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NAVY SHIPS

Lessons of Prior Programs May Reduce New Attack Submarine Cost Increases and Delays



**National Security and
International Affairs Division**

B-257866

October 20, 1994

The Honorable Edward M. Kennedy
Chairman, Subcommittee on Regional
Defense and Contingency Forces
Committee on Armed Services
United States Senate

The Honorable John Conyers, Jr.
Chairman, Legislation and National
Security Subcommittee
Committee on Government Operations
House of Representatives

As you requested, we assessed the Navy's plans to incorporate lessons learned from prior submarine programs, particularly the Seawolf SSN-21 program into the design and construction of the NSSN, a new class of nuclear-powered attack submarine. According to the Navy, the NSSN is to be smaller, less costly and less capable than the Navy's Seawolf submarine; it will also be expected to perform a variety of missions.

Several factors make the NSSN both an excellent opportunity and a challenge for the Navy to control acquisition costs and to improve the quality of the design and construction process. These factors are (1) a reduced antisubmarine warfare threat, which has resulted from the breakup of the former Soviet Union; (2) the U.S. defense budget, which has been more tightly constrained each year; and (3) the early stages of the NSSN acquisition cycle, which allow an agency to apply lessons of past programs to future programs.

Background

Believing that high Seawolf submarine program costs would lead to inadequate force levels, the Department of Defense (DOD), in October 1991, established a requirement for a more affordable new attack submarine. According to the Navy, the NSSN's estimated displacement weight will be about 7,100 tons, 2,000 tons less than the Seawolf's. The NSSN's missions include battlegroup support, covert strike warfare, covert intelligence, special warfare, covert mine warfare, antisubmarine warfare, and antisurface warfare operating in both open ocean and littoral (coastal) areas.

In August 1992, the Defense Acquisition Board authorized the Navy to initiate concept exploration and definition (milestone 0) studies. A project office was established to set out the basic design and to develop an acquisition strategy that included the schedule of detail design and production. The Navy initially planned for the Board to approve the NSSN acquisition strategy in August 1993, as part of the milestone I decision to enter the demonstration and validation phase. However, the milestone I meeting slipped until January 1994. That meeting resulted in requesting the Navy to perform additional studies and analyses. These were completed and submitted to the Board.

On August 1, 1994, the Board approved milestone I, and on August 18, 1994, issued an Acquisition Decision Memorandum. The memorandum directed the Navy to submit an updated documentation package for the Board's approval within 60 days. The package is to include an acquisition strategy report, reflecting the Navy's plan to initiate detail design and lead ship construction at Electric Boat. The Board also directed the Navy to initiate (1) advanced procurement of the lead ship's nuclear reactor in fiscal year 1996 and (2) lead ship construction in fiscal year 1998. Further, the Board directed the Navy to update the submarine's combat system acquisition strategy to reflect "a significant degree of private sector involvement in planning an open system architecture," which contains commercially available hardware and software that meet broad industry standards.

A September 1993 cost and operational effectiveness analysis prepared by the Center for Naval Analysis estimated the cost for comparison purposes of procuring 30 NSSNs and procuring 30 Seawolf submarines at 1 ship per year. In constant fiscal year 1994 dollars, the procurement cost for the NSSN was about \$45 billion (\$1.5 billion each) and for the Seawolf about \$56 billion (\$1.9 billion each).

Results in Brief

The Navy may be able to avoid some design and construction costs and schedule delays by applying the following five management lessons from prior submarine construction programs, which we have distilled from the reports of our reviews over the past decade: (1) contracting with a single shipyard to both design and construct the lead submarine, (2) delaying lead ship construction until the ship's design is substantially mature, (3) strengthening the specification development and approval process, (4) identifying critical components and supply vendors early in the program, and (5) reducing submarine combat system development risks.

While the Navy's project manager has said that he intends to incorporate these management lessons into the program's acquisition strategy, the extent to which they will be applied cannot be assessed until DOD approves the strategy and makes it public for evaluation.

