THE U.S. SUBMARINE PRODUCTION BASE

An Analysis of Cost, Schedule, and Risk for Selected Force Structures

EXECUTIVE SUMMARY

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John Birkler, John Schank, Giles Smith, Fred Timson, James Chiesa, Marc Goldberg, Michael Mattock, Malcolm MacKinnon

DTIC QUALITY INSPECTED 5

Prepared for the
Office of the Secretary of Defense

National Defense Research Institute

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The research described in this report was sponsored by the Office of the Secretary of Defense under RAND's National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies, Contract MDA903-90-C-0004.

Library of Congress Cataloging in Publication Data

The U.S. submarine production base : an analysis of cost, schedule, and risk for selected force structures : executive summary / John Birkler ... [et al.].
p. cm.
"Prepared for the Under Secretary of Defense for Acquisition and Technology."
"MR-456/1-OSD."
ISBN 0-8330-1587-7
1. Submarine boats—United States. 2. Navy—yards and naval stations—Economic aspects—United States. 3. United States. Navy—Submarine forces. 4. Shipbuilding industry—United States. 5. Defense industries—United States. I. Birkler, J.L., 1944– . II. United States. Office of the Under Secretary of Defense for Acquisition and Technology. III. Title: US submarine production base.
V858.U213 1994
359.9'3'0973—dc20 94-32570
CIP

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Cover design: Corinne Maiers

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Published 1994 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
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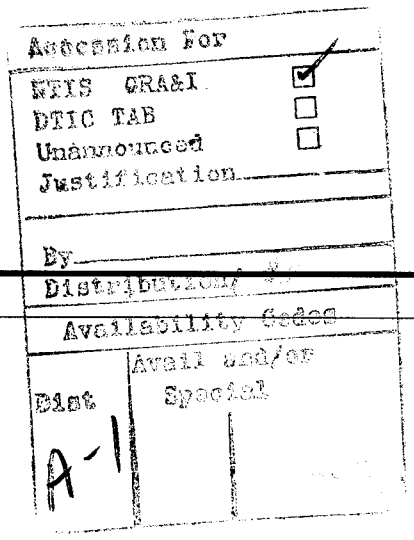

PREFACE

In January 1993, RAND's National Defense Research Institute was asked by the Office of the Under Secretary of Defense for Acquisition (now Acquisition and Technology) to compare the practicality and cost of two approaches to future submarine production: (1) allowing production to shut down as currently programmed submarines are finished, then restarting production when more submarines are needed, and (2) continuing low-rate production. The research was motivated by concerns that the submarine production base might not be easily reconstituted if production is shut down and by the countervailing recognition that deferring new submarine starts might yield substantial savings, particularly over the short term.

This report summarizes RAND's analysis, the results obtained, and the associated uncertainties. The reader should bear in mind, of course, that in a summary such as this, completeness and precision are in some degree sacrificed for brevity. A full treatment of methods and results is available from RAND in MR-456-OSD.

RAND's analysis was completed and briefed to the research sponsors and other interested parties in the summer of 1993. It reflects what was known then about cost, schedules, and other relevant factors.

This research was carried out within the National Defense Research Institute's Acquisition and Support Policy Program (now the Acquisition and Technology Policy Center). The institute is a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies.

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ACKNOWLEDGMENTS

This work could not have been undertaken without the special relationship that exists between the Office of the Secretary of Defense (OSD) and RAND under the National Defense Research Institute (NDRI). For that relationship we are grateful. Many individuals in OSD and RAND deserve credit for the work discussed in this report. Their names and contributions would fill several pages. If we were to single out a senior person in OSD and another at RAND who participated in and supported this work in extraordinary ways, we would mention Gene Porter, Director, Acquisition Program Integration, and David Gompert, Director, NDRI.

We also want to thank the leadership and staff of the Office of the Secretary of Defense, the Office of the Secretary of the Navy, the Naval Sea Systems Command, the Navy Nuclear Propulsion Directorate, the Navy Program Executive Officer for Submarines, Electric Boat Division of General Dynamics, Newport News Shipbuilding, Mare Island Naval Shipyard, and Norfolk Naval Shipyard. The shipyards arranged for us to visit their facilities and gave us the opportunity to discuss production issues with those most directly involved. The shipyards and the Navy offices provided all the data we requested in a timely manner. We appreciate their sharing their perspectives with us and their treating differing perspectives in a professional manner.

We are also indebted to the British and French Ministries of Defense for allowing us to visit their headquarters and submarine production facilities and to discuss their experiences with production gaps, low-rate production, and production issues.

Finally, we are grateful to Joseph P. Large for his review of this document and to both Mr. Large and James A. Winnefeld for their reviews of the comprehensive report on which this summary is based. These reviews led to many improvements in both reports.

This broad-based participation made possible the analysis described here.

Chapter One

BACKGROUND

The current U.S. submarine production program is coming to an end.

Only two shipyards build submarines for the U.S. Navy—the Electric Boat Division of General Dynamics, with principal production facilities in Groton, Connecticut, and Newport News Shipbuilding, a Tenneco subsidiary, in Newport News, Virginia. Together, they employ about 17,000 workers in submarine construction. Thousands more work for vendors supplying nuclear and nonnuclear components to the shipyards.

After many years of building three or more submarines annually, these shipyards have started no new submarines since 1991. Figure 1 shows the number of submarines commissioned each year and, for years in the future, scheduled to be commissioned. By 1999, submarine deliveries will drop to zero for the first time in decades.

This study focuses on attack submarines (SSNs, represented by the darker bar segments in Figure 1). Figure 1 includes the ballistic-missile-carrying Ohio-class submarines (SSBNs), which serve as one leg of the nuclear-deterrent triad, to show that that construction program is coming to an end along with the one for attack submarines.

The United States now has plenty of attack submarines.

A result of the construction activity shown in Figure 1 is the attack submarine fleet profile shown in Figure 2. The current total is down some from the peak but about the same as it was in 1980, in the midst of the cold war.

The number of attack submarines *needed* in the post–cold war era is uncertain. Clearly, the United States will need *some:* Many nations—North Korea, Iran, Libya, others—have submarines, and attack submarines afford the United States a flexible resource in the new strategic environment. They are the chief

