

Advanced SEAL Delivery System

Perspectives and Options

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PREFACE

The Deep Submergence Directorate (PMS 395) of the Naval Sea Systems Command asked RAND to undertake a brief analysis examining the technical, managerial, and cost issues in preparation for follow-on production of the Advanced SEAL Delivery System (ASDS). This documented briefing presents the study findings.

This study was conducted within the Acquisition and Technology Policy Center of RAND's National Defense Research Institute (NDRI). NDRI is a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the unified commands, and the defense agencies.

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ASDS Perspectives and Options

The Path Forward

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INTRODUCTION

Operational experience in the 1980s led the Special Operations Command (SOCOM) to look for a new, covert Navy Sea, Air, Land team (SEAL) insertion vehicle to replace/augment the existing SEAL Delivery Vehicle (SDV). The SDV is a “wet” submersible, which means that the embarked members have to endure extended and cramped periods in ocean waters with only a wet or dry suit to protect them from the elements. Traveling in extremely cold ocean waters for several hours during long offshore transits can have detrimental effects on the physical and mental performance of the SEALs. Sometimes it requires personnel to warm themselves on the beach before they can continue with their mission. This is what led SOCOM to pursue the concept of a “dry” (pressurized) hull for the SEALs in the Advanced SEAL Delivery System (ASDS). The ASDS also provides improved range, speed, payload, and habitability for the crew and divers over

the existing SDV. It provides the SOCOM with a true “mini-sub,” capable of significantly extending its combat radius.

ASDS is a battery-powered, shock-hardened, stealthy combatant. It will generally be transported to its designated operational area by a specifically configured SSN 688-Class submarine. Two 688-Class SSNs are currently being modified for this mission. ASDS has a hyperbaric chamber that is used to lock in/lock out swimmers from a bottom hatch at a variety of depths and also serves to create a passageway to the host submarine mating trunk when the ASDS is attached to the submarine’s hull. ASDS has sensors that include multiple sonars. Its navigation systems include both a global positioning system and an inertial guidance system. The mini-sub can be transported via land or air.

Because of the unique and challenging nature of the development and production of the ASDS vehicle and subsystems, the schedule and the initial contract cost were significantly exceeded. The first ASDS is undergoing final testing. The procurement decision regarding the following five boats is pending. The manufacturer of the first pressure hull, Chicago Bridge and Iron, decided to drop out of the program, and Northrop-Grumman Corporation (NGC) has selected Electric Boat Company (EB) to produce the follow-on hulls.

Outline	
• Technical Issues – Material Selection – Hull Fabrication – Testing – Intelligent Solid Modeling • Cost-Reduction Initiatives • Program Management • Recommendations	
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OUTLINE

In the fall of 2000, PMS 395 (the Deep Submergence Directorate) asked RAND to perform an independent review of the ASDS program. This research, which was conducted over a four-month period, had several objectives. The first chapter focuses on technical aspects of the ASDS design and development process. The second chapter reviews the cost-reduction initiatives and discusses the possibility of multiyear procurement. Third, we review areas related to NGC's management of the program. In the last chapter, we summarize our recommendations to the program office.

Material Selection: HY-80 versus HY-100	
Issues/Observations: • HY-80 requires a special mill run that may increase cost and schedule risk for ASDS – ASDS-1 hull is HY-80 – ASDS-2 cylinders planned to remain HY-80 • HY-100 now used for most submarine applications – Stronger material for equivalent weight – ASDS-2 hemi-heads proposed by NGC to be HY-100 to reduce weight – Navy requirements may make it difficult to realize additional weight savings for pressure hull Recommendation: • Explore design and cost-schedule trade-offs of using HY-80 vs. HY-100 for ASDS-2 and subsequent hulls	
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TECHNICAL ISSUES

Material Selection

HY-80 was once the standard submarine hull and structures material. However, about ten years ago, the Navy submarine program changed to HY-100 because of its greater strength for equivalent weight. Other users of HY-80 in U.S. industry have also switched to other alloys. Thus, HY-80 is no longer in routine production. EB advised us that its recent experience in procuring HY-80 and HY-100 for repairs and modifications to nuclear-powered submarines is that HY-80 is available, but only with a special mill run at greater cost than HY-100 and with a longer delivery time. However, NGC personnel advised us that they see no problem and that in fact, HY-80 is 2 percent less expensive than HY-100 in the amounts and dimensions required for ASDS follow-on pressure hulls.