The Navy has evaluated a number of technical lessons learned from past submarine construction programs and has approved plans to incorporate some of them in the NSSN program. The Navy estimates that NSSN procurement cost savings from these lessons could range from \$90 million to \$100 million.

Because of the importance of applying both management and technical lessons, we believe the formal DOD approved acquisition strategy should explicitly address how the Navy will avoid repeating the problems of prior programs.

Applying Management Lessons May Reduce Costs and Avoid Schedule Delays

By incorporating management lessons into the NSSN program, the Navy may avoid repeating many of the problems that caused Seawolf detail design and lead ship construction cost increases and schedule delays. In recognition of Seawolf problems, the NSSN project manager told us he intends, subject to DOD approval, to incorporate the five management lessons into the multibillion dollar NSSN program. However, because of the absence of a DOD approved acquisition strategy, the extent to which the NSSN acquisition strategy will include these lessons cannot be assessed now.

Use a Single Shipyard to Design and Construct the Lead Submarine

Under the split design/construction strategy used for the Seawolf program, Tenneco's Newport News Shipbuilding and Drydock Company was responsible for the overall design and detail design of the submarine's forward end, while General Dynamics' Electric Boat Division was responsible for designing the submarine's aft end and for constructing the SSN-21 and the SSN-22. The split design approach, with a requirement that design data be suitable for use at either shipyard, was originally instituted to instill competition for building 29 SSN-21 class submarines. This approach, which required additional time and resources as well as a high degree of coordination between the two shipbuilders, caused design and construction cost increases and additional time to approve design data and to resolve design drawing problems.

Electric Boat, to construct the SSN-21, still had to convert Newport News Shipyard's generic design data into Electric Boat specific work packages (instructions and materials). According to Seawolf program office officials, the two shipyards were unwilling to open their operations to one another. In addition, the Navy's Seawolf program office occasionally had to mediate the resolution of design drawing problems between the two shipyards. Confusion between the two shipyards over design drawing delivery schedules was one factor that led to late delivery of design drawings to Electric Boat, the shipbuilder, in 1990 and in the first 6 months of 1991.

A Seawolf program office official noted that the Seawolf program office has learned that having one shipbuilder design and construct the submarine can save time and money. The August NSSN Acquisition Decision Memorandum shows that one shipyard will design and build the lead NSSN.

**Delay Lead Ship
Construction Until Design
Matures**

The high degree of concurrent development and lead ship construction caused cost increases on Seawolf. The Navy awarded Newport News Shipbuilding the overall Seawolf detail design contract in April 1987. Construction of the first Seawolf, the SSN-21, started in October 1989, with delivery originally scheduled for May 1995.

In some cases, this concurrency required developing and issuing drawings before system designs were fully mature. Although this approach provided the shipbuilder with design data earlier, it also caused a higher degree of design rework and, in some cases, construction rework. For example, the Navy's data requirement lists developed during the early phase of Seawolf design were based, as was the case with prior submarine efforts, on providing the shipbuilder with engineering drawings as the basis for performing construction tasks. It was later discovered that because Seawolf submarines required a significantly greater level of modular construction and outfitting, new and more detailed sectional construction drawings were needed to initiate modular construction tasks. As a result, in June 1990, 8 months after SSN-21 construction started and about 37 months after detail design started, the Navy rebaselined and increased Newport News' original \$303 million detail design contract by \$168 million. The rebaselining was for Newport News to prepare and to provide Electric Boat with more detail design data and incorporate final submarine specifications into the detail design.

A September 1993 NSSL cost and operational effectiveness analysis found that an additional investment of between \$105 million and \$175 million in research and development funds to review the NSSL's specifications and to complete design before lead ship construction contract award could reduce procurement costs by \$141 million to \$173 million per ship.

Starting lead NSSL ship construction with a more mature detail design could result in a more cost-effective and efficient approach than that used under the Seawolf submarine program. In June 1994, the NSSL project manager stated that the Navy plans to begin lead NSSL construction when the detail design matures. However, lead ship construction will still begin in fiscal year 1998, despite the 1-year slip of milestone I. Under the current NSSL schedule, detail design is scheduled to begin in July 1995, with lead ship construction beginning about 27 months later in October 1997. However, we question whether the detail design will be mature enough to avoid repeating similar problems the Navy experienced with the Seawolf program. The Seawolf program experienced design and construction rework, significant cost increases, and schedule delays, despite a 30-month interval between starting detail design and lead ship (SSN-21) construction.