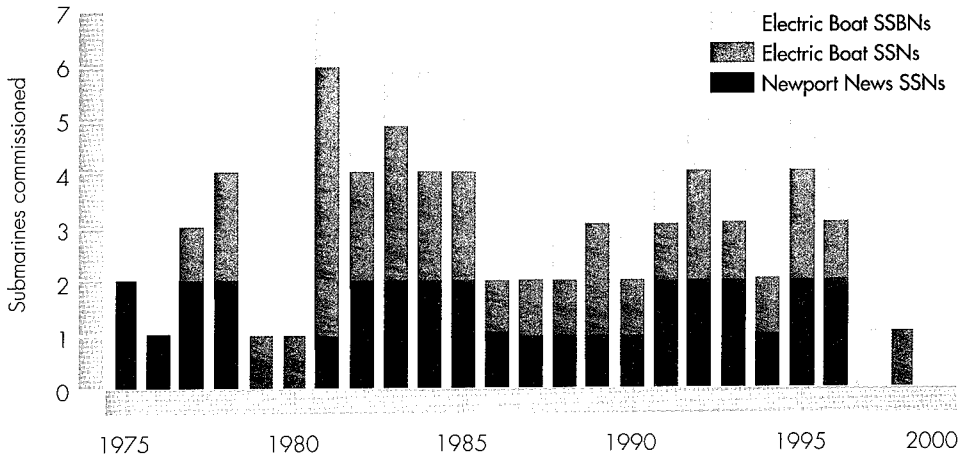


Figure 1—Recent U.S. Submarine Production

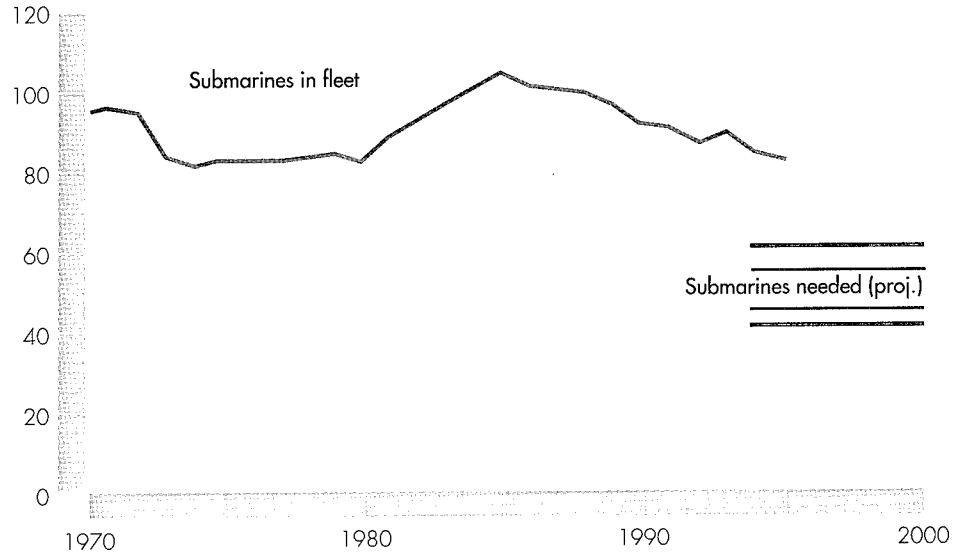


Figure 2—Attack Submarines in Fleet Compared with Number Needed

means of defending U.S. ships against enemy submarines, they can hold enemy surface ships at risk and attack land targets with cruise missiles, and they can transport special forces such as SEALs (sea, air, land teams). Furthermore, they can undertake these missions or position themselves to do so without calling attention to their presence; such stealth can be important if force projection is wanted but is undesirably provocative.

The Department of Defense's Bottom-Up Review suggests a post–cold war fleet of between 45 and 55 attack submarines. In Figure 2, we broaden the band by five ships (10 percent) in either direction to take into account the opinions of knowledgeable observers outside of DoD. But regardless of whether the requirement is 40 ships or 60 ships, the United States now has many more submarines than it needs. Why build more?

Eventually, it will be necessary to replace submarines now in the fleet.

Submarines, of course, do not last indefinitely. To ensure safe, reliable operation, submarines are retired from the force by the time they reach 30 years of service. As Figure 3 shows, the fleet will decline sharply in size as the older submarines built in the sixties are decommissioned—all by the year 2000. The first of the current class will reach age 30 in 2006. Shortly thereafter, the fleet will begin declining through the range of possible requirements, as ships con-

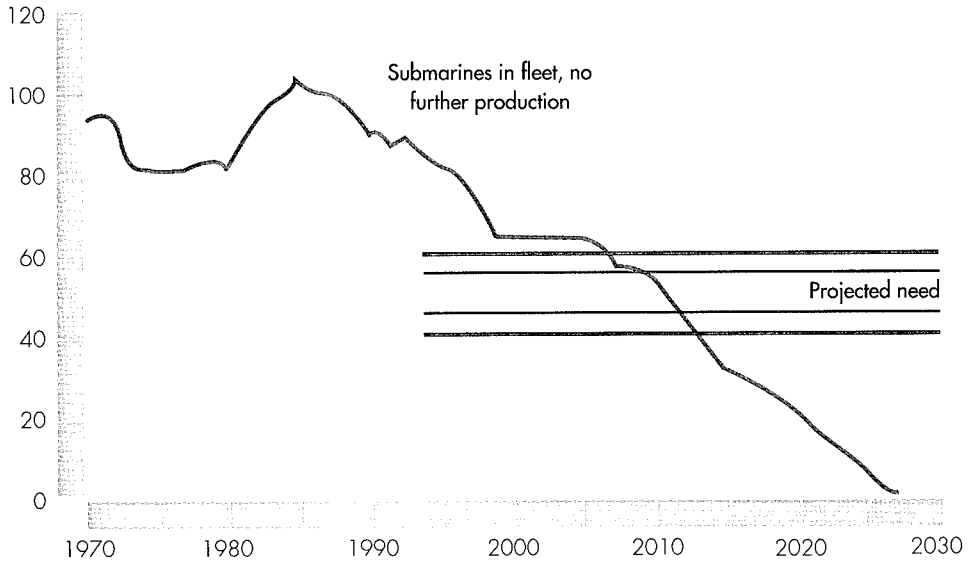


Figure 3—Projected Attack Submarine Fleet Profile with No Further Production

tinue to be retired at the rate at which they were built—about four per year. (Fleet replacement needs for SSBNs are more uncertain and, in any case, farther in the future than those for SSNs.)

By 2013, the attack submarine fleet will fall below the 40-ship level unless construction is started far enough in advance to have replacement boats ready. Because it now takes only six years to build a submarine, it may appear that there is adequate time for a money-saving gap in production. This, however, ignores an important issue.

Initiating a submarine construction program after a hiatus would face serious challenges.

Nuclear submarines are among the most complex structures built by man. Not only must they survive and function underwater for long periods of time in a hostile environment, they contain a nuclear reactor in immediate proximity to the crew. Despite these challenges, U.S. nuclear submarines have demonstrated their reliability in diverse conflict situations while maintaining an impressive safety record over almost four decades. That history can be credited in large part to the highly skilled submarine design, engineering, and construction workforce, both in the shipyards and at the factories of critical-component vendors.

The most recently started submarine is now three years into construction. Shipyard workers and component vendors needed only in the initial phase of construction are already dispersing or preparing to exit the business. More will leave as the industry shuts down in phases. If more submarines are not started soon, then rebuilding the workforce, reopening the shipyard facilities, and reestablishing the vendor base could be very costly and time-consuming. Reconstitution could also compromise the reliability and safety of submarines constructed before today's high standards are reattained.

We analyzed the production schedule, cost, and risk associated with postponing and with continuing production.

Motivated by the need to trade off costs and risks while meeting a fleet replacement schedule, the Deputy Secretary of Defense asked RAND to evaluate "the practicality and cost effectiveness of reconstitution of the submarine production base versus a continuing program for limited production." The two production options envisioned by the Deputy Secretary may be defined more specifically as follows:

- Wait to build more submarines until those coming out of the fleet must be replaced to maintain a sufficient force size. Then, build a new type of attack submarine. The expectation was that this approach might save money in the near term through postponement of production, but would run up extra costs—and risks—later, when it became necessary to restart production.
- Build another submarine of the Seawolf class—the latest class now under construction—while design work proceeds on the new attack submarine. Then start constructing ships of the new type as soon as practical. The effects on cost and risk were anticipated to be the opposite of those expected for the first option.

Our study thus had three purposes:

- To determine the practicality of extending the current gap between submarine starts, given the time required to restart production. We wanted to make sure we took into account the full potential advantages of deferring production. The advantages increase with the length of the gap—the longer production is put off, the more money should be saved. So we sought to find the longest gap possible that still allowed meeting force objectives.
- To compare the cost of producing submarines after the longest gap practical with that of continuing production. This is equivalent to determining which is greater—the savings from postponing production or the offsetting costs of shutdown and restart—and by how much.
- To characterize the largely unquantifiable risks involved in a reconstitution strategy.

