

# **THE U.S. SUBMARINE PRODUCTION BASE**

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

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

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1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

1200 South Hayes Street, Arlington, VA 22202-5050

201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516

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The current attack submarine production program is coming to an end. After decades of building three or more submarines annually, there have been no construction starts since 1991. It is generally believed that the current fleet of Los Angeles-class attack submarines is big enough to meet U.S. security needs for many years. Superficially, it may seem appropriate, especially given budgetary constraints, to suspend submarine production for a period of time.

At some point in the future, however, it will be necessary to build more submarines to replace the Los Angeles-class ships as they age and can no longer be operated with high standards of safety and reliability. Initiating such a construction program from scratch will involve serious challenges. Nuclear submarines are among the most complex structures built by man. Not only must they survive and function under water 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 a very good safety record over the years. 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.

The purpose of this study was to determine the practicality of extending the current gap between submarine starts, given the time required to restart; estimate the money likely to be saved, given the offsetting costs of shutdown and

restart; and characterize the largely unquantifiable risks involved in a reconstitution strategy. Our conclusions are as follows:

- 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 that the government judges consistent with anticipated national security needs are to be sustained.
- 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.
- Given the difficulties and challenges involved in restarting submarine production from scratch, our cost estimates for restart may be too low and our schedule estimates too optimistic. Further risks related to nuclear licensing and environmental and safety concerns may jeopardize the success of the nuclear submarine program.
- 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 a new class of submarines in the late 1990s.

In arriving at these conclusions, 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 critically reviewed all data, made adjustments as appropriate, and built and ran models to draw inferences where the nature of the data permitted it. We determined how stopping and restarting production affects shipyard and vendor costs and schedules and how decisions about future fleet size and production rate affect 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 gapping strategies. We accounted for the costs of producing, operating, and maintaining the submarine force until 2030, when the Los Angeles-class submarines will all have been retired. The results of the analyses underlying our principal conclusions are as follows.

**Shipyard Effects.** If submarine production is to be suspended for a number of years, substantial sums will have to be expended to shut down shipyard activi-

ties and facilities in a manner that preserves tooling and information to facilitate restart. Then, the yard and its production lines will have to be maintained in working order during the gap. Additional expenses will be incurred in reopening facilities and rebuilding the workforce at the end of the gap. These workforce expenses dominate the total (for an illustrative case, see Figure S.1). Costs of rebuilding the workforce include those of hiring and training new workers, plus those arising from inefficiencies in producing early submarines (when the workforce will have more workers at lower levels of productivity than it will later). We found that submarine production restart costs can be reduced if shipyards remain active with aircraft carrier construction or with submarine overhauls. (Currently, the latter are performed in Navy shipyards.)

The longer the production gap, the more skilled workers will be permanently lost from the industrial base, and the longer it will take to produce the first submarine and to ramp production up to the desired rate. If workers can be retained through other shipyard activities, these delays can be reduced. For example, whereas it would take over ten years after contract award to deliver the first submarine starting from a residual skilled workforce of 250, it would take only six years if 1000 skilled workers could be retained.