Strengthen Specification Development and Approval Process

Deficient government specifications for welding HY-100 strength steel¹ have increased SSN-21 construction costs and have delayed the submarine's delivery from May 1995 until May 1996. In June 1991, Electric Boat experienced problems welding this new steel. As a result, Electric Boat notified the Navy that it had discovered weld cracks where two hull rings were joined together. Further investigation revealed additional unacceptable welds on the SSN-21's pressure hull and on at least 21 government-and contractor-furnished items. By August 1991, all HY-100 welding had been stopped.

The chemical composition of the welding metal, among other things, had resulted in cracking and unacceptable metal yield strengths and ductility. Ultimately, however, the welding cracks were traced to deficient government HY-100 welding specifications. Electric Boat and the Navy took corrective action; all welding resumed by December 1991. As a result of this problem, the Navy paid Electric Boat \$77.8 million (in then-year dollars) to fix the cracks. It also caused a 1-year delay in the SSN-21's delivery.

¹HY-100, a high-yield steel used to construct the SSN-21's pressure hull, allows the submarine to achieve deeper diving depths. Prior to the Seawolf program, a U.S. submarine's pressure hull was constructed using primarily HY-80 strength steel.

During the determination of defective government specifications, the Commander, Naval Sea Systems Command, requested an independent assessment of the system for developing, preparing, and approving specifications. The assessment, completed in March 1992, showed that weaknesses in developing and qualifying specifications were caused by a lack of management priority and oversight, inadequate and untimely availability of funds, and a shortage of personnel needed to develop and update specifications. In addition, the assessment showed that only 39 percent of the specification parameters were supported by historical performance data and less than 5 percent of the parameters were supported by test data.

The NSSN project manager said he plans to incorporate a review process that supports developing specifications. In addition, he indicated that the Navy plans to work with critical NSSN vendors early during design to coordinate specifications, including revisions, whenever necessary. Moreover, according to the NSSN project manager, the NSSN, to the extent possible, will incorporate existing systems and components from prior submarine programs and off-the-shelf, commercially available technology. Nevertheless, some existing systems may require varying degrees of reengineering for installation into the NSSN.

Earlier Identification of Critical Components and Supply Vendors

DOD has identified the decline of the submarine industrial base and the resulting uncertainty surrounding submarine component vendors as key factors contributing to Seawolf cost and schedule delays.

Early identification of critical components and supply vendors can help determine whether to buy or manufacture some components in-house and can help reduce potential procurement problems. For the SSN-21, Electric Boat had to manufacture certain systems and components that it was originally planning to buy. This was due either to a lack of qualified vendors or the cost and schedule risks inherent in using a vendor for complex components that were under development (i.e., the weapons storage and handling system). Collectively, the absence of sufficient vendors contributed to Seawolf design and construction cost increases and schedule delays.

The Navy's March 1992 assessment showed an apparent incomplete coordination with industry and inadequate notification to and consultation with industry regarding major changes in Seawolf specifications as required by the Naval Sea System Command's specification process. The

assessment also showed that vendors were generally dissatisfied with government feedback to their comments during specification development and modification.

According to the NSSN project manager, Electric Boat will identify and obtain critical suppliers earlier than was done on the Seawolf program. To improve coordination with vendors and to identify issues that can affect the NSSN's design and construction, Electric Boat has assembled a team of 100 designers, construction trade people, and key vendors. However, the commitment to and the success of this effort will not be assessable until a later phase of design.

Reduce Combat System Development Risks

The Navy experienced problems developing the AN/BSY-1 combat system² for the Improved SSN-688 class submarine and the AN/BSY-2 combat system for the Seawolf submarine. Because the time to correct AN/BSY-1 combat system design and development problems was insufficient, the AN/BSY-1 became the major factor in delays to the Improved SSN-688 construction program. These problems resulted in an additional \$82 million in contract costs for five Improved SSN-688s. In addition, the first nine Improved SSN-688s equipped with AN/BSY-1 systems were delivered to the Navy an average of 17 months late.

