USCGC POLAR SEA Business Case Analysis

2013 Report to Congress

November 07, 2013

U. S. Coast Guard

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Foreword

I am pleased to present the following report, "USCGC POLAR SEA Business Case Analysis," which has been prepared by the U.S. Coast Guard.

Section 222 of the Coast Guard and Maritime Transportation Act of 2012 (Pub. L. 112-213) directs the Commandant to conduct a business case analysis of the options for and costs of reactivating and extending the service life of USCGC POLAR SEA until at least September 30, 2022, to maintain United States polar icebreaking capabilities and fulfill the Coast Guard's high latitude mission needs, as identified in the Coast Guard's July 2010, High Latitude Study Mission Analysis Report, during the Coast Guard's recapitalization of its polar class icebreaker fleet.

Pursuant to Congressional requirements, this report is being provided to the following members of Congress:

The Honorable Bill Shuster
Chairman, House Committee on Transportation and Infrastructure

The Honorable Nick J. Rahall II
Ranking Member, House Committee on Transportation and Infrastructure

The Honorable John D. Rockefeller IV
Chairman, Senate Committee on Commerce, Science, and Transportation

The Honorable John Thune
Ranking Member, Senate Committee on Commerce, Science, and Transportation.

I am happy to answer any further questions you may have, or your staff may contact my Senate Liaison Office at (202) 224-2913 or House Liaison Office at (202) 225-4775.

Sincerely,

R. J. PAPP, JR.
Admiral, U.S. Coast Guard
Commandant

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I. Legislative Language

This report responds to the language set forth in Section 222 *Coast Guard and Maritime Transportation Act of 2012* (Pub. L. 112-213) as per the following:

SEC. 222: COAST GUARD POLAR ICEBREAKERS.

(a) IN GENERAL.—The Secretary of the department in which the Coast Guard is operating shall conduct a business case analysis of the options for and costs of reactivating and extending the service life of the Polar Sea until at least September 30, 2022, to maintain United States polar icebreaking capabilities and fulfill the Coast Guard's high latitude mission needs, as identified in the Coast Guard's July 2010, High Latitude Study Mission Analysis Report, during the Coast Guard's recapitalization of its polar class icebreaker fleet. The analysis shall include—

(1) an assessment of the current condition of the Polar Sea;

(2) a determination of the Polar Sea's operational capabilities with respect to fulfilling the Coast Guard's high latitude operating requirements if renovated and reactivated;

(3) a detailed estimate of costs with respect to reactivating and extending the service life of the Polar Sea;

(4) a life cycle cost estimate with respect to operating and maintaining the Polar Sea for the duration of its extended service life; and

(5) a determination of whether it is cost-effective to reactivate the Polar Sea compared with other options to provide icebreaking services as part of a strategy to maintain polar icebreaking services.

(b) RESTRICTIONS.—The Secretary shall not remove any part of the Polar Sea until the Secretary submits the analysis required under subsection (a).

(c) DEADLINE.—Not later than 270 days after the date of enactment of this Act, the Secretary shall submit to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate the analysis required under subsection (a).

(d) REQUIREMENT FOR REACTIVATION OF POLAR SEA.—

(1) SERVICE LIFE EXTENSION PLAN.—

(A) IN GENERAL.—If the Secretary determines based on the analysis required under subsection (a) that it is cost-effective to reactivate the Polar Sea compared with other options to provide icebreaking services, the Secretary shall develop a service life extension plan for such reactivation, including a timetable for such reactivation.

(B) UTILIZATION OF EXISTING RESOURCES.—In the development of the plan required under subparagraph (A), the Secretary shall utilize to the greatest extent practicable recent plans, studies, assessments, and analyses regarding the Coast Guard's icebreakers and high latitude mission needs and operating requirements.

(C) SUBMISSION.—The Secretary shall submit the plan required under subparagraph (A), if so required, to the Committee on Transportation and

Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate not later than 180 days after the submission of the analysis required under subsection (a).

(2) DECOMMISSIONING; BRIDGING STRATEGY.—If the analysis required under subsection (a) is submitted in accordance with subsection (c) and the Secretary determines under subsection (a)(5) that it is not cost-effective to reactivate the Polar Sea, then not later than 180 days after the date on which the analysis is required to be submitted under subsection (c) the Commandant of the Coast Guard—

(A) may decommission the Polar Sea; and

(B) shall submit a bridging strategy for maintaining the Coast Guard's polar icebreaking services until at least September 30, 2022, to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.

(e) RESTRICTION.—Except as provided in subsection (d), the Commandant of the Coast Guard may not—

(1) transfer, relinquish ownership of, dismantle, or recycle the Polar Sea or Polar Star;

(2) change the current homeport of either of the vessels; or

(3) expend any funds—

(A) for any expenses directly or indirectly associated with the decommissioning of either of the vessels, including expenses for dock use or other goods and services;

(B) for any personnel expenses directly or indirectly associated with the decommissioning of either of the vessels, including expenses for a decommissioning officer;

(C) for any expenses associated with a decommissioning ceremony for either of the vessels;

(D) to appoint a decommissioning officer to be affiliated with either of the vessels; or

(E) to place either of the vessels in inactive status.

(f) DEFINITION.—For purposes of this section—

(1) the term ''Polar Sea'' means Coast Guard Cutter Polar Sea (WAGB 11); and

(2) the term ''Polar Star'' means Coast Guard Cutter Polar Star (WAGB 10).

II. Executive Summary

The Coast Guard has completed a business case analysis (BCA) of the options for and costs of reactivating and extending the service life of the Coast Guard Cutter (USCGC) POLAR SEA (WAGB 11) until at least September 30, 2022. The report focused on five main questions:

(1) an assessment of the current condition of the POLAR SEA;
(2) a determination of the POLAR SEA's operational capabilities with respect to fulfilling the Coast Guard's high latitude operating requirements if renovated and reactivated;
(3) a detailed estimate of costs with respect to reactivating and extending the service life of the POLAR SEA;
(4) a life cycle cost estimate with respect to operating and maintaining the POLAR SEA for the duration of its extended service life; and
(5) a determination of whether it is cost-effective to reactivate the POLAR SEA compared with other options to provide icebreaking services as part of a strategy to maintain polar icebreaking services.

Approach:

To conduct the analysis, the Coast Guard chartered a working group comprised of Coast Guard subject matter experts for operations, maintenance, mission support, and cost estimating and analysis. The Coast Guard employed third-party reviewers from Naval Sea Systems Command (NAVSEA) for sections III and V; University of Alaska-Fairbanks, Department of Geography & Arctic Policy for section IV; and Department of Homeland Security (DHS) Cost Analysis Division for section VI. NAVSEAs review is included as Appendix C and comments provided from the additional reviews were incorporated into the document.

The working group developed the following analytical approach:

- Assess the current condition of POLAR SEA via a site visit;
- Review findings and recommendations of the Polar Platform BCA from 2009 and the U.S. Polar Icebreaker Recapitalization from 2011, both completed by independent, non-governmental agencies for their use as independent third party comparative cost-benefit, and comprehensive acquisition impact analysis;
- Review and utilize recent POLAR STAR Reactivation Project work items and cost completion data in the cost estimate for reactivating POLAR SEA;
- Review the following documents:
    - High Latitude Study Mission Analysis Report Volumes 1 -3, July 2010;
    - Coast Guard High Latitude Mission Analysis Report (HLMAR), January 2012;
    - Coast Guard Polar Icebreaker Mission Needs Statement, 28 June 2013;
    - Operation Arctic Crossroads and Operation Arctic Shield planning documents and After Action Reports; and
    - Polar Icebreakers, Needs in a Changing World, 2007, National Research Council;
- Interview Coast Guard program management teams and review applicable program documents.

Findings:

A total of 43 mission critical systems in five general categories were assessed and assigned a condition rating. Overall, Propulsion, Auxiliary and Prime Mission Equipment are rated Poor to Fair, while Structure and Habitability are rated Fair to Good. POLAR SEA reactivation is estimated to cost $99.2 million (excluding annual operations and support costs) to provide 7-10 years of service to the Coast Guard. Given the age of the icebreaker, operations and support costs are projected to rise from $36.6 million in the first year of operation to $52.8 million in the tenth year of operation. Combining reactivation costs and point estimates for operating costs, reactivation would cost $573.9 million. Accounting for operational and technical uncertainties, using a 90% Confidence Level Risk Analysis, the total potential cost rises to $751.7 million.

Arctic seasonal icebreaking demands through 2022 can be met with existing and planned Coast Guard assets, as current requirements do not justify the need for heavy icebreaking capability in the Arctic. Heavy icebreaker capability is needed to perform Operation Deep Freeze in Antarctica, but Coast Guard assets may not be the only option available to the National Science Foundation to support this activity. Although a second heavy icebreaker would provide redundancy, the cost of this redundant capability would come at the expense of more pressing and immediate operational demands. POLAR STAR, when fully reactivated, will provide heavy icebreaker capability until a new icebreaker can be delivered to meet both current and emerging requirements.

III. Current Condition of CGC POLAR SEA

This section provides the details of the current condition of POLAR SEA as of April 2013. POLAR SEA's condition was assessed using a variety of methods, including Coast Guard-led studies, analyses and other historical documentation; discussions with Coast Guard *Polar*-Class icebreaker Subject Matter Experts, and an onboard inspection of the vessel.

Findings:

- Propulsion, Auxiliary and Prime Mission Equipment are rated Poor to Fair.
- Structure and Habitability are rated Fair to Good.
- POLAR SEA was removed from service in November 2011 and has been "cold-iron" and unmanned since that time. Long term layup procedures for inactive ships, in accordance with Naval Ships Technical Manual (NSTM) 050, were planned but not completed when the repair availability to conduct the layup was cancelled in June 2012.
- A total of 43 mission critical systems were assessed and assigned a condition rating:

Condition Rating	Number of Systems w/Rating
Excellent	10
Good	14
Fair	14
Poor	5
Total	**43**

Polar-Class icebreakers are unique and highly complex vessels designed for extended operations in the world's harshest environments. POLAR SEA's current condition is consistent with a vessel that is beyond its design service life; it would require significant resources to effectively reactivate and extend the service life an additional 7-10 years.

Background:

Table 3.1: POLAR SEA General Characteristics

Year commissioned:	1978
Hull Length:	399 feet
Beam:	83ft 6 in
Draft:	28 ft
Displacement:	13,194 tons
Propulsion:	diesel electric or gas turbine
Shaft Horse Power:	60,000 HP
Endurance:	28,274 NM
Speed:	13 knots
Continuous Icebreaking Capability:	6 ft at 3 kts
Back & Ram Icebreaking Capability:	21 ft
Crew Size:	146
Scientists:	35

POLAR SEA was commissioned in 1978 and is homeported in Seattle, WA. As of April 2013, POLAR SEA is five years beyond its originally designed 30 year service life.

POLAR SEA completed several major refit and repair periods over the decades in order to improve capabilities and reliability including the Polar Science Upgrades (PSU I & II) and Machinery Control and Monitoring System (MCAMS) refresh in the early 1990s and a Reliability Improvement Project (RIP) in the late 1990s. More recently, POLAR SEA completed an extensive, extended repair availability from 2004-2006 to address the significant degradation of the ship's electric propulsion motors. This work, which included the renewal of one of the motor armatures, in concert with other repair and recapitalization efforts, resulted in POLAR SEA's service life being extended to 2014. Additional recapitalization work was completed between 2006 and 2010.

With the National Science Foundation (NSF) decision to commercially contract the annual McMurdo break-in in Antarctica POLAR SEA saw very little service as a heavy icebreaker from 2007 to 2010.

While underway on a routine Arctic patrol in April 2010, POLAR SEA experienced a catastrophic failure of one of its Main Propulsion Diesel Engines (MDEs). As a result, all at-sea operations were suspended pending the results of a Root Cause Failure Analysis (RCFA). In May 2010 the ship entered a planned dry dock repair availability to conduct scheduled maintenance and system repair, improvements, renovations and upgrades and conduct the MDE RCFA. Additionally, the Coast Guard conducted a Ship Structure and Machinery Evaluation Board (SSMEB), a detailed, space-by-space condition assessment of the vessel. When POLAR SEA departed the shipyard in September 2010 the MDE RCFA determined that all nine of the vessel's ALCO 251 engines, six main propulsion engines (MDE) and three ship's service diesel generators (SSDG), required complete reconfiguration in order to prevent further catastrophic failures.

Limited diesel engine parts availability meant that both POLAR SEA and POLAR STAR (which was undergoing reactivation during this time period and had the same diesel engine configuration as POLAR SEA) could not complete the required engine work without significant schedule impact to either ship. This fact, considering the remaining service life of POLAR SEA, expected service life of POLAR STAR once reactivated, and limited personnel and resource availability, led to the decision in early 2011 to remove POLAR SEA from service and transfer its crew, operating budget, outfit and spares to POLAR STAR.

By November 2011 the transfer from POLAR SEA to POLAR STAR was complete; POLAR SEA was placed in cold-iron and unmanned at Base Seattle where it remained as of March 2013 when it was inspected as part of this report.

Approach:

The Polar class, and in particular POLAR SEA, has been subject to several comprehensive condition assessments within the past few years, including:

- Ships Structure and Machinery Evaluation Board, December 2010
- Machinery Supportability Review, November 2008
- Polar Platform Business Case Analysis, October 2010

As such there is a wealth of current documentation available from numerous sources that capture the physical state of the icebreaker. In addition, the reactivation of POLAR STAR has included extensive open-and-inspect requirements and total recapitalization of major systems. This effort has resulted in substantial insight as to the actual condition of the Polar Class and the true effort required to return these proud ships to heavy icebreaking service with an extended service life of 7-10 years.

The major reports were completed in 2010 so there is a notable gap in the documented condition from that point until today. POLAR SEA subsequently has had the crew, spares and outfit removed. The ship has sat cold-iron for nearly two years. Capturing these recent actions and assessing the impacts to the overall condition of POLAR SEA has been done through discussions with the cognizant Coast Guard personnel and a visit to the ship for a stem-to-stern inspection.

To determine the current condition of POLAR SEA, the approach used the existing documentation, along with the lessons learned from reactivating POLAR STAR, to form the foundation of the assessment. A follow-on ship inspection to identify and quantify any significant impacts that resulted from the ship's removal from service provided accompanying condition data. The resulting information provides the most up-to-date and conclusive assessment of the current condition of POLAR SEA.

Documentation Review:

Ship Structure and Machinery Evaluation Board (SSMEB)

SSMEB is the primary means the Coast Guard uses to determine the material condition of a specific cutter. The Coast Guard then uses this report to assess and make a recommendation regarding the expected remaining service life of that cutter's class. This information is intended to aid the Coast Guard in formulating cutter acquisition plans and modernization alternatives.

