two Subs	0.9
Transfer an SSN to Guam	0.2

SOURCE: Congressional Budget Office.

NOTE: SSGN = nuclear-powered guided-missile submarine; SSN = nuclear-powered attack submarine.

attack submarine would cost between $0.8 million and $1.2 million per additional mission day. In comparison, a new submarine would cost an estimated $2.7 million for each mission day it added to the SSN force.

The relative cost-effectiveness of those options is not particularly sensitive to changes in assumptions about operating or procurement costs. If a dual- or multiple-crewed attack submarine cost as much to operate as an SSGN or a Trident ballistic missile submarine (a reasonable upper limit) or even twice as much as a single-crewed submarine, Options IIA and IIB would still be more cost-effective than building submarines with respect to the additional mission days provided. Further, if costs for procuring new submarines were lower than what CBO assumed, the relative cost-effectiveness of the options would be almost unchanged. (If procurement costs were substantially higher than CBO's estimate, the cost per additional mission day of submarine construction would worsen relative to that of the alternatives.) Thus, to the extent that the costs both of operating attack submarines and of producing them are uncertain, all four options are still much more cost-effective than building additional submarines would be.

Chapter One

Submarine Requirements and Their Implications for the Navy's Budget

In recent years, the Navy has been looking to increase its fleet of attack submarines (SSNs) in keeping with a 1999 study conducted for the Chairman of the Joint Chiefs of Staff (CJCS).[1] That study concluded that the Navy would need 68 attack submarines by 2015—of which 18 should be from the new Virginia class—and 76 attack submarines by 2025 to meet the most critical peacetime requirements of the regional commanders in chief as well as requirements set by the national intelligence community. The study also concluded that 55 SSNs were necessary to meet potential requirements in wartime.

Those force goals are driven in part by the fact that under current policies, attack submarines spend an average of 36 days per year—or 10 percent of their service life—on-station performing missions identified as critical or high priority by the President, the Secretary of Defense, and the regional commanders in chief. Like other Navy ships, SSNs spend the rest of their service life in training missions, port calls, transit, and maintenance.

In this study, the Congressional Budget Office (CBO) looks at the composition of the SSN force today and its expected composition in 2025 under the Navy's long-term procurement plan. The study estimates the resources needed either to build more submarines to meet the CJCS force goals or simply to maintain a force of 55 attack submarines.

Because building a larger force would require much greater resources than the Navy expects to be able to devote to submarine construction over the next 20 years, this study also examines several options for providing additional mission days by using existing SSNs more cost-effectively. Those options involve keeping Trident ballistic missile submarines that would otherwise be retired and converting them to a guided-missile (SSGN) configuration so they could perform nonnuclear missions; using dual crews (two per sub) or multiple crews (in this study, three crews for two subs) to operate some SSNs more efficiently; and basing more attack submarines in the Pacific island of Guam. Each of those options would be more cost-effective than building additional submarines, CBO estimates.

In analyzing the cost-effectiveness of the options, CBO generally used cautious assumptions and methods to estimate such things as the expected cost of new Virginia class submarines or of SSGN conversions. Specifically, it assumed that Virginia class submarines would cost about $2.1 billion to produce, on average, and that the annual operating costs for an SSGN would be the same as for a Trident ballistic missile submarine. Operating costs for a dual- or multiple-crewed attack submarine would be greater than for a single-crewed attack submarine, CBO estimated, but not as high as for an SSGN or ballistic missile submarine (both of which employ a dual-crew system and have larger crews, a more stringent and costly maintenance program, and a more intensive operating tempo than a dual- or multiple-crewed attack submarine would have in this analysis).

1. Department of Defense, Office of the Joint Chiefs of Staff, *CJCS Attack Submarine Study* (November 1999). That study is classified as secret.

Further, because this study's dual- or multiple-crewed attack submarines and submarines based in Guam would be used more intensively than current single-crewed SSNs are, they would have a much shorter service life. CBO's cost-effectiveness analysis takes that shorter life into account.

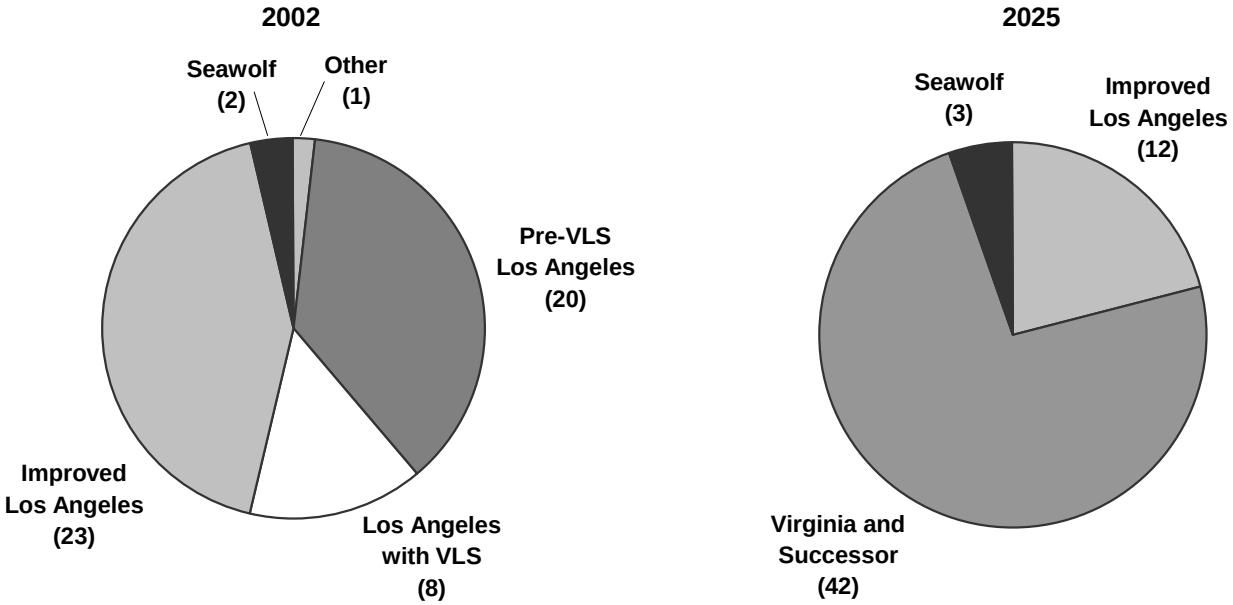
Setting Force Requirements for Attack Submarines

To estimate the necessary force level for SSNs, the CJCS study used a methodology based on required mission days. The Joint Staff asked regional military commanders in chief (CINCs) to identify the missions that attack submarines would perform in their respective regions in both 2015 and 2025. To generate their estimates, the CINCs used an analysis of the future global situation and threat environment by U.S. intelligence agencies. They also ranked each SSN mission by order of importance. The Joint Staff then totaled the number of days needed for those missions.

The Joint Staff combined those regional estimates of submarine needs with anticipated national requirements. For purposes of the CJCS study, they assumed that all of the critical and most of the high-priority missions would be performed. The desired size of the SSN force was established using a formula derived from historical experience that converts the total number of mission days needed into the total number of submarines needed (see Appendix A).

For this analysis, CBO retained the mission-day focus of the CJCS study. Specifically, CBO compared the number of mission days that alternative submarine force structures would provide. If, for example, one way of operating a submarine would provide twice the number of mission days per year, on average, as operating a submarine under current practices, that submarine would be considered equiv-

Figure 1.
Composition of the Attack Submarine Force, by Class, in 2002 and 2025 (By number of submarines)



SOURCE: Congressional Budget Office based on data from the Navy.

NOTE: VLS = vertical launch system.

alent to two submarines today (taking into account any reduction in its expected service life).

The Composition of the SSN Force

The Navy's current force of attack submarines comprises two new Seawolf (SSN-21) class submarines, 51 Los Angeles class (SSN-688) submarines, and one specially equipped submarine for high-value intelligence missions (see Figure 1).

The two Seawolfs are among the quietest and most capable nuclear-powered attack submarines in the world. They can launch Tomahawk missiles from their torpedo tubes, and their overall complement of weapons is greater than those of Los Angeles class submarines or the first boats of the new Virginia class (see Table 1).

The Los Angeles class forms the backbone of the current attack submarine force. That class, however, consists of three similar but distinct groups of submarines.

- The earliest group does not have vertical launch system (VLS) cells for launching Tomahawk missiles. It also lacks under-ice and minelaying capabilities, which are considered vital for modern submarine warfare. The Navy has 20 of those early submarines in the fleet today.
- The second group consists of eight Los Angeles class submarines that lack under-ice and minelaying capabilities but that are equipped with 12 VLS cells apiece.
- The third group is composed of 23 submarines, called the Improved Los Angeles class, or 688Is. Submarines in that group possess 12 VLS cells as well as the under-ice and mine-

Table 1.
Capabilities of Navy Attack Submarines

	Los Angeles Class (Improved)	Seawolf Class	Virginia Class
Size			
Displacement (Tons, submerged)	6,900	9,100	7,800
Length (Feet)	360	353	377
Draft (Feet)	32	35	31
Beam (Feet)	33	40	34
Speed (Knots)			
Maximum	More than 25	More than 25	More than 25
Tactical (Silent speed)	n.a.	20	n.a.
Operating Depth (Feet)	More than 800	About 1,600	More than 800
Crew Size	129	133	113
Armament (Number of missiles or torpedoes)	37	50	38
Weapon Launchers			
Torpedo tubes (21 inches)[a]	4	8	4
Vertical launch system cells	12	0	12

SOURCE: Congressional Budget Office.

NOTE: n.a. = not available.

a. The Seawolf has 26.5-inch torpedo tubes that launch its weapons.

laying capabilities missing in earlier groups. They also have much quieter machinery than other submarines of their class.

The sub used for special missions is the *Parche*, a Sturgeon class attack submarine that has operated in that role since 1976. The Navy specially fitted that boat with equipment for ocean-engineering missions (such as recovery of satellites and other equipment from the ocean floor) as well as highly specialized intelligence-gathering gear. The *Parche* is slated to retire in 2004 and will be replaced by another submarine.

By 2025, the attack submarine force will look very different, according to the Navy's current plans. Forty of today's submarines will have been retired, having reached the end of their notional service life of 30 to 33 years. (For a discussion of how the service life of a submarine is determined, see Box 1.) The fleet will still have three Seawolf submarines and 12 Improved Los Angeles class submarines, but the remainder will consist of 42 submarines from the Virginia class or its successor—for a total force of 57 attack submarines. As a result, the force in 2025 will carry about 275 more VLS cells and 450 more weapons than the current fleet (see Figure 2).

The Navy argues that its new Virginia class submarine will be much more capable than the Los Angeles class, especially with respect to quietness and sensors. The technological advances of the Virginia should enable it to perform SSN missions more effectively, but those advances will not necessarily make the Virginia more efficient than earlier submarines. In other words, the introduction of a new class of submarine does not appear likely to reduce the overall requirement for mission days. Indeed, the new capabilities of the Virginia and hoped-for (but not yet proven) technological improvements might allow it to

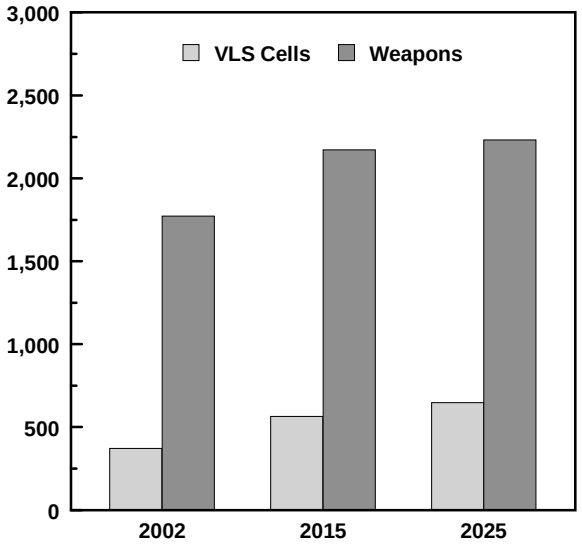
Box 1.
Estimating the Service Life of an Attack Submarine

Determining the useful service life of a submarine—and thus when it needs to be replaced—can be difficult. As recently as 1998, the official service life of both Los Angeles class attack submarines (SSNs) and Ohio class Trident ballistic missile submarines was 30 years. The Navy designs an SSN to withstand a specific number of events (such as dives) that stress the hull, as well as the cumulative effects that routine operations have on materials and equipment. More recently, the Navy studied the material condition of its submarines and determined that under current operating assumptions, the service life of most SSNs could be increased to 33 years and that of Trident submarines to 42 years. The Navy expects that new Seawolf and Virginia class attack submarines will also last for 33 years.

Some Los Angeles class submarines may be able to operate longer than 33 years, the Navy speculates. Los Angeles SSNs with hull numbers 719 or above were constructed with "life of the submarine" reactor cores, meaning that those reactors could operate for a full 33 years without needing to be refueled. Refueling a nuclear-propelled submarine is a time-consuming and expensive task. Earlier Los Angeles SSNs, with earlier-design reactors, were (or will be) refueled at around the 20-year point. With refueling, those submarines have enough nuclear fuel to last a total of 38 years under current operating assumptions. Whether the hulls of those submarines and other major components could last that long is not clear, however. In 10 to 15 years, when those submarines are approaching 33 years of age, the Navy may analyze their material condition and determine whether they can cost-effectively be retained for another five years.

Can the later Los Angeles or even the new Seawolf or Virginia class submarines last longer than 33 years? No one will know until some of those submarines start to reach the end of their notional service life around 2020. One outcome could be that those later submarines might be able to last for an additional five years but refueling them for such a short period would not be cost-effective. Another conceivable outcome is that all of those submarines will not last as long as 33 years. Historically, only a few U.S. nuclear attack submarines were in service for more than 30 years. The Navy has almost always retired nuclear submarines before 30 years because of reduced requirements or lower budgets or because the age and condition of the submarines made them unsuitable for continued operations.

Figure 2.
Total Weapons and VLS Cells in the Attack Submarine Force in 2002, 2015, and 2025



SOURCE: Congressional Budget Office.

NOTES: This figure assumes that the number of weapons on future Virginia class submarines will remain the same as on the first ship of that class.

VLS = vertical launch system.

perform new missions, possibly increasing requirements for SSNs.

Evolving Roles and Missions of Attack Submarines

The attack submarine force can perform a variety of peacetime and wartime missions. Those missions include covert intelligence, surveillance, and reconnaissance; covert insertion and extraction of special-operations forces; covert attack of targets on land with Tomahawk cruise missiles; offensive and defensive mine warfare; antisubmarine warfare; and anti-surface-ship warfare. All of those missions were part of the attack submarine's role during the Cold War (and some were part of that role as far back as World War II). Since then, however, the types of missions assigned to SSNs have changed, and they may continue to evolve.