In performing these tasks, we drew on quantitative data and qualitative information from private- and public-sector shipyards and vendors, relevant components of the U.S. Navy and the Office of the Secretary of Defense, and foreign governments with shutdown experience. Sources included persons with varying perspectives on the seriousness of the delays, costs, and risks associated with a production gap. We reviewed all data critically, made adjustments where we believed them appropriate, and built and ran analytical models to draw inferences where the nature of the data permitted them.

We ascertained how stopping and restarting production affects shipyard and vendor costs and schedules and how decisions about future fleet size and production rate determine the production gaps feasible. These results were then combined to yield discounted cost streams for sustaining the submarine production base under a strategy of continued production and under various postponement strategies. We accounted for the costs of producing, operating, and

maintaining the attack submarine force until 2030, when submarines in the the current fleet will all have been replaced.

This is what we found.

- It takes so long to restart production after shutdown that **construction of the next class of submarines must be started by around 2001** if fleet sizes of 40 or more are to be sustained. (This finding is discussed in more detail in Chapter Two.)
- For the longest gaps feasible, the discounted stream of costs required to sustain the submarine force to 2030 results in **savings of less than a billion dollars** compared to the cost of a more continuous program. That is **well within the margin of error** with which we can now project such costs. (For details, see Chapter Three.)
- **Risks, however, are substantial.** Given the difficulties and challenges involved in restarting submarine production from scratch, there is a risk that our cost estimates for restart are too low and our schedule estimates too optimistic. Further risks related to nuclear licensing and environmental and safety concerns may jeopardize the success of a restarted nuclear submarine program. (See Chapter Four.)
- Considering the limited savings realizable and the substantial risks incurred in extended-gap scenarios, **we recommend that construction of additional submarines be started soon.** Specifically, we recommend that the third Seawolf-class submarine, now planned for a 1996 start, be funded, and that the Navy proceed with plans for beginning construction of the new attack submarine in the late 1990s. (See Chapter Five.)

Chapter Two

HOW LONG CAN PRODUCTION BE SUSPENDED?

The length of the gap depends on how big a fleet is desired.

The bigger the attack submarine fleet the United States seeks to sustain, the sooner the next submarine must be delivered, and the sooner construction must start. To aid in understanding the relation between force objective and production gap, in Figure 4 we have added a new-production curve (blue) to the no-production curve and the illustrative 40-ships-needed line from Figure 3. Because fleet size is affected by the timing of *delivery,* and not construction, the lessons here are in terms of delivery date; we then infer the latest possible construction start date.

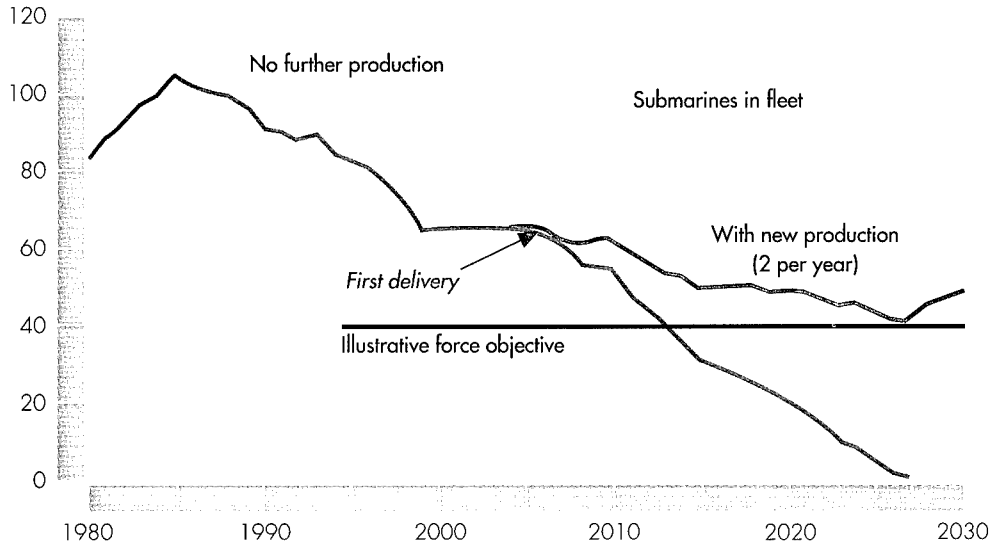


Figure 4—How Force Objective Determines Gap Length at a Given Production Rate

We can make several observations in connection with Figure 4:

- If delivery of new attack submarines gets under way in 2005 and continues at the rate of two per year, the inventory still falls off (blue curve) because submarines of the current Los Angeles class are retiring at the rate of about four per year (gray curve).
- Around 2027, the last of the current class of submarines will be decommissioned and the inventory will drop to a low mark of 41—just above the illustrative force objective.
- If delivery of the new attack submarine is postponed until after 2005—if the starting point of the blue curve is moved further down the gray one—it will not be possible to sustain a 40-ship fleet. If delivery is to be postponed further, the desired fleet size must be reduced. Conversely, if a larger fleet is desired, the gap in submarine deliveries must be shorter. (Or, in either case, production rate must be increased; see below.)
- As mentioned above, it takes at least six years to build an attack submarine. Thus, if a fleet size of 40 is to be sustained at a production rate of no more than two per year, *construction* of the new attack submarine must begin by 1999.

Production rate also limits fleet size.

Maximum gap, desired fleet size, and maximum sustained production rate are interrelated. The implications for gap length cannot be understood without understanding the constraints that production rate places on fleet size. Figure 5 illustrates these constraints. Here, we assume that construction of the new attack submarine begins in 1998—the earliest date practical (design is still under way). Because a later restart date would mean a lower sustainable force structure, the fleet sizes shown in Figure 5 are the maximums that each production rate can sustain. What we learn from this graph is that, given the rate at which submarines will be retired in the future,

- a production rate of *one* submarine per year following a 1998 restart cannot even sustain a fleet size of 30. The fleet size drops below 30 around 2023.
- two per year (as in Figure 4) will sustain 40 but not 50.
- it takes three per year (with two shipyards working) to sustain 60.

To complicate matters further, ship age at decommissioning is not necessarily a constant. If, for example, the service lives of the more recently built submarines could be extended from a maximum of 30 years to 35 years, the fleet size sustainable at a given production rate would increase. The reason is that in push-