The ASDS program currently uses a substantial amount of HY-80. The ASDS-1 pressure hull and hemi-heads are fabricated from HY-80. HY-80 is planned for the hull cylinders of ASDS-2. HY-100 is being considered by NGC for the bow and stern hemi-heads of the second hull to reduce weight. Navy requirements for cylinder design may not permit a similar weight reduction for the hull cylinder. These requirements impose a minimum material thickness for a cylinder. Therefore, it may not be possible to reduce the weight of the pressure hull by converting from HY-80 to HY-100 because the hull thickness cannot be reduced.

Because a change in pressure hull material will have cost and schedule implications, we recommend that the Navy undertake an analysis of the implications of changing to HY-100 versus continuing to use HY-80 in subsequent hulls. The original design approach was based on optimum materials then available. Whether any material change is necessary or appropriate depends on cost and performance implications. Specifically, any cost study will need to look at not only the differential material costs, but also the added design, fabrication, and testing costs.

Material Selection: Alloy 6-4 Titanium	
Issues/Observations: • Alloy 6-4 titanium ELI used for many ASDS parts, e.g., – Battery bottles – Environmental bottles – Brackets • In full-size submarines, alloy 6-4 titanium is not used, because of stress corrosion and cracking in seawater • Additional review by the Navy and NGC indicates that the ELI version of alloy 6-4 titanium does not suffer the same shortcomings of the base 6-4 alloy Recommendation: • No further action	
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Alloy 6-4 titanium ELI is used in many areas of the ASDS to reduce weight. This alloy is used in the free flood volume for the battery bottles, environmental bottles, and interior brackets.

EB and NAVSEA 05M have advised us that alloy 6-4 titanium is subject to two performance concerns, fracture toughness and stress corrosion cracking in seawater, in that order of importance. Once cracked by whatever mechanism, alloy 6-4 titanium (unlike some other titanium materials) will fail immediately. For these reasons, this material is not authorized or used in safety boundaries in full-size submarines. The Navy now widely uses alternate high-strength lightweight materials such as commercially pure (CP) titanium in full-size submarines for weight reduction and performance improvements. The Navy is also nearing completion of the development of a new titanium alloy, termed alloy 5-1-1-1 titanium, that corrects for the shortcomings of alloy 6-4 titanium. We also observe that the International Titanium Association does not list alloy 6-4 titanium as a corrosion-resistant material.

During our research into this question, we encountered conflicting views on the use of alloy 6-4 titanium. Since that time, the Navy and NGC have conducted a review of the suitability of alloy 6-4 titanium as applied in the ASDS. The ELI version of this titanium alloy is used on the ASDS. Since the ELI version is manufactured through a different process compared with the straight alloy 6-4 titanium, the ELI alloy does not suffer the same shortcomings as the basic alloy 6-4. Therefore, the review concluded that the ELI alloy is a suitable and safe material as used on the ASDS.

Pressure Hull Fabrication
Issues/Observations: • EB concerns: – Completeness of the drawings – Potentially overly stringent dimensional tolerances and structural details – Deviation from proven hull fabrication processes in use at EB • NGC concerns: – Significant design progress made since EB concerns were expressed – Felt EB was trying to wrest program from them • Some issues resolved by recent NGC-EB discussions Recommendations: • Affirm NGC's role as prime contractor for project • Facilitate EB and NGC discussions on pressure hull details
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Pressure Hull Fabrication

Over the past year, there has been an ongoing dialog between EB and NGC over the producibility and affordability of the design for the ASDS hull and other components. This dialog has raised concerns by some within and outside the program, slowing progress. Many of the producibility issues have since been resolved by the recent progress of NGC, but some affordability details remain to be resolved. Before coming to any specific recommendations, we feel that it is important to discuss the viewpoint of each of the contractors.

When EB was asked to bid on the second pressure hull, it received a two-dimensional computerized drawing package that included numerous, documented paper design changes. Based on this material, EB raised concerns about whether the drawings were complete and whether there were appropriate design configuration controls. EB also felt that there were many overly stringent dimensional tolerances

and structural details in the drawings (for the hull and other items upon which it was asked to bid) that might result in high costs.

Further, since the drawings provided for EB's review were not three-dimensional (3-D), an industry standard, EB offered and some Navy officials considered using EB's systems and techniques, including the use of EB's 3-D computer-aided design/computer-aided modeling (CAD/CAM) process, CATIA. This process may improve producibility and thereby reduce the manufacturing cost of the ASDS boats. However, there were considerable non-recurring costs associated with adopting CATIA, which raised questions about whether those costs were warranted.¹

At this time, NGC became concerned that EB was trying to gain control of the program. We base this interpretation on correspondence between and other comments from the two firms. Unfortunately, the net effect of this discord was to strain the relationship between EB and NGC. However, as a result of this discord, NGC took steps to reduce and control costs.