Missions During the Cold War

The principal purpose of U.S. attack submarines during the Cold War was to conduct antisubmarine warfare in the open ocean. Their job was to locate and trail Soviet submarines, especially ones carrying ballistic missiles, so those subs could be destroyed in the event of war.

Other important missions included covert intelligence, surveillance, and reconnaissance of the Soviet Union or its allies and the insertion of special-operations forces. Although most of the fleet's attack submarines could conduct those missions, the Navy converted several submarines to have special capabilities to perform particularly high-value missions.

The development of the Tomahawk cruise missile in the 1970s gave Navy submarines a modern land-attack capability. The first attack submarines armed with Tomahawks—the Sturgeon class—could only launch those missiles horizontally from their torpedo tubes. Today, many Los Angeles class submarines (as well as the planned Virginia class submarines) have 12 vertical launch system cells from which to launch cruise missiles.[2] During the Cold War, attack submarines carried nuclear-tipped versions of the Tomahawk. In the post-Cold War era, however, Navy ships (other than ballistic missile submarines) do not carry nuclear weapons. All of the Tomahawk missiles now deployed on attack submarines have conventional warheads.

Current Missions

The primary missions of attack submarines today are intelligence, surveillance, and reconnaissance (ISR). The exact nature of those missions is highly classified. In general, the types of ISR missions that submarines can perform include intercepting important communications of target countries or observing their military exercises so as to give the United States a better understanding of those countries' weapons, operations, and military doctrine. Navy officials contend that submarines perform only those intelligence-

2. Those submarines can also launch cruise missiles through their torpedo tubes, as can the three Seawolf class submarines, which do not have VLS cells.

collection missions "for which there is not another national collection capability to achieve the desired end."[3]

In addition, the submarine force is increasingly focused on operating in the world's littoral (coastal) regions. Most intelligence operations are likely to take place in fairly shallow waters, since few of the probable target countries have naval forces capable of sustained operations away from their coasts.

Submarines have also played an important role in land-attack operations since the Gulf War. The Tomahawk missile has been the weapon of choice in many punitive operations, such as the 1998 cruise missile strikes on Afghanistan and Sudan and Operation Desert Fox against Iraq in 1998. Tomahawks are also an effective weapon in the earliest stages of a broader conflict, when an opponent's antiair and antiship defenses have not yet been destroyed. During the Gulf War, for example, two submarines launched some of the 288 Tomahawks used in the war. And during the 1999 campaign against Serbia, submarines launched 25 percent of the Tomahawk missiles used. In short, different missions are in high demand today than was the case during the Cold War.[4]

Nevertheless, some critics have argued that the attack submarine is a Cold War relic. If its principal role during that era was to trail Soviet ballistic missile submarines and that mission essentially no longer exists, then a large fleet of attack submarines may not be necessary. Some defense analysts who take that view argue that the United States could make do with as few as 35 or even 25 attack submarines.[5]

Future Missions

How might SSN missions evolve in the future? Several studies of that question have been conducted by the Navy as well as by outside analysts.[6] For example, according to the CJCS study, the intelligence and surveillance missions that attack submarines perform today will still be necessary in 2025. Moreover, if Russia or China emerged as a "peer competitor" of the United States, trailing its ballistic missile and attack submarines would probably again be a high priority for U.S. submarine forces. The CJCS study predicted that a growing proportion of SSN missions will take place in the Asia-Pacific region. Today, 26 attack submarines—about half of the force—are assigned to the Pacific Fleet. By 2015, according to the CJCS study, 41 of the 68 required SSNs would be needed in the Pacific Fleet "to counter the threat in the Asia-Pacific region."[7]

The changing nature of the security environment, combined with new technologies, could lead to even greater demands for attack submarines than the 1999 CJCS study envisioned. Of course, new technologies might also handle many of the intelligence missions that attack submarines now perform.

The Navy has become increasingly concerned about the proliferation of relatively inexpensive weapons that could greatly limit its freedom of action, thereby undermining U.S. foreign policy interests. Countries that invested in such weapons as antiship cruise missiles, fast-attack torpedo boats, diesel-electric submarines, and mines could implement an "access-denial" strategy. That strategy would not attempt to challenge and defeat U.S. naval forces directly. Instead, it would seek to inhibit the Navy's operations in a region by strewing coastal areas with

3. Rear Admiral Malcolm I. Fages, Director of Submarine Warfare for the Chief of Naval Operations, quoted in "The U.S. Submarine Force Today: Operational Demands Grow as Numbers Fall," *Sea Power* (July 1999), p. 10.

4. Edward C. Whitman, "Submarines in Network Centric Warfare," *Sea Power* (July 1999), p. 33.

5. See Michael O'Hanlon, *How to Be a Cheap Hawk: The 1999 and 2000 Defense Budgets* (Washington, D.C.: Brookings Institution Press, 1998), pp. 125-126; and Ivan Eland, *Subtract Unneeded Nuclear Attack Submarines from the Fleet*, Foreign Policy Briefing No. 47 (Washington, D.C.: Cato Institute, April 2, 1998).

6. See, for example, Defense Science Board Task Force, *Submarine of the Future* (Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, July 1998); and Naval Studies Board, *Technology for the United States Navy and Marine Corps, 2000-2035*, 9 vols. (Washington, D.C.: National Academy Press, 1997).

7. Rear Admiral Albert H. Konetzni, "How Many Subs Do We Need?" *Proceedings*, U.S. Naval Institute (November 2000), p. 57. Admiral Konetzni is the former commander of the U.S. Pacific Fleet's submarine force.

mines, putting hundreds of antiship cruise missiles along the shore, and having several quiet diesel-electric submarines roam littoral waters.

If the Navy's operations were inhibited, ground and tactical air forces would also suffer. The Army and, to a much lesser degree, the Air Force require substantial amounts of sealift (transport ships) to conduct operations far from U.S. shores. If the Navy cannot clear the way, sealift and other forces cannot follow. As the Navy puts it, "In future crises and conflicts . . . access-denial weapons could make the projection of U.S. power so costly that the United States might be deterred from acting."[8]

Some analysts see the attack submarine as the main solution to the access-denial problem. Unlike surface warships, submarines are stealthy, making them difficult to detect and locate. That stealth renders them immune to the threats posed by antiship cruise missiles and fast-attack torpedo boats. (However, a diesel-electric submarine can threaten an attack submarine, and mines can constrain its operations.)

Currently, one major limitation of attack submarines is their small payloads, relative to those of surface ships. Los Angeles class submarines and the first Virginia class subs each carry fewer than 40 Tomahawk land-attack missiles and torpedoes combined. Another drawback of SSNs is their limited ability to understand from underwater what is happening on a battlefield. Those problems may have technological solutions, but probably not in the near future (see Box 2).

In short, if naval forces as a whole represent the vanguard of U.S. military power—preparing the path and securing the beachheads for much larger ground and air forces in areas where they do not have access to land bases—then submarines may be key to clearing the way for other naval forces that are more vulnerable to an enemy's access-denial strategy. Whether such a broad mission would require more or fewer submarines than the Navy now says it needs would depend in part on how the Navy operated its submarines.

Box 2.
Possible Future Capabilities of Attack Submarines

The Navy, in conjunction with the Defense Advanced Research Projects Agency, is pursuing a dramatic leap in attack submarine capabilities through its Payloads and Sensors Program. The vision underlying the program is that advances in missile accuracy and miniaturization could permit future classes of submarines, including the Virginia, to be equipped with hundreds of missiles and dozens of underwater and aerial sensors launched from unmanned underwater or aerial vehicles. Weapons modules loaded with dozens of weapons could be deposited on the ocean floor in a theater of operations and linked back to the submarine. The sub could then launch those missiles against targets that were far from the weapons modules and whose locations were relayed to it through the aerial sensors—without ever revealing its position.

If that technology came to fruition, attack submarines could destroy enemy weapons that posed a threat to surface ships and arriving ground and air forces. Cruise missile emplacements, surface-to-air missile batteries, command-and-control systems, and important operating bases could all be eliminated by weapons that the opponent had never seen or detected. Once that was accomplished, other forces could operate more easily in the theater.

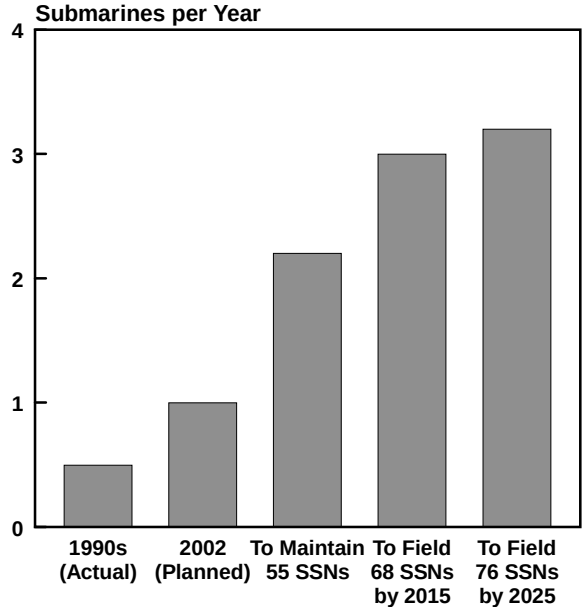
The technological barriers to that vision are considerable, however. For submarines to operate as described above, substantial leaps in technology would be necessary in a number of areas: accuracy and miniaturization of ballistic missiles, connectivity between submarines and aerial or satellite sensors, and the ability to quickly retarget strike weapons on board a submarine so they could destroy mobile targets.

The Resource Implications of Building a Larger SSN Force

Defense officials' goals for the attack submarine force have fluctuated in recent years. The submarine requirements in the CJCS study represented a sub-

8. Department of the Navy, *Vision . . . Presence . . . Power: A Program Guide to the U.S. Navy* (1999), p. 3.

Figure 3.
Average Annual Production Rate for Attack Submarines



SOURCE: Congressional Budget Office.

NOTE: SSN = nuclear-powered attack submarine.

stantial increase from the force goals published two years earlier in the 1997 Quadrennial Defense Review. That review had determined that the Navy needed 50 attack submarines to perform necessary missions. More recently, the Department of Defense under Secretary William Cohen appeared to endorse 55 as the right size for the SSN force. The Secretary of Defense's 2000 *Annual Report* used language that supported 55 attack submarines while dropping references to the 1997 goal. However, the 2001 *Annual Report* (the last one written by Secretary Cohen) was more ambiguous and did not mention any force level as being the right one.[9]

Although the force goals in the CJCS study represent future requirements, Navy admirals argue that they already need more than 55 attack submarines. In the past two years, some admirals and civilian Navy officials have told the Congress and the media that the SSN force is overworked—specifically, that submarines on deployment have spent 80 percent to 90 percent of their time under way, mostly performing missions. That figure is much higher than the Navy's notional operating tempo for deployed submarines: 65 percent of their time under way.[10] The Navy fears that if the higher rates continue, they will undermine the morale of submarine crews (possibly causing fewer sailors to remain in the service) and shorten the lives of submarines (by using up their reactor cores faster). Moreover, the Navy says that the SSN force has had to decline some missions because it lacked the submarines to accomplish them.

Meeting the CJCS Force Goals

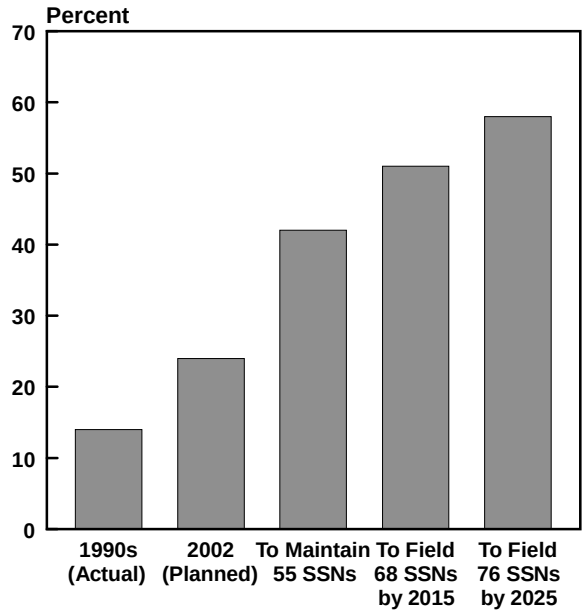
Building a force of 68 SSNs by 2015 and 76 by 2025 would require a much higher construction rate for submarines than is now funded. The Navy would need to build 24 submarines between 2002 and 2009—an average of 3.0 per year—to meet the requirement for 2015 (see Figure 3). To achieve the goal for 2025, it would have to build 58 submarines between 2002 and 2019—an average of 3.2 per year.[11]

9. See Secretary of Defense William S. Cohen, *Annual Report to the President and Congress* (2000), p. 47; and Secretary of Defense William S. Cohen, *Annual Report to the President and Congress* (2001), p. 60.

10. See the statements of Rear Admiral Albert H. Konetzni, Commander, Submarine Force, U.S. Pacific Fleet, and Rear Admiral John B. Padgett III, Commander, Submarine Group Two and Navy Region Northeast, before the Subcommittee on Procurement of the House Committee on Armed Services, June 27, 2000. Press reports have also emphasized submarines' relatively high operating tempo. See William Matthews and Bradley Peniston, "Taking a Dive: Is the Navy Wasting Its Best Asset?" *Navy Times* (March 22, 1999), pp. 16-18; Robert Holzer, "Overwork Strains U.S. Sub Fleet," *Defense News* (March 15, 1999), p. 4; and Don Ward, "New Horizons: As Subs Surface from Cold War, the View Is Friendlier but Busier," *Navy Times* (November 15, 1993), pp. 14, 18.

11. The Congressional Research Service (CRS) performed a similar analysis of this issue and reached similar conclusions. CRS, like CBO, determined that the Navy would need to build 58 submarines between 2002 and 2019 to meet the 2025 force goal. CRS was slightly more optimistic than CBO in stating that the Navy would need to build 20 new submarines between 2002 and 2009 to meet the 2015 force goal. The difference between that number and CBO's estimate of 24 submarines derives from slightly different assumptions about the service lives of existing Los Angeles class submarines. CRS assumes that all of them will operate for 33 years, whereas CBO, on the basis of information provided by the Navy, assumes that some of those submarines will last between 30 and 32 years. See Ronald O'Rourke, *Navy Attack Submarine Programs: Background and Issues for Congress*, CRS Report for Congress RL30045 (Congressional Research Service, June 1, 2000).

Figure 4.
Share of the Navy's Annual Shipbuilding Budget Devoted to Attack Submarines



SOURCE: Congressional Budget Office.

NOTES: This figure assumes a future shipbuilding budget of $10.5 billion per year (adjusted for inflation)—the average under the 2003 Future Years Defense Program.

SSN = nuclear-powered attack submarine.

Boosting submarine construction to meet the CJCS force goals would require much more money than the Navy has been spending on submarines. To reach and sustain the 2015 force level would cost an average of about $5.4 billion a year between 2002 and 2025 for submarine construction and $2.1 billion a year for operations, CBO estimates. To reach and sustain the 2025 force level would require an average of $6.1 billion per year in submarine construction and $2.1 billion in operating costs. At that level, the SSN force would cost about $2.7 million for each mission day it performed.