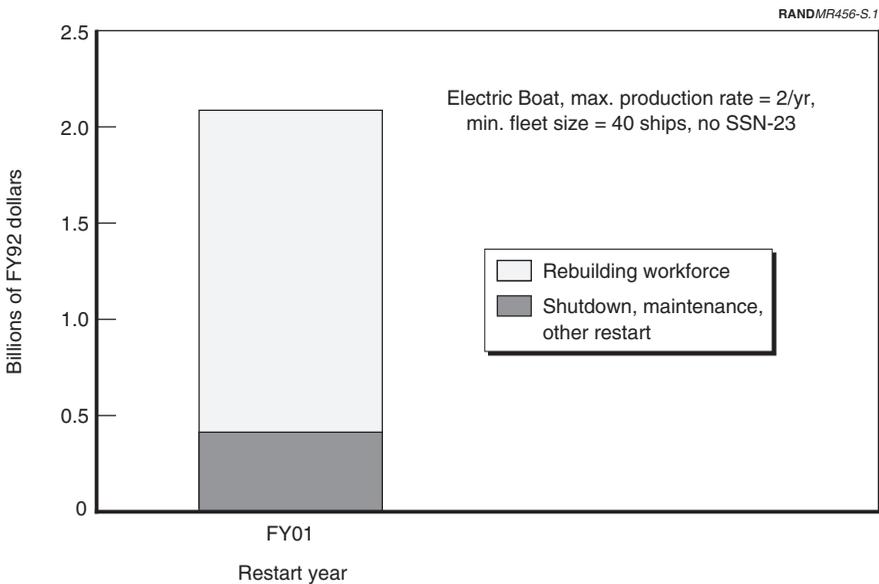
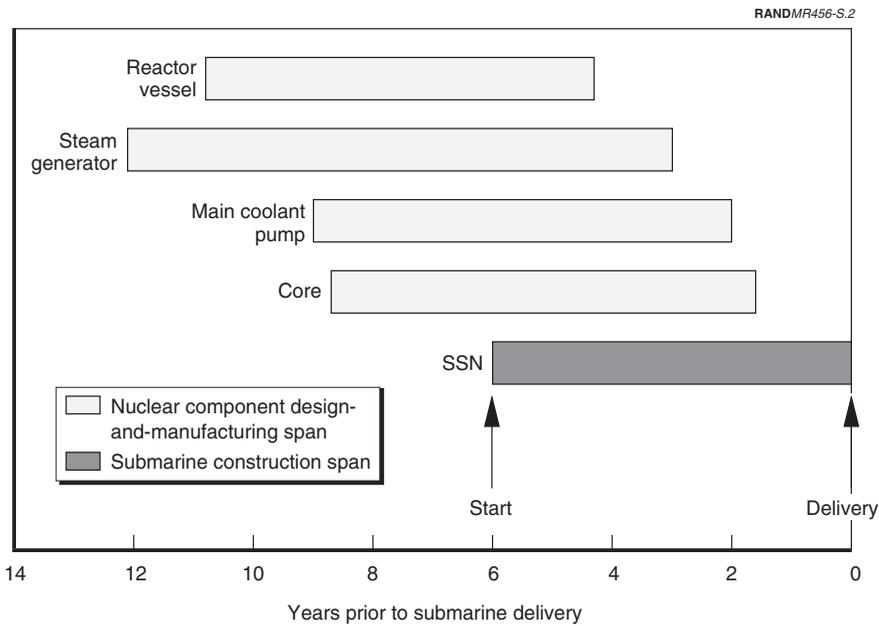


Figure S.1—Total Cost to Shut Down, Maintain, and Restart a Shipyard

**Vendor Effects.** 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 S.2). Current work will keep nuclear-system vendors busy for the next two or three years (assuming a new aircraft carrier is built). Design work has already begun on the longest-lead components 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. Neither is it necessary to shut down the sole remaining U.S. producer of naval reactor cores, as that firm is engaged in producing cores to refuel aircraft carriers and the Trident-missile-carrying submarines. Shutting the remaining nuclear vendors down for several years would result in hundreds of millions of dollars in reconstitution costs, assuming reconstitution is feasible at all.

Although the nuclear-vendor base is small, there are on the order of a thousand suppliers of nonnuclear submarine-specific components. For the most part,



NOTE: The times assume an active industrial base; required lead times could be longer following an extended production gap.

**Figure S.2—SSN-21 Shipyard Need Dates and Design-and-Manufacturing Spans for Selected Nuclear Components**

supply of these latter components could be quickly resumed once demand for them is renewed following a production gap. A few, 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 nonnuclear 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.

**Effects of Fleet Size and Production Rate on Delivery Gap.** We have referred to the “production gap” that began in 1991 and will extend until construction on the next submarine starts. Since fleet size effects are determined by the time of submarine entry into the force, we now refer to the “delivery gap,” or time between delivery of the last submarine now under construction and the next one.

Fleet size, maximum sustained production rate, and delivery gap are interrelated. The implications for gap length cannot be understood without understanding the constraints that production rate places on fleet size. Estimates of future required attack submarine fleet size range roughly from 40 to 60. 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 sustain a fleet size of 30 (see Figure S.3).<sup>1</sup> Two per year will sustain 40 but not 50; it takes three per year to sustain 60. If 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. 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 it.

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<sup>1</sup>In steady state, one new submarine per year could sustain a fleet of 30 submarines with 30-year lives. However, submarines of the Los Angeles class were built at an average rate of three per year and will be decommissioned at least as rapidly. At a production rate of one per year and a retirement rate of three per year, the fleet will shrink until all current ships are decommissioned (in 2027).