The AN/BSY-2 combat system scheduled for installation on the SSN-21 experienced cost increases and schedule delays. Changes to the system's design caused a portion of the submarine to be redesigned at an additional cost.³ The Navy originally provided Newport News with general space and weight information for the system that the shipyard used to begin designing its portion of the Seawolf. The Navy later provided the shipyard with more specific information that caused considerable redesign of the submarine and increased design costs, according to Newport News.

The Navy estimated in August 1994 that system development would cost \$123 million more than the original contract target cost of \$1 billion. Our November 1992 report⁴ showed that delivery of the system's first phase capabilities (all hardware and the majority of software) had been delayed from its original November 1993 delivery to between late March and June 1994. Because the HY-100 welding crack problem delayed the submarine's

²A submarine combat system detects, classifies, localizes, tracks, and destroys enemy targets.

³Status of SSN-21 Ship Construction Program (GAO/NSIAD-90-163, Apr. 19, 1990).

⁴Status of SSN-21 Design and Lead Ship Construction Program (GAO/NSIAD-93-34, Nov. 17, 1992).

delivery 1 year, until May 1996, the Navy revised the AN/BSY-2 system's first phase delivery to February 1995. According to a February 1994 Defense Acquisition Executive Summary prepared by the Seawolf program office, maintaining the AN/BSY-2 software development schedule to support lead ship delivery remains a challenge. The AN/BSY-2 hardware is complete and ready for delivery to Electric Boat.

To reduce combat system cost, schedule, and technical risks the Navy encountered developing the systems for the Improved SSN-688 (AN/BSY-1) and Seawolf (AN/BSY-2) class submarines, the NSSN project manager stated that whenever possible, the NSSN's combat system will be developed using what he termed an open systems architecture, which consists of commercial, off-the-shelf hardware and software. The Acquisition Decision Memorandum specifies a combat system acquisition strategy that involves "a significant degree of private sector involvement in planning an open system architecture." Nevertheless, some existing systems may require varying degrees of reengineering for installation into the NSSN.

Applying Technical Lessons May Save Millions of Dollars

The NSSN project office compiled a database that identified about 1,350 primarily technical lessons from prior Navy programs. Electric Boat, Newport News, and other Navy organizations provided the input for this database. Personnel transferring into the NSSN project office from earlier submarine programs also provided some lessons. After consolidating duplicate lessons, the Navy reduced the database to 954 lessons. The NSSN project office's evaluation process is ongoing, and new lessons are added to the database periodically.

Of these 954 lessons, 290 had been approved for incorporation into the NSSN design as of May 1994. Examples of approved lessons are (1) centralizing the ship's service hydraulic power plant, (2) simplifying the ship's deck design, and (3) simplifying the ship's pipe hangers. These three lessons are expected to save over \$10 million in acquisition costs. The Navy estimates that NSSN savings from all approved lessons could range from \$90 million to \$100 million. However, because individual lessons' costs can offset each other, savings must be assessed on a lesson-by-lesson basis. The potential exists for additional savings because the project office has not completed its review of almost 600 lessons. (See table 1 for status of the lessons.)

Table 1: Navy’s Disposition of Technical Lessons Learned as of April 1994

Status	Number of lessons
Approved for incorporation into NSSL design	290
Deferred until a later stage of development	84
Open until additional reviews are completed	504
Rejected for NSSL purposes	76
Total	954

The NSSL’s project manager noted that the Navy plans to incorporate the 290 technical lessons into the submarine’s preliminary design during the submarine’s demonstration and validation phase.

Recommendation

To allow an assessment of how the Navy will avoid a repetition of past problems, we recommend that the Secretary of Defense ensure that the formal NSSL acquisition strategy explicitly documents how the Navy is to address and incorporate the management and technical lessons from prior submarine programs.