The effect on future shipbuilding budgets would be significant. For example, under the fiscal year 2003 Future Years Defense Program (FYDP), the Navy plans to spend an average of $10.5 billion per year on ship construction. If that budget remained constant through 2025 (adjusted for inflation) and the Navy chose to build to the 2025 requirement, submarines would account for about 58 percent of ship construction, CBO projects—more than twice the current average (see Figure 4). Conversely, if the percentage of ship construction devoted to submarines remained the same as under the 2003 FYDP, the total budget for shipbuilding would have to rise to about $30 billion a year.

Sustaining the Existing Fleet Under Current Construction Rates and Budgets

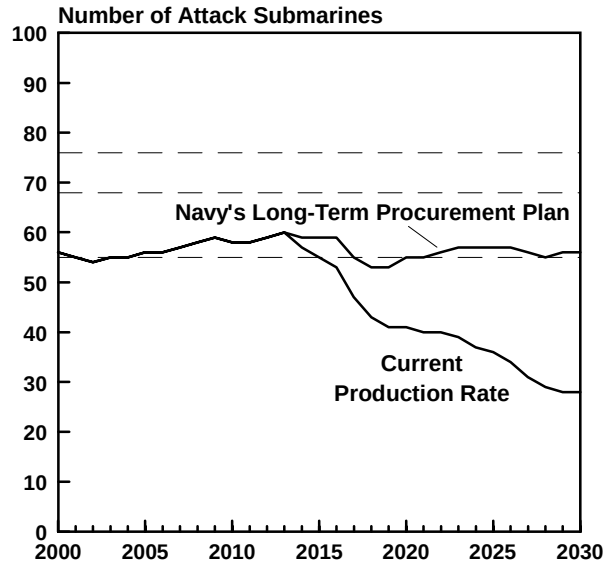
Keeping the fleet at 55 attack submarines through 2015 would require fewer resources than building at a rate to achieve the CJCS force goals. The current construction rate of one submarine per year will be sufficient to maintain the fleet at 55 SSNs through 2015.[12] If that rate is not increased, however, the size of the force will fall to 36 by 2025 (see Figure 5). To prevent that decline, the Navy envisions building an average of 2.2 submarines a year between 2002 and 2020.[13] If it can achieve that rate of construction, the SSN force will remain at about 55 submarines through 2030. A fleet that size would cost an average of $4.5 billion per year for procurement and $1.9 billion per year for operations between 2002 and 2025, CBO estimates.

During the 1990s, the Navy devoted 14 percent of its shipbuilding budget to attack submarines, or about $1.1 billion annually (in 2002 dollars). According to the 2003 FYDP, the Navy expects to devote about 21 percent of its shipbuilding budget to submarine construction between 2003 and 2007, or approximately $2.1 billion per year. However, to maintain 55 submarines, the Navy would need to spend 43 percent of its shipbuilding budget through 2020 ($4.5 billion a year) on submarines, assuming a future annual shipbuilding budget of $10.5 billion (adjusted for inflation). Conversely, if the Navy had

12. That statement assumes that all of the existing Los Angeles class submarines are refueled to last their full notional service life of 30 to 33 years. At this writing, that appears to be the Navy's intention.

13. Maintaining a 55-submarine force under a steady rate of procurement would normally require building an average of 1.67 submarines per year. But since 1991, the Navy has ordered only five submarines, an average of 0.5 per year. Thus, a "backlog" of submarine construction is building up. See O'Rourke, *Navy Attack Submarine Programs*, for a more extensive discussion of the backlog.

Figure 5.
Number of Attack Submarines Through 2030 Under the Navy's Plan and the Current Production Rate



SOURCE: Congressional Budget Office.

NOTES: The Navy's plan assumes an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, it assumes a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

to keep the share of the shipbuilding budget devoted to submarine construction the same as under the 2003 FYDP, that budget would have to rise to $22 billion a year, on average.

SSNs Are Central to the Navy's Long-Term Procurement Shortfall

A steady-state comparison of the Navy's force goals and its recent shipbuilding budgets shows that attack submarines represent by far the greatest shortfall that the Navy faces in its shipbuilding account.[14] By the end of the year, the Navy expects to have devoted 22 percent of its ship construction budget between 1998 and 2002 to attack submarines, or an average of about $1.9 billion out of $8.8 billion annually. If those numbers were held constant (a steady state), they would purchase 30 attack submarines at an average price of $2.1 billion apiece (using CBO's estimate)—well below the force goal of 55. That shortfall amounts to about $1.6 billion per year (see Table 2).

Other types of Navy ships, notably ballistic missile submarines, also have shortfalls. But the Navy will not need to buy a new ballistic missile submarine until 2020, when the first of the planned force of 14 Trident submarines is retired. Amphibious ships actually have a small "surplus," in that during the past five years the Navy has spent more on them than is necessary to maintain a fleet of 36, the current force goal.

Bridging the Gap: Basing Three Attack Submarines in Guam

Last year, the Navy announced that it would base three of its SSNs in Guam by the end of 2003.[15] The purpose of the change is to use those submarines more efficiently in two ways.

First, by moving attack submarines some 3,300 nautical miles west of Pearl Harbor, the Navy will have SSNs centrally located in the area of responsibility of the Seventh Fleet Commander. As a result, the time those submarines would otherwise have spent traveling from Pearl Harbor or San Diego to their areas of operation in the Far East can instead be used for conducting missions.

Second, and more significant, stationing submarines in Guam allows them to follow a different operating concept, further increasing the number of mission days they can perform. Attack submarines based

14. That steady-state analysis divides the force goals for different types of ships by the ships' estimated service life to determine the average annual purchases necessary to meet those goals and sustain the resulting force. Those annual purchases are then multiplied by estimates of the unit (per-item) cost for each type of ship. CBO used the same methodology in its October 2000 study, *Budgeting for Naval Forces: Structuring Tomorrow's Navy at Today's Funding Level*.

15. Today, Navy attack submarines in the Pacific Fleet are based at Pearl Harbor, Hawaii; San Diego, California; and Bangor, Washington. SSNs in the Atlantic Fleet are based at Norfolk, Virginia, and Groton, Connecticut.

Table 2.
Shortfall in Recent Ship Construction, by Type of Ship

	Percentage of Ship Construction Budget, 1998-2002	Steady-State Fleet Resulting from That Level of Construction	Current Force Goal	Difference Between Steady-State Fleet and Force Goal	
				Number of Ships	Millions of 2002 Dollars
Aircraft Carriers	12	9	12	-3	-380
Attack Submarines	22	30	55	-25	-1,580
Ballistic Missile Submarines/SSGNs	1	1	18[a]	-17[a]	-910[a]
Surface Combatants	36	110	116	-6	-170
Amphibious Ships	10	38	36	2	50
Support Ships	3	29	70	-41	-350

SOURCE: Congressional Budget Office.

NOTES: This table assumes a future steady-state budget of $8.8 billion for ship construction—the average of actual 2002 funding and the Navy's 2003 budget request.

SSGN = nuclear-powered guided-missile submarine.

a. This number may be overstated because it includes the four SSGNs, which the Navy has not said it will replace when they are retired. The current force goal for ballistic missile submarines is 14.

in the United States typically deploy for a 180-day stretch every two years or so. Submarines based in Guam will deploy for periods of up to 56 days, but much more often, so they will spend about 182 days a year at sea and 183 days a year in their home port.[16] Except for periods of at-sea training, most of the days in those short deployments will be available for conducting missions (because of Guam's proximity to important areas of operation). According to the Navy, the average number of mission days for submarines based in Guam will be 88 to 123 a year (depending on how the submarine is operated)—about three times what an SSN provides today.[17]

Transferring three submarines to Guam will entail some costs, both monetary and personnel-related. The Navy says it will need to improve military housing, medical services, schools, and maintenance facilities on the island. However, most of the improvements in maintenance will involve moving additional support staff to Guam rather than building more infrastructure, so the Navy expects the overall cost to be nominal.

Furthermore, although the planned schedule for Guam-based subs complies with the Navy's rules for personnel tempo, the crews of those submarines will spend more days a year at sea, on average, than their counterparts in other submarines. (The personnel tempo for a submarine based in Guam will be slightly less than 50 percent, compared with about 48 percent for a U.S.-based submarine.) The Navy does not know what effect, if any, that increase will have on the morale and, ultimately, the retention of personnel.

16. That schedule complies with the Navy's policies about the amount of time that sailors can spend away from their home port. Those policies require that after a deployment of 57 days or more, crews must spend at least twice as long as the deployment time in their home port. With the Guam-based submarines, because no individual deployment will be as long as 57 days, a crew can return to its home port, rest for a few weeks, and then return to sea.

17. Navy briefing to the Congressional Budget Office, 2001. The briefing put that estimate at 100 to 140 mission days per year, but according to the Navy, it did not take into account long-term, shipyard-level maintenance. The Navy has determined (and CBO assumes) that a single-crewed attack submarine would spend about 12 percent of its service life in long-term maintenance. When that time is factored in, 100 to 140 mission days becomes 88 to 123 mission days.

Generally, the Navy's personnel experts suspect that retention will be no better or worse than for U.S.-based subs. (CBO's analysis suggests that even if very high bonuses were necessary to retain Guam-based submariners, the plan would still be cost-effective. See the discussion of Option III in the next chapter.)

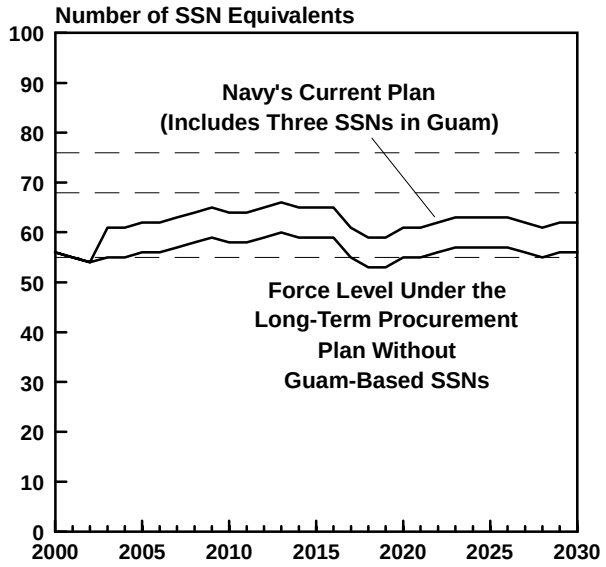
Finally, Guam is not a good base for Navy personnel to "homestead." The island offers few shore-based assignments that a submarine officer or crew member could move to after his or her tour of duty at sea was finished. Consequently, personnel would have few opportunities to stay there for any length of time. In fact, the Navy's current rules prohibit people from being assigned to Guam for longer than two years; the Navy expects to increase that period to three years to provide some stability to the crews of the transferred submarines.

How Long Will the Change Last?

Right now, the Navy considers the stationing of three SSNs in Guam to be a temporary measure, lasting only as long as those submarines' remaining service life (until about 2015).[18] When it is transferred, each submarine will have just completed a major maintenance and refueling overhaul. Thus, it will have more nuclear fuel available for operations than could be used over its remaining service life. As a result, the higher operating tempo associated with Guam-based submarines will not reduce their service life to less than 33 years.

CBO assumed in this study that the decision to base some SSNs in Guam will be permanent. If the benefits prove to be as great and the costs as low as the Navy expects, the service will have a substantial incentive to continue the practice after the first set of submarines is retired. However, any replacement submarines based in Guam would have a service life of about 27 years rather than the notional 33 years because the higher operating tempo would use up their nuclear fuel more quickly.

Figure 6.
Effect on Equivalent Force Levels of Basing Three Attack Submarines in Guam



SOURCE: Congressional Budget Office.

NOTES: Both the Navy's current plan and the long-term procurement plan assume an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, they assume a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

SSN = nuclear-powered attack submarine.

Effects on Force Goals and Procurement

Basing three submarines in Guam will substantially increase the mission capability of the SSN force. The Navy estimates that Guam-based attack submarines could provide 88 to 123 mission days per year, compared with 36 for today's U.S.-based submarines.[19] For the purposes of this analysis, CBO assumed an average of 106 mission days per year (midway between those numbers). Thus, one SSN based in Guam would be equivalent to about three SSNs based in the United States.

18. For example, Rear Admiral Konetzni, the former commander of the Pacific Fleet's submarine force, told *Inside the Pentagon* that the move was a temporary, "band-aid" solution. See P.J. Skibitshi, "Pacific Submarines Consider Basing Nuclear Attack Boats in Guam," *Inside the Pentagon* (July 13, 2000), p. 1.

19. The Navy will not know exactly how many mission days Guam-based submarines can provide until it actually begins operating them from that location this autumn.

That difference has implications for the CJCS force goals, the Navy's long-term procurement plan, and the current construction rate and budget. The requirements in the CJCS study (which was released more than a year before the Navy decided to station SSNs in Guam) were based on the notion of each submarine providing an average of 36 mission days per year. With three submarines in Guam, the force goals can be reduced to 62 attack submarines by 2015 and 70 by 2025. The average construction rate necessary to meet the CJCS goal in 2025 would thus fall to 2.7 SSNs per year between 2002 and 2019. That decline would save an average of about $500 million annually in potential procurement and operating costs between 2002 and 2025 and reduce the cost per mission day of the SSN force from $2.7 million to $2.5 million.

Basing three subs in Guam does not fundamentally alter the Navy's long-term problem, however. If the Navy can implement its long-term procurement plan as well as transfer three SSNs to Guam, equivalent force levels will stay well above 55 through 2025 and even exceed the CJCS minimum for that year of 62 attack submarines (see Figure 6). If not, the current production rate of one submarine per year will keep the equivalent force level at or above 55 for only one year longer with Guam-based submarines than without them (until 2016).

Chapter Two

Options for Increasing the Mission Capability of Attack Submarines

To reduce the cost of meeting its force goals for attack submarines, the Navy could increase the number of mission days that the current force provides. This chapter looks at several ways to do that, all of which expand on ideas that the Navy intends to implement or that have been discussed in policy debates. The first option would convert four retiring Trident submarines to perform missions identified in the 1999 study published by the Chairman of the Joint Chiefs of Staff. The Congress appropriated $430 million this year to begin the process of converting those submarines. The second option would use more than one crew to operate some Virginia class attack submarines. The third option would base up to 11 SSNs in Guam, building on the Navy's plan to transfer three submarines there from the United States.

To evaluate those options, the Congressional Budget Office examined whether they could provide enough extra mission days to meet the force goals laid out in the CJCS study. CBO also calculated the options' cost per additional mission day (above the level provided by the Navy's planned force of 55 SSNs) to compare their cost-effectiveness.[1] Each option assumes that the Navy will base three SSNs in Guam indefinitely. In addition, although all of the options assume that the Navy will implement its long-term procurement plan, CBO examined how the options would affect equivalent force levels if the Navy was unable to increase submarine construction from the current rate of one per year.