Since the submission of the pressure hull bid package to Electric Boat, NGC has been updating and converting the design into its corporate 3-D solid-model CAD/CAM system (by Unigraphics). Now a year later, NGC appears to have captured a large percentage of the ASDS design in this 3-D solid-model CAD/CAM system and has assembled a systematic approach to reduce and control costs. NGC will be completing this work shortly.

At present, the Navy needs to continue to facilitate discussions between EB and NGC to clarify and resolve any remaining areas of concern. Having an effective working relationship between the two contractors will greatly benefit the program. To create a sense of trust, the Navy needs to reaffirm that NGC is the prime contractor for the ASDS program. EB also needs to come forward and formally state that it is not interested in becoming the prime contractor (as it has done with RAND²) and that NGC should determine who does other production

¹The issue of the conversion of the ASDS design into CATIA is discussed in detail later.

²EB states that there have been several informal meetings with senior management at NGC where EB has expressed its interest in the success of the program.

work. For NGC's part, it should provide EB with the 3-D hull design package as soon as it is complete. With this information, and assuming that EB will be able to translate the information into its own systems, EB should be able to validate the design and producibility, thereby entering into a constructive dialog with NGC to resolve any remaining issues. In addition, NGC should discuss recent hull changes made for cost-reduction reasons.

Outer Hull Fabrication

Issues/Observations:

- **BFG/EPP concerns:**
 - Completeness and timeliness of drawings for ASDS-1
 - ASDS-1 not an optimal design for composite materials; many ideas possible for improvements in ASDS-2 and follow on
 - Not party to recent NGC redesign yet called “supplier of choice” by NGC
- **NGC concerns:**
 - Performance of BFG/EPP on ASDS-1
 - Supplier choice not yet finalized

Recommendation:

- **Facilitate supplier and NGC discussions on outer hull details**

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Outer Hull Fabrication

The outer hull vendor for ASDS-1, BF Goodrich's Engineered Polymer Products division (BFG/EPP), was interviewed by representatives of the study team. BFG/EPP reported that much of the difficulty with production of the ASDS-1 outer hull was caused by late and incomplete drawings and a less-than-optimal composite design. BFG/EPP had original responsibility for the initial design work; but because of manufacturing and management problems, NGC took it over early in the program. Both NGC and BFG/EPP noted that the ASDS-1 outer hull was essentially a design suited for steel construction but not composites and involved a large number of different materials, fabrication processes, and complex designs. BFG/EPP also noted that while it is aware that NGC has developed a redesigned outer hull, it was not party to this work despite being designated by NGC as the “‘supplier of choice’ for the fabrication of the composite exostruc-

ture.”³ Thus, BFG/EPP cannot determine whether the new design will in fact cost less and be easier to produce. This BFG/EPP position conflicts with the fact that BFG/EPP not only attended the redesign discussion sessions held on February 24, 2000, March 8, 2000, and March 9, 2000, but also participated in those reviews. Clearly, there is a communication and expectation gap between the two firms. NGC acknowledges that the ASDS-1 composite design was not optimal and the lateness and incompleteness of the drawings were issues. However, NGC believes that much of the difficulty in production was due to poor manufacturing production controls and supervision at BFG/EPP. This shortcoming was acknowledged by BFG during our discussions. BFG/EPP says that it has fixed these shortcomings. Further, BFG has hired an experienced former NGC composites engineer to head a future outer hull project. Nonetheless, NGC remains concerned with BFG/EPP’s ability to produce parts for future ASDS hulls and has not made a final decision on a manufacturing source.

We recommend that NGC identify the supplier for the fabrication of the outer hull. We recommend the selected supplier be one of those that are fully familiar with the design and production of underwater marine composite systems. We recommend that the Navy facilitate discussions between NGC and the selected supplier on outer hull design and production details.

³NGC letter to BF Goodrich, Subject: ASDS Exostructure, Future Procurement, December 14, 1998.

ASDS-1 Testing

Issues/Observations:

- NGC and Navy are working well together
- Facilities are first rate
- Shake-down and testing problems are normal for first-of-a-kind complex systems
- Operator (pilots and copilots) are concerned with long-term reliability
- Operators feel their concerns are being ignored

Recommendation:

- Pilots and copilots should be given a forum to express concerns

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Testing

We reviewed progress on ASDS-1 testing in Hawaii. We found that NGC and Navy personnel are working together in harmony and that the facilities for the system are first rate.