The SSMEB was convened onboard USCGC POLAR SEA (WAGB-11) 29 June - 09 July 2010 in Seattle, WA during a routine dry dock availability at Todd Pacific (now Vigor) Shipyards. The final report was signed by the board president in February 2011.

In the report, the board consolidated the space-by-space details of the condition assessment into primary system areas providing a summarized account in order to determine remaining service life. The specific remaining service life is of less concern in terms of this report, but the conclusions were reached via assessing the condition in detail and thus remain valid. The condition rating criteria used by the SSMEB is as follows:

- **Excellent** – Nothing required; no attention is expected for 10 or more years;
- **Good** – May need attention within 10 years;
- **Fair** – Will need attention within 5 years;
- **Poor** – Needs attention immediately during next repair period.

Throughout this section the SSMED is directly quoted, leading to time/tense discrepancies between the 2010 assessment and the current condition assessment. In general, the 2010 quotations are followed by lessons learned during the POLAR STAR reactivation and the results of the recent on board walk through.

- **Main Propulsion:** Overall, the main propulsion machinery is rated POOR for mechanical condition and FAIR for preservation and supportability. POOR rating is driven by Main Diesel Engine and Diesel Electric Propulsion Control System reliability issues.

- **Auxiliary:** Overall, the auxiliary machinery is rated FAIR for material condition and FAIR for supportability. This rating is driven by non-environmentally compliant air conditioning system, extensive ventilation system repair requirements and the continued retention of the gravity fed, salt-water sewage and sanitary systems.

- **Prime Mission Equipment:** Overall, the prime mission equipment is rated POOR for material condition and POOR supportability. The cargo cranes are unreliable, unsupportable and have significant safety issues. The science winches have not been properly maintained. In addition the control system is obsolete and unsupportable.

- **Structural:**

  Shell Plating
  The condition of the structure from the exterior is FAIR with the exception of two dents. The maximum depth of dents was approximately 4 inches.

  A review of the ultrasonic readings indicated little or no wastage. Overall, based on visual examination and ultrasonic thickness measurements supplied, the exterior of the shell plate is in GOOD condition.

  The stem, stern frame and stern tube bossings were in GOOD condition.

  Watertight Bulkheads
  Overall, the structure and preservation of interior watertight bulkheads were rated FAIR. Superstructure is in FAIR condition.

  Framing and Longitudinals
  Overall, structure and preservation of the framing and longitudinals were in FAIR condition.

  Bilges
  There are limited coating failures and corrosion throughout the bilge area, tanks and voids. The bilges contain lead paint, a known hazardous material. Overall, the bilges were rated FAIR.

  Decks
  Exterior decks are in FAIR condition. Non non-skid areas are in FAIR condition with corrosion occurring around several weld seams at the base of machinery and rails. Estimated life expectancy of the exterior decks is the life of the vessel.

  Deck Covering
  Overall, the structural and preservation of the deck covering systems were rated in FAIR condition.

  Mast

Main mast was found to be in GOOD condition. The condition of preservation is FAIR.

Hull Fittings
Hull fittings are rated FAIR.

Habitability
Overall, habitability was found to be FAIR.
Berthing areas are adequate and livable, but in need of cosmetic updating (painting, new carpeting, updated lighting). False bulkheads prevented a full evaluation of the structure in some spaces like berthing areas. There are extensive amounts of asbestos-containing materials throughout the ship and particularly in the berthing areas.

Overall, the SSMEB concluded that the ship's structure is sound, though in need of extensive preservation work, and that most machinery and distributed systems are in dire need of overhaul, repair, or outright replacement. This conclusion is consistent with the conditions found on POLAR STAR during reactivation and the condition assessment conducted as part of the Polar Platform BCA.

Events Since the Completion of the SSMEB:

POLAR SEA Removal from Service:

The Coast Guard officially decided to remove POLAR SEA from service in April 2011, with a planned transfer to the Maritime Administration (MARAD) and induction into the National Defense Reserve Fleet (NDRF) in Suisun Bay, CA. Following a transfer of its outfit and spare parts to POLAR STAR, POLAR SEA was tied up cold-iron and unmanned at Pier 36 in Seattle, WA. On 01 November 2011, the Coast Guard placed POLAR SEA in Inactive status via Operational Facilities Change Order (OFCO) 038-11.

While awaiting disposition, POLAR SEA has not had maintenance or preservation work needed to prevent deterioration and continues to degrade at a steady rate. At Pier 36, POLAR SEA has only those systems operating considered essential to keep the ship safe and secure including: limited ventilation and lighting; fire and flooding monitoring with off-ship and external alarms; and main propulsion motor and generator heaters.

Main Diesel Engine Testing:

POLAR SEA's catastrophic MDE failure in April 2010 led to a RCFA to identify the underlying reasons for the casualty. Ultimately the RCFA did not discover a definitive root cause; the Coast Guard Technical Authority directed the Polar Class icebreakers to re-build all ALCO 251 diesel engines from the Plus upgraded configuration to the original Premium configuration that served reliably for over two decades. This re-configuration to Premium style engine parts introduced significant schedule and cost impacts to POLAR STAR's reactivation. In order to minimize risk and increase confidence in the Premium configuration, two MDEs on POLAR SEA were re-built and then test run for 500 hours at high power levels as a proof of concept during the winter/spring of 2011. Inspections at the conclusion of testing showed significantly improved wear characteristics using the Premium configuration so the installation proceeded on POLAR STAR. Since POLAR SEA was slated for disposal, the engines were not fully restored after testing, major components were secured for sea, and plastic tarps draped over the open engine blocks, which is how the engines remain today.

Condition Assessment:

An inspection of POLAR SEA was carried out on 27 March 2013 at the ship's mooring at Pier 36, Base Seattle. For each mission critical system identified in the SSMEB, the results of the 2010 report are quoted as a baseline condition assessment. The actual condition found and work completed during POLAR STAR Reactivation for each system provides further information for evaluation of the system. Final amplifying information and a projected work list from the Onboard Inspection conducted in March 2013 is provided.

Main Propulsion

Overall the main propulsion system was rated POOR.

The *Polar*-Class icebreakers utilize a Combined Diesel or Gas Turbine (CODOG) main propulsion system arrangement which permits two independent modes of propulsion to turn the same propeller depending on the particular demands of the vessel's mission. In diesel-electric mode, each of the three propeller shafts has two 3,000 horsepower (HP) MDEs that generate electrical power to turn a 6,000HP Direct Current (DC) electric motor for a total installed capacity of 18,000HP. This mode is used for light icebreaking and open water transits since it affords significantly increased fuel economy compared to the gas turbine mode. In gas turbine mode each propeller shaft has one 20,000HP gas turbine connected to it via a reduction gear (the main motors are disconnected) for a total capacity of 60,000HP and this mode is used for heavy icebreaking and substantially increases fuel consumption. The engine technology is 1960's era, but is still supported by Original Equipment Manufacturer (OEM).

Main Diesel Engines:

- *SSMEB:* The propulsion diesel engines are in POOR mechanical condition and there is a long lead-time for many parts. The propulsion diesel engines were upgraded from the Fairbanks Morse 251 Premium version to the 251 Plus in 2008. A RFCA is currently being conducted to determine the reason for the failures being seen by both Polar Icebreakers.

- *POLAR STAR Reactivation:* The RCFA did not identify a single root cause for the diesel engine failures, thus the Coast Guard Technical Authority directed that all Polar Class icebreaker ALCO 251 diesel engines be re-configured from the Plus to the Premium configuration. This will require that all nine ALCO 251 (6 MDEs & 3 SSDGs) be rebuilt to the Premium configuration.

- *On Board Inspection:* Block Renewal. During routine overhaul of two MDEs (1A and 3A) in the fall of 2010, both engines were found to have several main crank bearing clearances out of tolerance. Repair and renewal options were investigated but for all intents and purposes the engine blocks were condemned. POLAR SEA was removed from service prior to a repair option being finalized, so for the purpose of this assessment it is anticipated that both of those MDE blocks will require renewal in addition to reconfiguration to Premium.

  Engines Not Restored After Testing. The two MDEs (2A and 2B) used for Premium diesel engine testing in the spring of 2011 were not maintained in operable condition at the completion of testing due to the planned decommissioning (Figure 1). Both engines are in various states of disassembly and are covered with plastic sheeting.

Figure 3.1: Current condition of 2A MDE (left) and 2B MDE (right).

Propulsion Gas Generators and Turbines:

- *SSMEB:* The gas turbines are in FAIR condition, both mechanically and logistically.

  The Main Gas Turbine (MGT) Digital Fuel Control System (DFCS) system recap was installed as a prototype on the #1 MGT in 2009 and has successfully operated in all modes except extended heavy icebreaking.

- *POLAR STAR Reactivation:* MGT Renewal. All three MGTs, which consist of two components; a gas generator and power turbine, were renewed due to improper layup while POLAR STAR was inactive.

- DFCS Upgrade. The DFCS was successfully installed and tested on all three MGTs during POLAR STAR reactivation.

- *On Board Inspection:* MGT Renewal. POLAR SEA's MGTs have not operated since 2010 and were not properly laid up prior to removal from service; it is anticipated that all three MGTs will require renewal.

  Digital Fuel Control System. #2 and #3 MGTs will require installation of the DFCS. The prototype system on the #1 MGT will require modification to incorporate lessons learned from the POLAR STAR installation in order to bring it up to standard configuration.

Propulsion Generators:

- *SSMEB:* The propulsion generators are in GOOD condition. They are operational and there have been no major support problems, despite Westinghouse no longer supporting this machinery. Alternate technical and parts support is available.

- *POLAR STAR Reactivation:* All of the propulsion generators were inspected, cleaned and several required minor dynamic balancing.

- *On Board Inspection:* It is anticipated that POLAR SEA will require similar effort as was done on POLAR STAR.

Propulsion Motors:

- *SSMEB:* The Propulsion Motors are in EXCELLENT condition. All Main Propulsion Motors were completely cleaned and overhauled and the #2 Main Propulsion Motor armature was renewed with the deep insurance spare on POLAR SEA during their extended availability in 2005-07. The Westinghouse propulsion motor has no OEM technical support, but alternate sources are available.

- *POLAR STAR Reactivation:* All three main propulsion motors were cleaned and overhauled, no armature renewals were required.

- *On Board Inspection:* Motor heaters are energized, only routine maintenance work would be anticipated to return to service.

Main Motor Lube Oil System:

- *SSMEB:* The main motor lube oil system is in EXCELLENT condition. It is operational and has fair parts support for the pump. No major problems were identified.

- *POLAR STAR Reactivation:* Routine repairs and maintenance were completed.

- *On Board Inspection:* Routine repairs and maintenance would be expected.

Propulsion Control System: Switchgear, Rectifiers, and Exciters:

- *SSMEB:* The Propulsion Control System is rated FAIR.

  The Polar Class employs obsolete 1973-vintage Westinghouse analog motor and generator field supplies. Westinghouse left the DC drive market in the early 1990s. There is currently no support or spare hardware for these controls available. If the 35 year old analog boards fail or are damaged, the icebreaker's electric propulsion system will be inoperable, potentially leaving the ship dead in the water in the middle of a mission. There are commercial and military (NAVSEA) sources available to recapitalize the drive system. Immediate research into either a scaled or wholesale replacement is needed.

  The existing switchboard, rectifiers, and exciters are operational. However, as stated in numerous cutter engineering reports, the system is antiquated, technically difficult to repair, and the equipment is unsupported by Westinghouse. The [Equipment Supportability Review] ESR deemed this equipment as having no end item or repair parts support. Immediate research into either wholesale replacement or reverse engineering is needed.

  Propulsion Rectifiers - The propulsion rectifiers are in fair condition, both mechanically and preservation. They are rated POOR for parts and technical support. The diodes are hard to locate because the Westinghouse system is obsolete. The breakers are supportable. Circuit boards are the weakest link. For each cabinet, there are six relay boards and each relay board has 6 relays.

  Propulsion Generator Exciter-Regulators – Even though the OEM does not make this any longer, parts circuitry can be refurbished. Faulty circuit boards can be sent out for commercial repair. Current digital technology far surpasses the installed analog system.

- *POLAR STAR Reactivation:* Propulsion rectifiers were cleaned.

  The near term solution for supply support of the propulsion control system for POLAR STAR was to remove all the installed components and spares from POLAR SEA once it was removed from service.

- *On Board Inspection:* With all the critical propulsion control components and spares removed to support POLAR STAR, restoration of this system on POLAR SEA would be a significant undertaking in order to avoid cascading impacts to the operational availability of POLAR STAR. An engineering investigation into recapitalizing this system is in the early stages with the scope already increasing to include the marginally supportable generator governor controls and drive units. Recapitalization carries substantial risk as known technical challenges and the engineering, design, funding, procurement, testing, integration and final full installation would produce minimal viable return on investment when considering the limited remaining service life.

Reduction Gears:

- *SSMEB:* The reduction gears are in EXCELLENT condition and are still fully supported by the Philadelphia Gear Company. They were overhauled in 2008 and appear to be in good working condition.

- *POLAR STAR Reactivation:* All three reduction gears were completely overhauled along with installation of all new bearings. The starboard and centerline reduction gears require two bearings to be modified to permit oil flow to the visual indicators (bubblers). All pumps, motors and coolers were inspected, cleaned and repaired as required.

  Reduction Gear Lube Oil Sump Heaters. Redesigned lube oil sump heaters were installed but all failed in service during the reduction gear flushing. Several design deficiencies were identified and modified heaters are due to be installed.

- *On Board Inspection:* The type of lube oil sump heater that failed on POLAR STAR is still installed on POLAR SEA and will need to be renewed with the improved design.

Propulsion Shafting and Bearings:

Aft Stern Tube Bearings:

- *SSMEB:* The Aft Stern Tube Bearings have recently been modified and untested. Results are expected to achieve a minimum rating of GOOD. The original design of the aft stern tube bearing system utilized bearing shell lands that were integrally cast into the HY80 steel stern tube bossings. The icebreaking loading on the shafting over the service life of the ship has caused the clearance between the lands and the bearing shell to open up to beyond acceptable limits. Since they are cast steel it is not possible to return the lands to their original dimensions by weld build up so a complete redesign of the aft stern tube bearing system was required. The new design utilizes a modified bronze bearing shell that is continuously supported in the stern tube bossing using Chockfast Orange. The bearing shell was further modified to accept a split cylindrical Thordon bearing in lieu of the original dovetail style Thordon staves.