1. For details of how CBO made those calculations, see Appendix B.

Option I: Convert Four Trident Submarines to SSGNs

In this approach, the Navy would maintain a force of 55 attack submarines. In addition, as it plans to do, the Navy would convert four Trident ballistic missile submarines scheduled for retirement in 2003 or 2004 to a guided-missile, or SSGN, configuration so they could perform nonnuclear missions. Those SSGNs would employ a system of dual crews similar to the one that Trident submarines use now. As a result, four SSGNs could provide about the same number of mission days as 12 attack submarines. That increase would boost the mission capability of the attack submarine force substantially through about 2025. After that, however, the equivalent force level would fall below 68 as the SSGNs were retired.

The SSGN Concept

The Navy currently operates 18 Ohio class submarines that carry Trident strategic ballistic missiles. Ten of those submarines have D5 missiles; the other eight are fitted with older C4 missiles, which are less accurate and have a shorter range than the D5. The Navy plans to upgrade four of the submarines armed with C4s over the next several years so they can carry D5 missiles. The other four C4 submarines had been slated for retirement but will now be turned into SSGNs instead.

Adapting a Trident submarine for cruise missiles involves altering 22 of its 24 missile tubes to carry seven conventional missiles each, for a total of 154 missiles per submarine. Those weapons will give each SSGN about the same land-attack capability as a group of three or four surface combat ships. In addition to that capability, the SSGNs will have electronic-warfare, intelligence-collection, communications, navigation, and sonar equipment comparable to that of the new Virginia class attack submarine. Further, the space freed up by the two unused missile tubes will be converted to launching areas or equipment storage for special-operations forces.

What Missions Would SSGNs Perform?

The Navy has provided conflicting information to CBO about the missions that SSGNs could perform. One source suggests that, at a minimum, they could conduct covert precision strikes with cruise missiles and clandestine operations with special forces. Other missions would ultimately depend on the equipment installed, but according to the Navy, "it is foreseen that the SSGN would be capable of most of the missions of current SSNs, to include undersea warfare (with limited torpedo room capacity), sea control, intelligence, surveillance and reconnaissance, offensive mining, and Naval forward presence."[2] SSGNs could also be useful as platforms for demonstrating new technologies in undersea warfare. However, they would probably not be as effective as SSNs in helping aircraft carrier battle groups train, operating under ice, or conducting antisubmarine warfare exercises with other navies.

Other data provided by the Navy suggest that the missions an SSGN could perform, at least with respect to those identified in the CJCS study, would be limited. In constructing this option, CBO relied on that more conservative view.

Most of the discussion of SSGNs, both inside and outside the Navy, focuses on having those submarines available to perform strike (land-attack) or special-operations missions. But strike was not mentioned in the CJCS study as a required mission for attack submarines, nor were some of the special operations that the Navy has in mind for SSGNs. Thus, if SSGNs were used for those purposes, they would probably not be available most of the time to perform missions identified in the CJCS study. Ultimately, how to use SSGNs is a choice for policymakers.

For the purposes of this option, CBO chose to use the SSGNs to conduct missions identified in the CJCS study. In a document provided to CBO, the Navy stated that SSGNs could fully perform 12 percent of the mission days in the CJCS study and partially perform another 10 percent. For analytic purposes, CBO assumed that SSGNs could carry out 17 percent of the CJCS mission days (halving the 10 percent to 5 percent and adding it to the 12 percent).

Mission Days and Force Levels

In a 1999 report to the Congress, the Department of Defense (DoD) anticipated that with a force of four SSGNs, two could remain forward deployed in different theaters at all times.[3] Achieving that high level of forward presence would require retaining the blue/gold crew model used for operating Trident submarines, albeit with some modifications. (That model is described in detail in Option II.) Each SSGN would most likely employ a 224-day operating cycle in which the submarine would be deployed for 174 days followed by a 50-day period in port. If the blue crew took the submarine on patrol, the gold crew would fly out and change places with the blue crew in the middle of the patrol (see Figure 7).[4] On every third patrol, the SSGN would undergo a process to certify that it was qualified to perform special operations.

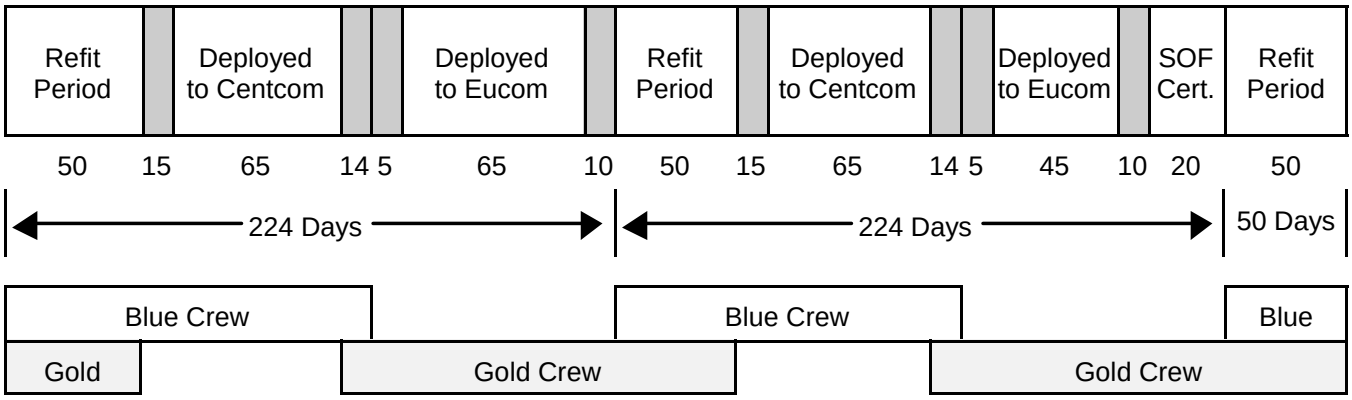
CBO calculated that an SSGN could provide up to 142 mission days per year. That figure originates

2. Information paper provided by the Navy to CBO, February 4, 2001.

3. See the unclassified portions of Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, *Assessment of Potential Benefits of Converting Trident-Class Ballistic Missile Submarines (SSBNs) to Nuclear-Powered Guided-Missile Submarines (SSGNs)*, August 1999. (This is the second of two reports on this subject. The first is *Analysis of Converting Trident-Class Ballistic Missile Submarines (SSBNs) to Nuclear-Powered Guided-Missile Submarines (SSGNs)*, June 1999.)

4. Although the Navy has used such an operating concept for ballistic missile submarines, it has not done so for attack submarines.

Figure 7.
Deployment Cycle for an SSGN Assigned to the Atlantic Fleet and Based in King's Bay, Georgia



SOURCE: Congressional Budget Office based on information from Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, *Analysis of Converting Trident-Class Ballistic Missile Submarines (SSBNs) to Nuclear-Powered Guided-Missile Submarines (SSGNs)*, June 1999.

NOTES: Shaded areas in the top line represent short periods of transit, in-theater crew exchanges, or maintenance.

SSGN = nuclear-powered guided-missile submarine; Centcom = Central Command; Eucom = European Command; SOF Cert. = special-operations forces certification, which would occur every third cycle.

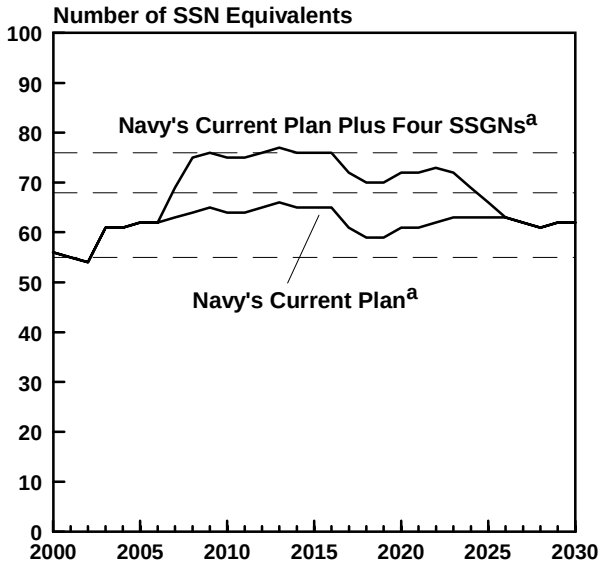
from information in DoD's 1999 report to the Congress, which stated that in the course of three 224-day operating cycles (672 days), an SSGN would spend 150 days in its home port being refitted, 90 days going to and from a theater of operations, 42 days undergoing crew exchanges and some maintenance in-theater, and 20 days for the special-operations certification. The report was trying to quantify presence (simply being in the theater of operations), however, so it did not include time spent moving from one location to another within a theater to perform different missions. CBO added 72 days for in-theater transit to that list on the basis of historical averages for attack submarines.[5] Thus, out of 672 days, an SSGN would devote 298 days to missions—the equivalent of 162 mission days per year.

That number, however, does not take into account the time a submarine spends in long-term, shipyard-level maintenance. A Trident ballistic missile submarine that has been refueled is expected to spend about 5 percent of its remaining service life in long-term maintenance, compared with 12 percent for an attack submarine. But because an SSGN would be used more like an attack submarine than a ballistic missile submarine, CBO chose the 12 percent figure. Subtracting that time for maintenance reduces the average annual mission days for an SSGN to 142—equal to four attack submarines based in the United States.

As noted above, though, CBO assumes that SSGNs will be limited in the types of missions in the CJCS study that they can perform. In accordance with data given to CBO, this option assumes that each SSGN will provide about the same number of mission days as three attack submarines rather than four. The rest of that time could be used to conduct missions that are not identified in the CJCS study or (as discussed in the next section) to train at sea. Nevertheless, the four SSGNs in this option would add substantially to the mission capability of the attack submarine fleet until about 2026, when the last of them would reach the end of its service life (see Figure 8). Replacing those SSGNs with new submarines

5. DoD appears to have excluded port visits from those numbers, so CBO did as well. Port visits are necessary to give the crews of attack submarines liberty from being cooped up underwater during a 180-day deployment. An SSGN crew would be at sea for only 90 days on a much larger ship.

Figure 8.
Effect on Equivalent Force Levels of Converting Four Trident Submarines to Perform Conventional Missions



SOURCE: Congressional Budget Office.

NOTES: This figure assumes that each SSGN would be equivalent to about three SSNs with respect to mission days provided. Actual force levels would be lower than the equivalent force levels shown here.

The Navy's plan assumes an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, it assumes a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

SSN = nuclear-powered attack submarine; SSGN = nuclear-powered guided-missile submarine.

a. Includes three SSNs based in Guam, each one of which is equivalent to about three SSNs based in the United States with respect to mission days provided.

would probably not be cost-effective unless the Navy built a new class of ballistic missile submarines.[6]

Maintenance and Training

In the Navy's plans (and in this option), most maintenance on an SSGN would take place at the submarine's home port. The Navy's notional deployment cycle for SSGNs provides for some in-theater maintenance, perhaps with the support of a tender. But that in-theater maintenance period (14 days) is shorter than the current maintenance period for a Trident submarine (38 days, all of them spent at the home port). Therefore, to compensate, the SSGN would also spend 50 days undergoing maintenance at its home port, including maintenance on its Tomahawk missile systems.

In terms of crew training, SSGNs would resemble Trident submarines more than attack submarines. Unlike attack submarines, they would not perform at-sea training prior to deployment. The crew that did not deploy would conduct its training in the submarine's home port, similar to the way that the crew of a Trident sub performs its training, but adjusted for the difference in missions. That training would occur primarily at the on-shore training facilities in Kings Bay, Georgia, or Bangor, Washington. According to the Navy, "the plan is to use the existing Trident Training Facilities (TTFs) as much as practical and the base-line plan includes installing training facilities associated with the Tomahawk systems at the TTFs, and modifying the ship control trainers to include SOF [special-operations forces] operations simulations."[7]

That plan is consistent with the information that DoD provided to the Congress in its 1999 reports on converting Trident submarines. Indeed, to achieve the level of presence envisioned in those reports—two SSGNs forward deployed at any time—the Navy would have to use the Trident subs' existing training facilities and concepts, which do not provide for at-sea training.

In reality, the Navy cannot be certain yet whether SSGN crews will need at-sea training and certifications to perform their required missions (whatever those might be). The Navy is trying to determine that, although it may have to wait for actual experience with SSGNs to know for sure.

If it turns out that SSGNs cannot perform their missions without at-sea training, then the conversion concept will have been oversold and probably will not be able to provide the desired level of overseas

6. If the Navy wants to maintain the planned size of the Trident fleet at 14, it will need a replacement for its Trident submarines when they begin to retire in 2026. At this point, however, it is far from certain what such a replacement would look like or how much it would cost.

7. Information paper provided by the Navy to CBO, February 4, 2001.

presence. Conversely, if SSGNs can carry out their missions without at-sea training, then it would validate the concept of having a dual-crewed submarine perform many of the missions of an attack submarine (see Option II).

For the purposes of this option, an SSGN could spend more than 35 days a year conducting at-sea training and certifications without undercutting its effectiveness in performing the missions identified in the CJCS study.

Other Issues

Some Navy officials are concerned that four SSGNs (with only two operational at any given time) would not be able to provide the same geographic coverage as 12 attack submarines. If some of the missions that SSGNs can perform needed to be done simultaneously, a few might go unfulfilled. There is no way to know for certain whether that will be the case 15 or 25 years from now, but it does represent a measure of additional risk in this option.

Table 3.
Average Annual Costs of Different Options for the Attack Submarine Force (In millions of dollars)

	Procurement Costs	Operation and Support Costs	Other Costs[a]	Total Costs
Average Annual Costs Through 2007				
Navy's Current Plan[b]	2,870	1,840	0	4,710
Costs in Addition to the Navy's Current Plan				
Build 68 SSNs by 2015	3,500	0	0	3,500
Build 68 SSN equivalents by 2015[c]	1,540	0	0	1,540
Build 76 SSNs by 2025	2,510	0	0	2,510
Build 76 SSN equivalents by 2025[c]	1,440	0	0	1,440
Option I: Convert four Trident subs to SSGNs	550	60	0	610
Option IIA: Use dual crews on some SSNs	0	0	0	0
Option IIB: Use three crews to operate two SSNs	0	0	0	0
Option III: Base more SSNs in Guam	0	0	0	0
Average Annual Costs Through 2025				
Navy's Current Plan[b]	4,480	1,870	0	6,350
Costs in Addition to the Navy's Current Plan				
Build 68 SSNs by 2015	880	260	20	1,160
Build 68 SSN equivalents by 2015[c]	530	140	10	680
Build 76 SSNs by 2025	1,640	230	30	1,900
Build 76 SSN equivalents by 2025[c]	1,130	170	20	1,320
Option I: Convert four Trident subs to SSGNs	170	190	10	370
Option IIA: Use dual crews on some SSNs	0	110	20	130
Option IIB: Use three crews to operate two SSNs	0	60	10	70
Option III: Base more SSNs in Guam	0	10	10	20

SOURCE: Congressional Budget Office.