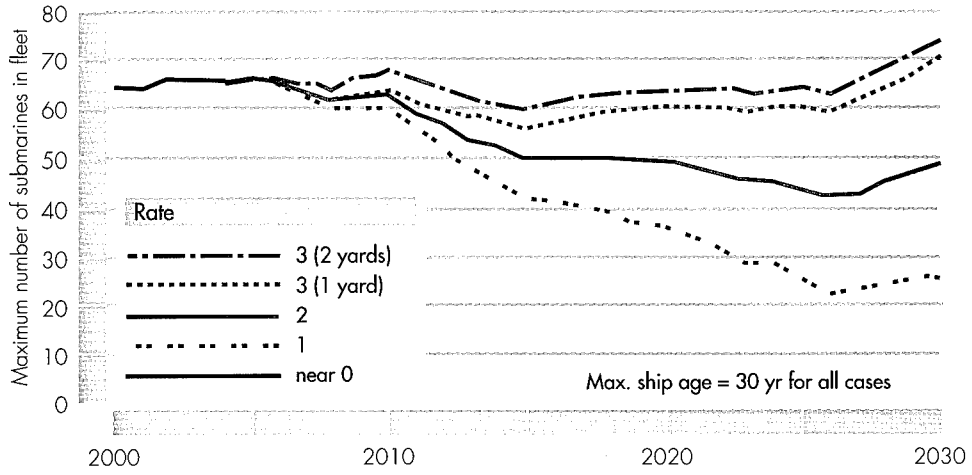


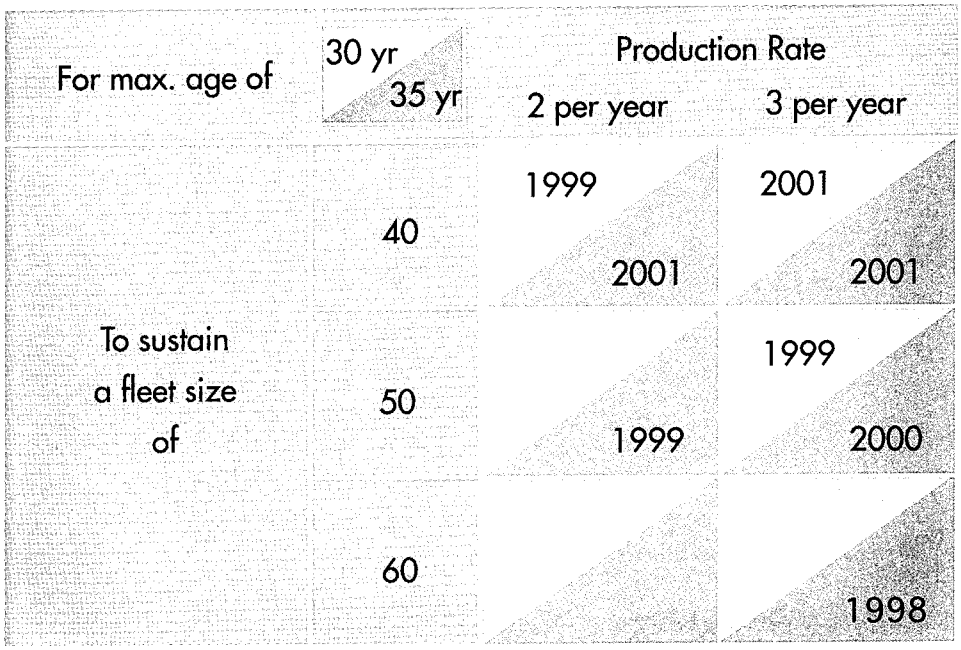
Figure 5—Influence of Production Rate on Fleet Size Sustainable

ing the decommissioning curve into the future, gains in inventory could be realized in the early delivery years following 2005, and the inventory curves would all rise. A fleet size of 50, for example, could then be sustained at two new submarines per year. However, *extending the lives of nuclear submarines is not a trivial task.* Much additional technical study and analysis of cost and military effectiveness is required before a decision could be made to implement such a plan. (As we will discuss in Chapter Three, ships can also be decommissioned early.)

Taking all these factors into account simultaneously, how long can the next submarine start be postponed?

A fleet size of 40 cannot be sustained if restart is postponed much beyond the end of the decade.

Figure 6 shows the latest year to start construction of the next submarine if various fleet sizes are to be maintained at a maximum production rate of two or three ships per year from a single shipyard, with a maximum ship life of 30 or 35 years. For several combinations of production rate, fleet size, and service life, it is not possible to sustain the fleet size minimum unless the first new attack submarine is started before 1998, which is unlikely. (These impractical combinations are represented by the blank triangles in Figure 6.)



NOTE: No third Seawolf; blank triangle indicates restart needed earlier than is feasible.

Figure 6—Latest Year to Restart Submarine Construction

The 1999 date in the upper left corner of Figure 6 represents the case shown in Figure 4—40 ships sustained at two per year. If ship life could be extended to 35 years, then ships come out of the fleet later and construction need not be started so soon; production can be postponed until 2001.

If it is decided that a bigger fleet is needed, then more of the ships being retired from the fleet must be replaced and construction must start sooner. For most cases involving 50 or 60 ships at two per year, construction start for the first new attack submarine falls into the impractical range.

Building ships at three per year affords more flexibility. It would then be possible to sustain the fleet in two of the three cases in which it would be impractical to do so at two per year. In two of the three other cases, later restarts would be possible. In no case, however, is it possible to wait beyond 2001. (We also investigated the use of two shipyards at three per year, and again it would be necessary, even in the less demanding cases, for construction to start by 2001.)

Note the difference between the top two dates in Figure 6 (for 40 ships with a 30-year service life). The production rate is increased by 50 percent; it would seem that, at three ships per year, a 40-ship fleet might be built in about 13 years instead of the 20 years it would take at two per year. Despite this seven-

year difference, only a two-year relaxation of the restart date is possible. If service life is 35 years instead of 30 years, increasing the production rate from two to three per year permits no further postponement of restart. Why isn't a bigger gap attainable?

The longer restart is postponed, the longer it takes to deliver the first submarine.

For the cases marked 2001 in Figure 6, the first submarine is not actually needed until 2010. In the interval between the end of currently planned submarine production in 1998 (shown by the longest of the gray bars in Figure 7) and 2001, part of the submarine workforce disperses. Because that workforce has to be rebuilt, the production time for the next ship stretches out from six years (as shown by the near-future restarts represented by the light blue bars) to nine years (the dark blue bar). (We derive this difference in construction from a workforce reconstitution model that we will discuss in Chapter Three.) If restart is postponed beyond 2001, the first submarine will not be ready until after 2010, and the 40-ship force will not be sustained. (We use the 40-ship fleet as an example here and in subsequent analysis because it permits a long gap without requiring a possibly unaffordable production rate of three per year.)

The light blue bars in Figure 7 represent what we have been calling a "continuous production" strategy. In fact, however, skills and resources required at one stage of submarine construction are not always needed at another. This is not a problem when submarine starts occur within a year or so of each other. In that case, workers employed in, for example, the last phase of submarine construction can find another submarine in final phase to work on when they finish their current one. Such a situation—one with truly continuous production—is illustrated by the stacked gray bars in Figure 7.

But some loss of capability occurs whenever analogous stages of construction do not follow each other closely. It is thus more accurate to refer to the "continuous production" strategy represented by the light blue bars as a "minimum gap" strategy. Even with the earliest restart now feasible (1996), some loss of early-phase construction expertise can be anticipated. A production gap is already under way, and it will result in a delivery gap.

Because we care mainly about the timing of delivery, we measure the gaps in Figure 7 from delivery to delivery: four years for the minimum-gap strategy (followed by another three-year gap) and 12 years for the maximum gap in the case shown. In the next chapter we will compare costs for the various maximum-gap strategies whose restart dates are shown in Figure 6 with the minimum-gap strategy depicted by the light blue bars in Figure 7.