  This new aft stern tube bearing system was installed on POLAR SEA during their extended repair availability in 2005-07. During the dry docking in 2010 the bearings were inspected for the first time. The hardware used in the Thordon shell wedge retainer was found broken and suffering from excessive corrosion. Investigation by the bearing system designer (Lamalo) and Thordon found that the hardware was undersized and that the material needed to be changed to provide increased corrosion resistance. These changes were incorporated on both POLAR SEA and POLAR STAR which is scheduled to receive this modification as part of the reactivation availability. This redesign is still considered a prototype since the bearing system has not been proven in the heavy icebreaking conditions encountered during a Deep Freeze Mission.

- *POLAR STAR Reactivation:* All three aft stern tube bearings were modified during reactivation.

- *On Board Inspection:* No further work would be anticipated.

Forward Stern Tube Bearings:

- *SSMEB:* The forward stern tube bearings are rated GOOD. They still utilize the original Thordon dovetail design carried in a bronze bearing shell and are only used on the port and starboard wing shafts. The forward bearing shell lands differ from the aft in that they are welded steel rings and can be more readily replaced when they exceed their design wear limits. The starboard forward bearing land rings were replaced on POLAR SEA during the 2010 dry dock availability along with the bronze carrier which was machined to match fit the new rings. The port side was still within dimensional tolerance, but will most likely require repairs at the next dry dock.

- *POLAR STAR Reactivation:* The port forward stern tube bearings lands and shell were found beyond tolerance. The lands, shell and staves were renewed.

- *On Board Inspection:* It is anticipated that the port forward lands, shell and staves will require renewal during a reactivation.

Cooper Split Roller Bearing:

- *SSMEB:* The Cooper Split Roller Bearing is in GOOD condition. It is used on the significantly longer centerline shaft in lieu of the forward stern tube bearings on the wing shafts.

- *POLAR STAR Reactivation:* The Cooper Bearing was renewed. Once POLAR STAR was back in the water and the final propulsion shaft alignment checks were completed it was found that the Cooper Bearing could become misaligned after several years of bearing wear. Re-adjustment to prevent possible future misalignment is scheduled for the next dry dock availability in 2014.

- *On Board Inspection:* The Cooper Bearing has seen very little use and should continue to be useable.

Propulsion Shafting:

- *SSMEB:* Propulsion Shafting is rated EXCELLENT. Shafts are expected to last 20 years or more. Frequent repairs of the internal oil tubes are required. Technical support is available and there are two spare shafts.

Thrust Bearing:

- *SSMEB:* The Thrust Bearing is rated EXCELLENT. There have been no problems associated with the thrust bearings and no leaks have been observed. The large size of the thrust bearing makes it unique to the USCG. Thrust bearing foundations have been prone to cracking in the past, careful inspection after each icebreaking mission has identified repairs when required.

- *POLAR STAR Reactivation:* The thrust bearings were opened and inspected and found in wear good condition and alignment.

Controllable Pitch Propellers (CPP):

- *SSMEB:* The CPPs are rated POOR.

  The following discussion is quoted from the Polar Service Life Extension Project (SLEP), Option A, Scope and Feasibility Analysis submitted by M. Rosenblatt and Son/AMSEC LLC, May 2006 and is an excellent description of the challenges that still confront the CPP system:

  Controllable Pitch Propellers and Associated Hydraulic Systems. This remains the most significant problem that must be solved if the cutters are to continue to provide reliable service. The propellers are subject to particularly severe conditions during heavy icebreaking conditions and a significant failure may lead to cancellation of a mission, as well as presenting the potential for leakage of hydraulic fluid to the environment. There are issues relating both to the propeller hubs themselves and the internal hydraulic system components. The following discussion will continue to address the propeller hubs separately from the rest of the CPP system for three reasons: 1) their current condition is different than the rest of the system, 2) the likelihood for a known fix is different, and 3) the propeller hubs cannot be repaired while the ship is deployed or while in the water which vastly impacts operational availability.

  Propeller Hubs. The hubs are rated POOR. In recent years, it has been necessary to dry dock the cutters and inspect the propeller hubs after every heavy icebreaking deployment. Throughout the 50 years of experience with the two Polar Class ships, the interval between hub overhauls has never been more than two heavy icebreaking missions. According to the Coast Guard Technical Point of Contact for the CPP hub overhaul contract, every time the hubs have been overhauled there has been some unusual wear, scoring, cracking, leaking, broken parts or other indicator that it was appropriate that the hubs be overhauled before an additional heavy icebreaking mission was attempted. In other words, there has been no indication that overhauls were unnecessarily being performed at too short an interval. Over the past 25 years, dozens of modifications have been made to the hubs attempting to eliminate the negative conditions found. Typically corrections in one spot have lead to new symptoms in another location. Sizes, clearances, and material strengths are in critical balance. While the hubs have undoubtedly been improved over the past 25 years, their service life without overhaul remains relatively short. In addition to explaining the basics of Operational Availability (Ao), Appendix G develops an estimated Ao for the CPP hubs. This appendix develops a range of estimates for CPP hub [Mean Time Between Failure] MTBF that equate to a range of Ao of 24% to 44%, all clearly below the goal of 90%. Appendix G also provides the rationale for stating that heavy icebreaking hours (measured by MGT hours) should be held below 400 hours between overhauls to ensure mission success. Since there is no known means to significantly increase the MTBF of the CPP hubs and the current maintenance budget of $7.5M per year is insufficient to dry dock both ships every year, a major constraint in this report is keeping the number of heavy icebreaking hours for each ship under 400 hours in each two year period. This means that each ship can perform the heavy icebreaking of the Deep Freeze mission (up to 250 hours of MGT operations) once in each two year period and perform other scientific missions in their non-Deep Freeze year as long as the total

MGT operation hours remain less than 400 hours. Hours on the centerline gas turbine should be used for this metric since the ships are occasionally operated in combinations of MDEs on the wing shafts and the MGT on the centerline (known as 2-T-2). The current condition of the CPP hubs would be judged as fair in a physical inspection; however in the context of this report predicting future reliability, the hubs must be judged as POOR due to their inherently short MTBF with no known means of significantly increasing the MTBF.

Open Loop Controllable Pitch Propeller System Conversion. A prototype open-loop CPP system has been installed on the starboard shaft of the POLAR SEA in 2009. This comprehensive and complex prototype replaces all the mechanical and piping systems including the servo, pilot and charge pumps, hydraulic piping and filtration, salt water cooling system, control interface to MCAMS, pitch setters, etc. and installs a 600 gallon CPP oil tank with heater. Only the oil distribution box, shafting and CPP hubs are retained. The prototype system has so far performed well in open water and moderate icebreaking conditions once the typical challenges of a prototype of this complex scope and scale were addressed. POLAR STAR is scheduled to complete the conversion to all three shafts during reactivation; POLAR SEA will receive the conversion to the centerline and ports shafts as schedule and funding permit.

- *POLAR STAR Reactivation:* All three shafts were converted to the open loop CPP system, all three oil distribution shafts were open and inspected, all three propeller hubs were renewed with overhauled spares during the reactivation. As of April 2013 the open loop system still has not been operated in heavy icebreaking conditions, ice trials scheduled in the summer of 2013 should provide an opportunity to verify operability at the high loading levels encountered in heavy ice conditions.

- *On Board Inspection:* The starboard shaft still has the functioning prototype open loop CPP system while the other two shafts retain the old closed loop system. The open loop equipment and parts that were slated for installation on the two remaining shafts on POLAR SEA were redirected to POLAR STAR so two additional ship sets would need to be procured along with back fitting of any lessons learned from POLAR STAR on to the prototype to bring it in alignment with the most current configuration.

Propeller Hubs.

There are three complete ship sets of Polar Class CPP hubs, at any one time two sets are installed on the icebreakers and one set is undergoing overhaul. Additionally, the Coast Guard once had deep insurance spares and replacements for major propeller components, such as the blades. However, due to casualties to the propellers over the years, all spares and replacements have been consumed. Manufacture of replacements could take up to two years. With only POLAR STAR in service, the plan was to remove one right hand and one left hand propeller from POLAR SEA to replenish the supply of deep insurance spare components in case of damage to one of the in-service hubs. If POLAR SEA is reactivated, spare blades would be procured as deep insurance spare. This cost is accounted for in the reactivation estimate.

Machinery Control and Monitoring System (MCAMS):

- *SSMEB:* The MCAMS is rated FAIR. The ESR determined that the machinery control system is no longer supported by TANO. All parts must be custom built. Naval Surface Warfare Center (NSWC) Dam Neck is supporting the MCAMS and Propulsion Control and Monitoring System (PCAMS). The organization has been providing excellent support. MCAMS will require annual funding to provide updates. A three phased effort to replace obsolete hardware and software has been implemented on POLAR SEA with substantial success; POLAR STAR will receive the upgrades during their reactivation. There is no immediate need to renew the [Machinery Plant Control and Monitoring System] MPCMS, particularly if phased recapitalization continues. The ten-year forecast for support of the MPCMS has improved since 2002 due to the solid performance by NSWC.

- *POLAR STAR Reactivation:* The MCAMS and PCAMS were completely renewed by NSWC Dam Neck during reactivation.

- *On Board Inspection:* POLAR SEA's MCAMS and PCAMS upgrade installation was halted when it was removed from service. It is estimated to be about 50% complete and would require back-fit of lessons learned from POLAR STAR.

Auxiliary Machinery:

Ship Service Diesel Engine:

- *SSMEB:* The Ship Service Diesel Engine is rated POOR. Two of the three diesel generator engines have recently been recapitalized from the Fairbanks Morse 251 Premium version to the 251 Plus version. This version exhibits early failure similar to the 251-Plus configured MDEs.

- *POLAR STAR Reactivation:* All three SSDGs were converted to the ALCO 251 Premium configuration.

- *On Board Inspection:* All three SSDGs would require conversion to the ALCO 251 Premium configuration, to varying extents depending on each engine.

Lube Oil Purifiers:

- *SSMEB:* The Lube Oil Purifiers are rated GOOD. Although they work well mechanically, the Alfa Laval Lube Oil Purifier parts have a long lead time (3 months). Technical support from the OEM tech reps has been excellent.

- *POLAR STAR Reactivation:* Routine overhaul and maintenance completed.

- *On Board Inspection:* Routine overhaul and maintenance would be expected.

Ship Service Diesel Generator (SSDG):

- *SSMEB:* The SSDG is rated FAIR.

- The POLARs employ obsolete 1973-vintage Westinghouse analog motor and generator field supplies. Westinghouse left the DC drive market in the early 1990's. There is currently no support or spare hardware for these controls available. If the 35 year old analog boards fail or are damaged, the icebreaker's electric propulsion system will not operate, potentially leaving the ship dead in the water in the middle of a mission. There are commercial sources available to recapitalize the drive system.

  Currently the diesel generator sets are operational. The generators have no overload capacity. Two generators are always running, and if one generator fails under load, the other generator trips offline. The ship service bus needs to be evaluated. More research is needed to determine whether additional electrical capacity is required.

- *POLAR STAR Reactivation:* All three SSDGs were opened, inspected and cleaned. Functional components and spares were removed from POLAR SEA to provide supply support for POLAR STAR.

- *On Board Inspection:* All three SSDGs will need to be opened, inspected and cleaned. Functional components and spares that were removed from POLAR SEA to provide supply support for POLAR STAR will need to be acquired.

- Electrical Load. An Electrical Load Analysis (ELA) was conducted on POLAR SEA during the last leg of its last mission in 2010.The results were not conclusive as additional load measurements are required while the ship is operating in tropical conditions. Further investigation will have to be conducted on POLAR STAR during a tropical transit.

Emergency Diesel Generator (EDG):

- *SSMEB:* The EDG is rated EXCELLENT. It remains operational and fully supportable through commercial, off-the-shelf (COTS) equipment.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Auxiliary Boilers:

- *SSMEB:* The auxiliary boilers are rated EXCELLENT. They have recently been re-tubed and incorporate new fuel controls. Despite their large size, they are relatively generic auxiliary boilers that can interchange vendor parts and components.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Boilers have only been drained and dried out; they have not been prepared for a long term layup.

Evaporators:

- *SSMEB:* The Evaporators are rated GOOD. The Beaird Industries Maxim Desalinator Model 2-TCFE-10-SC evaporators were installed new as part of the Reliability Improvement Program (RIP) Phase II. "New" units installed, but 10 years old at installation, therefore, supportability is marginal because some parts are not readily available. The reverse osmosis unit has been removed leaving only the evaporators onboard the POLAR SEA.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Incinerator:

- *SSMEB:* The incinerator is operational and is rated GOOD. However, operation is labor intensive, particularly when trying to burn sludge. The current supportability (technical and parts) of the incinerator is limited. Therefore, the ESR deemed this equipment as having no end item or repair parts support. The incinerator is maintained by ship's force, and the onboard machine shop fabricates custom-made parts.

- *POLAR STAR Reactivation:* Routine maintenance and repairs.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Oily Water Separator:

- *SSMEB:* The oily water separator is operational and is rated GOOD. The separator has been updated to a plate-type separator.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Steering Gear:

- *SSMEB:* The steering gear system is operational and is rated FAIR. It is not currently supported technically or with parts since it was a Coast Guard unique system. The ESR determined that the manufacturer cannot identify the item. The steering box, which is unique and barely supportable by ship's force, has a + or – 5 degree variance. The servo pumps have no support and cannot be integrated with the bridge.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Helicopter Power Supply:

- *SSMEB:* The helicopter power supply is a newly installed system and is rated EXCELLENT.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Local Monitoring & Alarm System:

- *SSMEB:* A Siemens fire detection system was recently installed and is in EXCELLENT condition. The system is fully supported.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Ventilation System:

- *SSMEB:* The ventilation system is rated FAIR. Numerous sections of ducting and topside intakes have been renewed in the past few years. Ventilation ducting must be replaced throughout the ship.

  The air-conditioning (AC) plants are currently operational but the refrigerant needs to be replaced from R22 to a non-ozone-depleting equivalent. The ESR found it to be fully supportable.

  An air conditioning system replacement engineering study has been completed but electrical load issues surrounding the desire the up-rate the capacity of the system need to be resolved before moving forward.

- *POLAR STAR Reactivation:* Extensive deterioration was found throughout the ventilation system resulting in substantial repairs. Air conditioning plant and chill water system underwent routine maintenance and repairs.

- *On Board Inspection:* No ventilation systems were opened, but equivalent conditions to those found during POLAR STAR reactivation are anticipated. Further engineering investigation into the AC plant/ventilation system found that the original design requirements for make-up air greatly exceed normal standards, which have a significant effect on AC plant performance in the tropics where cooling problems manifest themselves the greatest. Further engineering study and system performance measurements need to be taken during a tropical transit.