There is a reasonable concern on the part of the pilot and copilots that there might be long-term reliability problems deriving from shake-down and testing. While disruptive and costly, the problems we observed appear typical for such a complex, first-of-a-kind system as the ASDS. Pilots and copilots were initially involved in program development, and their views were listened to and acted upon; however, they now feel excluded. In view of the operational complexity of ASDS and the opportunity for valuable operator input to the design of subsequent ASDS boats, we recommend that the Navy give pilots and copilots the opportunity to be involved and make them part of the larger effort to ensure that ASDS-2 is as cost-effective as possible.

Intelligent Solid Modeling

Issues:

- **EB felt that there would be substantial benefit to applying its intelligent solid model (CATIA) to the ASDS design**
- **NGC has applied a Unigraphics CAD/CAM system to ASDS (95% complete)**
- **The two design tools are functionally equivalent**
 - **No benefits to converting hull design to CATIA**
 - **No benefits of converting from Unigraphics to CATIA for whole design, which would be an expensive task**

Recommendation:

- **No change from current NGC system**

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Intelligent Solid Modeling

Intelligent, 3-D solid computer-aided design/computer-aided modeling systems are rapidly becoming part of the standard design process at all contractors. Not only do these systems produce “drawings,” but they also provide seamless entry into other areas of the engineering and program management processes. For example, the more advanced systems generate machining instructions, integrate with purchasing and supplier management systems, and link to simulation and visualization packages. While the benefits of such systems are difficult to quantify in terms of cost and schedule, most experts agree that the systems yield higher-quality products and reduce the number of design changes later in programs.⁴

⁴Cynthia R. Cook and John C. Graser, *Military Airframe Acquisition Cost: The Effects of Lean Manufacturing*, Santa Monica, Calif.: RAND, MR-1325-AE, 2001.

To facilitate validation and production of the pressure hull, EB recommended the design be translated into its corporate 3-D solid CAD/CAM system based on the CATIA system. EB's recommendation arose from review of the 2-D drawings that were provided by NGC for the purpose of bidding on production of the ASDS-2 hull.

Meanwhile, NGC was updating and converting the design to its own corporate 3-D solid CAD/CAM Unigraphics system. This work is nearly complete.

In our view, either integrated CAD/CAM tool is functionally equivalent to the other (although each system may have differing features and implementation details). Since NGC has updated the design in its Unigraphics system, EB now agrees that there would be no further benefit from using the CATIA CAD/CAM system. In addition, the Unigraphics system is the standard CAD/CAM tool for the division of NGC responsible for the ASDS. Given the substantial up-front investment⁵ in fully transferring the design to CATIA and no discernible benefit, RAND recommends that the design not be converted to CATIA.

⁵While no estimate for the complete conversion of the boat design to CATIA was ever produced, the cost to convert the pressure hull into a CATIA smart model was estimated to be about \$1 million. The conversion of the entire boat would certainly be much more expensive.

Cost-Reduction Initiatives	
Issues/Observations:	
• NGC has demonstrated cost-reduction initiatives in eight areas to reduce the cost of producing ASDS-2 by \$10 million – Electrical Systems Optimization – Nose and Aft Body Project – Structures Optimization – Thruster Cost Reduction – Mid-Body Panel Project – Piping Systems Optimization – Modularity Project – Supplier Opportunities • Non-recurring costs for the work is \$6 million in 2000 and \$4 million in 2001 • Will result in vastly simplified design and potentially improved product quality	
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COST-REDUCTION INITIATIVES

Overview

NGC has demonstrated a series of eight selected initiatives to reduce the production cost of subsequent ASDS boats. These initiatives are expected to save approximately \$10 million per boat. The current plan to realize these savings is for the government to fund a \$10 million detailed design effort. The \$10 million investment is split over two years: \$6 million in 2000 and \$4 million in 2001.