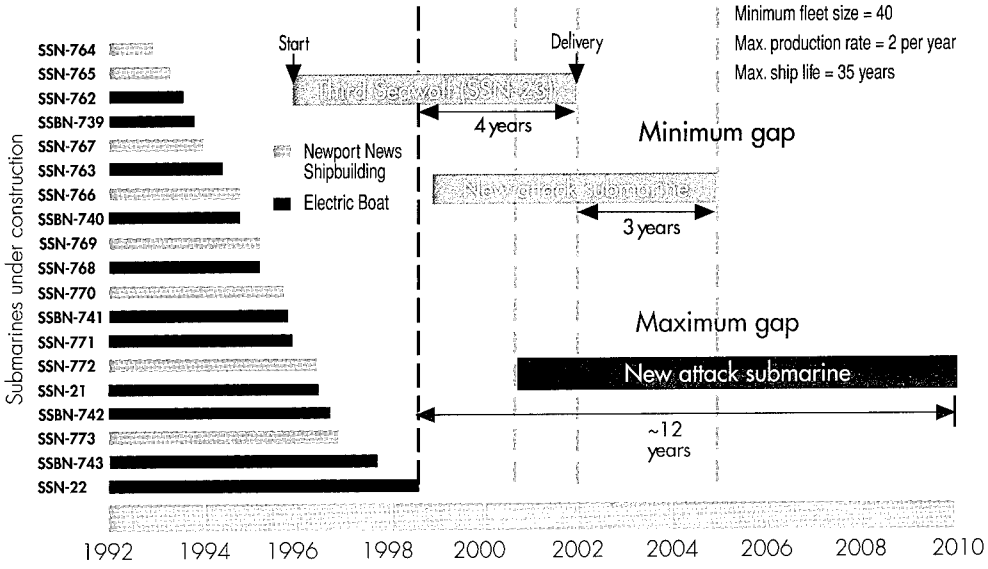


Figure 7—Relation Between Delivery Gap and Production Start

Chapter Three

HOW MUCH CAN BE SAVED BY POSTPONING PRODUCTION?

Extending the production gap both saves money and costs money.

It saves money for two reasons:

- First, submarine production is postponed, so that the cost of replacing the fleet is less when discounted to present-day dollars.
- Second, if production is deferred long enough, the next class of submarines will be designed and ready for construction. As ships of that class are likely to cost less than the current Seawolf class, which was designed for a Soviet-era threat, money can be saved by waiting.

Longer gaps run up extra shipyard costs of three kinds (see Figure 8):

- If submarine production is to be suspended for a period of years, substantial sums will have to be expended to shut down shipyard activities and facilities and do so in a manner that preserves tooling and information that might facilitate restart. Further expenses are incurred in association with releasing personnel.
- Then, the yard and its production lines will have to be maintained in working order during the gap. The yard still has to pay utilities, security and maintenance personnel, taxes, and so forth. And a cadre of skilled personnel will have to be retained if the yard is not to lose the know-how necessary to build submarines.
- Finally, additional expenses will be incurred when production is restarted. Some of that is for reconstituting facilities, but most of it is for rebuilding the workforce.

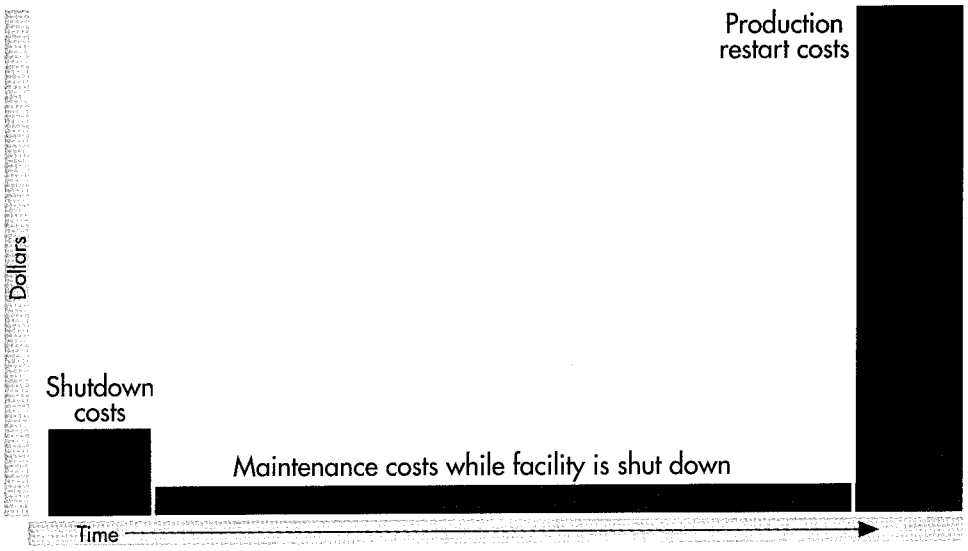


Figure 8—Course of Expenditures Associated with a Production Gap

To calculate workforce reconstitution costs, we built a model.

The shutdown and maintenance costs are straightforwardly calculated, but determining the cost and schedule effects of rebuilding the workforce required taking into account a number of variables. The model that does so is illustrated schematically in Figure 9.

The diagram shows the cadre mentioned above. We input a mentor:trainee ratio—how many new workers each cadre member could train—and also took account of how worker efficiency and pay increase (and attrition decreases) with experience. We also considered the cost to hire and train each new worker and the effect on overhead per ship when production is just starting. (Data used in the model were derived from public and private shipyard experience, including apprentice programs.) The model calculates how long it would take to build the first ships after restart and how long it would take to reach a steady-state production rate. The model also estimates how much more it would cost to build those pre-steady-state ships than it would have at steady state.

We found that the cost of restarting production at a shipyard could run well over a billion dollars. Much of that could be saved if workers could be retained through other shipyard activities (e.g., overhauls) during the submarine production hiatus.

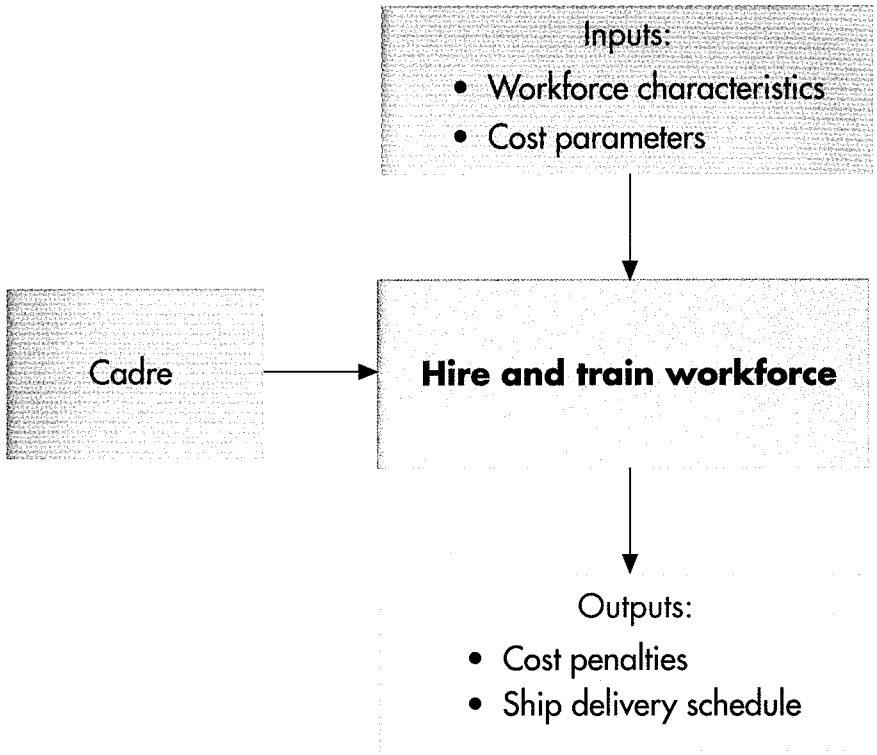


Figure 9—Workforce Reconstitution Model

Besides the extra costs to the shipyards, an extended gap means additional costs to reconstitute submarine component vendors.