Uncontaminated Seawater System:

- *SSMEB:* The seawater system is in POOR condition and requires replacement. Continuous/numerous leaks occur and the Carver pumps are not supported and require replacement. The ESR deemed this equipment as having no end item or repair parts support.

- *POLAR STAR Reactivation:* Science systems were not addressed during the reactivation. The Coast Guard is waiting for the National Science Foundation (NSF) to formally address science system needs on *Polar*-Class cutters.

- *On Board Inspection:* Inspection was deferred pending a National Science Foundation (NSF) determination of science system needs on *Polar*-Class cutters.

Fire Main and Flushing (Seawater) System:

- *SSMEB:* The fire main system is maintenance intensive and is rated FAIR. The fire pumps are a recurring repair item. They are nearing the end of their service life and are no longer supported by Carver, resulting in lead times in excess of 11 months for parts. Full replacement of the fire pumps is needed so that they can be operational and fully supported. The ESR deemed this equipment as having no end item or repair parts support.

- *POLAR STAR Reactivation:* Fire main valves and piping required extensive repairs. A supportable fire pump replacement (common to the 378' High Endurance Cutter, WHEC) is slated for installation in the next year on the POLAR STAR.

- *On Board Inspection:* Fire pumps would need to be replaced with the system installed on POLAR STAR.

Sanitary Systems:

- *SSMEB:* The sanitary systems are rated FAIR. The piping has issues since it is a gravity system suffering from stagnant water "pooling" within the pipes, which causes corrosion and results in continuous pipe replacement and repairs. The sewage pumps are not supported. The ESR deemed this equipment as having no end item or repair parts support.

- *POLAR STAR Reactivation:* Sewage system piping and tanks required extensive repairs.

- *On Board Inspection:* The sewage system was flushed with fresh water prior to removal from service, but no long term layup was undertaken. Substantial repairs would be anticipated if the POLAR SEA were to be reactivated.

Fresh Water Systems:

- *SSMEB:* The potable water system is operational and is rated GOOD. The ESR deemed this equipment as having no end item or repair parts support.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Chilled Water System:

- *SSMEB:* The chilled water system is operational and is rated GOOD. There are currently condensation problems that need to be addressed so that increased maintenance issues do not result.

- *POLAR STAR Reactivation:* Routine maintenance and repairs.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Diesel Fuel Transfer & Purification System:

- *SSMEB:* The diesel fuel transfer and purification system is rated EXCELLENT. No major problems presently exist.

- *POLAR STAR Reactivation:* Lack of use of the system while POLAR STAR was inactive resulted in extensive maintenance and repairs to valves and valve manifolds.

- *On Board Inspection:* The system was not laid up and will not be used while POLAR SEA is inactive so extensive maintenance and repairs to valves and valve manifolds similar to what was found on POLAR STAR during reactivation would be anticipated.

Starting Air System:

- *SSMEB:* The starting air compressors have recently been renewed to Ingersoll Rand compressors which are fully supportable.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Aqueous Film Forming Foam (AFFF) Systems:

- *SSMEB:* The AFFF system is rated FAIR. The KIDDE/FEECON inline inductors are no longer operational and are not supported, thus requiring replacement. The AFFF system piping has lost over 50% of the wall thickness due to corrosion. It requires replacement. The ESR deemed this equipment as having no end item or repair parts support.

- *POLAR STAR Reactivation:* Maintenance and repairs. POLAR STAR encountered difficulty post-reactivation in getting the Machinery Foam system to proportion correctly and was still troubleshooting the cause at the time this report was completed. Currently there is no Pending Time Compliant Technical Orders (TCTO) in process to renew the

AFFF system, the outcome of POLAR STAR's troubleshooting may result in a new TCTO request.

- *On Board Inspection:* Routine maintenance and repairs would be expected, pending the outcome on POLAR STAR.

Halon Systems:

- *SSMEB:* The Halon system is rated GOOD. It is operational and fully supported by the USCG. Due to the ban on Halon gas because of its ozone depleting properties, the Coast Guard is dependent on the Navy, which has stockpiled the gas for military vessels that have Halon systems already installed, and also commercial entities who reclaim gas for redistribution.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Routine maintenance and repairs would be expected.

Central Hydraulic System (CHS):

- *SSMEB:* The central hydraulic system is rated FAIR. It is operational, but piping decay has resulted in system-wide contamination that impacts the safe and reliable operation of the equipment. Furthermore, the piping design requires improvement in order to mitigate future repairs. The piping often leaks, resulting in continuous maintenance needs. Leaks are especially prevalent in the pumps and filter/manifold room. The current system has excess capacity because major loads have been removed (heeling system pumps and boat davits).

- *POLAR STAR Reactivation:* As part of renewal of the cargo cranes the CHS has been eliminated and replaced with redundant Hydraulic Pump Units (HPUs) for each major piece of equipment.

- *On Board Inspection:* The system would need to be removed and renewed with new cargo cranes as was done aboard POLAR STAR.

Anchor Windlass:

- *SSMEB:* The anchor windlass is rated FAIR. It is operational, but not supportable. The ESR deemed this equipment as having no end item or repair parts support. All replacement parts are custom made and come at a premium cost, many times the list price for similar parts in production.

- *POLAR STAR Reactivation:* The anchor windlasses share a common hydraulic system with the new forward 3 ton crane. The anchor windlasses were overhauled.

- *On Board Inspection:* The anchor windlasses would share a common hydraulic system with a new forward 3 ton crane and would need to be overhauled.

400 Hz Switchboard:

- *SSMEB:* There are two 400 Hz Switchboards, rated GOOD.
- *POLAR STAR Reactivation:* Routine maintenance and repair completed.
- *On Board Inspection:* Routine maintenance and repairs would be expected.

Bus transfer switches:

- *SSMEB:* The bus transfer switches are for emergency gear and are rated FAIR. Parts support is POOR.
- *POLAR STAR Reactivation:* Routine maintenance and repair completed.
- *On Board Inspection:* Routine maintenance and repairs would be expected.

Electrical distribution system:

- *SSMEB:* The distribution system has been rated GOOD for mechanical, FAIR for preservation, and POOR for parts and technical support.
- *POLAR STAR Reactivation:* Routine maintenance and repair completed.
- *On Board Inspection:* Routine maintenance and repairs would be expected.

Prime Mission Equipment:

Overall System:

- *SSMEB:* The remaining service life for prime mission equipment was zero (0) years, driven primarily by the condition of the cranes. However, knowing replacement cranes are imminent, the overall service life for the vessel is depicted at five (5) years.

Cargo Cranes:

- *SSMEB:* Both the forward 3-ton and the aft 15-ton cranes are rated POOR. They are far beyond their economical service lives and have become a major safety issue due to their reliability. The effort to renew the cranes and eliminate the central hydraulic system is well underway.
- *POLAR STAR Reactivation:* Cargo cranes were renewed.
- *On Board Inspection:* Cargo cranes would require renewal. Two sets of cranes (one set for POLAR STAR and one set for POLAR SEA) were previously purchased and delivered as part of a planned recapitalization. POLAR SEA's cranes were placed in long term storage following its removal from service.

Boat Davit:

- *SSMEB:* The Motor Surf Boat Davit is not rated by the SSMEB. It was removed and replaced with the Miranda style boat davit which is highly supportable, but it has not yet been tested. The original davit location was not considered satisfactory for safe launch and recovery of the cutter boat so the davit has been moved aft during POLAR SEA's recent dry dock availability. At sea testing of the new davit location and cutter boat is required.

- *POLAR STAR Reactivation:* The Miranda davit was removed from POLAR SEA and installed on POLAR STAR during reactivation. Interface testing indicates that the davit's move aft, while safe to operate, requires additional work to meet operational requirements.

- *On Board Inspection:* A replacement davit would need to be purchased if the cutter were reactivated.

Oceanographic Winches:

- *SSMEB:* The Oceanographic Winches are rated FAIR to POOR. The electronics associated with the winches and Data Acquisition System are obsolete. Significant costs to repair in both time and monies indicate that the Oceanographic winch electronics and Data Acquisition system require an End of life Cycle review to include the status of the winch, Winch Electronic Drive, and Data Acquisition system. Support for the winches is provided by InterOcean and was rated as FAIR. The Board noted that per the existing Required Operational Capability/Projected Operational Environment (ROC/POE) Document, marine science is a primary mission requirement. The National Science Foundation primarily uses CGC HEALY for all scientific research, and has provided little to no funding to maintain the science equipment on the Polar Class vessels.

- *POLAR STAR Reactivation:* Science systems were not addressed during the reactivation. The Coast Guard is awaiting the National Science Foundation formally addressing science system needs on *Polar* Class cutters.

- *On Board Inspection:* Inspection pends determination of science system needs.

Structural:

- *SSMEB:* Based on the results of the inspection, the structure is rated EXCELLENT and the average remaining service life for the structure remains 25+ years. No significant wastage or corrosion was noted and no major repairs have been necessary since the last report.

- *POLAR STAR Reactivation:* Routine maintenance and repairs completed.

- *On Board Inspection:* Exterior coating systems are beginning to fail and would require renewal.

Habitability:

SSMEB: Habitability by today's standards on CGC POLAR SEA is FAIR.

- There are extensive amounts of asbestos containing materials throughout the ship and particularly in the berthing areas including deck tiles and insulating underlayment above the fuel tanks and joiner bulkhead panels. Current policy is to abate only when a contaminated area is disturbed, but the cost of this piecemeal approach can be upwards of ten times greater than that of repairing non-contaminated areas. Simple maintenance and routine repairs can be so costly that the ship's own funding is rapidly overwhelmed. Wholesale abatement should be considered if the ship is intended for service beyond 5 years.

- *POLAR STAR Reactivation:* Extensive abatement and living space overhauls were completed.

- *On Board Inspection:* Extensive abatement and living space overhauls would be required.

Electronic Systems:

- The majority of electronic systems have been removed and reclaimed from POLAR SEA to be used on POLAR STAR and other Coast Guard assets.

Outfit and Spares:

- Impacts since removal from service. POLAR SEA and POLAR STAR were rafted side by side for two weeks during August of 2011 in order to facilitate the transfer of outfit and spares from POLAR SEA to POLAR STAR. Storerooms were emptied, hard to replace parts were removed (i.e. Westinghouse propulsion control system circuit cards) and the majority of the POLAR SEA's outfit was moved over to POLAR STAR. Outfit and spares that remain onboard POLAR SEA have not been maintained (i.e. fire extinguishers have not had preventive maintenance completed) and continue to degrade with only the minimal amount of ventilation running.

IV. Analysis of POLAR SEA's Operational Capabilities

Traditional Missions

The Navy transferred icebreakers to the Coast Guard in 1965. The Coast Guard's polar icebreakers support all statutory missions, to include providing icebreaking support, both in the Arctic and Antarctic waters, to other government agencies engaged in scientific research.

From 1955 to 2007, the Coast Guard supported the United States presence in Antarctica, primarily through Operation Deep Freeze, the annual break out of the channel used for ship-based resupply of McMurdo Station. During that period, Coast Guard icebreakers also supported Antarctic Treaty inspections and scientific research through expeditions along the Ross Ice Shelf, throughout the Ross Sea, and around the entire continent. Since 2005, NSF, the lead federal agency for Antarctic operations, contracted foreign icebreakers to complete the break-in and escort. In FY 2005, FY 2006 and FY 2007, the foreign vessels served as back-up to the Coast Guard vessels. Beginning in FY 2008, with the POLAR STAR in caretaker status, the NSF retained the POLAR SEA as a standby icebreaker until engine failure sidelined the vessel in 2010. With the reactivation of POLAR STAR planned for the end of 2013, the Coast Guard is scheduled to support Operation Deep Freeze.

As a multi-mission asset, these icebreakers provide search and rescue capability and are prepared to assist other emergency operations, as needed. Due to the remote and harsh environment and ice-covered waters there has been limited need for an icebreaker to execute traditional Coast Guard statutory missions in the Arctic.

Current Operational Capability

POLAR SEA exceeded its 30-year design service life in 2008. Commissioned in 1978, POLAR SEA was designed to perform icebreaking and support high latitude science activity. With reinforced hull and a dual power plant capable of producing 60,000 horsepower continuously, the *Polar*-class vessel can break up to 21 feet of ice by backing and ramming, or 6 feet of level ice at a continuous speed of 3 knots. The dual-power plant configuration allows for economical cruising across open water using the diesel-electric plant and powerful icebreaking capability using the gas turbines when in ice. POLAR SEA is designed to carry two H-65 Coast Guard helicopters for mission and logistics support. Berthing is available for 146 crew members and as many as 35 scientists and technicians. It is equipped with five internal laboratories and space for seven additional portable laboratories on deck. An onboard fiber-optic data network facilitates data collection and archiving, and computers onboard have the capability to process real-time satellite images to aid in ice navigation, science planning, and weather forecasting.

The characteristics of POLAR SEA are provided in Table 4.2.

Table 4.2: CG Cutters with Icebreaking Capability in the U.S. Maritime Arctic

	POLAR SEA
Year commissioned	1978
Hull Length	399 ft
Beam	83 ft 6 in
Draft	28 ft
Displacement	13,194 tons
Propulsion:	Diesel electric or gas turbine (CODLOG)
Horsepower	D: 18,000 HP T: 60,000 HP / 75,000 peak
Cruising Range	28,274 nm
Endurance (unreplenished)	80 days
Speed	18 kts
Continuous Icebreaking Capability	6 ft at 3 kts
Back and Ram Icebreaking Capability	21 ft
Aviation Facilities	Flight Deck, Hangar for 2 x H-65
Oil Spill Response	N/A
Crew Size	146
Scientists/Surge Capacity	35

POLAR SEA is not an optimal platform for execution of Search and Rescue (SAR), Living Marine Resources (LMR), Marine Environmental Protection (MEP), and Ports, Waterways, & Coastal Security (PWCS) missions due to poor sea-keeping characteristics in open water. While excellent for heavy icebreaking and capable of executing some missions in ice-covered waters, the complex curvature of the hull design and lack of stabilizers results in limiting boat and aviation operations to Sea State 3 and below in open water. Furthermore, POLAR SEA's limited C4ISR capabilities reduce the ability to conduct effective Maritime Domain Awareness patrols.

With regards to scientific and logistics support, POLAR SEA possesses the necessary icebreaking capability and scientific laboratories, equipment, and space to provide dedicated support. However, the inability to independently ballast with water and the resultant need to ballast with fuel to maintain optimal icebreaking efficiency makes the *Polar*-class design suboptimal for the Antarctic resupply mission.