The cost-reduction efforts largely focus on design simplifications and producibility improvements. These redesign efforts will result in a higher-quality, lower-cost product when compared to ASDS-1. As rough metrics, the combined effect of the NGC efforts is purported to reduce the total parts count by over 6,000 items, decrease the dry

weight by 5,925 pounds, and decrease the wet weight by 4,294 pounds. The following are the eight efforts reviewed by RAND:

1. **Electrical Systems Optimization:** This initiative is a multicomponent effort to improve connector technology, improve and simplify wiring runs, modularize rack design, and eliminate unneeded connections.
2. **Nose and Aft Body Project:** The nose and aft body improvements focus on applying NGC's aircraft composite design methods to those structures. In doing so, the revised design becomes much more producible—easier to assemble (fewer parts and less weight)—resulting in lower production cost. In comparison, ASDS-1 did not leverage all the design advantages of composite structures and relied on a more traditional design approach suitable for steel structures.
3. **Structures Optimization:** This cost initiative focuses on simplifying the design and reducing the parts count for a series of structural elements for the ASDS. Most notable in this area is a reduction in the number of external hull studs.
4. **Thruster Cost Reduction:** The thruster redesign effort focuses on simplifying the door and deployment mechanism. The door size has been reduced by over 50 percent, and the mechanism parts count was reduced by over 450 items. This improvement will also slightly reduce the boats' beam when the thrusters are in the deployed position.
5. **Mid-Body Panel Project:** This cost initiative simplifies the mid-body panel structures. The major elements of this work are the outer-hull flat panel design, flat panel attachment methods, and battery panel design.
6. **Piping Systems Optimization:** This effort focuses on simplifying the design of all the piping systems in the vessel: hydraulics, the environmental control system, the life support system, and associated heat exchangers. The optimization will substantially reduce the number of pipe runs, hoses, connectors, and hull penetrations.
7. **Modularity Project:** This project is an effort to improve the assembly efficiency of the hull by providing for a modular assembly

approach and off-hull-component outfitting and testing. The effort aims to reduce the building time.

8. **Supplier Opportunities:** This effort focuses on more efficient procurement of material and better use of NGC suppliers. The idea is to simplify/group vendor specifications, combine purchases of common raw materials, and off-load more finishing of subassemblies to the vendors. Although there is some design effort involved, this effort has more of a management/procurement focus than do the other seven items.

Net Present Value and Internal Rate of Return for NGC Cost-Reduction Initiatives

Item	NPV (\$M)	IRR
Electrical Systems Optimization	\$ 2.8	35%
Nose and Aft Body Project	\$ 5.8	75%
Structures Optimization	\$ 1.5	53%
Thruster Cost Reduction	\$ 1.0	48%
Mid-Body Panel Project	\$ 5.8	69%
Piping Systems Optimization	\$ 2.9	33%
Modularity Project	\$ 3.8	617%
Supplier Opportunities	\$ 8.8	1,768%
Total	\$ 32.3	80%

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Net-Present-Value and Internal-Rate-of-Return Evaluation

When doing a cost-benefit analysis of potential future savings, an accepted practice is to use net present value (NPV) and internal rate of return (IRR) as metrics to quantify benefits. These methods balance the fact that cash flows do not occur in the same year. Because there is an opportunity cost of capital, receiving a dollar today is more desirable than receiving a dollar five years from now. This statement does not relate to inflation but rather reflects the fact that if we forgo use of capital, we lose the ability to spend it on something else. Likewise, we benefit if we have the ability to use it sooner. For the case of the ASDS cost-reduction program, we are incurring additional cost up front for potential future savings.

The Office of the Secretary of Defense (in circular A-94) prescribes that any cost-benefit analysis include a discounted cost evaluation. To evaluate the effectiveness of the cost-reduction initiatives, we ap-

plied those standard methods of A-94 using a discount rate of 4 percent. It was assumed that five hulls would be procured, one hull every other year starting in fiscal year (FY) 2001. Further, the time phasing of the non-recurring investment required was split between FY 2000 and FY 2001. These splits are based on the percentage completed of each initiative as reported to us by NGC during our meeting on November 8, 2000. The unit savings and investment costs come from NGC's analysis presentation to us on that date, as well.

In industry, a good investment has a positive NPV and an IRR of 15 percent or more (somewhat dependent on which business sector is being evaluated). As shown in the chart, the NPV and IRR are very large, indicating that the initiatives, if successful, would be of substantial benefit to the program. If the number of hulls drops to three (one procured every other year), the overall NPV falls to \$17 million with an IRR of 76 percent. Therefore, even if there is a significant reduction in the procurement quantity, the cost initiatives are still an attractive investment for the program.