Shipyards buy or receive through the government many submarine components—nuclear and nonnuclear—produced by outside suppliers. To be ready for installation at the correct point in submarine construction, work on some key *nuclear* components must begin well in advance (see Figure 10). Currently planned work should keep nuclear-system vendors busy for the next two or three years (assuming a scheduled new aircraft carrier is built). Design work has already begun on the longest-lead components (e.g., the reactor vessel and steam generator) for a new attack submarine. Unless there is a lengthy production gap, it would not be practical to shut down the suppliers of such components. Reconstituting them might require more lead time than the gap would make available and would result in hundreds of millions of dollars in extra costs. As for reactor cores, there is no point in shutting down the sole remain-

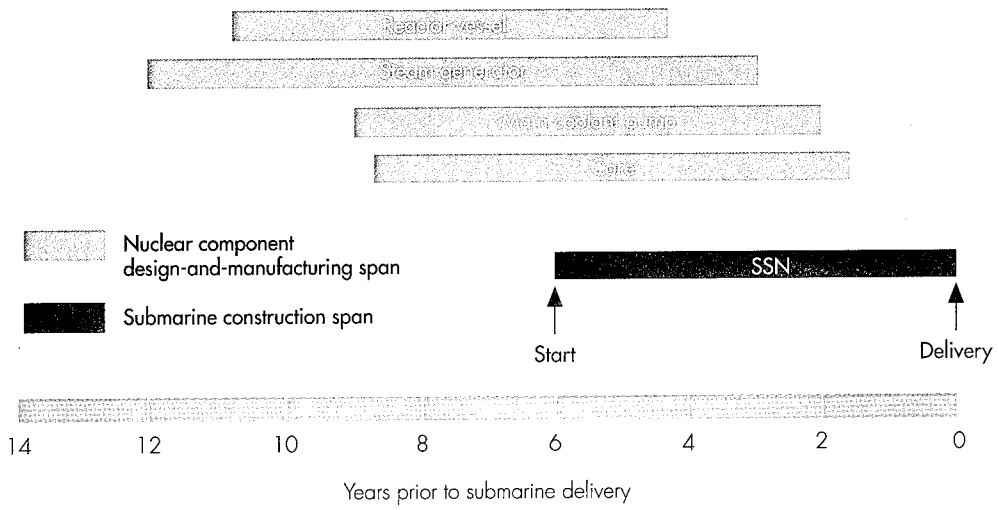


Figure 10—Shipyard Need Dates and Design-and-Manufacturing Spans, Selected Nuclear Components, First Ship of Seawolf Class

ing U.S. producer, as that firm is engaged in producing cores to refuel aircraft carriers and SSBNs.

The nuclear-vendor base is small, but there are on the order of a thousand suppliers of *nonnuclear* submarine-specific components. For the most part, supply of these components could be quickly resumed once demand for them is renewed following a production gap. A small fraction, however, require special skills or technologies that may be difficult to recover should the firms producing them go out of business during a gap. For these cases, comprising at least a few products and at most a few dozen, reconstitution costs could amount to half a billion dollars.

If submarine orders are delayed, the government could take a variety of actions that could help avoid the need to reconstitute the nuclear and nonnunclear vendor bases. Such measures include funding the production of items in advance of need, paying the firms to develop and prototype advanced methods to manufacture the needed components, or allocating other Navy work to those firms. Each of these measures has its drawbacks. *But whatever is chosen, it must be done soon, as critical nonnuclear suppliers may otherwise begin to go out of business within the next year.*

Gap-related costs could approach $3 billion.

We combined shipyard shutdown and maintenance costs and shipyard and vendor restart costs for each of several scenarios at Newport News and Electric Boat. Figure 11 shows two such scenarios. Both represent a maximum-gap strategy with restart in 2001 and buildup to a maximum rate of two ships delivered per year. But the column on the left assumes no work in the shipyard between the end of current construction and 2001; the one on the right assumes sufficient submarine overhaul work is directed to the yard in the interim to sustain 1000 workers. Without further work, gap-related costs are on the order of $2.75 billion. With overhauls, that number drops to about $1.5 billion. (This does not take into account negative effects on the yard that had the overall work before it was redirected to the construction yard—or what to do with the overhaul work once construction resumes.)

The breakdown of these totals into categories is as shown in Figure 8 and described in the text accompanying that figure, except that we have added vendor restart costs. Some of the shipyard costs are for restarting facilities, but the bulk is personnel-related and reflects the reconstitution of the labor force, the speed of which is limited by the availability of skilled workers for rehire and men-

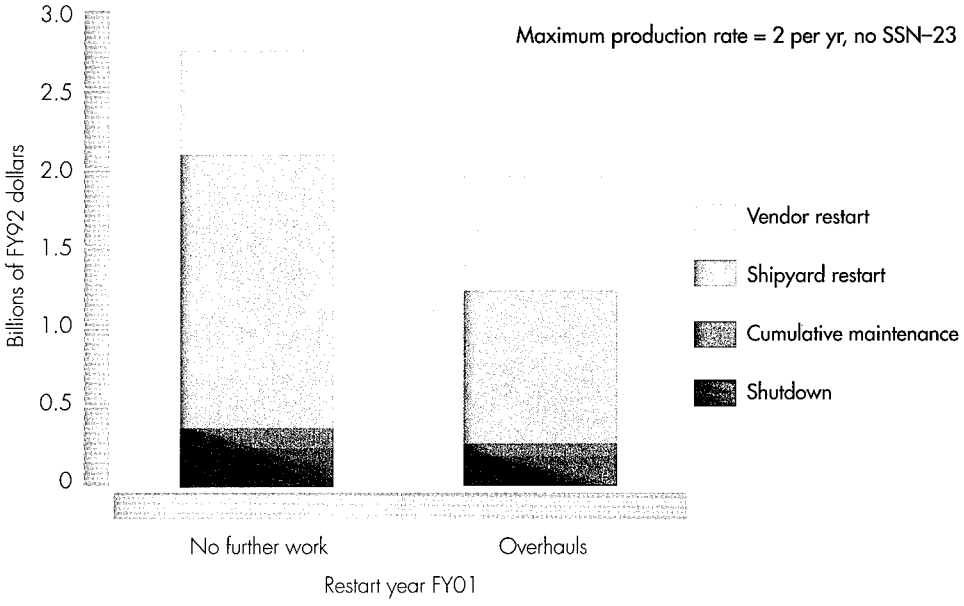


Figure 11—Illustrative Shutdown, Maintenance, and Restart Costs

tor:trainee ratios that must be maintained, among other things. The reconstitution-related cost penalty includes greater per-ship overhead charges that accrue when the initially small size of the labor force limits the number of ships in the yard. It also reflects inefficiencies from having a high proportion of trainees on the job, along with hiring and training costs. Vendor costs are predominantly for reconstituting nonnuclear vendors, which, as we mentioned above, are more likely than nuclear vendors to exit the business in the near future. Again, we consider only the production base; these costs do not include the costs of maintaining the R&D, technology, and design base over the course of the gap or reconstituting it afterwards.

To estimate non-gap-related costs, we built a second analytical model.

Figure 12 is a schematic representation of our fleet composition analysis model. The elements are as listed below.

- The variables we considered are shown in the gray boxes as inputs to the model. The first three boxes include the items discussed in Chapter Two. In addition, the Navy plans to decommission some ships early. To the extent this is done while there is an excess of ships in the fleet, it can save maintenance and operating costs without requiring earlier restart. We also incorporated data on current costs and fleet inventory.
- The model, shown here in dark blue, determines a schedule of construction and decommissioning over the next 36 years that minimizes the net present value (NPV) of the costs of production and operating and supporting (O&S) the fleet.
- Thus, the output, in the light blue boxes, is in the form of a delivery schedule, a resulting fleet-size profile, and a profile of costs over time.