Expanding Operations

Interest in Arctic natural resource development and maritime activity is increasing with projections of an oncoming, long-term retreat of Arctic sea ice. Increased human activity and economic presence in the Arctic region is expected to intensify the Coast Guard mission demand in areas such as search and rescue, marine environmental response and law enforcement. The three volumes of the High Latitude Study project an increase in Coast Guard mission performance in the high latitudes, particularly in the Arctic. The HLMAR analyzed the Coast Guard's 11 mission programs with regard to projected changes in performance levels for both the Arctic and Antarctic. The projected change in mission performance levels were characterized as significant, moderate or low (Table 4.1).

Table 4.1: High Latitude Mission Performance Gaps[1]

Arctic	
Significant	Defense Readiness (DR); Ice Operations (IO); Marine Environmental Protection (MEP); Ports, Waterways, & Coastal Security (PWCS)
Moderate	Aids to Navigation (ATON), Other Law Enforcement (OLE), Search and Rescue (SAR)
Low	Living Marine Resources (LMR), Marine Safety (MS)
Antarctic	
Significant	Defense Readiness (DR); Ice Operations (IO);
Moderate	Other Law Enforcement (OLE), Marine Environmental Protection (MEP)
Low	Living Marine Resources (LMR), Marine Safety (MS), Search and Rescue (SAR)

No specific timeframe is assigned to these projections and current evidence is insufficient to conclude that significant or moderate changes would occur during the next 7-10 years.

[1] Coast Guard High Latitude Study Mission Analysis Report (HLMAR)

V. Reactivation and Service Life Extension Cost Estimate

This section provides the details of the estimated cost of reactivating USCGC POLAR SEA (WAGB 11) and extending the service life until at least 2022. The estimate is comprised of the industrial work required to reactivate and extend the icebreaker's service life, the costs of the management and oversight of the reactivation project and the costs of restoring the on-board repair parts, outfit and critical components and spares transferred to POLAR STAR prior to POLAR SEA's removal from service.

General Assumptions:

- Schedule. The reactivation of POLAR SEA would closely follow the schedule used for POLAR STAR during its reactivation.
    - The project would span four years; planning and procurement would start in FY14 and end with POLAR SEA ready for operations in FY17. Annual activities would include:
        - FY14: Receive funding for contracted project staff, engineering, Long Lead Time Materials (LTTM) purchases, stand up project team and initiate project planning.
        - FY15: Start industrial work effort; dockside and dry dock availabilities.
        - FY16: Complete industrial work effort; dockside and dry dock availabilities. Reconstitute crew.
        - FY17: Dock/Sea Trials, Ice Trials, Crew training and certification, Ready For Operations.

- Scope. The scope of work to reactivate POLAR SEA and extend its service life is anticipated to be very similar to what was required to reactivate POLAR STAR, thus the cost data from POLAR STAR is applicable to POLAR SEA with adjustments made where necessary.

- Service Life: Based upon scheduled reactivation timeline, scope of work, and available data, the project would provide a 7-10 year service life extension with a corresponding EOSL 2024-2027 for POLAR SEA. No time or cost savings are realized by reducing the scope of industrial work to plan to an EOSL of 2022.

- Contract Vehicle. POLAR STAR utilized the Multi-Ship, Multi-Option (MSMO) contract with Vigor Industries in Seattle, WA for its reactivation. This was a Cost-Plus Incentive Fee (CPIF) contract; the current solicitation to re-compete this contract changes it to two separate Firm Fixed Price (FFP) contracts, one for dock side availabilities and one for dry dock availabilities. It is anticipated POLAR SEA reactivation industrial work effort would utilize the FFP MSMO.

- Inflation. All actual costs from POLAR STAR's reactivation are indexed to FY12 and POLAR SEA's reactivation costs are indexed to FY15. The Congressional Budget Office provides discussion regarding inflation in shipbuilding as part of their review of the Navy's FY12 shipbuilding plan:

  "An important factor affecting the Navy's and the Congressional Budget Office's (CBO's) estimates are assumptions about future increases in the cost of building naval ships. The Department of Defense (DoD) has an overall estimate of future inflation (known as an inflator) that it uses to project increases in the costs of its procurement programs. However, according to

the Navy, DoD's inflator is lower than the actual inflation that occurred in the naval shipbuilding industry in the past decade. The Navy provided CBO with a shipbuilding index that reflects the growth in the costs of labor and materials that the industry has experienced in the past. The service developed that index using a weighted composite of annual percentage changes in the costs of labor and materials specific to shipbuilding, based on shipyards' data about labor costs in the past, advance pricing agreements, vendor surveys, and projections of the cost of materials from the Bureau of Labor Statistics. From 2011 through at least 2016, the Navy's index is projected to grow at an average annual rate of 3.1 percent. By comparison, the gross domestic product (GDP) price index, which measures the prices of final goods and services in the economy, will grow at an average annual rate of 1.6 percent, in CBO's estimation. The difference between the two rates implies that annual inflation will be 1.5 percentage points higher for shipbuilding programs during that period than for the economy as a whole."
This estimate thus uses 3.1% for the inflator per the Navy's projection between 2011-2016.

- This estimate does not include the cost to reconstitute the crew for POLAR SEA. That cost is accounted for in the Life Cycle Cost Estimate.

Estimated Cost:

- The total estimated cost of the industrial work to reactivate and extend the service life of POLAR SEA is $99,199,767.20

Table 5.1: Polar Sea Reactivation & Service Life Extension Cost Summary

POLAR SEA REACTIVATION & SERVICE LIFE EXTENSION COST SUMMARY	
Inflation Rate[1]	3.1%
Major System Upgrades	$24,680,031.67
Backlog Depot Level Maintenance	$30,722,825.65
Habitability Upgrades	$1,496,036.03
ELEX Upgrades	$4,337,155.41
Pending TCTOs	$ 6,663,588.13
Project Staff	$6,545,981.28
Availability Project Support	$15,814,945.43
OBRP-Outfit Restoration	$4,215,405.16
Management Reserve 5%	$4,723,798.44
Total	$99,199,767.20

[1] (US Navy FY12 Ship Building Plan Inflator 2011-2016)

This estimate uses the reactivation of POLAR STAR as its principle source of data. Since the contract was a CPIF type, the estimate uses actual costs incurred for the same work required on POLAR SEA. Our confidence in the accuracy of this estimate is very good, but two factors present an unknown level of risk that could significantly impact the estimate's accuracy:

- Lack of a long-term layup preparations and continuous degradation of the ship as it remains cold-iron and unmanned. There will likely be significant amounts of discovery work due to the ship's complex systems lying dormant for so long compounded by the absence of proper layup. The estimate attempts to capture this issue by assigning a scaling factor to systems known to be at high-risk, but unknowns can significantly impact POLAR SEA reactivation scope, cost and schedule.

- Cost variation due to converting the MSMO contract type from CPIF to FFP. Cost risk to the shipyard in a CPIF contract is minimal; the Coast Guard bears the risk and pays what it takes to get the work done. However, the shipyard bears the preponderance of cost risk in a FFP contract and they will price the risk into their bid. The shipyard's pricing would probably be substantially higher due to the unknown conditions resulting from the situation described above.

Approach:

The principle approach in assembling this estimate was to use actual cost data from the same or similar work that was completed on POLAR STAR during its reactivation. The source for the cost data is the Coast Guard's ship repair contract project management tool called the Contract Workbook which tracks and captures all the costs incurred for each contract work item, including growth and incentive fees. The costs extracted from the Contract Workbook were originally organized according to the reactivation phase when the contract work items were awarded, i.e. 3DD=Phase 3, Dry Dock. The POLAR SEA reactivation would not necessarily follow the same sequencing and, to better emphasize the scope of work required, the costs are re-grouped into primary areas according to the type of work being performed:

- Major System Upgrades.
- Backlog Depot Level Maintenance.
- Habitability Upgrades.
- Electronic Systems Upgrades.
- Pending TCTOs.
- Project Staff.
- Availability Project Support.
- Restore On Board Repair Parts and Outfit.
- Management Reserve.

Details of how each primary area of the estimate were compiled, along with an assessment of the confidence in the accuracy and identification of risks that could cause excessive cost variation follows.

Major System Upgrades (MSU).

- *Principle Source Of Cost Data:* POLAR STAR reactivation, Contract Workbook.

- *Accuracy Assessment:* Accuracy is considered High due to close alignment of work scope between vessels and the lack of layup has a low impact since this removes the old systems and replaces with new.

- *Cost Risk Factors:* Since the scope of the MSUs is well understood there should be low cost risk when contracting this work via a FFP contract type.

The Major System Upgrades (MSU) are intended to replace a number of low reliability and obsolete systems (most of which are called out in the SSMEB) with new higher reliability and supportable ones, but with no increase in operational capability (except for the cranes). POLAR SEA had limited scale prototypes of several of the MSUs installed while still in service (CPP Open Loop Conversion & Main Gas Turbine Digital Fuel Control Upgrade) so the scope is reduced slightly from what was done on POLAR STAR and is accounted for in the estimate.

The diesel engine block renewal on POLAR STAR occurred in the Diesel 2 engineering space, for POLAR SEA the blocks that require renewal are in the Diesel 1 engineering space. From experience accomplishing similar work in the past it is assumed that the cost of renewal is nearly equal so the costs from POLAR STAR convey directly to POLAR SEA.

The replacement cranes and attendant hydraulic power systems and controls were purchased and delivered to the Coast Guard at the same time as POLAR STAR's and are currently in storage. It assumed that these would be provided as Government Furnished Equipment (GFE) and the purchase cost is not included in this estimate.

<u>Backlog Depot Level Maintenance.</u>

- *Principle Source Of Cost Data:* POLAR STAR reactivation, Contract Workbook.

- *Accuracy Assessment:* Accuracy is considered Moderate since the alignment of work scope between vessels is not exact and the lack of layup has a high potential impact because the actual state of many of the systems cannot be discerned until they are opened and inspected. Systems at the highest risk from lack of layup have been identified in the estimate and a scaling factor applied to individual costs in an attempt to account for this unknown.

- *Cost Risk Factors:* The scope of depot level maintenance would be similar but not the same between the ships and the lack of layup has the potential to greatly impact the scope, cost and schedule of POLAR SEA's reactivation. The shipyard's pricing in a FFP contract type would thus have to incorporate this uncertainty and even then significant unplanned growth remains a distinct possibility.

  The work items listed are from the POLAR STAR reactivation and were initially developed from maintenance due lists, long range maintenance plans and other historical documentation. But it was the detailed efforts of the Port Engineer staff and the POLAR STAR crew and their intrinsic knowledge of the actual state of the vessel that led to the final work list. As such, the depot level work items may not match one-for-one with those required to reactivate POLAR SEA, but they substantially reflect the level of effort required and are considered an accurate representation nonetheless.

Habitability Upgrades.

- *Principle Source Of Cost Data:* POLAR STAR reactivation, Contract Workbook.

- *Accuracy Assessment:* Accuracy is considered High due to close alignment of work scope between vessels and since this primarily renovates living spaces that are not greatly affected by the lack of layup.

- *Cost Risk Factors:* The scope of work is good approximation between the ships, but there is a long history high growth for hazardous material remediation on the *Polar*-Class due to the presence of asbestos in paneling and deck underlayment.

  POLAR STAR crew provided a large proportion of the labor to complete the berthing area renovations prior to moving onboard, however, due to the presence of asbestos and other hazardous materials, additional costs could be incurred by having the shipyard complete this work.

Electronic Systems Upgrades.

- *Principle Source Of Cost Data:* POLAR STAR reactivation, actual costs, CG-6 (Assistant Commandant for C4IT) funding documents.

- *Accuracy Assessment:* Accuracy is considered High due to close alignment of work scope between vessels and since this primarily replaces electronic systems that have already been removed and thus are not greatly affected by the lack of layup.

- *Cost Risk Factors:* Cost risks are low as most labor would be provided by organic Coast Guard resources.

  Electronic systems recapitalization cycle times are typically much shorter than Hull, Mechanical and Electrical (HM&E) systems and improvements in capability can come with a commensurate increase in cost.

Pending Time Compliant Technical Orders (TCTOs).

- *Principle Source Of Cost Data:* *Polar*-Class TCTO Documentation and Files.

- *Accuracy Assessment:* Accuracy is considered Moderate due to the majority of the TCTOs being in the early stages of technical and engineering development, more accurate cost estimates will follow as development proceeds.

- *Cost Risk Factors:* Due to the complexity of the Westinghouse Propulsion Control system and its critical interface with the diesel engine governor renewal, these two projects would need to be closely coupled during engineering, procurement and installation.

  Additional TCTOs will be proposed and approved as POLAR STAR re-enters active service, so it is anticipated that this work list would expand over the time if the POLAR SEA is reactivated.

Project Staff.

- *Principle Source Of Cost Data:* GSA Professional Engineering Services – Schedule 871and CG HQ Standard Personnel Costs (SPC) Worksheet.

- *Accuracy Assessment:* Accuracy is considered High as the personnel costs can be directly calculated from the above mentioned sources.

- *Cost Risk Factors:* POLAR STAR reactivation had ready access to a large cadre of inspectors from the caretaker and regular crew. POLAR SEA will not have that resource available so the number of inspectors might have to increase to accommodate the work load.

  POLAR STAR reactivation again provides the template for the number and types of personnel that would be required to successfully manage and oversee a similar project on POLAR SEA. The principle difference is that POLAR STAR had a caretaker crew which ended up being the primary source for the majority of the project staff. POLAR SEA does not have a caretaker crew. It is assumed that organic Coast Guard resources would not be made available to staff the Project Team. Except for the inherently governmental positions required for contracting roles, the Project Team would be comprised of contractors, primarily on site in the shipyard.

Availability Project Support.

- *Principle Source Of Cost Data:* POLAR STAR reactivation, Contract Workbook.

- *Accuracy Assessment:* Accuracy is considered High due to close alignment of work scope and duration between vessels and that the lack of layup has a low impact.

- *Cost Risk Factors:* Converting to a FFP contract type could potentially increase the price for this type of effort, but the risk is considered minimal.

  The relatively small size of the POLAR STAR reactivation Project Team was made possible by using shipyard resources to the maximum extent for the planning, preparation, procurement and execution of the industrial work effort. In order to keep the Project Team size small and to minimize impacts to the Long Range Enforcer Product Line (LRE PL) due to a POLAR SEA reactivation, similar use of shipyard resources is assumed.

Restore On Board Repair Parts and Outfit.