Evaluation of Cost-Savings Initiatives

Caveats to Cost Savings

- Difficult to forecast savings
- Cost basis on ASDS-1
- Redesign not complete enough for NGC to obtain revised bids for certain key items
- No quantitative evaluation of life-cycle cost

Even if total savings were half of those expected, NPV = +\$11 million and IRR = 29 percent

Recommendation:

- Fully fund second phase of initiatives

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Evaluation of Cost Savings

Before making any recommendation on the cost-savings initiatives, we must make the following qualifications:

1. With any cost-savings projection, there is a level of inherent uncertainty in the values. One can never truly know the cost of the path not taken, i.e., if one never pursued the cost savings in the first place. Moreover, some of the items for which there are improvement efforts (such as the modularity effort or the supplier opportunities) are very difficult areas to quantify. While we do not dispute the savings values reported by NGC, we caution the reader that the numbers are forecasts and not realized values.
2. The cost basis for the savings is a modification of the costs for ASDS-1. NGC has attempted to remove any elements of rework or non-recurring items that would not be part of ASDS-2's cost. The extent to which they were successful may or may not overstate

the level of savings. If there were some ASDS-1 costs that were not removed from the new basis, the estimated savings might be high. A related issue is that there is no “learning” or cost improvement assumed between ASDS-1 and ASDS-2. This improvement comes from the experience gained by already having produced an item. Again, we are not in the position to validate the estimate basis of ASDS-2; rather, we point this fact out as a limitation of our analysis.

3. NGC has yet to finish the redesign for certain items that have been improved. Most important among these items are the inner hull and the outer hull fairings. Thus, NGC has not yet obtained revised bids from critical suppliers nor received input on the producibility of the new NGC designs from the suppliers. The savings for these items could change substantially, in either direction, based on the suppliers’ input and bids.
4. While the acquisition benefits are quantified, there is no quantification of the life-cycle cost benefits (or costs). One particularly important area is the maintenance and operational costs. Most of the NGC cost-reduction initiatives should improve this area because the ASDS design is greatly simplified (fewer parts). However, a complete cost-benefit analysis should include the full spectrum of life-cycle costs.

We believe that the cost-reduction efforts are a worthwhile activity and encourage the Navy to fully fund the second phase.⁶ Even if the Navy realizes half of the planned savings, the NPV and IRR are still significant: \$11 million and 29 percent, respectively. Further, the overall maintainability improvement is an additional, difficult-to-quantify benefit of the work.

⁶Technically, a proper cost-benefit analysis of further funding would be slightly different from the analysis we presented. Since the investments in FY 2000 are now “sunk” costs, those expenses should be excluded from the evaluation. But because this exclusion would result in substantially *higher* IRR and NPV values, our conclusions do not change. We presented the cost-benefit evaluation of the entire cost-reduction program to demonstrate its effectiveness.

Multiyear Procurement

Issues/Observations:

- Reduces costs through larger quantity purchases and economies of scale
- However,
 - Five-year maximum contract
 - Greater congressional hurdle
 - Must demonstrate minimum of 10–15% savings
 - Obligates the government to paying cancellation fees
 - Only effective if design is stable and production cost established
- Recommendations:
 - Do a thorough study of multiyear option for ASDS
 - As an alternative, explore changing procurement plan to one boat per year

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Multiyear Procurement

Multiyear procurement is a contracting method to procure several years' system requirements with one contract. The primary advantage of multiyear contracts is that the government often gets lower and more stable prices compared with individually procured systems. The price improvement results from lower contractor costs due to bulk/quantity purchases, increased economies of scale, and an incentive to improve productivity. Price stability, in part, results from the prime contractor being able to obtain longer-term contracts with its suppliers and vendors.

However, there are several restrictions to multiyear programs. The maximum contract term is five years. Beyond this period, a new contract has to be established. Additionally, multiyear procurements typically receive congressional oversight. Therefore, the legislative burden is increased to the program office. Further, the government is

obligated to cancellation penalties if the contract terminates early. Finally, there are specific criteria that acquisition programs must meet to qualify for multiyear funding. Programs must

- demonstrate significant savings through multiyear procurement (the minimum value is typically on the order of 10–15 percent)
- have a stable and realistic cost estimate
- have a requirement that is stable, i.e., a long-term demonstrated need
- show stable and available funding
- have a stable and fixed design
- show that multiyear procurement would promote national security
- demonstrate no adverse effects on the industrial base.

We recommend that the program office perform a careful evaluation of the benefits of multiyear procurement for the ASDS program. The potential savings could be quite significant (at a 10 percent level, it would equal the savings from the cost-reduction initiatives). However, given the current cost and design basis, it is probably unrealistic to implement a multiyear contract starting with ASDS-2. Hopefully, when ASDS-2 is completed, a firmer cost and design basis will be available to do such an evaluation.