NOTE: SSN = nuclear-powered attack submarine; SSGN = nuclear-powered guided-missile submarine.

a. These costs, which include such things as infrastructure improvements, would occur between 2008 and about 2015.

b. Does not include the cost of converting four Trident submarines to SSGNs.

c. This alternative includes the basing of three submarines in Guam, which reduces the total number of attack submarines required under the Chairman of the Joint Chiefs of Staff's submarine study to 62 by 2015 and 70 by 2025.

Table 4.
Cost-Effectiveness of Different Options for the Attack Submarine Force (In millions of dollars)

	Total Cost per Mission Day Provided by the SSN Force
Navy's Current Plan	2.5
Build 68 SSNs by 2015	2.7
Build 68 SSN Equivalents by 2015[a]	2.5
Build 76 SSNs by 2025	2.7
Build 76 SSN Equivalents by 2025[a]	2.5
Option I: Convert Four Trident Subs to SSGNs	2.2
Option IIA: Use Dual Crews on Some SSNs	2.2
Option IIB: Use Three Crews to Operate Two SSNs	2.2
Option III: Base More SSNs in Guam	2.0

SOURCE: Congressional Budget Office.

NOTES: Cost per mission day is calculated using steady-state estimates of procurement and operation and support costs. Other costs, such as changes in infrastructure, are also included.

SSN = nuclear-powered attack submarine; SSGN = nuclear-powered guided-missile submarine.

a. This alternative includes the basing of three submarines in Guam, which reduces the total number of attack submarines required under the Chairman of the Joint Chiefs of Staff's submarine study to 62 by 2015 and 70 by 2025.

Although present, that risk is probably overstated. The three attack submarines that each SSGN would nominally replace would not have been deployed at the same time but at different times, to provide more continuous coverage. One SSGN, with its larger number of mission days, would simply provide the same level of coverage.

What is not overstated about this option is the potential loss of flexibility. If a crisis or war occurred and most or all of the Navy's submarines were deployed, having 12 attack submarines would give military leaders more flexibility to meet the emergency than having four SSGNs would. Nevertheless, because this option envisions maintaining a force of 55 attack submarines, the four SSGNs would represent a force in addition to what the CJCS study says the United States needs for wartime missions.

Overall Cost-Effectiveness

Option I would be relatively cost-effective through 2026, CBO estimates. It would require some significant investment—a total of approximately $4 billion to refuel, convert, and arm the SSGNs.[8] Average annual costs through 2007 would be $610 million more per year than in the Navy's plan (see Table 3 on the previous page).[9] However, the cost per mission day of the total force of attack submarines and SSGNs would be $2.2 million, substantially less than if the Navy built an equivalent number of attack submarines (see Table 4). That cost-effectiveness would not change even if the remaining service life of the SSGNs was only 15 years rather than the 20 years that the Navy assumes.

Option II: Use More Than One Crew on Some Virginia Class Submarines

This option also envisions a fleet of 55 attack submarines, but some of them would have either two alternating crews (dual crewing), similar to Trident submarines, or three crews rotating between two submarines (multiple crewing). In either case, the force of 55 attack submarines would provide about the same number of mission days as a force built to meet the

8. That estimate includes the cost of buying Tomahawk missiles to arm the SSGNs. Navy officials argue that they will not need new missiles because they plan to convert Tomahawks that are launched through torpedo tubes to ones that can be shot from VLS cells. Doing that might save about a billion dollars, improving the cost-effectiveness of this option.

9. For the purposes of this analysis, the Navy's plan does not include the four SSGN conversions that the President proposed to the Congress in February in the 2003 Future Years Defense Program.

CJCS goals of 68 SSNs by 2015 and 76 by 2025—at much lower cost.

Current Operating Cycles and Crewing Concepts

Understanding the changes that Option II would make requires knowing some basic information about the Navy's current operating cycles and crewing concepts for submarines. The Navy operates one class of ship with dual crews: the Ohio class submarines that carry Trident missiles. The approach used for those subs is very different from the single-crew operating concept used for attack submarines. Navy officials have expressed a number of concerns about applying the Trident dual-crew model to attack submarines.

The Blue/Gold Crewing Concept for Trident Submarines. The Navy's current model for using more than one crew to operate a ship is the blue crew/gold crew concept used with Trident submarines.[10] Under that operational concept, two crews (named blue and gold) are assigned to each Trident sub. The blue crew takes the submarine on a 74-day patrol, after which it brings the sub back to port and both crews conduct 38 days of maintenance.[11] The gold crew then takes the submarine on another 74-day patrol and returns home, at which point both crews again carry out 38 days of maintenance.

That cycle repeats throughout the 42-year service life of a Trident submarine, broken only for longer periods of maintenance. For example, after 14 years, the sub requires an extended refit period in which it goes into dry dock for four months. At about the 21-year mark, the submarine returns to dry dock for two years, during which its reactor core is replaced (refueling the submarine) and additional long-term maintenance is performed. Another extended overhaul period occurs at around the 33-year mark.

With that cycle, the operating tempo of a Trident submarine (the amount of time, on average, that it spends under way in a year) is 65 percent, whereas the personnel tempo (the amount of time, on average, that a sailor spends at sea in a year) is only about 40 percent. Consequently, a Trident submarine is at sea for the majority of its service life.

Supporting that operating concept required a unique effort in submarine design and precise procedures for maintenance and training. First, the Ohio class submarine was designed and engineered to be operated in that manner. Specific features were incorporated in the sub to accommodate faster maintenance, such as an extra-large hatch—called a logistics escape trunk—and removable decks to facilitate the replacement of large pieces of equipment. (Removing large items from a Los Angeles class submarine, by contrast, might require dismantling them onboard the sub, which takes time, or cutting a hole in the hull to remove them.)

Second, the Navy instituted the Trident Planned Equipment Replacement Program for conducting periodic, large-scale equipment changes to ensure that Trident submarines operate with "like-new" equipment during each deployment. Rather than wait for equipment to fail and be replaced as needed, the Navy replaces equipment on Trident submarines according to a regular schedule, whether they need it or not. The maintenance facilities at the Trident submarine bases in Kings Bay, Georgia, and Bangor, Washington, include large dry docks, rail-mobile pier-side cranes to quickly remove or insert large pieces of equipment in the submarines, and advanced machine shops. In addition, those maintenance facilities are given enough resources to ensure a readily available supply of parts that a Trident submarine might need. Consequently, CBO estimates, the annual operating costs for a Trident submarine are about twice those for an attack submarine.

The Operating Cycle of an Attack Submarine. Notionally, the full operating cycle of an SSN is 24 months. The first 18 months make up the interdeployment training cycle (IDTC), followed by a six-month deployment (see Figure 9). In the past, the Navy sent some attack submarines on shorter periods of deployment. But given the post-Cold War reduction in the force, all SSN deployments now last for

10. A similar concept was used with the previous class of ballistic missile submarines.

11. Until recently, those figures were 77 days of patrol followed by 35 days of maintenance.

Figure 9.
Current Notional Deployment Cycle for an Attack Submarine

Rest, Maintenance, and At-Sea Training	Rest, Maintenance, and At-Sea Training	At-Sea Training and Maintenance (Pre-overseas movement)	Deployment
180 Days	180 Days	180 Days	180 Days

SOURCE: Congressional Budget Office based on information from the Navy.

six months in order to make more efficient use of the time a submarine can spend at sea.[12]

During the IDTC, the submarine normally operates at sea for a limited amount of time—no more than 28 days per quarter. During the first year of that 18-month period, the crew periodically takes the submarine to sea for activities such as drills, sound trials, tactical development exercises, support of other submarines preparing to go on deployment, and port calls to U.S. cities. (The submarine might also give underway demonstrations to officials and visitors during those activities.) In the last six months of the IDTC, the submarine conducts what is called pre-overseas movement as the crew prepares to go on its next deployment. The crew must spend between 30 and 58 days at sea to pass its predeployment evaluations and certifications.

The crew also performs maintenance and upkeep on its submarine during the IDTC, especially during the pre-overseas-movement period. The amount of time devoted to that activity is usually no more than 35 days per quarter. Moreover, about 28 days of maintenance are supposed to be performed during deployment. That results in a ratio of maintenance time to at-sea time of 0.87 to 1 (excluding shipyard-level work).

Over the course of its notional 33-year service life, an attack submarine will go through 14 deployment cycles. In between deployments, it will undergo several major maintenance periods. They include stints as short as two months (called selected restricted availabilities) for work at a shipyard. During those periods, the submarine, with some effort, could be sent to sea again in a fairly short time. At approximately the 12-year point, the submarine will undergo a 12-month modernization period in which major repairs and upgrades are performed at a shipyard. At about the 23-year point, it will return for a longer period of maintenance and improvement called an engineering overhaul. During neither of those more-extensive maintenance periods could the submarine be recalled to duty quickly.

That operating and maintenance cycle means that an SSN will spend about four years—or 12 percent—of its service life in long-term maintenance. It will spend about 37 percent of its time at sea, including training near the submarine's home port as well as deployment. An SSN will theoretically spend about 21 percent of its time on deployment, of which about 10 percent represents mission days.

In reality, submarines do not always match the Navy's notional schedules and cycles. In periods when submarines are in high demand, the IDTC can be shortened to return subs to sea more quickly. For the purposes of this analysis, however, CBO used the Navy's notional operating concept in its calculations.

The Navy's Concerns About Using More Than One Crew on SSNs

In written statements, Congressional testimony, interviews with the media, and briefings and information papers provided to CBO, Navy officials have raised various concerns about the concept of using more than one crew on attack submarines. Many of those concerns focus on the differences between dual-crewed Ohio class Trident missile submarines and single-crewed Los Angeles class attack submarines,

12. That will no longer be true beginning this autumn, when the first of three attack submarines is transferred to Guam. As explained in Chapter 1, the operating cycles of Guam-based SSNs will be more intensive than those of U.S.-based attack submarines.

which are the mainstay of today's SSN fleet. Those concerns cover three broad areas: maintenance, training, and the development of new crews.

Maintenance. As noted above, Trident submarines and their bases were designed and built to support a dual-crew concept. Many design features of the subs as well as the Trident Planned Equipment Replacement Program and the design of the subs' bases facilitate quick refits of a Trident submarine so the second crew can quickly return it to sea, thereby maintaining the submarine's relatively high operating tempo. Los Angeles class submarines and their home ports have none of those features, making it difficult for those submarines to use dual crews. Consequently, none of CBO's options envision using more than one crew for Los Angeles class submarines.

Training. Trident submarines perform essentially one mission: strategic deterrence. That mission begins as soon as the submarine leaves its home port and involves slow, quiet patrols in which contact with other ships and operations in other countries' waters are avoided. Training for that mission takes place in the extensive on-shore training facilities at Trident bases.

Attack submarines, by contrast, perform multiple missions, far from U.S. shores. According to the Navy, SSN crews need to conduct extensive at-sea training for those multiple missions before a deployment; shore training alone might not be effective. For example, Admiral Bowman, director of the Naval Nuclear Propulsion Program and the most senior submariner in the Navy, stated that the service would have to invest in more on-shore infrastructure and trainers to adopt a dual-crewing concept for SSNs. But that might not be enough, he argued: "There may be no substitute for at-sea training." Similarly, Rear Admiral Malcolm Fages, former director of undersea warfare for the Chief of Naval Operations, stated: "We are not at all sanguine that, even if we had unlimited funds, we could put in place a sufficiently robust training capability so that, in an off-crew status, the crews would be proficient to go to sea and do those missions."[13]

13. See Admiral F.L. Bowman, "Remarks to Corporate Benefactors," *Submarine Review* (April 2001), p. 24. Rear Admiral Malcolm Fages was quoted in John G. Roos, "Weighing the Options: U.S. Navy Faces Tough Choices in Modernizing Its Attack-Sub Fleet," *Armed Forces Journal International* (April 2001), p. 54.

Developing New Crews. The Navy also argues that it could not put together new submarine crews quickly. If attack submarines were to begin operating with more than one crew, the Navy says, developing the first of those new crews would take at least 10 years. Although some development time would certainly be necessary, 10 years may be an overestimate. In testimony before the Congress, the Navy has vigorously pressed for a larger attack submarine fleet, which would also require more crews. It has not indicated that if the construction rate for attack submarines increased to two per year in the 2003 or 2004 budget—resulting in more submarines six or seven years later—the Navy's personnel system would be unable to staff those submarines.

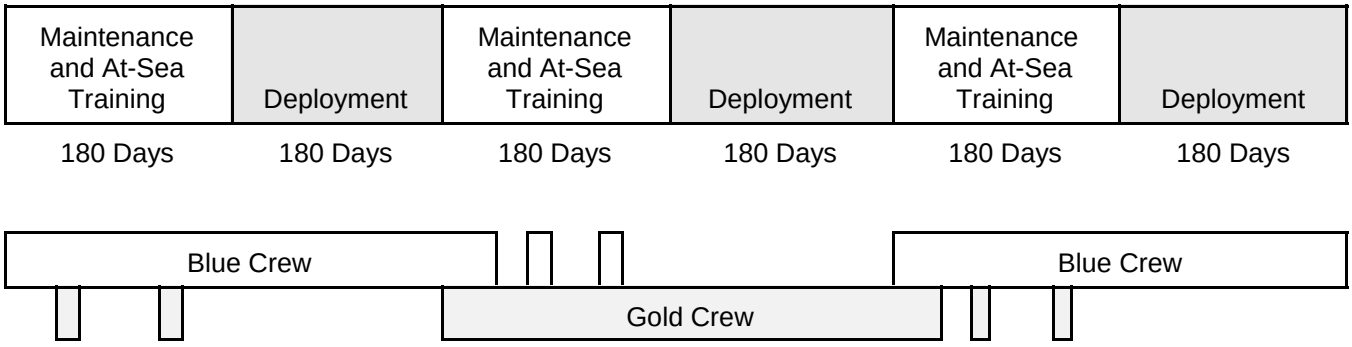
Option IIA: Adapting the Blue/Gold Crewing Model to Attack Submarines

The discussion above demonstrates that applying a dual-crew concept to part of the SSN force would require developing new training and maintenance concepts for attack submarines as well as expanding shore-based infrastructure. Further, since not all attack submarines would have dual crews, the Navy would have to maintain two sets of procedures for its SSN force: one for single-crewed submarines and one for dual-crewed submarines. Offsetting those challenges, however, would be substantial gains in mission days and overall cost-effectiveness.

Under this option, the Navy would adopt a dual-crew operating concept for its new Virginia class submarines beginning with the one authorized in 2003, which would be commissioned in 2009. By 2015, nine Virginia class subs would be dual crewed; by 2025, 19 would have dual crews. Such a schedule would allow the Navy to develop the additional infrastructure that would be necessary for the concept.