- *Principle Source Of Cost Data:* POLAR STAR reactivation AFC30 funding request and Total Asset Visibility (TAV) extract from POLAR SEA Annualized Operating Materials and Supply (OM&S) Consumption Report dated Feb13.

- *Accuracy Assessment:* Accuracy is considered Moderate due to the significant amounts of spares and outfit that were removed from POLAR SEA to POLAR STAR that may not have been properly captured in the data. The lack of layup has a moderate impact since outfit and spares degrade over time and require periodic replacement.

- *Cost Risk Factors:* POLAR SEA would not have a sister ship to receive excess spares and outfit from as POLAR STAR did during its reactivation. Limited ventilation throughout ship could lead to further degradation of spares and outfit compared to what was found on POLAR STAR since it had a caretaker crew and functioning heating and cooling.

  POLAR SEA and POLAR STAR were rafted side by side prior to POLAR SEA's removal from service in order to maximize the re-use of spares and outfit from POLAR SEA on POLAR STAR.

Management Reserve.

- *Principle Source Of Cost Data:* POLAR STAR reactivation Below Threshold Reprogramming (BTR).

- *Accuracy Assessment:* Accuracy is considered High due to close alignment of work scope and duration between vessels and that the lack of layup has a low impact.

- *Cost Risk Factors:* Discovery work that imposes significant growth in scope and schedule changes could rapidly outpace the management reserve.

  The POLAR STAR reactivation requested approximately $3M in additional funding via a Below Threshold Reprogramming as the industrial period neared the end in order to fund dock and sea trials and to have sufficient reserves to cover future cost increases due to labor rate adjustments inherent to the CPIF contract type. A POLAR SEA reactivation would not be subject to the labor rate adjustments since it would be under a FFP contract type, but POLAR SEA is at a significantly greater risk of cost growth due to discovery work resulting from the lack of layup and sitting cold-iron and unmanned for so many years. A management reserve acknowledges this predicament and sets aside funding to support contingencies that may arise once the ship enters the industrial period.

VI. Life Cycle Cost Estimate

Scope

POLAR SEA Life Cycle Cost Estimates (LCCE) collect and analyze historical data and apply quantitative models to determine anticipated costs associated with a project throughout its life. This includes costs from pre-operations through operations and disposal. For this LCCE, POLAR SEA is assumed to be reactivated in FY2017, in service for 10 years, and decommissioned in FY2026 using the most optimistic estimates.

POLAR SEA's LCCE Operating & Support (O&S) cost elements were primarily based on historical financial data for multiple United States Coast Guard icebreakers, including: POLAR SEA; POLAR STAR; HEALY; and MACKINAW.

The Department of Homeland Security Standard Ship Work Breakdown Structure (WBS) was used to develop the LLCs for O&S to ensure that all LCCs were accounted for within a comprehensive, consistent framework. The DHS Standard Ship WBS is documented in accordance with a standardized Cost Element Structures (CES) that is consistent with Department of Defense (DoD) guidance (MIL-HDBK-881, DoD Handbook, Work Breakdown Structure for Defense Materiel Items, 30 July 2005; Office of the Secretary of Defense, Cost Analysis Improvement Group, October 2007). Within each of the life cycle phases described below, cost elements were distributed in proportion to anticipated levels of resources expended for key activities, tasks, and milestones.

Operating and Maintenance (O&M) – Cost of operating and maintaining the POLAR SEA, including: all direct and indirect costs incurred in operating and maintaining the ships (e.g. crew; unit level maintenance personnel, petroleum, oil, and lubricants; organization/depot levels of maintenance; sustaining support; continuous improvement for both hardware and software modifications or modernization; facilities sustainment and maintenance).

Disposition – The safe disposal of replaced/failed equipment. Includes cost to dispose of POLAR SEA after its useful life (demilitarization and other related costs).

The POLAR SEA O&S LCCE was developed in the cost estimating tool, Automated Cost Estimating Integrated Tools (ACE-IT) software.

A quantitative risk analysis was performed at two confidence levels, 80 and 90 percent, in order to quantify, in dollar terms, the inherent risks of the POLAR SEA O&S LCCE.

Estimating Plan

The LCCE was developed by United States Coast Guard, CG-9283: the Office of Acquisition: Office of Resources & Metrics, Independent Cost Estimating Team. The team worked with CG-45 and Surface Forces Logistic Center Long Range Enforcer Product Line (SFLC LRE PL) Subject Matter Experts (SMEs) to identify and validate POLAR SEA requirements, and receive past and current cost data for the POLAR SEA and other USCG icebreakers. All estimated costs were cross-checked with CG-45 and SFLC LRE PL SMEs to ensure accuracy and consistency with past

POLAR SEA operation costs. CG-9283 will house the POLAR SEA LCCE and will perform updates to any necessary changes.
An independent reviewer, who is a senior cost estimator from the Department of Homeland Security Program Accountability Risk Management, Cost Estimating and Analysis, reviewed the estimate and methodologies simultaneously as CG-9283 developed the estimate. The independent reviewer provided gaps, overlaps, and areas of improvement during the development of the LCCE which were incorporated into the final document.

Ground Rules and Assumptions

Ground rules and assumptions were established in order to generate the LCCE. These assumptions are documented in detail in Appendix I and include the following major/key assumptions:

- Base Year (BY) of estimate is FY2017
- Inflation indices: US Coast Guard FY2012
- Coast Guard Standard Personnel Costs (SPC) FY13 used to determine Military and Government Civilian pay
- Service Life of POLAR SEA: 10 years
- Start of Service Life: 2017
- End of Service Life: 2026
- Operational Crew is a total of 134 personnel, 15 Officers and 119 Enlisted
- The crew will be assembled at a minimum of 1 year to 2 years prior to deployment of POLAR SEA
- Baseline estimate reflects total Operation and Support (O&S) life cycle cost over the entire program
- Operation – tempo target maximum is 185 days per year at sea
- Fuel Oil, Naval, Distillate: Code 76 was used
- POLAR SEA Burn Rate is 10,316 (gallons per day) based on POLAR SEA FY10 Fuel Data
- Two-tier maintenance philosophy – organizational and depot level maintenance
- Two year maintenance cycle; Year 1 a dock side, Year 2 a dry dock, this would initiate with a dock side in 2018, a dry dock in 2019 and repeat until end of 10 year extended service life.
- O&S Life Cycle Cost Estimate

WBS Element 1.1 - Unit-Level Manpower

Definition: This element consists of costs associated with operators, maintainers, and other support manpower assigned to operating units. May include government and/or contractor manpower. Excludes manpower associated with general and indirect support, such as manpower supporting base level functions (see element 1.6).

WBS Element 1.1.1 - Operations Manpower

Definition: All costs associated with government and contractor manpower required to operate a system. Includes, for example, the costs of command staff, combat information center personnel, fire control (if operations, maintenance and other support categories are estimated separately). It includes both military and civilian personnel effort associated with operations manpower, i.e. fully burdened salaries, benefits, relocation expenses, retirement actuarial, etc.

Methodology: The engineering build-up methodology was used to develop the Headquarters Government Personnel element, where actual POLAR SEA crew billets and USCG pay rates were used.

Basis of Estimate: The 134 crew billets are multiplied by the appropriate SPC rates for the respective rank to get an annual salary. The rates include Allotment Fund Codes (AFC): AFC 01, AFC 20R, AFC20NR, and AFC56NR rates which are in Appendix B in Table B.1. In Appendix B in Table B.2, the billet numbers for rank are provided. The annual salary for each crew member is then multiplied the number of years the ship will be operational plus the prior years for when the crew will be assembled.

Operational Crew Total = Cost per Person per Year*Persons per Ship*(O&S Years per Ship+Prior Years)

Fiscal Year Phasing Results (BY2017 $K):

FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022
$9,816.5	$9,816.5	$8,968.6	$8,968.6	$8,968.6	$8,968.6	$8,968.6	$8,968.6

FY2023	FY2024	FY2025	FY2026	Total
$8,968.6	$8,968.6	$8,968.6	$8,968.6	$109,318.8

WBS Element 1.1.2 - Unit-Level Maintenance Manpower

Definition: The costs of all government and contractor manpower that performs unit-level level maintenance on a primary system, associated support equipment, and unit-level training devices. This element includes the costs of organizational maintenance manpower (usually resident in the system operating unit). Includes both military and civilian personnel effort associated with unit-level maintenance manpower, i.e. fully burdened salaries, benefits, relocation expenses, retirement actuarial, etc.

Assumptions: The Unit-Level Maintenance Manpower is assumed to already be set-up at the time the POLAR SEA would be reactivated. The assumption was made that the billets senior to these listed would already be a part of the SFLC or Base (for example, the existing LRE PL Engineering Branch Chief billet would already be on Personnel Allowance List (PAL) to manage the LRE Systems & Equipment Section 1 (SES1) Section Chief). Second, the LRE SES1 & LRE Supply Section 1 (SUP1) staffs currently support 378s, ALEX HALEY, HEALY & POLAR STAR, and would support the New Polar Icebreaker. It is hard to predict what effect cutter decommissionings would have on LRE PL billets over the next 10 years. If the current LRE SES1 & LRE SUP1 sections exist when the new cutter is delivered, new section chiefs would not be needed. Third, since LRE SES1 & LRE SUP1 Sections' workloads are driven more by how many different classes of cutters they support than the number of cutters in each class, adding a new class of cutter would require these sections to be staffed to at least this size. Any billets listed in these sections not already on PAL when the cutter is delivered would need to be added back to PAL.

Based on discussions with the SMEs, the total Unit-Level Maintenance Support a reactivated POLAR SEA is in Appendix B, Table B.3. There are 13.8 military and 7.2 civilian staff members that would be dedicated to support the POLAR SEA.

Methodology: The engineering build-up methodology was used to estimate the government Unit-Level Maintenance Manpower, which was based off of the HEALY Support Staff. It includes the SFLC LRE PL staff, the dedicated SFLC Contracting and Procurement Division staff (Contracting Officer) and BASE Seattle Naval Engineering & Electronics Support Staffs as well as contracted SFLC & Base employees. The contractor unit-level maintenance was based on using actual POLAR SEA contract data from Vigor Shipyard.

Fiscal Year Phasing Results (BY2017 $K):

The 21 government billets are multiplied by the appropriate SPC rates for the respective rank to get an annual salary. The rates include Allotment Funding Codes (AFC): AFC 01, AFC 08, AFC 20R, AFC20NR, and AFC56NR rates which are in Appendix C in Table C.1. In Appendix C in Table C.3, the billet numbers for rank are provided. The annual salary for each military and civilian is then multiplied the number of years the ship will be deployed.

The contractor unit-maintenance support would follow the two year maintenance cycle, using the costs in Table 6.1

Table 6.1: Contractor Unit-Maintenance Support

Description	**Cost(BY2017$K)**	**# of Occurrences**	**Total Cost (BY2017$K)**
Dockside Total	**$2,000**		**$10,000**
Basic Planning Work Item	$500	5	$2,500
Production Control and Project Management	$1,500	5	$7,500
Dry Dock Total	**$3,000**		**$12,000**
Basic Planning Work Item	$500	4	$2,000
Production Control and Project Management	$2,500	4	$10,000

Summing the government and contractor cost gives the total cost of unit-maintenance support.

Support = Government: (Cost per Person per Year * Number of Persons * O&S Years per Ship) + *Contractor:* (Cost of Work Item * # of Maintenance Occurrence)

Fiscal Year Phasing Results (FY2017 $K):

FY2017	**FY2018**	**FY2019**	**FY2020**	**FY2021**	**FY2022**	**FY2023**	**FY2024**
$1,940.7	$3,940.7	$4,940.7	$3,940.7	$4,940.7	$3,940.7	$4,940.7	$3,940.7

FY2025	**FY2026**	**Total**
$4,940.7	$3,940.7	$41,406.9

WBS Element 1.2 - Unit Operations

Definition: This element consists of costs associated with unit operating material (e.g., fuel, electricity, expendable stores and training material), unit support services and unit travel. These costs include cost of petroleum, oil and lubricants (POL), propulsion fuel, and fuel additives used by systems in performing their normal peacetime missions.

Methodology: The engineering build-up methodology was used to estimate the annual fuel cost per year.

Basis of Estimate: Using DESC data, the fuel price for Naval, Distillate: Code 76 is $3.72 per gallon, which is $156.24 dollars per barrel. Multiplying the fuel price ($ per barrel) times the burn rate of 10,316 barrels per day times 185 days at sea per year equals the annual fuel cost of $7,099,471 in BY2013. The annual fuel cost rate is then multiplied by the continuous service life of the POLAR SEA.

Energy Total = Burn Rate (Gal) per day*Fuel Cost per Gal*Number of days at Sea*O&S Years per Ship

Fiscal Year Phasing Results (BY2017 $K):

FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024
$7,609.6	$7,609.6	$7,609.6	$7,609.6	$7,609.6	$7,609.6	$7,609.6	$7,609.6

FY2025	FY2026	Total
$7,609.6	$7,609.6	$76,096.2

WBS Element 1.3 - System Maintenance

Definition: This element consists of costs, including labor and materials, associated with all maintenance in support of the primary system, simulators, training devices and associated support equipment and may include contractor maintenance. Associated costs other than maintenance manpower assigned to operating units (see element 2.1) are excluded. This cost element includes the fully burdened cost of labor, material, and overhead incurred in performing major overhauls or other depot level maintenance on a system, its components, or other associated equipment at centralized repair depots, contractor repair facilities, or on site by depot teams.

Assumptions: POLAR SEA maintenance data from the Fleet Logistics System (FLS) from FY2000 to FY2010 with the Subject Matter Experts (SME) at the LRE product line inputting the maintenance costs was used to estimate the cost of the new Polar Icebreaker. Prior to 2000 there was a loss of data, and after FY2010 POLAR SEA was put in inactive status, so data collected before or after these years does not appropriately reflect the maintenance of POLAR SEA. From 2006 to 2010, some POLAR SEA maintenance projects were deferred. Furthermore, some of the cost data extrapolated from the database was based on a bottom-up estimate of what the maintenance projects should cost, not what it actually did cost. Based on SME discussions and cost estimating judgment, the estimated maintenance that POLAR SEA needed was used to estimate what it would cost to maintain POLAR SEA in the out years. These estimates are based off of labor and material

dollars. Lastly, the data was unable to be distinguished between the organizational and depot (O&D) level maintenance so it is assumed that this element accounts for both levels of maintenance.

Dry docking availabilities for the POLAR SEA would be necessary. Reviewing the history of POLAR SEA maintenance, on average a major overhaul occurred every two years. This was crosschecked and confirmed with the POLAR SEA SMEs.

Methodology: An analogy was done based on historical POLAR SEA maintenance costs.