An alternative approach the program could explore is changing the procurement plan from one boat every other year to one boat a year. Bunching of production might reduce the cost inefficiencies of repeated stops and starts to production. It may also allow NGC the ability to better leverage production experience (the learning curve). An additional option the program could consider is early procurement or block purchases of certain items where there may be significant economic advantage (HY-80 material is one such example). Again, these concepts should be explored at a greater level of detail once the design and cost basis are stable.

Program Management: Past

The ASDS program has experienced many problems:

- **Product definition problems at the beginning**
 - \$70–90 million bid for a \$170 million project
- **Management and execution**
 - An “island” project at Westinghouse/NGC
 - NGC/Navy attempt to manage for unrealistic price
- **Performance by some subcontractors**
- **Certification of products**
- **NGC concern with potential competition from EB**
- **Funding constraints**

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PROGRAM MANAGEMENT

Past

The ASDS program has had many problems. The original program started off with poor definition when three vendors all bid about half as much as the government’s own cost and operational effectiveness analysis estimates. Clearly, the vendors did not envision the same project as the government did. The trend continued when the winner, Westinghouse, attempted to meet requirements within or close to the original bid, despite many indications that this was not possible. This lack of definition and catering to an unrealistic price resulted in a significant number of design changes and decisions that resulted in dramatic cost and schedule growth.

NGC inherited these problems when it acquired the Westinghouse division building the ASDS. These preexisting problems were further

compounded because the program was initially run outside NGC's normal practices. For example, until recently, the project was kept outside of the typical NGC business and technical models used for other major, successful NGC projects. The ASDS program was left as an island project—largely confined to the experience limits of the Annapolis facility where it began. The program did not benefit from the management experience that has led NGC to be a very successful provider of major weapons systems.

While suffering from a lack of top management attention at NGC, the project also suffered from poor design decisions and poor vendor performance. NGC cited the composite outer hull and the failure of NGC's vendor material certification system as examples that have led to delay and increased cost. More recently, NGC's concern with competition from EB has also disrupted program management.

Program Management: Present

NGC has taken several “round turns”

- **ASDS is now imbedded in the standard NGC 3-D CAD/CAM system used for other projects**
 - **Confident configuration control, assessment of changes**
- **New talent at all levels**
- **New facilities**
- **New processes**

These changes have not necessarily solved all problems but, in our view, provide a good prognosis for the way ahead

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Present

NGC has taken several “round turns” and made many changes to ASDS program management during the past two years. The project has received day-to-day management attention at the senior vice president level and has benefited from a large infusion of experienced talent. NGC has designed new facilities for production of subsequent vessels and has developed new processes and hardware for testing major systems before they are landed in the vessel.

The fundamental change has been to transform the ASDS project from what NGC called an “island project” at its Annapolis facility—a project drawing from the resources within Annapolis but little from elsewhere—to a full-fledged NGC project that is imbedded in the NGC corporate design, development, production, and programmatic systems.

We were briefed in detail on the application of this new approach to the eight-part cost-reduction program, and we found it to be comprehensive and effective from a technical perspective.

While the new technical and management approach has likely not solved all of ASDS's problems, we find that it is solid and comprehensive, which will provide a good basis for identifying solutions when unanticipated problems arise.

Building Effective Communication

Effective Communication Critical Success Factor for Programs

- **Integrated Product Teams (IPTs) a vehicle for effective teams (mandated by DoD directive 5000.2)**
- **Means to improve communication and buy-in**

Issues:

- **Environment of “finger-pointing” as a result of earlier problems**
- **Complaints of insufficient involvement (EB, BFG/EPP, operators)**

Recommendation:

- **Improve communication by**
 - **Strengthening applicable IPTs to allow maximum participation**
 - **Establishing a Program Manager’s Advisory Group (PMAG) to review design for further opportunities for producibility and life-cycle cost savings**
 - **Facilitating technical discussions**

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Building Effective Communication

Effective communication between stakeholders is viewed as a critical success factor for programs. Teams that communicate well internally and solicit advice generally develop and produce high-quality products efficiently. To that end, Department of Defense directive 5000.2 mandates the use of Integrated Product Teams (IPTs) as a means of facilitating this communication. IPTs involve all the key participants in the decisionmaking process. The team membership includes not only program management employees but also other government stakeholders, contractors, suppliers, and operators.