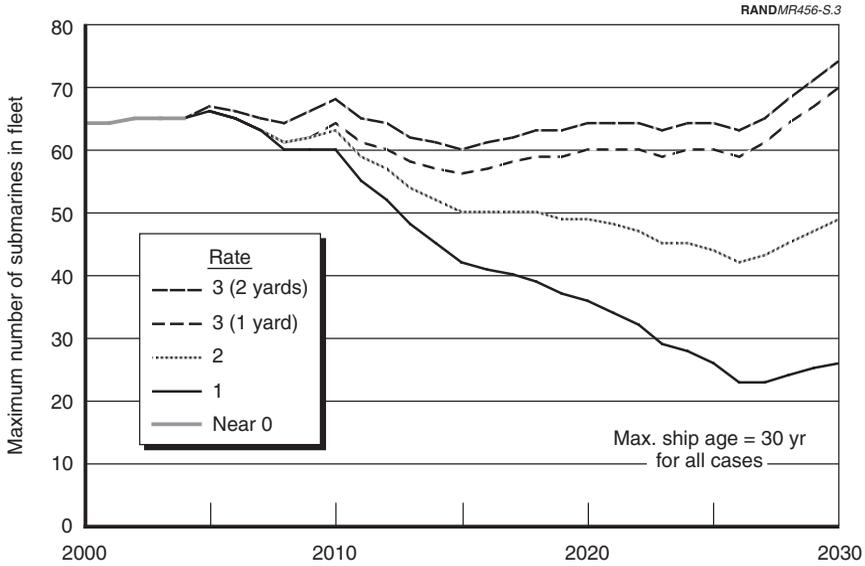


Figure S.3—Production Rate Influences the Fleet Size That Can Be Sustained

Figure S.4 shows the latest possible delivery date for 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 delivered before 2004, which is impractical. (Such combinations are represented by the blank triangles in Figure S.4.) Maximum gaps are to 2010 if a 40-sub fleet is to be sustained and to 2007 if a 50-sub fleet is the objective. Given the inefficiencies of restart, such gaps mean that *construction* of the next submarine must start by 2001 at the latest.

For each of the maximum gaps shown in Figure S.4, it is possible to define a corresponding minimum gap as a baseline against which the savings of an extended gap can be compared. For example, as the figure shows, if an eventual fleet size of 40 is to be sustained at a maximum production rate of two ships per year, the delivery gaps must end in 2005 or 2010. The earlier date holds if submarine life is to be held to 30 years and the later if the more recently built subs can be extended to 35 years. The gap from delivery of the last ship currently under construction, scheduled for 1998, is then 7 years in the 30-year case and 12 years in the 35-year case (for the latter, see the lower bar in Figure S.5). The minimum gap achievable in either case entails initiating construction of a Seawolf-class submarine in 1996. The Seawolf’s delivery date of 2002 would

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Latest year to deliver next submarine

For max. age of		Production Rate	
		2 per yr	3 per yr
To sustain a fleet size of	30 yr / 35 yr		
	40	2005	2010
	50	2010	2010
	50	2005	2006
	60		2007
			2004

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

**Figure S.4—No Matter the Scenario, Restart Cannot Be Long Delayed**

then result in a four-year delivery gap, followed by a three-year gap (upper bars in Figure S.5).

**Gap Savings.** Assuming the current submarine service life, a 40-ship fleet, and a two-per-year production rate, the maximum gap strategy saves about \$700 million (net present value [NPV]) relative to the minimum gap case; for the 35-year option, roughly \$200 million (see Figure S.6). These savings take into account all costs related to production restart, construction, and fleet operations and maintenance through 2030. The savings for both cases are much smaller than the uncertainty to which our projections are subject and the \$2 billion savings achievable through extending ship life by five years.

When a production rate of three ships per year is allowed, extending the gap does not always result in savings, but the difference is, in all cases we examined, less than a billion dollars. 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.

**Gap Risks and Constraints.** The modest savings from extending the production and delivery gaps are achieved at a substantial increase in program risk. Some of this risk arises from the inherent uncertainty in making any kind of cost or