Basis of Estimate: Data was collected from the three different reports in the FLS database: costs at the projects required date, completed date, and estimated projects summed. To avoid what maintenance could only be done due to the budget, the maximum cost for each year was chosen from the reports, then summed and averaged for annual cost of $10,059 (BY2017$K). An electronic support maintenance cost was also included; using what was estimated for POLAR SEA in FY11, based off of the HEALY FY11 Project Plan estimate, the total for POLAR SEA was $476 (BY2017$K). Additionally, deferred maintenance was also taken into account, and it was found that the average deferred amount per year between FY00 and FY10 was $2,475 (BY 2017$K). Summing these costs provide the annual maintenance costs for the Polar Icebreaker $13,010 (BY2017$K) if it were to be reactivated. This information is provided in Table. 6.2.

A dry docking availability is expected for the POLAR SEA every other year. This will cause a spike in annual maintenance costs every other year that the POLAR SEA is operational. The average POLAR SEA historical cost spike was $5,837 (BY2017$K), which is shown in Table 6.2.

Table 6.2: Data Summary for Maintenance Costs

PSEA Maintenance Costs	BY2017$K
Annual O&D Level Maintenance Cost	$10,059
Annual Electronic Support Cost	$476
Annual Deferred Maintenance	$2,475
Total Annual Maintenance Cost	**$13,010**

Dry-docking Availability Cost	**$5,837**

Maintenance Cost = (Annual O&D Level Maintenance Cost + Annual Electronic Support Cost + Annual Deferred Maintenance) * O&S Years per Ship + (Dry-docking Availability Cost * Dry-docking Years per Ship)

Fiscal Year Phasing Results (BY2017 $K):

FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023
$13,009.9	$13,009.9	$18,846.7	$13,009.9	$18,846.7	$13,009.9	$18,846.7

FY2024	FY2025	FY2026	Total
$13,009.9	$18,846.7	$13,009.9	$153,445.8

WBS Element 1.4 - Sustaining Support

Definition: This element consists of costs associated with support activities other than maintenance that can be attributed to a system and are provided by organizations other than operating units. The cost includes system-specific specialty training for individuals that need to be replaced due to attrition and normal rotation. Training costs include the costs of instructors, training support personnel, training devices, course support costs, and course materials, as well as all the costs of trainees, per diem, and travel directly associated with the training.

Assumptions: The number of different training courses for the POLAR SEA is 46, which was determined by MTL WAGB-399. The assumption is that the crew rotates out every three years and the instructors every two years. Additionally, the training support applies only to the POLAR SEA crew.

Methodology: The engineering build-up methodology was used to determine the POLAR SEA costs based off actual POLAR SEA data and HEALY average TONO costs.

Basis of Estimate: Using the average TONO costs for HEALY for all student and instructor costs, the annual POLAR SEA sustaining support cost was determined to be $141, 092 (BY2017$). See Table 6.3 for data summary. The average annual cost is incurred each year the POLAR SEA would be operational.

Table 6.3: Data Summary for Specific Training

	Student			Instructor
Average TONO Cost per Student	$ 1,667.00		**Average TONO Cost per Instructor**	$ 2,146.00
# of PSEA classes per Year	46		**# of PSEA classes per Year**	46
Average # of Students per Class	5.00		**Average # of Instructors per Class**	0.27
Total Cost = (Student Cost) * (# Classes) *(# Students) per Year	$ 383,410.00		**(Instructor Cost)*(# Classes)*(# Instructors) per Year**	$ 26,577.38
Rotation Every 3 years	3		**Rotation Every 2years**	2
Annual Student Total Cost = Total Cost / Rotation Every 3 years	$ 127,803.33		**Annual Instructor Total Cost = Total Cost / Rotation Every 2 years**	$ 13,288.69

System-Specific Training = ((Training Cost per Instructor * Number of Training Classes * Number of Instructors per Course) / Instructor Rotation Years) + ((Training Cost per Student * Number of Training Classes * Number of Students per Course) / Student Rotation Years) * O&S Years per Ship

Fiscal Year Phasing Results (BY2017 $K):

FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024
$141.1	$141.1	$141.1	$141.1	$141.1	$141.1	$141.1	$141.1

FY2025	FY2026	Total
$141.1	$141.1	$1,411.1

WBS Element 1.5 - Continuing System Improvement

Definition: This element consists of costs associated with hardware and software updates that occur after deployment of a system that improve a system's safety, reliability, maintainability, or performance characteristics to enable the system to meet its basic operational requirements throughout its life. This includes costs associated with modifying the sea system, support equipment, and training devices. All costs associated with developing, producing, and installing the modifications are included. Also, it includes the labor, material, and overhead costs incurred after deployment in supporting the update, maintenance and modification, integration, and configuration management of software.

Methodology: The analogy methodology was used based on HEALY and POLAR SEA historical data that was provided by the Naval Engineering Program Manager and LRE Product Line Branch Chief Manager.

Basis of Estimate: The information in Table 6.4 was provided by the Polar Icebreaker Program Manager in the Naval Engineer Office. The following cost summary is history or recapitalization dollars spent from FY06-FY10 for HEALY and POLAR SEA.

Table 6.4: HEALY and POLAR SEA Historical Data Summary

FY	HEALY ($M)	POLAR SEA ($M)
2006	$3.41	$3.40
2007	$0.96	$1.86
2008	$0.50	$3.84
2009	$3.57	$6.14
2010	$2.51	$4.08
Average	$2.19	$3.86

By the direction of the SME's, the average of the HEALY $2.19 M and POLAR SEA $3.86M is $3.01M, which is POLAR SEA's annual continuous improvement cost. This number is expected to be incurred each year the POLAR SEA would be operational.

Continuing System Improvement = Cost of Continuous Improvement per Ship * O&S Years per Ship

Fiscal Year Phasing Results (BY2017 $K):

FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024
$3,030.0	$3,030.0	$3,030.0	$3,030.0	$3,030.0	$3,030.0	$3,030.0	$3,030.0

FY2025	FY2026	Total
$3,030.0	$3,030.0	$30,300.0

WBS Element 1.6 - Indirect Support

Definition: This element consists of costs associated with support activities that provide general services that cannot be directly attributed to a system. Indirect support is generally provided by centrally managed activities that support a wide range of activities. It includes the costs for the acquisition, initial training, and quality of life programs necessary to maintain a quality force, which includes the costs for medical care for active duty personnel and their dependents. Provisions for patient care in regional defense facilities, station hospitals and medical clinics, and dental facilities as well as care in non-defense facilities and costs for general training and education not associated with a specific weapon or other system are provided through central activities. This element includes the costs of recruit and initial skills training; professional military education; and academic education programs.

Methodology: The engineering build-up methodology was based off of the Operational Crew, and Unit-Maintenance billets.

Basis of Estimate: The number of billets expected for Military personnel for both operational crew and unit-maintenance billets is multiplied by the appropriate SPC rates for respective grade and rank. The rates include medical support (AFC 57) recurring rates and general training and education (AFC 56). All assumptions and methodologies have been provided under WBS element 1.1.1 and 1.1.2. Table 6.5, provides the total annual cost of medical support and general training and education for all operational and unit-maintenance billets.

Table 6.5: Indirect Support Annual Costs

Description	Total Annual	Units
Indirect Support	$1,847.3	(BY2017 $K)
Medical Support	$1,506.4	(BY2017 $K)
General Training & Education	$341.0	(BY2017 $K)

Indirect Support = Cost per Person per Year*Persons per Ship*(O&S Years per Ship + Prior Years)

Fiscal Year Phasing Results (BY2017 $K):

FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022
$1,459.8	$1,459.8	$1,847.3	$1,847.3	$1,847.3	$1,847.3	$1,847.3	$1,847.3

FY2023	FY2024	FY2025	FY2026	Total
$1,847.3	$1,847.3	$1,847.3	$1,847.3	$21,393.1

WBS Element 1.7 - Facilities Sustainment & Maintenance

Definition: This element includes all costs associated with the sustainment, maintenance, preservation, repair and modernization of industrial facilities and equipment required for production, inventory and contractor depot maintenance.

Methodology: The analogy methodology was used based on Great Lakes Icebreaker (GLIB) facilities sustainment and maintenance cost.

Basis of Estimate: The GLIB budget for FY2013, $70,000 (TY$) for facilities, sustainment and maintenance, was used to estimate the POLAR SEA costs. It was normalized to $84,963 (BY2017$). The cost is expected to incur at the start of deployment and continue throughout POLAR SEA operational years.

Facilities Sustainment & Maintenance = Cost of Facilities Sustainment & Maintenance * O&S Years per Ship

Fiscal Year Phasing Results (BY2017 $K):

FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024
$85.0	$85.0	$85.0	$85.0	$85.0	$85.0	$85.0	$85.0

FY2025	FY2026	Total
$85.0	$85.0	$849.6

WBS Element 1.8 - Other Operations & Maintenance

Definition: This cost element includes all costs that have not been captured in the other sub-elements.

Methodology: All O&M costs have been captured under other sub-elements.

WBS Element 3.0 - Disposition

Definition: This element consists of costs associated with the disposal of a system at the end of its useful life. Costs associated with disposal may include disassembly, materials processing, decontamination, hardware, collection/storage/disposal of hazardous materials and/or waste, safety precautions, and transportation of the system or materials to and from a disposal site.

Assumptions: Both POLAR SEA decommissioning dry dock and dockside availabilities were cancelled with Vigor Shipyard during negotiations. The dockside portion of this estimate is based on pre-negotiation Rough Order of Magnitude (ROM) cost with a 20% Growth. However, the dry dock portion was completed and that element of this estimate is based on the actual negotiated price. Additionally, this estimate reflects that the POLAR SEA would need to be towed from Seattle to MARAD's Defense Reserve Fleet in Suisun Bay, CA.

Methodology: Actual negotiated and contract pricing proposal to decommission POLAR SEA and subject matter expertise methodologies were used to estimate the decommissioning of POLAR SEA.

Basis of Estimate: The decommissioning of the POLAR SEA negotiation costs in 2012 inclusive of both dry docking and dockside cost was normalized to $5,977 (BY2017$K). Additionally the expected towing cost would be $750 (BY2017$K). These costs are expected to be incurred the final year the POLAR SEA would be operational.

Decommission = Decommissioning Cost + Towing Cost

Fiscal Year Phasing Results (BY2017 $K):

FY2026	**Total**
$6,727	$6,727

Phased Cost Summary

Table 6.6: Point Estimate Summary BY2017$K by WBS Element

	Total	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
POLAR SEA O&S Estimate Total	$439,412	$11,276	$11,276	$36,478	$38,478	$45,315	$38,478	$45,315	$38,478	$45,315	$38,478.	$45,315	$45,206
Operations & Maintenance	**$432,685**	**$11,276**	**$11,276**	**$36,478**	**$38,478**	**$45,315**	**$38,478**	**$45,315**	**$38,478**	**$45,315**	**$38,478**	**$45,315**	**$38,478**
Unit-Level Manpower	**$150,726**	$9,816.	$9,816	$10,909	$12,909	$13,909	$12,909	$13,909	$12,909	$13,909	$12,909	$13,909	$12,909
Operations Manpower	**$109,319**	$9,816	$9,816	$8,969	$8,969	$8,969	$8,969	$8,969	$8,969	$8,969	$8,969	$8,969	$8,969
Unit-Level Maintenance Manpower	**$41,407**			$1,941	$3,941	$4,941	$3,941	$4,941	$3,941	$4,941	$3,941	$4,941	$3,941
Unit Operations	**$76,096**			$7,610	$7,610	$7,610	$7,610	$7,610	$7,610	$7,610	$7,610	$7,610	$7,610
System Maintenance	**$153,446**			$13,010	$13,010	$18,847	$13,010	$18,847	$13,010	$18,847	$13,010	$18,847	$13,010
Sustaining Support	**$1,411**			$141	$141	$141	$141	$141	$141	$141	$141	$141	$141
Continuing System Improvement	**$30,300**			$3,030	$3,030	$3,030	$3,030	$3,030	$3,030	$3,030	$3,030	$3,030	$3,030
Indirect Support	**$19,856**	$1,460	$1,460	$1,694	$1,694	$1,694	$1,694	$1,694	$1,694	$1,694	$1,694	$1,694	$1,694
Facilities Sustainment & Maintenance	**$850**			$85	$85	$85	$85	$85	$85	$85	$85	$85	$85
Other Operations & Maintenance													
Disposition	**$6,727**												**$6,727**

Table 6.7: Point Estimate Summary TY2017$K by WBS Element

	Total	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
POLAR SEA O&S Estimate Total	$474,732	$11,027	$11,123	$36,599	$39,250	$47,022	$40,586	$48,632	$41,967	$50,298	$43,395	$52,021	$52,812
Operations & Maintenance	$466,793	$11,027	$11,123	$36,599	$39,250	$47,022	$40,586	$48,632	$41,967	$50,298	$43,395	$52,021	$44,873
Unit-Level Manpower	$159,759	$9,599	$9,683	$10,909	$13,103	$14,330	$13,499	$14,763	$13,907	$15,209	$14,327	$15,669	$14,760
Operations Manpower	$115,271	$9,599	$9,683	$8,969	$9,103	$9,240	$9,378	$9,519	$9,662	$9,807	$9,954	$10,103	$10,255
Unit-Level Maintenance Manpower	$44,488			$1,941	$4,000	$5,090	$4,121	$5,244	$4,245	$5,402	$4,374	$5,566	$4,506
Unit Operations	$82,984			$7,648	$7,786	$7,926	$8,069	$8,214	$8,362	$8,512	$8,665	$8,821	$8,980
System Maintenance	$167,549			$13,076	$13,311	$19,630	$13,795	$20,343	$14,296	$21,082	$14,815	$21,848	$15,353
Sustaining Support	$1,539			$142	$144	$147	$150	$152	$155	$158	$161	$164	$167
Continuing System Improvement	$33,042			$3,045	$3,100	$3,156	$3,213	$3,271	$3,329	$3,389	$3,450	$3,513	$3,576
Indirect Support	$20,994	$1,428	$1,440	$1,694	$1,719	$1,745	$1,771	$1,798	$1,825	$1,852	$1,880	$1,908	$1,937
Facilities Sustainment & Maintenance	$927			$85	$87	$88	$90	$92	$93	$95	$97	$98	$100
Other Operations & Maintenance													
Disposition	$7,939												$7,939

Risk

Risk Overview

Risk analysis was completed on the POLAR SEA O&S LCCE using the RI$K application (RI$K is the name of a software application within ACEIT 7.3a), which employs a specific statistical technique: Monte-Carlo (MC) analysis using Latin Hypercube Sampling (LHS).