Agency Comments and Our Evaluation

In commenting on a draft of this report, DOD generally concurred with the report and indicated that the Navy intended to apply the lessons learned from the prior programs. However, DOD did not believe it was necessary to explicitly document in a formal acquisition strategy how the Navy is to address and incorporate those lessons. DOD stated it was confident the current process provides adequate emphasis on lessons learned from prior programs.

After considering DOD’s position, we continue to believe that implementation of our recommendation is warranted. This is a multibillion dollar program; the lessons that should have been learned have already been identified; therefore, it seems that documenting how they are to be incorporated is merely a completion of the cycle—a way of better assuring that the Navy avoids a repetition of cost and scheduling difficulties. Further, we believe such documentation will serve as a valuable tool for guiding the implementation of the program.

DOD comments are presented in their entirety in appendix I. DOD’s suggestions for improving the clarity of the report have been incorporated in the text where appropriate.

Scope and Methodology

To determine the types of experiences the Navy should apply to the NSSN effort, we reviewed our prior products on the SSN-21, SSN-688, Trident, the combat systems, and other organizations' reports on lessons learned. We held discussions with Navy program officials for the Seawolf program, the AN/BSY-1 and the AN/BSY-2 combat system programs, and the SSN-688 and the Trident submarine programs. We held discussions with the Supervisors of Shipbuilding in Groton, Connecticut, and with Naval Undersea Warfare Center officials in Newport, Rhode Island. We also held discussions with Navy officials responsible for planning the NSSN's development in Washington, D.C.

We reviewed the NSSN project office's database of technical lessons learned experiences or suggestions and reviewed and analyzed Navy studies and assessments. We obtained, reviewed, and assessed suggestions provided by Electric Boat, Groton, Connecticut; and Newport News Shipbuilding, Newport News, Virginia. Electric Boat provided more detailed information on views on selected lessons learned that should be applied to the NSSN program, but Newport News Shipbuilding did not because of other business pressures.

We conducted our review from June 1993 to June 1994 in accordance with generally accepted government auditing standards.

We are sending copies of this report to the Secretaries of Defense and the Navy and to congressional oversight committees. We will also make copies available to others upon request.

Please contact me at (202) 512-4841 if you or your staff have any questions concerning this report. The major contributors to this report are listed in appendix II.



Brad Hathaway
Associate Director, Systems Development
and Production Issues

Contents

Letter	1	
Appendix I Comments From the Department of Defense	14	
Appendix II Major Contributors to This Report	17	
List of SSN-21 GAO-Related Products Since 1991	18	
Table	Table 1: Navy's Disposition of Technical Lessons Learned as of April 1994	9

Abbreviations

DOD Department of Defense

Comments From the Department of Defense



ACQUISITION AND
TECHNOLOGY

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16 SEP 1994

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and International
Affairs Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Conahan:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report "NAVY SHIPS: Lessons of Prior Programs May Reduce New Submarine Cost Increases and Delays," dated August 2, 1994 (GAO Code 707017), OSD Case 9705-A. The DoD partially concurs with the report.

While the DoD generally agrees with the information reported by the GAO, the Department would like to provide clarification of two important points: (1) the savings applied to the lead and follow ship costs as a result of acceptance of a previous class lesson and (2) the extent to which a design must mature prior to initiating lead ship construction. With regard to the lead and follow ship costs, it should be recognized that savings from some Navy technical lessons from prior programs are already included in the overall New Attack Submarine (NSSN) ship cost estimates. Adding the savings from each of the technical lessons contained in the NSSN program database should indicate the maximum possible savings. In some cases, the cost savings from one lesson may offset those from another and hence, the total savings may not be a summation of the cost savings from each lesson.

With regard to the design maturity element, the draft GAO report points out that the more mature the design product, the more successful the construction effort. The DoD agrees. To benefit from that concept, producibility review of the specifications and design package will be conducted during their development to assess production readiness. Prior to initiation of lead ship construction, a Defense Acquisition Board review of program progress, prior to lead ship construction initiation, will also be conducted. That review will focus on the design maturity to verify readiness for production.