We observed in our discussions that the communication between NGC and its potential subcontractors is not as effective as it could be. Given the early history of the ASDS program, it does not surprise us that there are communication difficulties currently, too. When significant problems arise, people naturally tend toward blame assessment

rather than problem solution. Further complicating the situation is that some of the contractor participants are competitors. With most of the problems, hopefully, behind the program, it is an opportune time to rebuild working relationships on the program. Again, we are not assigning blame, but rather presenting an opportunity for improvement.

To improve the communication between the parties, we suggest strengthening the appropriate IPT membership (or an IPT-like team, such as a design review team). The strengthened team should include major suppliers as well as the key operators (pilots and copilots) to maximize its utility. Specifically, it is felt that as a minimum, EB, BFG/EPP, Draper, other potential and critical suppliers, and the current assigned key operators should be given such a forum to incorporate lessons learned and to increase reliability.

In addition, the establishment of a Program Manager's Advisory Group (PMAG) would also facilitate better communication and provide an open forum to discuss common issues. We recommend that the program office form such a group, with a charter to examine additional affordability issues and areas of remaining risk (as well as any other topics the PM deems appropriate). The membership of the team should include representatives similar to those of the IPT, as described above, but it should be led and facilitated by a neutral party. This team should exist for a short period of time—no more than 30 days.

Conclusions

- **Program is moving in the right direction**
- **Several technical issues remain**
- **Opportunities exist to further reduce costs**
- **Additional management actions by Navy and NGC will further strengthen and benefit the program**

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Conclusions

After an uncertain start, the ASDS program is proceeding on a more solid foundation. However, there are still a few areas for potential improvement that the program office should consider. Some other technical areas need to be examined at a greater level of detail as well. These issues mostly center on materials suitability and affordability. While the cost-reduction efforts are a good step toward improved affordability, we feel that the program should fully explore alternative acquisition strategies, such as multiyear procurement, to further cost savings. Lastly, we feel that the program office and prime contractor should work to build better relationships and foster improved communication among the various stakeholders in the production of follow-on ASDS vehicles. Because the program is still early in its life cycle, such improvements will help ensure a successful outcome.

Recommendations	
• Arrange for independent exploration of the design and cost-schedule trade-offs of using HY-100 • Affirm NGC's role as prime contractor • Facilitate EB/BFG/supplier and NGC discussions on hull details • Fully convert the design to the Unigraphics CAD/CAM system • Fully fund second phase of cost-reduction initiatives • Do a thorough study of multiyear option for ASDS-3 to 5 • As alternatives to multiyear, explore changing procurement plan to one hull per year and/or bulk procurement of certain items	
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RECOMMENDATIONS

First, the matter of HY-80 versus HY-100 for the pressure hull should be explored independently. There is conflicting information from our sources. A switch to HY-100 may result in cost and weight savings.

In addition, the Navy should affirm NGC's roll as prime ASDS contractor to remove any doubt or concern within NGC or any of the major vendors as to the Navy's position. This should help free up the flow of information between NGC and its vendors, potentially leading to better and less-expensive ASDS boats.

Also, the Navy should facilitate discussions between NGC and EB (for the inner hull) and the selected composite supplier (for the outer hull). These two items are among the most expensive parts of ASDS. Full and free discussions may lead to more cost savings, better performing ASDS, or both. In addition to fully converting the design to

the Unigraphics CAD/CAM system, the Navy should fully fund the second phase of the cost-reduction initiative.

Furthermore, multiyear or steady-rate production of ASDS should be explored. RAND (with concurrence from NGC) believes that these options encompass the opportunity to significantly reduce the cost of the ASDS fleet.

Recommendations (cont.)	
• Strengthen IPT-like activities – Make sure EB, BFG, key suppliers, and operator ideas are heard and considered • Establish a Program Management Advisory Group to review life-cycle cost-savings opportunities and risk issues – Membership • Chaired by neutral individual • All contractors involved • Draw on outsider experience – Short, 30-day timeline	
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A forum should be provided for substantive involvement of vendors and key operators. This forum should focus on cost and weight reductions as well as long-term reliability. RAND has concentrated on production cost savings in this study. Significant savings may also lie in the life-cycle costs of the system. The Navy should therefore establish an ad hoc team to review the design for life-cycle savings. The team should involve NGC, all vendors, ASDS operators, and outside submarine operator and maintenance experts. We recommend a short time frame for this review to keep it from being institutionalized. Lastly, the program office should establish a PMAG to provide input to assist the program manager in assessing all aspects of the ASDS program including technical, programmatic, financial, and contractor performance.