How It Would Work. In this approach, two crews would take turns conducting maintenance and at-sea training before taking an attack submarine on a 180-day deployment. The first crew (say, the blue crew) would conduct maintenance and the required at-sea training and certification in the first 180 days, followed by a deployment of equal length (see Figure 10). Before and during the blue crew's deployment, the gold crew would be resting, visiting with family, and training on shore for its deployment. However,

Figure 10.
Notional Blue/Gold Deployment Cycle for an Attack Submarine



SOURCE: Congressional Budget Office.

NOTE: The small bands outside a crew's regular rotation phase represent one-week periods at sea to help maintain the crew's proficiency during the time it is undergoing on-shore training.

during the blue crew's maintenance and training period, the gold crew might also take the submarine out to sea for one-week periods to help maintain that crew's proficiency.

On the submarine's return from deployment, both crews would initially work on conducting necessary maintenance. After a couple of months, however, the gold crew would completely assume maintenance duties and begin its at-sea training and certification. That period would last 180 days and then the crew would take the submarine to sea for 180 days. On the sub's return, the cycle would repeat.

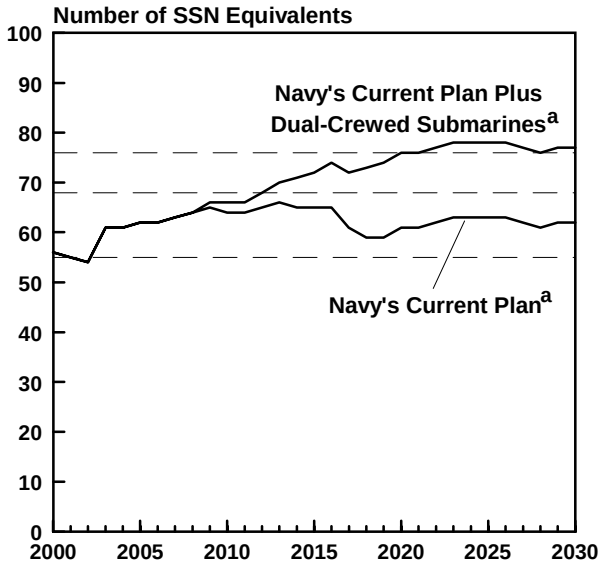
All of the dual-crewed submarines in this option would be based in Groton, Connecticut. The submarine base there has the most extensive facilities for maintaining and supporting attack submarines and thus would be best suited to handle a new way of operating the subs. That concentration, however, might lead to an excess of mission days provided by the Atlantic Fleet. To compensate, the Navy could transfer seven Atlantic-based submarines to the Pacific Fleet. By 2025, some of the dual-crewed submarines would be needed in the Pacific, given U.S. military strategy's increasing emphasis on Asia, as discussed in the 2001 Quadrennial Defense Review.

The Navy argues that the stealthy characteristics and technological capabilities of Virginia class submarines will be needed in the Pacific before 2025. Therefore, to put the dual-crewed Virginias in Groton —where they could perform missions only in the European and Central Asian theaters and the Western Hemisphere—might not be wise. However, this option assumes that the first four Virginia class submarines, which would not be dual crewed, would be assigned to the Pacific Fleet. Further, by 2016, the three submarines based in Guam would also be Virginia class subs (assuming that the Navy replaced the three Los Angeles class subs it is transferring to Guam after they were retired).

Mission Days and Force Levels. Using data from 1995 through 1998, the CJCS study assumed that a single-crewed submarine spends an average of 36 days per year on-station conducting missions. By the same methodology, a dual-crewed submarine as envisioned in this option would spend an average of 65 days per year on-station conducting missions—an increase of about 80 percent. (For a detailed discussion of how those numbers were calculated, see Appendix A.)

Those figures imply that the Navy could achieve the same number of mission days provided by a 68-submarine force with just 55 SSNs so long as it implemented its current plan—that is, the Virginia class program remained intact (see Figure 11). Achieving a force equivalent to 68 attack submarines in 2015 would require that nine of the Virginia class subs that the Navy is building now or intends to order by 2009 be dual crewed and that the remaining 46 Los Angeles class and Seawolf class submarines remain single crewed. The requirement for 18 Virginia class submarines by 2015 would be met with respect to

Figure 11.
Effect on Equivalent Force Levels of Using Dual Crews on Some Virginia Class Submarines



SOURCE: Congressional Budget Office.

NOTES: This figure assumes that dual crewing would begin with the fifth Virginia class submarine and that each SSN operated by a dual crew would be equivalent to 1.8 SSNs with a single crew. Actual force levels would be much lower than the equivalent force levels shown here.

The Navy's plan assumes an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, it assumes a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

SSN = nuclear-powered attack submarine.

a. Includes three SSNs based in Guam, each one of which is equivalent to about three SSNs based in the United States with respect to mission days provided.

mission days, though not actual subs. For the Navy to achieve the equivalent of 76 attack submarines by 2025, 19 of the 30 Virginia class subs that the Navy plans to have in service would need to be dual crewed and the other 36 SSNs single crewed.

If the Navy was unable to raise the construction rate from one submarine a year, however, the equivalent force level would decline over the next three decades, dropping below 55 by 2025.

Perstempo and Optempo. Compared with the way the Navy operates attack submarines today, Option IIA would reduce personnel tempo (perstempo) and increase operating tempo (optempo). The dual crews under this option would each have a perstempo of 34 percent over the two-year deployment cycle of a submarine, compared with a notional 48 percent for today's single crews. That difference might conceivably cause morale problems on single-crewed submarines. At the same time, the optempo of a duel-crewed SSN would rise from a notional 42 percent to 57 percent. In addition, by operating submarines more intensively, this option would exhaust the reactor of a dual-crewed SSN at around 25 years, reducing its notional service life by eight years compared with that of a single-crewed submarine.

Addressing the Navy's Concerns. This option for dual crewing attack submarines takes into account the Navy's concerns about maintenance and development of new crews. However, it only partially addresses the Navy's concerns about training.

Maintenance. The greater optempo of dual-crewed Virginia class submarines would most likely make additional maintenance necessary between deployments. Currently, the Navy nominally devotes 35 days per quarter to routine maintenance and upkeep of an attack submarine when it is not either deployed or in long-term maintenance or overhaul. The Navy could increase that number significantly—by about two-thirds, to 56 days per quarter—for dual-crewed submarines and still keep the ratio of routine maintenance to time at sea almost the same as for a single-crewed attack submarine (0.82 to 1 for the former compared with 0.87 to 1 for the latter). In addition, CBO assumed that the dual-crewed submarines under this option (as well as the multiple-crewed and Guam-based SSNs in Options IIB and III) would spend more time in shipyard-level maintenance than a single-crewed attack submarine does. For that reason, CBO did not assume that any substantial design modifications to the Virginia class would be necessary other than the ones the Navy is already planning.

Training. The Navy's plan for operating converted Trident submarines in an SSGN configuration raises questions about how much at-sea training is really necessary for attack submarines (assuming that the infrastructure for shore-based training is expanded). As noted in Option I, the Navy has stated in reports to the Congress and briefings to CBO that it believes an SSGN will be capable of performing most of the

missions of an attack submarine, including strike, insertion of special-operations forces, undersea warfare, sea control, intelligence collection, offensive mining, and forward presence. Even so, the Navy plans to continue using the Trident's blue/gold crewing concept to operate those submarines, which would mean that essentially all crew training would be conducted on shore. If the Navy can implement that concept for SSGNs, it might also be able to do so for dual-crew attack submarines. Nevertheless, Option IIA would continue to provide a 180-day period before deployment in which the crew of an attack submarine could take the ship to sea for 28 days per quarter to perform at-sea training and certifications.

During that 180-day period, the alternate crew would have several opportunities to conduct at-sea training. It could spend about seven days per quarter training at sea when its submarine was in home port. Those at-sea training opportunities would mean that the largest gap between a crew's times at sea would be 180 to 190 days, compared with 130 days for the crew of an SSGN or 150 days for the crew of a Trident ballistic missile submarine.

Option IIA assumes that some investment would be necessary to increase the size of shore-based training facilities for SSNs. The principal training facility for attack submarines is located in Groton, Connecticut. As part of the overall downsizing of the submarine force, that facility was reduced. Thus, it could not easily accommodate training the extra nine to 19 submarine crews that would exist under this option without additional training equipment, instructors, classrooms, and associated infrastructure. SSN training facilities in San Diego or Hawaii, which are less extensive than those in Groton, would also need some additional equipment and facilities. CBO estimates that the total cost to expand SSN training and other facilities would be about $500 million.

Developing New Crews. This option would not attempt to employ dual crews for large portions of the attack submarine fleet quickly. Nevertheless, the Navy would have to recruit and retain nine additional crews by 2015 and 19 by 2025. Compared with its current plan for a 55-submarine force, the Navy would need an extra 380 officer billets and 2,000 enlisted billets by 2015. By 2025, an additional 800 officer billets and more than 4,200 enlisted billets would be necessary.

How much of a challenge would those additions pose for the Navy? CBO questioned Navy officials about whether the service could recruit and train 13 additional submarine crews by 2015 and 21 by 2025. In a thorough and highly detailed answer, the officials stated unambiguously that the Navy could meet those goals. Thus, the smaller addition—nine crews by 2015 and 19 by 2025—that this option would require to dual crew Virginia class SSNs beginning with the fifth ship should prove slightly easier to achieve.

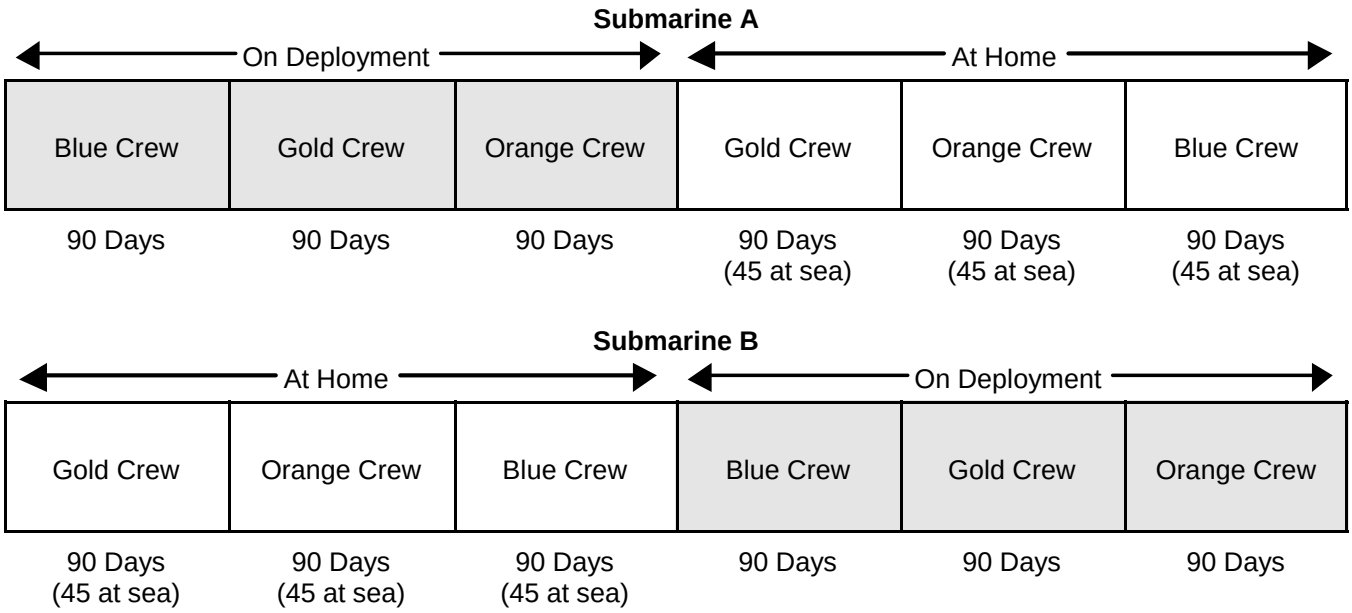
Overall Cost-Effectiveness. Although this option would pose some policy challenges for the Navy, it would improve the cost-effectiveness of the SSN force. This option would cost an average of $130 million more per year than the Navy's plan between 2002 and 2025 (mostly for operations and support), but it would reduce the force's total cost per mission day by $0.5 million. Starting with a base force of 55 single-crewed attack submarines (including three in Guam) that provides a certain number of mission days, the average cost to meet the CJCS requirements under this option would be $2.2 million per mission day. By comparison, building more attack submarines to meet those goals would cost an average of $2.7 million per mission day.

Even if some design modifications were necessary to accommodate the dual-crew concept, the cost-effectiveness of this option would not change. For example, an additional $1 billion in design changes to the dual-crewed SSNs would keep the cost per mission day of the SSN force under this option at $2.2 million.

Option IIB: Using Three Crews to Operate Two Submarines

Adopting the Trident blue/gold crewing model is not the only way to improve the efficiency of attack submarines by using more than one crew. This option envisions an operating concept in which three crews would rotate between two Virginia class submarines on nine-month deployments. Under this option, eight

Figure 12.
Notional Deployment Cycle for Two Submarines Operated by Three Rotating Crews



SOURCE: Congressional Budget Office.

submarines would operate with multiple crews in that manner by 2015 and 14 submarines by 2025. The principal advantage of this option is that it would change the crewing model for fewer SSNs than Option IIA would. However, that change would represent the most significant departure from the Navy's current practices for either attack submarines or ballistic missile submarines of the options that CBO examined; thus, implementing it would pose the greatest challenges for the Navy.

How It Would Work. In this approach, three crews would take turns operating a pair of Virginia class submarines. When one submarine was on deployment for 270 days, the other submarine would be in the same home port so that the crews not on deployment could use it for at-sea training.

The schedules of the two submarines would be divided into 90-day increments (see Figure 12). One crew (say, the blue crew) would deploy with the first sub for three months. Meanwhile, the gold crew would be training with the second submarine, preparing for deployment. The orange crew would not receive any at-sea training during those three months. Near the end of that period, the gold crew would be flown to the theater of the deployed submarine to exchange places with the blue crew.[14] The orange crew would then assume control of the second submarine to prepare for its deployment. The blue crew, which had flown home, would rest and not receive any at-sea training during that second 90 days. After that second three-month period, the orange crew would rotate out to the deployed submarine, eventually bringing it back to the home port, while the blue crew was preparing the other submarine for its deployment. Each deployed submarine would stay at sea for a total of 270 days, three months longer than is the Navy's current practice.

In contrast to the Trident model, the crews in this option would not all have the same operational experience. The blue crew would always conduct its deployment with the submarine that it had used for training. The other two crews would never have that advantage. The blue crew would always take a submarine on deployment and the orange crew would

14. The concept of rotating crews to a forward-deployed submarine was suggested in Department of Defense, *Analysis of Converting Trident-Class Ballistic Missile Submarines (SSBNs) to Nuclear-Powered Guided-Missile Submarines (SSGNs)*. As described in that report, the blue crew would take the SSGN on deployment and the gold crew would be rotated to the submarine halfway through its patrol, eventually bringing it home.

always bring it back. The gold crew would not do either; thus, it would never conduct long transits. However, all three crews would be at sea for comparable periods.