Recall that we sought the maximum gap, not the cost-minimizing gap. That is why we estimated gap-related costs separately from the model. We then combined the costs directly associated with the gap (those in Figure 11) with the subsequent production, operation, and maintenance costs obtained through the model shown in Figure 12. The result was the total costs associated with minimum- and maximum-gap strategies for various combinations of fleet size, production rate, and ship life.

When all costs are taken into account, extending the production gap saves little, if anything.

Figure 13 is a cumulative depiction of discounted costs over time to maintain a fleet of 40 ships with the standard 30-year service life at a maximum production

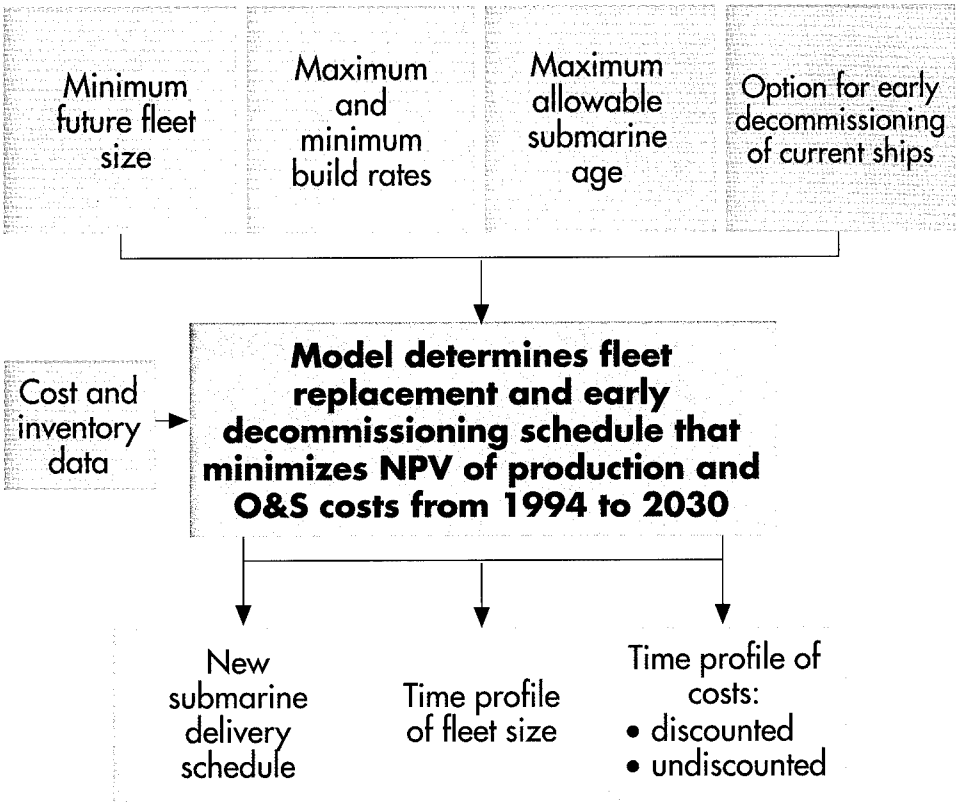


Figure 12—Fleet Composition Analysis Model

rate of two ships per year. Relative to the total, there is not much difference between the minimum- and maximum-gap strategy over the long run. In fact, considering the uncertainties involved in projecting costs over such a long period, we cannot say with confidence that there is *any* difference at all.

Savings *are* realized over the short term, or by extending ship life.

The profile of savings over the course of time is shown more clearly in Figure 14, where the cost of the minimum-gap strategy for a 30-year ship life is depicted as a baseline and the savings of other strategies are shown relative to it. Note the following comparisons:

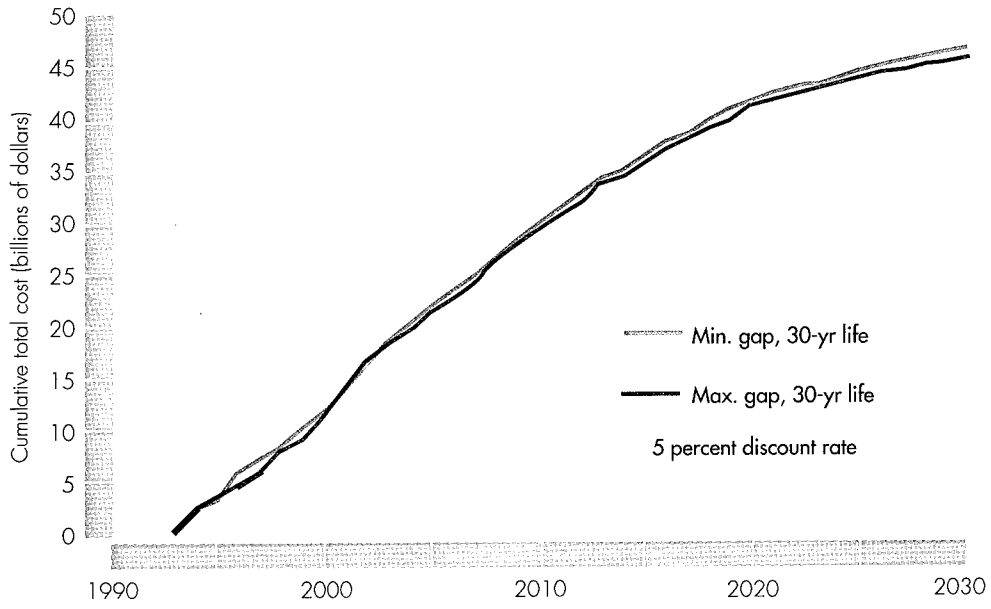


Figure 13—Cumulative Total Cost of Minimum- and Maximum-Gap Strategies to Sustain a 40-Ship Fleet at Two Ships Delivered per Year

- Over most of the time frame we looked at and assuming a ship life of 30 years, the maximum gap has a cumulative cost advantage of a half a billion dollars or so—again, less than our estimating error.
- If ship life can be extended to 35 years, maximizing the production gap saves even less (compare the lower pair of curves to each other).
- However, for both comparisons, *there are larger differences over the short term,* and these might be meaningful to some decisionmakers. (Note that in the 35-year case this "short-term" advantage lasts much longer. It may also be of interest that the short-term savings in the 30-year case arise largely from not proceeding with the third Seawolf-class submarine.)
- Much larger savings are realized from extending ship life than from extending the production gap. (But again, extending ship life entails important costs we do not consider here.)