The DoD does not agree that there is a need for a formal Navy NSSN acquisition strategy that explicitly documents lessons learned from prior submarine programs. Under the present Integrated Product and Process Development (IPPD) approach, program management already monitors and incorporates both



Appendix I
Comments From the Department of Defense

management and technical lessons learned from past submarine programs. The DoD is confident that through use of the IPPD and acquisition review processes, there is adequate insight into the lessons learned from prior programs.

Although the Milestone I Defense Acquisition Board review was not held at the time originally planned, in early 1994 the Assistant Secretary of the Navy for Research, Development, and Acquisition directed that the program office continue with the IPPD efforts, thereby permitting the seamless design approach to proceed. That action contributed to continued progress toward lead ship construction beginning in 1998.

In August 1994, the Defense Acquisition Review Board met to consider Milestone I approval of the NSSN program. As a result of that review, the Principal Deputy Under Secretary of Defense (Acquisition and Technology) authorized, on August 18, the NSSN program to enter the demonstration and validation phase to support lead ship construction in FY 1998 at the Groton, Connecticut, shipyard.

The detailed DoD comments on the GAO recommendation are provided in the enclosure. The DoD appreciates the opportunity to comment on the draft report.

Sincerely,



George R. Schneiter
Acting Director
Tactical Warfare Programs

Enclosure

GAO DRAFT REPORT - DATED AUGUST 2, 1994
(GAO CODE 707017) OSD CASE 9705-A

"NAVY SHIPS: LESSONS OF PRIOR PROGRAMS MAY REDUCE
NEW SUBMARINE COST INCREASES AND DELAYS"

DEPARTMENT OF DEFENSE COMMENTS ON
THE GAO RECOMMENDATION

* * * * *

- o **RECOMMENDATION:** The GAO recommended that the Secretary of Defense ensure that the formal New Attack Submarine (NSSN) acquisition strategy explicitly documents how the Navy is to address and incorporate the management and technical lessons from prior submarine programs. (p. 14/GAO Draft Report)

DOD RESPONSE: Nonconcur. The DoD does not agree that there is a need for a formal process to document lessons learned from prior submarine programs. Under the current approach, the Navy Integrated Product and Process Development effort, together with the established acquisition process, monitors and incorporates into the NSSN program the management and technical lessons learned from prior submarine programs. That approach was recently certified as part of a Defense Acquisition Board Milestone I review of the NSSN program. On August 18, 1994, the Principal Deputy Under Secretary of Defense (Acquisition and Technology) authorized the NSSN program to enter into the demonstration and validation phase to support lead ship construction in FY 1998.

Now on p. 9.

Major Contributors to This Report

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List of SSN-21 GAO-Related Products Since 1991

GAO has performed work on the Seawolf program since 1985. The following chronology presents products issued since 1991.

- Navy Ships: Seawolf Cost Increases and Schedule Delays Continue (GAO/NSIAD-94-201BR, June 30, 1994).
- Navy Ships: Problems Continue to Plague the Seawolf Submarine Program (GAO/NSIAD-93-171, Aug. 4, 1993).
- Navy Ships: Plans and Anticipated Liabilities to Terminate SSN-21 Program Contracts (GAO/NSIAD-93-32BR, Nov. 27, 1992).
- Navy Ships: Status of SSN-21 Design and Lead Ship Construction Program (GAO/NSIAD-93-34, Nov. 17, 1992).
- SSN-21, Seawolf Contract Terminations (GAO/NSIAD-93-41R, Nov. 6, 1992).
- Navy Shipbuilding: Effects of Reduced SSN-21 Procurement Rates on Industrial Base and Cost of Program (GAO/NSIAD-92-140, Apr. 8, 1992).
- Submarine Combat System: BSY-2 Development Risks Must Be Addressed and Production Schedule Reassessed (GAO/IMTEC-91-30, Aug. 22, 1991).
- Submarine Combat System: Status of Selected Technical Risks in the BSY-2 Development (GAO/IMTEC-91-46BR, May 24, 1991).
- A May 24, 1991, letter to Representative Herbert H. Bateman discussing cost projections of several SSN-21 procurement scenarios.

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