Mission Days and Force Levels. Submarines that used multiple rotating crews as envisioned in this option would spend an average of 73 days per year conducting missions over the course of their service life—twice the average for a single-crewed submarine. Achieving a force equivalent to 68 submarines by 2015 would require the Navy to begin this multiple-crewing concept with the Virginia class submarines authorized in 2004. By 2025, when 14 Virginia SSNs would employ multiple crews, the equivalent force level would exceed 76 (see Figure 13). Like Option IIA, this alternative would meet the requirement for 18 Virginia class submarines by 2015 with respect to amount of presence though not actual number of submarines.

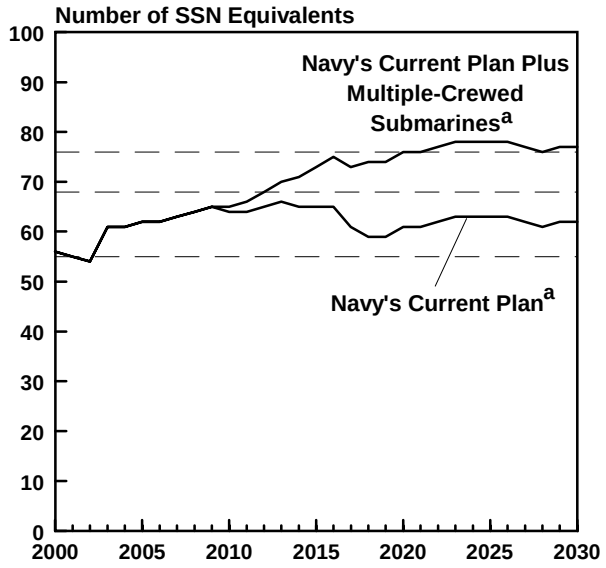
Perstempo and Optempo. If, as this option assumes, crews spent half of their three-month training period at sea, their perstempo would be exactly 50 percent. That figure is slightly higher than the current perstempo for single-crewed submarines (48 percent) but essentially equal to the perstempo anticipated for the submarines that the Navy is stationing in Guam. The optempo of the multiple-crewed submarines would be 63 percent, higher than in Option IIA. That higher operating level would reduce the reactor life of a multiple-crewed submarine to 24 years, the shortest among the options in this study.

Addressing the Navy's Concerns. This option answers the Navy's concern about at-sea training better than Option IIA does, but it could require very controlled design and construction parameters for the submarines that would use multiple crews. Developing the additional crews would not be difficult, although the Navy would have to find suitable sites for exchanging crews in-theater. Maintenance, however, would be a greater challenge for the Navy than under Option IIA's dual crewing.

Maintenance. In this option, multiple-crewed submarines would spend nine months at sea, compared with six months for today's single-crewed SSNs. The operating cycle envisioned in this option would reduce the subs' ratio of maintenance time to at-sea time to 0.65 to 1 (from the current ratio of 0.87 to 1).

Keeping a submarine at sea longer increases the risk of not being able to maintain it in good working order. As mentioned in Option IIA, the crew of an attack submarine on deployment notionally conducts maintenance about 28 days out of 90. In practice, the crew is always performing some degree of maintenance on the ship's systems. Crew members can fix some problems, but others require the support of maintenance facilities on a tender or, better yet, at the home port. Although a submarine may encounter a difficult repair problem at any point in its deploy-

Figure 13.
Effect on Equivalent Force Levels of Using Multiple Crews on Some Virginia Class Submarines



SOURCE: Congressional Budget Office.

NOTES: This figure assumes that three crews would take turns operating two Virginia class submarines and that each submarine crewed that way would be equivalent to two SSNs with single crews. Actual force levels would be much lower than the equivalent force levels shown here.

The Navy's plan assumes an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, it assumes a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

SSN = nuclear-powered attack submarine.

a. Includes three SSNs based in Guam, each one of which is equivalent to about three SSNs based in the United States with respect to mission days provided.

ment, staying at sea longer increases the probability that it will need the support of a tender to perform necessary maintenance during its voyage.

In an attempt to minimize maintenance problems, this option envisions adopting a more aggressive maintenance concept for the Virginia class submarines that would use multiple crews. Specifically, the Navy would need to replace important components at more regular intervals—as it does with Trident submarines—rather than wait until they failed or were about to fail. Although this option's notional operating cycle probably includes enough time to perform all necessary maintenance, sending the multiple-crewed submarines to sea with their important components replaced would help reduce the risk of breakdowns.

A further complication associated with this option involves scheduling the longer, shipyard-level maintenance periods (when a ship is unavailable for at-sea operations). The submarines with multiple crews would need to undergo such periods in pairs, in the same way that they operated.

Training. One advantage of this option is that it would provide up to 45 days of training at sea prior to each 90-day deployment. Thus, the longest period in which a crew would not be able to go to sea would be 90 days. That number is a considerable improvement over Option IIA, in which crews would spend at least 180 days without the opportunity to practice and maintain their skills at sea.

A disadvantage of this option's schedule, however, is that it would not provide enough time at sea to perform all of the training and certifications necessary for a submarine to deploy with an aircraft carrier battle group. Thus, the submarines that used multiple crews might be limited to independent operations. Although such operations represent the majority of attack submarines' missions, that limitation would create additional complexity in operating the SSN force and, therefore, in providing support to battle groups.

Another element of complexity is that in order for the at-sea training to be as effective as possible, submarines would have to be designed as well as operated in pairs to minimize any engineering differences between the sub used for training and the one taken on deployment. (Alternatively, the entire class would need stringent configuration controls.) Submarines, like other types of ships, are not all exactly alike. The Navy and submarine manufacturers try to ensure that each new sub incorporates the most up-to-date technology available. With a construction rate of one per year, every submarine is a little different from every other. How much that difference actually matters would depend on the specific technological discrepancies between two submarines. If the construction rate for attack submarines remained at one per year rather than rising to more than two, this option could still work, but it would require discipline in the engineering process from year to year.

How difficult would achieving such uniformity be? If two manufacturers each built one complete submarine every other year, this approach might be unworkable. However, the current teaming arrangement between Electric Boat and Newport News Shipbuilding, in which the same company builds the same sections for each submarine, has made it much easier to maintain such engineering discipline. Furthermore, the Virginia class submarine is the first Navy ship to be designed entirely by computer before any construction has begun. As a result, the first Virginia class submarine has had 90 percent fewer design changes during construction than the third Seawolf class submarine had at the same stage.

Developing and Exchanging Crews. This option would require far fewer additional crews than Option IIA: only four by 2015 and seven by 2025. However, the Navy would have to plan, and find appropriate locations for, the in-theater crew exchanges. Attack submarines on routine deployments periodically visit foreign ports as part of exercises as well as to give the crews some shore leave. Whether a foreign government would allow such visits for the purpose of exchanging crews is not clear. Missing a crew exchange would complicate the rest of the schedule of both submarines as well as potentially violate pers-tempo rules.

Overall Cost-Effectiveness. This option is every bit as cost-effective as Option IIA. It would cost slightly more than the Navy's current plan—an average of $70 million more per year between 2002 and 2025—but, like Option IIA, it would reduce the average cost per mission day of the SSN force to $2.2 million. On the flip side, the policy changes required to carry out this option are more dramatic, and the risks that the

Navy would assume are greater, than in any of the other options.

Option III: Base More Attack Submarines in Guam

Under this option, the Navy would continue to operate a fleet of at least 55 attack submarines, but it would station seven of them in Guam by 2015 and 11 by 2025. Unlike altering crewing concepts, basing another four to eight submarines in Guam would not be conceptually difficult to do. The additional submarines would operate in exactly the same way as those the Navy already plans to base in Guam. Moreover, although this approach would require some up-front spending to improve the infrastructure on Guam, it would produce a more cost-effective fleet than any of the other options examined in this study.

Mission Days and Force Levels

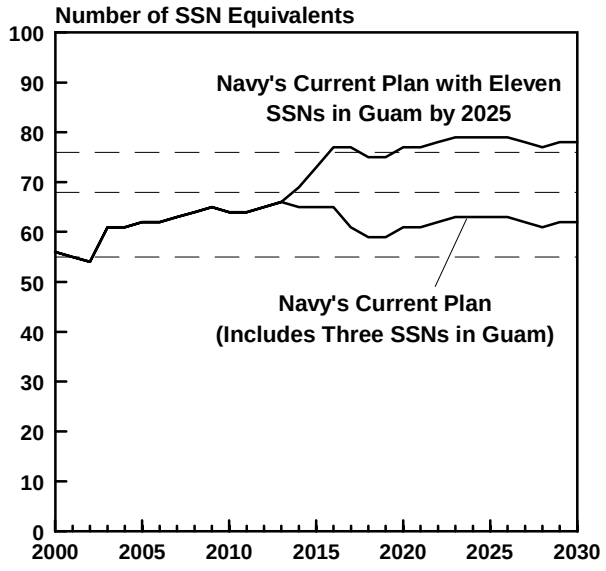
As explained in Chapter 1, a Guam-based submarine would spend an average of 106 days per year conducting missions, compared with 36 for a U.S.-based SSN today. Those additional mission days would come from a combination of reduced transit time and, especially, the different operating concept that the Navy plans to use for attack submarines stationed in Guam. Consequently, a force made up of seven Guam-based attack submarines and 48 other attack submarines would provide the same number of mission days as a force of 68 SSNs based in the United States. Similarly, a force of 11 Guam-based submarines and 44 other attack submarines would provide slightly more mission days than a force of 76 SSNs based in the United States (see Figure 14).

Furthermore, if the additional submarines assigned to Guam by 2015 were from the new Virginia class, they would almost satisfy the mission-day requirement associated with the goal of having 18 Virginia class submarines by 2015. That would be true even if the Navy was unable to increase the construction rate for Virginia class submarines above one per year. In that case, 11 Virginia class submarines would be operational by 2015; if three of them were based in Guam, the force could provide an equivalent number of mission days as 17 Virginia class submarines based in the United States. (Guam is not the Navy's only alternative for basing submarines outside the United States. For information on how other forward-basing options would affect force levels, see Box 3.)

Maintenance and Training

The Navy expects that any short-term maintenance necessary for its three Guam-based submarines will be done in that port. But more-major overhauls, re-

Figure 14.
Effect on Equivalent Force Levels of Basing Eleven Submarines in Guam by 2025



SOURCE: Congressional Budget Office.

NOTES: This figure assumes that each attack submarine based in Guam would be equivalent to about three SSNs based in the United States. Actual force levels would be much lower than the equivalent force levels shown here.

The Navy's plan assumes an average production rate of 2.2 subs a year between 2002 and 2020, compared with the current rate of one per year. After 2020, it assumes a production rate sufficient to maintain a force of 55 attack submarines.

Dashed lines identify the force goals of 55, 68, and 76 submarines.

SSN = nuclear-powered attack submarine.

Box 3.
Other Forward-Basing Options for Attack Submarines

Although the Congressional Budget Office used Guam to illustrate the potential gains from basing more attack submarines near their likely areas of operation, that island is not the only place in the Pacific where U.S. submarines could be stationed. The United States has formal alliance relationships with Japan, South Korea, the Philippines, and Australia. It also bases an aircraft carrier battle group in Japan. What advantage would there be to stationing attack submarines in those countries?

A U.S.-based submarine performs 36 mission days per year, on average, and a submarine based in Guam will perform 88 to 123 mission days, according to the Navy. If the Navy was able to station attack submarines in Japan or South Korea, they could probably provide eight to 10 more mission days per year than subs based in Guam, CBO estimates, if their mission area was the western Pacific. Submarines based in the Philippines would provide about the same number of mission days as those based in Guam, under the same assumption. Submarines stationed in Australia might provide five to seven more mission days per year than subs based in Guam if their mission area was the Middle East.

Those estimates do not take into account the political ramifications or the potential costs of such a move. But they do illustrate the relative advantages of finding overseas bases for Navy submarines, especially across the vast Pacific Ocean.

quiring between two and 16 months in a shipyard, will be conducted in the continental United States or Pearl Harbor. If the Navy based more subs in Guam, it might want to build better repair facilities there. CBO assumed that the Navy would do so and included those costs in its analysis.

Shore-based training would be a more complicated issue. Guam does not have adequate training facilities, so the Navy would either have to build some there or fund a larger travel budget to fly the sailors from Guam-based submarines to training facilities in Hawaii or Connecticut (the current plan for the three subs that will be based in Guam by next year).

Other Issues

Although this option would enable the Navy to meet the CJCS force goals fairly easily with the currently planned fleet, it would have drawbacks. Basing a large force of attack submarines in Guam might prevent them from providing support to carrier battle groups that were preparing to go on deployment or from providing other services to the Navy fleet. In addition, the Navy would have to invest substantially in the shore facilities on Guam to accommodate a doubling—and ultimately a tripling—of submarines, crews, and their families. Even so, the quality of life of those crew members and families could suffer.

Battle-Group Support and Fleet Services. Half of the Pacific Fleet's aircraft carrier battle groups are based in San Diego. If the submarines transferred to Guam under this option were removed from San Diego, the SSN presence there would end, making it difficult for attack submarines to train with carrier battle groups and thus to support them during their deployments. That difficulty may not matter if more and more of the submarine force's missions are geared toward intelligence collection. However, the issue would not arise if the submarines transferred to Guam were taken from Hawaii rather than San Diego.

Regardless of the source of the transferred submarines, another effect of this option would be to reduce the availability of SSNs to assist other Navy units in training exercises. Attack submarines periodically serve as the opposition force for surface ships practicing antisubmarine warfare. This option would offer fewer opportunities for that, unless a surface unit took time for such practice during its deployment in the western Pacific (assuming that it was passing near Guam).[15]

15. A relatively inexpensive yet highly effective solution to that problem would be for the Navy to purchase several diesel-electric submarines to serve as an opposition force on each coast for ships practicing antisubmarine warfare. See Congressional Budget Office, *Budget Options* (February 2001), pp. 137-138.

Infrastructure. Probably the largest monetary cost associated with Option III is the additional investment that would be needed in Guam's shore-based infrastructure. To accommodate four to eight more submarines on the island (and their crews and families), the Navy would have to build a floating dry dock and additional pier spaces, barracks, stores, medical facilities, and schools—all of the things needed for a submarine base equivalent to the one in San Diego. Those additional facilities would cost $200 million, CBO estimates.[16]

Quality of Life. A potential difficulty with this option—as with the Navy's decision to base three submarines in Guam—is the quality of life of the sailors and their families. As noted in Chapter 1, Guam does not offer the same homesteading opportunities as submarine bases in San Diego and Pearl Harbor. At those large bases, it is relatively easy for members of a submarine crew to find other jobs in the Navy when they finish their sea tours.[17] Thus, they and their families can put down roots and stay in one place longer than a few years. Such opportunities are few in Guam. That might become less true if the Navy adopted this option and invested in a much larger shore infrastructure. But even if that happened, the opportunities would not match those of places like San Diego or Honolulu—in part because there would be many fewer chances for the spouses of submariners to find jobs in the neighboring community.