We made comparisons like this for larger fleet sizes and for three ships produced per year and, while the short-term results varied somewhat, the lesson for the long term was the same: little or no cost advantage for delaying

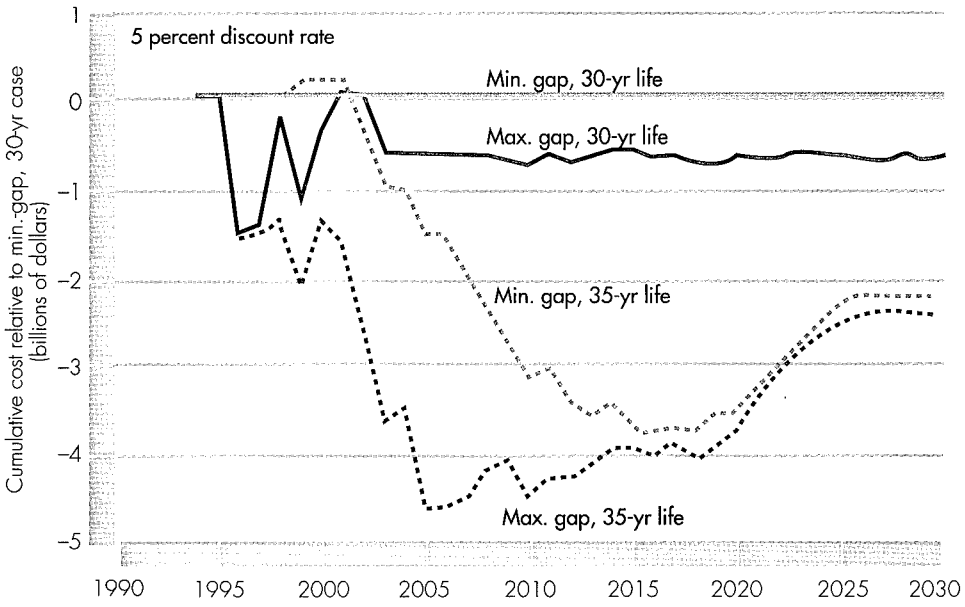


Figure 14—Difference in Cumulative Costs Between Each Strategy and the Minimum-Gap, 30-Year-Ship-Life Strategy

production of the next submarine. For example, when a production rate of three ships per year is allowed,

- the long-term difference between minimum- and maximum-gap strategies is less than a billion dollars (not necessarily in favor of the maximum gap);
- life extension, on the other hand, results in savings ranging from about a billion to about two and a half billion dollars, depending on the case.

The outcome of these analyses can be summarized as follows: when taking the long view, cost is *not* a good criterion for deciding between production strategies.

WHAT ARE THE RISKS?

The modest savings from extending the production and delivery gaps are achieved at a substantial increase in program risk. Sources of risk can be grouped into three classes.

Lack of analogues may have led us to underestimate costs and delays.

Some risk arises from the inherent uncertainty in making any kind of cost or schedule estimate for an action that has no real analogue. No dormant industries have experienced production restarts recently. Also, we have made no allowance for problem resolution in our estimates, although British experience indicates that it would be challenging to produce submarines that integrate new technologies developed during the gap years—and the British were resuscitating diesel technology. The challenges—and the associated extra costs and delays—could only be greater for nuclear submarines.

We do know of potential infrastructure failures that we have been unable to assess quantitatively.

Such failures could substantially postpone or even jeopardize a restart program's successful completion. They include the following:

- For some of the longer gap scenarios, submarine design and development skills may atrophy, further lengthening the production phase. Talented engineers faced with unproductive work during a gap may look for opportunities elsewhere. Potential recruits may see the shutdown and decide to pursue other career opportunities. How much could it cost to attract people back to submarine design who have committed elsewhere? We don't know.

- It is uncertain whether construction skills can be reconstituted at any reasonable price; again, once firms and individuals leave the industry, it may not be possible to lure them back.
- Submarine construction requires specialized management and oversight skills, both at the shipyards and vendors and in the government. Persons with these skills might move on to other opportunities during an extended gap.
- Nuclear licenses and environmental permits may be lost if production is suspended.
- If restarting production at a lower skill level results in an eventual accident, particularly one involving a nuclear reactor, the ship's crew and everyone else in the vicinity could be endangered, and public pressure could halt submarine construction and curtail operations indefinitely.

Other risks include failure to meet national security objectives and the possibility of future production gaps.

Extending the production gap constrains the fleet sizes and production rates that can be chosen. World events may lead to a decision that a fleet size of 60 is needed to ensure national security. Such a fleet size cannot be sustained if construction on the next submarine is not initiated before 2000. Even for a 50-ship fleet, delaying the next submarine start to 2000 or beyond would require a production rate greater than two per year. It is uncertain whether submarine production of three per year would be viewed as affordable, and such a program would produce a full fleet of 30-year-life submarines in less than 20 years, resulting in another production gap in the 2030s.

Chapter Five

CONCLUSIONS AND RECOMMENDATIONS

It is impractical to postpone submarine production much beyond the year 2000.

- Production schedule options are limited. Construction of the first submarine of the next class probably cannot be started before 1998. (Current plans call for a third submarine of the Seawolf class to be started in 1996.) But construction of the new attack submarine *must* start by about 2001 if a fleet close in size to the one now planned is to be sustained at reasonable production rates. The difference between the shortest gap now feasible (to 1998) and the longest practical (to 2001) is thus only three years (without the third Seawolf; with the third Seawolf, it is five years—1996 to 2001).
- The longer the gap, the more difficult it will be to sustain a fleet large enough to meet the nation's projected needs. If the next submarine is not started until after 1999 and ships are still retired at the age of 30, it will not be possible to sustain a fleet size of 50; a production rate of three per year would be required to keep the fleet from falling below 40 ships.
- If the more recently built Los Angeles–class submarines could be operated beyond the normal decommissioning age of 30 years, greater flexibility in production scheduling could be realized. It would be possible to sustain a greater fleet size at the same production rate or the same fleet size at a lower production rate than would be the case with the current decommissioning age.

It is not clear that an extended production gap would result in any savings over the long term.

- For some combinations of desired fleet size and maximum production rate, savings may be realized by extending the gap; for others, losses may result. In all cases, the projected gains or losses are smaller than the errors that ac-

company our prediction methods over that time frame, so they cannot be asserted with any confidence. However, it appears that, for some combinations of fleet size and production rate, substantial gains (on the order of a few billion dollars) will accrue over the next 10 years if the gap is extended.

- Larger long-run savings may be realized by extending ship life beyond 30 years. However, we do not in this analysis account for any costs of determining the feasibility of ship life extension or any costs necessary to effect such extensions beyond those of a standard overhaul.

These marginal savings are realized at substantial risk.

- In extending the production gap, the Department of Defense would run several risks that could add to the delays and costs we have been able to estimate. The industrial base may lose the expertise of individuals and the capabilities of firms that are essential for efficient reconstitution following a gap. It may be very difficult for those design and production workers who do remain to integrate all the technologies becoming available in the interim into high-performance submarines. And environmental and nuclear regulatory impediments could add years to the time required to reconstitute.
- There can be little tolerance for trial and error in nuclear-submarine design and construction. Losses of cumulative individual and institutional expertise could raise the risk of system malfunction and of an accident, possibly a nuclear one. Obviously, a nuclear accident would have grave consequences.

We recommend that DoD act to minimize the submarine production gap that is now under way.

- Considering that the savings from extending the current production gap are uncertain and that the risks of doing so are great, we recommend that construction on the next submarines begin as soon as practicable.
- Specifically, we recommend, first, that the third Seawolf-class submarine (SSN-23) be started around 1996 and that the first new attack submarine be started as soon as feasible, around 1998.
- Finally, considering that savings may be realized by extending the life span of many of the current class of submarines, we recommend that the Navy carefully evaluate this option.

Our recommendations are based on our own judgment regarding prudent weights to be attached to the results of our quantitative cost and schedule analysis and our qualitative risk assessment. Others using the same methodology would arrive at a different course of action if they took either (or both) of two alternative viewpoints.

- First, in reaching a restart decision, they might have a high tolerance for risk. This would be more defensible over the short run (e.g., in deciding not to proceed with SSN-23) than over the long run.
- Second, they might attach much greater weight to the short-term savings of the maximum-gap strategies. The latter approach might be taken by someone who had little or no confidence in cost projections running 20 or 30 years into the future or who for other reasons heavily discounted future costs.