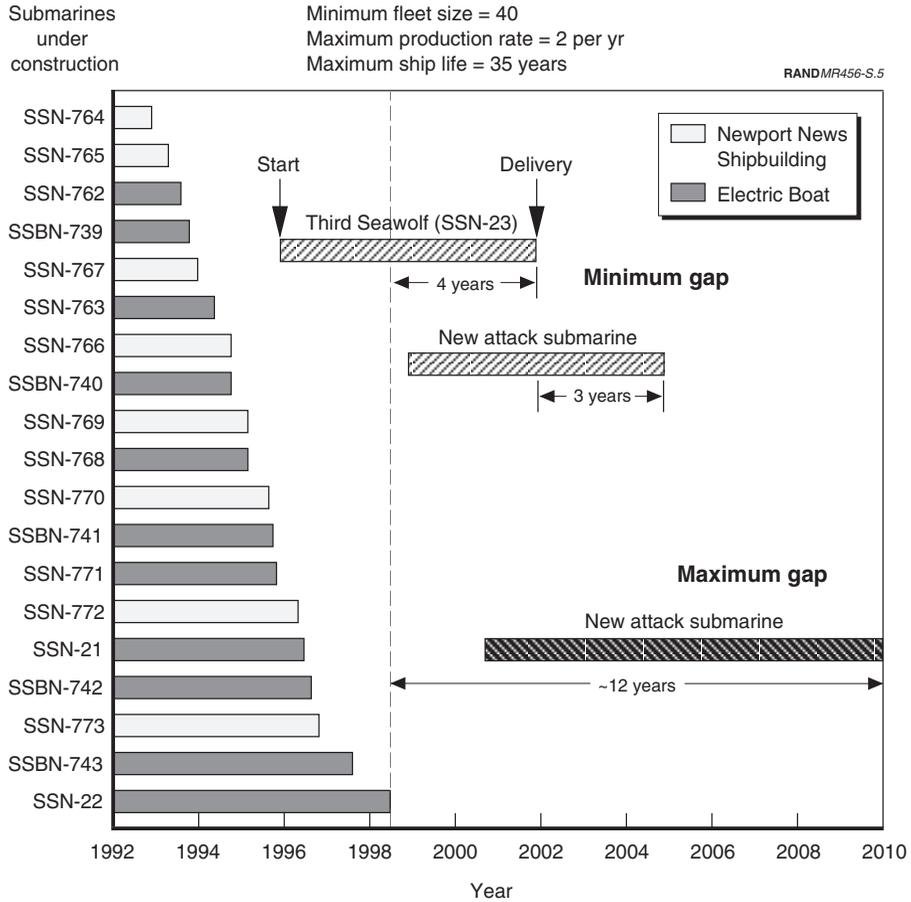
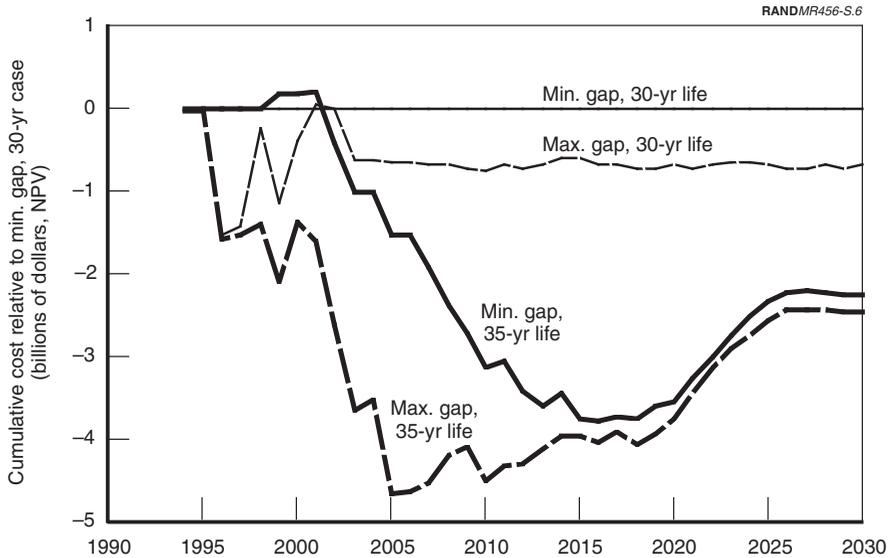


Figure S.5—Gapping and Restart Relations Between Minimum- and Maximum-Gap Strategies

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.

Other risks relate to more specific infrastructure failures that could substantially postpone or even jeopardize a restart program’s successful completion. For some of the longer gap scenarios, for example, submarine design and development skills may atrophy, further lengthening the production phase. It is uncertain whether construction management, technical, and trade skills can be



**Figure S.6—Long-Term Cost Differences Between Minimum and Maximum Gaps Are Small**

reconstituted at any reasonable price; once firms and individuals leave the industry, it may not be possible to lure them back. Shipyard nuclear licenses and environmental permits may be lost if production is suspended; considering the urban locations of the shipyards, restoring those permits could be characterized conservatively as a serious political challenge. 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.

Gapping production also 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, and the same would be true of a 40-ship fleet if the current 30-year lifespan is retained. It is uncertain whether submarine production at three per year would be viewed as affordable, and such a program would produce a full fleet of 30-year-lifespan submarines in less than 20 years, resulting in another production gap in the 2030s.

**Recommendations.** Given the limited savings achievable through gapping production and the substantial risks incurred, we recommend a “minimum

gap” strategy that entails constructing the next Seawolf-class submarine beginning in 1996, to be followed by the first attack submarine incorporating a new design beginning around 1998. We also recommend that the Navy examine carefully the feasibility of extending the life of the more recently built attack submarines.