If the Navy found that Guam-based duty led to much lower levels of retention for submariners, monetary bonuses might help. But there is no way to know for certain at this point because the Navy has not based submarines in Guam for more than 20 years and will not begin doing so until the end of the year.

Overall Cost-Effectiveness

Offsetting the possible drawbacks of this option is its cost-effectiveness—the greatest of any of the options in this analysis. Basing additional submarines in Guam permanently would not cost much more than the Navy's current plan for a 55-SSN force. The principal additional cost would be for infrastructure. In return, the cost per mission day of the SSN fleet would fall to $2.0 million, less than in any of the previous options and substantially lower than if the Navy built a larger submarine force. Even if the Navy found that it had to pay each crew member of a Guam-based submarine an extra $25,000 per year as a retention bonus, the cost per mission day under this option would not change significantly.

16. Even if CBO has greatly underestimated the cost of building a submarine base in Guam, Option III would still be far more cost-effective than the others in this study.

17. Although San Diego is not a large submarine base, it is home to three aircraft carriers and their battle groups.

Implications of the Options

A number of conclusions emerge from the analysis of the options. First, transferring an attack submarine to Guam would be more cost-effective than building a new SSN, using an alternative crewing pattern, or converting and operating a Trident submarine in an SSGN configuration. Each mission day gained by building a new submarine would cost $2.7 million, by far the most expensive choice (see Table 5). Con-

Table 5.
Relative Costs of Different Ways to Add Mission Days to the Attack Submarine Force (In millions of dollars)

	Cost per Additional Mission Day Provided
Build a New Submarine	2.7
Convert a Trident Sub to an SSGN	0.8
Operate an SSN with Two Crews	1.2
Operate an SSN with Three Crews per Two Subs	0.9
Transfer an SSN to Guam	0.2

SOURCE: Congressional Budget Office.

NOTE: SSGN = nuclear-powered guided-missile submarine; SSN = nuclear-powered attack submarine.

verting a Trident sub to an SSGN or using more than one crew to operate a Virginia class submarine would cost between $0.8 million and $1.2 million per additional mission day provided. Transferring an SSN to Guam would cost just $0.2 million for each mission day it added. Those results do not imply that transferring additional submarines to Guam is unequivocally the best approach, however. Other factors, such as those discussed in this study, must be considered in determining where an additional dollar spent on the submarine force should go.

The relative cost-effectiveness of the options is not particularly sensitive to changes in assumptions about operating or procurement costs. If a dual- or multiple-crewed attack submarine actually cost as much to operate as an SSGN or a Trident ballistic missile submarine (a reasonable upper limit) or even twice as much as a single-crewed submarine, Options IIA and IIB would still be cheaper per additional mission day provided than building new submarines would be (see Table 6). Further, if procurement costs for new submarines were lower than what CBO assumed, the relative cost-effectiveness of the options would be virtually unchanged. (And if procurement costs were substantially higher than CBO's estimate, the cost per additional mission day for submarine construction would worsen considerably relative to the costs for the alternatives.) Thus, to the extent that the costs of producing or operating attack submarines are uncertain, all four options would still be substantially more cost-effective for the Navy than building a larger submarine force would be.

A second conclusion of this analysis is that if the official force goal remained at 55, these options

Table 6.
How CBO's Estimates of Cost per Additional Mission Day Would Change Under Alternative Assumptions (In millions of dollars)

		Alternative Cost Assumptions			
	CBO's Estimate	Operating Costs for Non-Single-Crewed or Guam-Based SSNs Are Equal to Those for Trident SSBNs	Operating Costs for Non-Single-Crewed or Guam-Based SSNs Are Equal to Twice Those for Single-Crewed SSNs	Operating Costs for Non-Single-Crewed or Guam-Based SSNs Are Equal to Twice Those for Single-Crewed SSNs and Procurement Costs Are 20 Percent Lower	Operating Costs Are Equal to CBO's Estimate but Procurement Costs Are 20 Percent Higher
Build a New Submarine	2.7	2.7	2.7	2.4	3.1
Convert a Trident Sub to an SSGN	0.8	0.8	0.8	0.8	0.8
Operate an SSN with Two Crews	1.2	1.8	1.9	1.7	1.3
Operate an SSN with Three Crews per Two Subs	0.9	1.5	1.5	1.4	1.0
Transfer an SSN to Guam	0.2	0.7	0.7	0.6	0.3

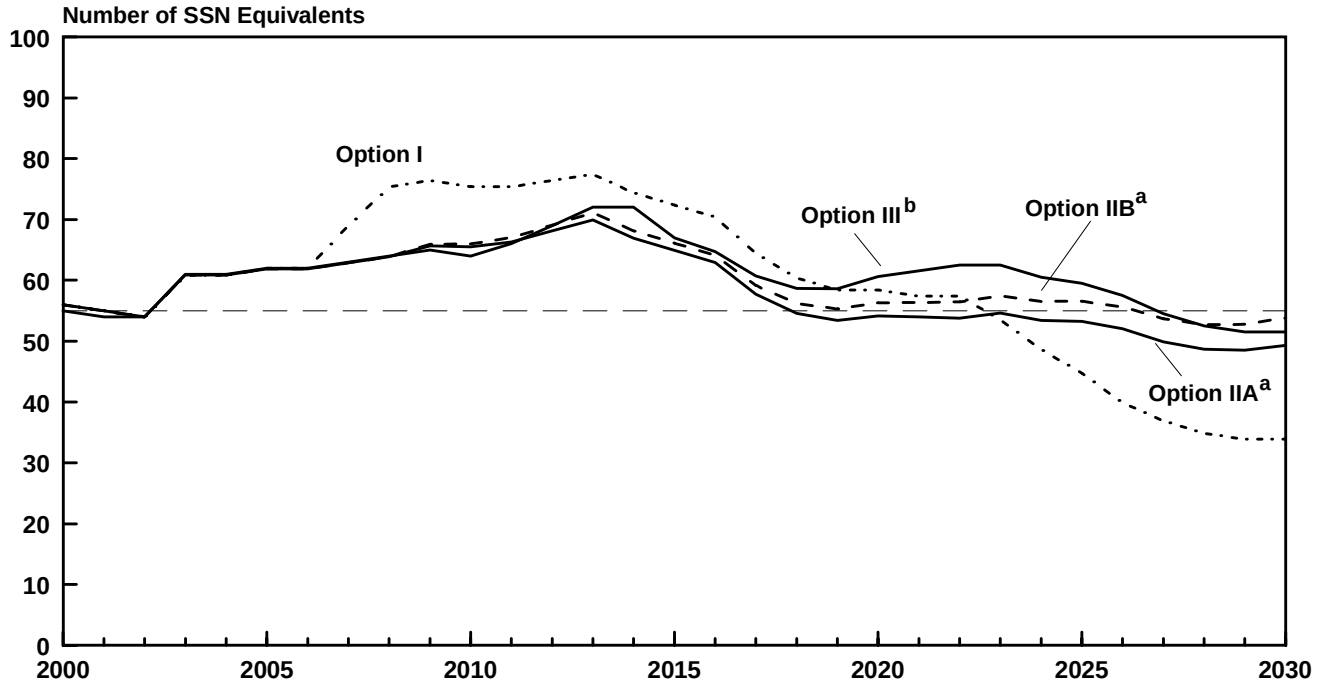
SOURCE: Congressional Budget Office.

NOTE: SSN = nuclear-powered attack submarine; SSBN = nuclear-powered ballistic missile submarine; SSGN = nuclear-powered guided-missile submarine.

could help delay for many years the need to increase the production rate for SSNs. The options assume that the Navy will implement its long-term procurement plan to keep the size of the attack submarine force at 55. However, as Chapter 1 illustrated, carrying out that plan could be difficult because of its cost.

If the construction rate remained at the current level of one submarine per year, for how long could the approaches represented in these options maintain an SSN force equivalent to 55? Option I would sustain that level until 2023 (see Figure 15). But because of the six-year interval between authorizing a new submarine and fielding it, the production rate would have to increase to two or more SSNs per year in 2017. Under Options IIA and IIB, production would have to increase in 2013 or 2021, respectively, to maintain a force equivalent to 55 SSNs—assuming that *all* new Virginia class submarines after the fourth ship were dual or multiple crewed rather than the smaller numbers envisioned in the options. Finally, if the Navy based as many as 12 SSNs in Guam (probably the largest number it might reasonably want stationed there), the production rate would not have to increase until 2022. Under all of those scenarios, however, the SSN force would fall below 55 actual submarines (as opposed to their equivalent in mission days), which is the wartime requirement stated in the CJCS study.

Figure 15.
Equivalent Force Levels Under Various Options, Assuming a Construction Rate of One Attack Submarine per Year



SOURCE: Congressional Budget Office.

NOTES: See the text for a description of the options.

The horizontal dashed line identifies the force goal of 55 submarines.

SSN = nuclear-powered attack submarine.

a. Equivalent force level assuming that all new Virginia class submarines after the fourth ship use dual or multiple crews (rather than the smaller number of submarines included in the option).

b. Equivalent force level assuming that 12 attack submarines—about two squadrons—are based in Guam (rather than the 11 submarines included in the option).

A third conclusion of the analysis is that adopting the new crewing concepts in Options IIA or IIB would require the Navy to make substantial changes in the way attack submarines operate, both as stand-alone units and as part of broader fleet operations. However, such changes do not appear to be any more radical—indeed, in some ways are less radical—than what the surface Navy is proposing with the new DD(X) destroyer, whose crew would eventually be one-third the size of a destroyer crew today. If the Navy executes that program as envisioned, those ships may need wholesale changes in crewing concepts, watch standing, damage control, supervision, training, and maintenance.

Even so, adopting the notional crewing approaches in Options IIA or IIB would require careful planning and analysis. For example, the Navy might want to try a pilot program using one or two submarines on each coast before committing to such alternative operating concepts for Virginia class submarines. However, the analysis of those options suggests that although carrying them out would require a substantial departure from the way the Navy operates attack submarines now, the dual- or multiple-crewing concepts do not appear to be impossible, or even infeasible, to implement. Along with the other options, they represent several ways to bridge the gap between the Navy's actual or planned force structure and its desired force structure 15 or 25 years from now.

Appendixes

Appendix A

Determining the Size of the Submarine Force

The Congressional Budget Office's (CBO's) analysis of the attack submarine force is designed to address the force structure requirements posited in the 1999 study issued by the Chairman of the Joint Chiefs of Staff (CJCS). Those requirements are 68 attack submarines by 2015 and 76 attack submarines by 2025. The Navy endorsed that study's methodologies and shares the desire for more attack submarines.

In making its own calculations of force structure for this analysis, CBO employed the same methodology as the CJCS study. On the basis of submarine deployments from 1995 through 1998, that study determined that the average 180-day deployment of an attack submarine would comprise 77 days of operations (or mission days), 54 days of transit time, 27 days of maintenance, and 22 days of port visits. From those numbers, the study developed the following formula to determine force structure requirements:

$$\text{Force Structure} = \frac{\text{(Op Rqmt/yr)}}{\text{(Ops/Depl)}} * \frac{\text{(6 mos/depl)}}{\text{(12 mos/yr)}} * (\text{TAR} + 1) * \frac{1}{\text{MF}}$$

where:

Op Rqmt/yr = number of days of operations requested per year

Ops/Depl = number of days of operations per deployment (77)

TAR = turnaround ratio

MF = maintenance factor

The turnaround ratio is the time a submarine spends in its home port relative to the time it spends on deployment. (For example, if a submarine spends 18 months in its home port followed by a six-month deployment, the turnaround ratio is 3.0.) Historically, Navy attack submarines have averaged a TAR of between 2.8 and 3.0. The maintenance factor is the amount of time an attack submarine will spend in long-term, shipyard-level maintenance and thus removed from its deployment cycle.

According to that formula, one submarine with a turnaround ratio of 2.8 and a maintenance factor of 0.88—the assumptions of the CJCS study—provides, on average, 35.7 mission days per year over the course of its 33-year service life. The study divided the total number of mission days required by civilian and military leaders by that figure to calculate the necessary size of the attack submarine force. As the formula makes clear, changing the estimates for the number of mission days per deployment, the turnaround ratio, or the maintenance factor would yield different results.

Appendix B

Estimating the Total Cost per Mission Day and Cost per Additional Mission Day Under Various Options

A key measure that the Congressional Budget Office (CBO) used to evaluate the cost-effectiveness of different options for attack submarines is the total cost of each mission day that a particular force of submarines would provide. To estimate that cost, CBO calculated the total costs for a given option, including procurement, operation and support, and any other costs, such as for infrastructure. It then annualized those costs, amortizing them over the useful service life of the submarines to arrive at a steady-state level of spending that would be required to sustain a given force indefinitely. That number was then divided by the total number of mission days that the option would provide.

For example, a force of 100 attack submarines would provide about 3,600 mission days per year (for the source of that figure, see Appendix A). If those submarines cost $2.1 billion apiece to build and had a service life of 33 years, the annualized procurement cost for those 100 submarines would be $6.4 billion per year. If they each cost $33 million a year to operate, then 100 would cost $3.3 billion per year. Finally, if $10 million of additional infrastructure was required to support those submarines and that infrastructure had an average service life of 50 years, then the annual infrastructure cost of the force would be $0.2 million per year. Thus, the total yearly cost for the 100 submarines would be $9.7 billion. Dividing that number by 3,600 yields a total cost of about $2.7 million for each mission day provided by that force.

CBO also calculated the cost of each mission day that would be *added* to the force by a new attack submarine based in the United States, a converted Trident ballistic missile submarine, a Virginia class submarine operated by more than one crew, and a submarine based in Guam. Consider the following example: a new submarine based in the United States would have a service life of 33 years and cost $2.1 billion to build, CBO estimates. Its annual operating cost would be $33 million, and it would provide about 36 mission days per year. Thus, the cost per additional mission day of building a new submarine and basing it in the United States would be $2.7 million.

By comparison, a new submarine based permanently in Guam would also cost about $2.1 billion to build but would have a service life of only about 27 years. Its annual operating cost would be $36 million per year, CBO estimates. As discussed in Chapter 1, it is assumed to provide 106 mission days per year, on average. Consequently, the cost per additional mission day that results from basing a new submarine in Guam rather than the United States is:

$$\frac{[(\$2{,}100 \text{ million}/27 \text{ years}) + \$36 \text{ million}] - [(\$2{,}100 \text{ million}/33 \text{ years}) + \$33 \text{ million}]}{(106 \text{ mission days} - 36 \text{ mission days})} = \$0.24 \text{ million}$$

In other words, the slightly higher annual cost of basing a submarine in Guam instead of the United States (because of its shorter service life) is more than offset by the greater number of mission days it provides.

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