The triangular distribution was used for defining risk to appropriate cost and technical elements in the cost model. Using engineering judgment and historical data, the low, most likely, and high points were defined to account for the uncertainty around cost and technical elements that are defined in Appendix E.

Risk Results

Table 6.8 provides the results of the risk analysis at the 80% confidence level (CL) and the 90% CL in Then Year (TY) dollar amounts.

Table 6.8: Risk Results Comparison

WBS Elements	Point Estimate (TY$K)	80% CL (TY$K)	90% CL (TY$K)
POLAR SEA O&S Estimate Total	**$474,732**	**$607,961**	**$652,535**
Operations & Maintenance	**$466,793**	**$599,782**	**$644,235**
Unit-Level Manpower	$159,759	$157,799	$158,203
Unit Operations	$82,984	$97,720	$104,427
System Maintenance	$167,549	$264,741	$294,109
Sustaining Support	$1,539	$1,730	$1,814
Continuing System Improvement	$33,042	$56,138	$63,971
Indirect Support	$20,994	$20,704	$20,748
Facilities Sustainment & Maintenance	$927	$951	$962
Other Operations & Maintenance			
Disposition	**$7,939**	**$8,179**	**$8,299**

VII. Cost Effectiveness Analysis

The United States and the Coast Guard face a difficult challenge in seeking to balance the allocation of resources against emerging and not yet fully defined polar requirements. Execution of high latitude missions will require the ability to:

(1) Continuously transit through at least six feet of polar ice reliably and efficiently;
(2) Operate for long periods of time without replenishment due to long distances to the nearest re-supply ports;
(3) Operate effectively in high sea states; and
(4) Quickly transition from open water to operations in a variety of rapidly changing polar ice conditions.

The POLAR SEA exceeded its 30-year design service life in 2008. After decades of continuous service in the world's harshest environments, the overall material condition has degraded due to systemic obsolescence and the cutter requires a significant investment in system-wide recapitalization in order to meet current mission requirements. Although POLAR SEA completed a major maintenance availability in 2006, it did not receive all of the upgrades that POLAR STAR received during reactivation. In order for it to reliably operate with common equipment and capability to the POLAR STAR, it will need the uncompleted system upgrades and improvements that POLAR STAR received during reactivation, in addition to the other bridging strategy work items. This work is estimated to cost $99.2M (excluding annual operations and support costs). Given the age of the icebreaker, operations and support costs are projected to rise from $36.6M in the first year of operation to $52.8M in the 10th year of operation. Combining reactivation costs and point estimates for operating costs, reactivation and operation of the POLAR SEA will cost $573.9M. Accounting for operational and technical uncertainties, using the 90% Confidence Level Risk Analysis, the total cost rises to $751.7M. Executing a Service Life Extension Project on POLAR SEA will mitigate some reliability and support problems, but will not provide the additional long-term capabilities necessary to meet the new High Latitude Study/MAR missions and mission functional requirements.

The most significant impact of not extending the service life of POLAR SEA is a loss of redundancy in mission capability for support of McMurdo resupply in Antarctica. Unlike other Coast Guard surface assets that can backfill one another to maintain mission presence, there are only two heavy polar icebreakers in the fleet and they have unique capabilities that the rest of the Coast Guard surface fleet cannot replicate. Until a new polar icebreaker is delivered, this can be mitigated through focused efforts to maintain POLAR STAR and the option for NSF to use icebreakers from partner nations as in prior years.

As POLAR STAR completes reactivation and embarks upon 7-10 years of service conducting operations in the harsh polar environment, POLAR STAR will require extensive maintenance and upkeep to ensure continued availability. Despite the maintenance and equipment overhaul, POLAR STAR is by no means a new vessel. Equipment obsolescence will continue to be a challenge as the cutter ages beyond the 40-year mark.

Arctic seasonal icebreaking demands through 2022 can be met with existing and planned Coast Guard assets. Current requirements do not justify the need for heavy icebreaking capability in the Arctic. Heavy icebreaker capability is needed to perform Operation Deep Freeze in Antarctica, but Coast Guard

assets may not be the only option available to the National Science Foundation to support this activity. Although a second heavy icebreaker would provide redundancy, the cost of this redundant capability would come at the expense of more pressing and immediate operational demands. POLAR STAR, when fully reactivated, will provide heavy icebreaker capability until a new icebreaker can be delivered to meet both current and emerging requirements.

VIII. Appendices

Appendix A: References

- 399 Required Operational Characteristics – Projected Operating Environment, MAR 1988, USCG
- High Latitude Study Mission Analysis Report Volumes 1 - 3, July 2010
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- "CMP-WAGB_399 xlsx", v2010-12-23 (Class Maintenance Plan)
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- Email "RE:POLAR SEA LCCE Discussion", Subject Matter Expert: Towing Vessel from Seattle to MARAD's Defense Reserve Fleet in Suisun Bay, CA, APR2013, USCG: CG-45
- Congress of the United States Congressional Budget Office (CBO), An Analysis of the Navy's Fiscal Year 2012 Shipbuilding Plan, June 2011. Pages 12-13, Box 1, Inflation In Shipbuilding.

Appendix B: POLAR SEA Reactivation & Service Life Extension Detailed Cost Analysis

Major System Upgrades	POLAR STAR REACTIVATION		POLAR SEA REACTIVATION	
Description	Total Item Cost	Labor Rate	Total Item Cost	Notes
3 & 15 Ton Crane Renewal/CHS Removal				Cranes, HPUs and controls already purchased & built - GFE
3 & 15 TON CRANE REMOVAL	$353,620.00	$63.86	$387,536.68	
CHS SYSTEM REMOVAL	$426,891.00	$63.86	$467,835.31	
3T & 15T CRANE RECAP	$1,420,218.00	$63.86	$1,556,435.07	
3T, 15T Crane Hydraulic & Ancillary Piping Systems Install	$1,027,090.00	$65.00	$1,125,601.07	
3T Crane Electrical	$312,219.00	$65.00	$342,164.80	
3T & 15T Crane Electrical	$-	$65.00	$-	
15 Ton Crane Electrical Installation and Testing	$519,439.00	$65.00	$569,259.84	
Miscellaneous Cranes Modifications	$14,512.00	$65.00	$15,903.89	
3/15 T Crane: Engineering/install spec	$517,173.00	$59.00	$566,776.51	
Total	$4,591,162.00		$5,031,513.16	
Open Loop CPP Installation (2 of 3 Shafts)				
CPP System Equipment LLTM	$573,990.00	$59.00	$629,042.98	
CPP Gage Boards & Stbd Hydraulic Pump Units	$-	$59.00	$-	
Hydraulic pump SKF, parts	$-	$59.00	$-	
CPP OPEN LOOP MOD PRE-FAB	$412,181.00	$63.86	$451,714.43	
CPP SYSTEM REMOVAL	$329,962.00	$63.86	$361,609.58	2 of 3 shafts
CPP OPEN LOOP MOD INSTALL	$2,450,967.00	$63.86	$2,686,046.09	2 of 3 shafts
CPP Gage & STBD pumps	$104,898.00	$63.86	$114,959.06	
Total	$3,871,998.00		$4,243,372.13	
Diesel Engine Reconfiguration to Premium (9 of 9)				
Engine Resilient Mounts LLTM Purchase	$16,776.00	$59.00	$18,385.03	
MDE, SSDG Premium CSO LLTM	$3,147,978.00	$59.00	$3,449,909.36	
MDE 1A, 3A, & SSDG 1 and 3	$-	$59.00	$-	
MDE 1B, 2A, 2B, 3B & SSDG 2	$-	$59.00	$-	

Major System Upgrades	POLAR STAR REACTIVATION		POLAR SEA REACTIVATION	
MDE BLOCK REPAIRS, CORRECTIONS SUPPORT	$1,231.00	$63.86	$1,349.07	
1B MDE CSO	$341,076.00	$63.86	$373,789.55	
MDE TURBOCHARGER MODIFICATION: 1A,1B,2A,2B,3A, & 3B	$370,478.00	$63.86	$406,011.58	
MDE RESILIENT MOUNT RENEWAL	$332,392.00	$63.86	$364,272.64	
REMOVAL SUPPORT FOR NR 2 SSDG	$81,497.00	$63.86	$89,313.60	
INTERFERENCE REMOVAL FOR NR 2 SSDG	$127,467.00	$63.86	$139,692.72	
CENTER SECTION OVERHAUL NR2 SSDG	$268,671.00	$63.86	$294,439.99	
Installation Support for No 2 SSDG	$104,102.00	$63.86	$114,086.71	
Interference Reinstallation for No 2 SSDG	$206,929.00	$63.86	$226,776.14	
MDE and SSDG Hot Oil Flush	$525,510.00	$65.00	$575,913.13	
MDEs Premium Configuration Change (1A, 3A MDE, #1 SSDG); Ovhl/exchange	$160,965.00	$65.00	$176,403.60	
MDE's NO. 1B, 2A, 2B, 3B & SSDG #2 Premium Configuration Change; overhaul/exchange	$878,156.00	$65.00	$962,382.39	
Diesel Engine Resilient Mount Bolt Final Torque	$71,101.00	$65.00	$77,920.50	
1B, 2A, 2B, 3B MDE & 2 SSDG Gages and Thermometers Calibrate	$66,735.00	$65.00	$73,135.74	
1A, 3A, 1 & 3 SSDG Gauge Calibration	$64,532.00	$65.00	$70,721.44	
Diesel Generator Rm No 1 & 2 Catwalk Mods	$220,639.00	$65.00	$241,801.10	
No 1 SSDG Cam Gear Removal	$16,563.00	$65.00	$18,151.60	
Diesel Engine Spray Shields	$-	$65.00	$-	
Diesel Engine (ALCO 251) Dock Trials	$366,412.00	$65.00	$401,555.60	
No. 3 SSDG Cam Bore Repairs	$74,271.00	$65.00	$81,394.54	
Total	$7,443,481.00		$8,157,406.04	
Main Propulsion Diesel Engine Block Renewal (2 of 6)				
1A MDE BLOCK REPLACEMENT	$386,058.00	$63.86	$423,085.90	

Major System Upgrades	POLAR STAR REACTIVATION		POLAR SEA REACTIVATION	
3A MDE BLOCK REPLACEMENT	$375,252.00	$63.86	$411,243.47	
REMOVAL OF INTERFERENCES DSL 1	$552,493.00	$63.86	$605,484.15	
REMOVAL SUPPORT OF 1A, 3A MDE's	$449,872.00	$63.86	$493,020.48	
INSTALLATION SUPPORT OF 1A, 3A MDE's	$659,080.00	$63.86	$722,294.20	
INSTALLATION OF INTERFERENCES - DSL 1	$473,638.00	$63.86	$519,065.94	
Total	$2,896,393.00		$3,174,194.14	
Main Gas Turbine Digital Fuel Control System Upgrade	$990,000.00		$813,715.25	2 of 3 shafts required, assumed 75% of STAR cost
Machinery Control and Monitoring System (MCAMS) Upgrade	$3,150,000.00		$1,726,062.65	50% installation completed so far on POLAR SEA
Boat Davit Installation				
Miranda Davit Relocation Adv. Planning	$70,209.00	$63.86	$76,942.94	
Miranda Davit LLTM purchase			$712,343.31	POLAR STAR received a $650,000 davit from CG Inventory
Miranda Davit Installation	$429,326.00	$65.00	$470,503.85	
Miranda Davit Compatible Cutter Boat			$273,978.20	POLAR STAR received a $250,000 boat from CG Inventory
Total	$499,535.00		$1,533,768.31	
Major System Upgrades Grand Total	$23,442,569.00		$24,680,031.67	

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
Description	Total Item Cost	Labor Rate	Growth Scaling Factor	Total Item Cost	Notes
HULL PLATING, U/W BODY INSPECT	$47,017.00	$63.86		$51,526.53	
HULL PLATING, U/W BODY	$603,287.00	$63.86		$661,149.94	

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
PRESERVE					
Hull Plating Freeboard, Preserve (All)	$116,832.00	$63.86		$128,037.68	
Sea Strainer and Transducer Compartments Preservation	$283,788.00	$63.86		$311,006.90	
CLEAN AND INSPECT ALL TANKS	$541,255.00	$63.86		$593,168.28	
Appendages (Underwater) and Voids (Non-Accessible) Leak Test	$50,110.00	$63.86		$54,916.19	
Voids (Non-Accessible) Preserve	$156,269.00	$63.86		$171,257.20	
Tank Repairs and Preservation	$969,953.00	$63.86	50%	$1,594,475.85	Standing, stagnant water, fuel, etc.
AIR COOLERS, RECTIFIERS, MDE & SSDG, CLEAN, INSPECT & HYDRO	$191,591.00	$63.86	50%	$314,950.54	Stagnant water in coolers
MP MAIN MOTOR AIR TEMP REG VALVE OVERHAUL	$19,996.00	$63.86		$21,913.87	
PROPULSION SHAFT - STRAIN GAUGE (ALL)	$208,474.00	$63.86		$228,469.32	
PROPULSION SHAFT COATING, INSPECT (ALL)	$38,008.00	$63.86		$41,653.45	
PROP. SHAFT SEAL - CLEAN, INSPECT, REPLACE (STBD)	$52,638.00	$63.86		$57,686.66	
PROPULSION SHAFT SEAL - RENEW (PORT)	$53,437.00	$63.86		$58,562.29	
PROP. SHAFT SEAL - INSPECT, CLEAN, REPLACE (C/L)	$52,619.00	$63.86		$57,665.84	
STERN TUBE RUB RAIL, INSPECT & REPAIR (STBD)	$6,643.00	$63.86		$7,280.15	
STERN TUBE RUB RAIL, INSPECT & REPAIR (PORT)	$6,643.00	$63.86		$7,280.15	
STERN TUBE RUB RAIL, INSPECT & REPAIR (C/L)	$6,643.00	$63.86		$7,280.15	
FSB & BEARING LAND MEASUREMENT, INSPECTION, REMOVAL AND INSTALLATION (ALL)	$519,655.00	$63.86		$569,496.56	
THRUST BEARING (ALL) OPEN, INSPECT AND CHECK CLEARANCES	$461,837.00	$63.86		$506,133.08	
COOPER BEARING REPLACEMENT	$16,708.00	$63.86		$18,310.51	

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
PROPULSION SHAFT - REMOVE & INSTALL (STBD)	$845,028.00	$63.86	40%	$1,296,507.79	Possible water intrusion into CPP system
PROPULSION SHAFT - REMOVE & INSTALL (Port)	$816,261.00	$63.86	40%	$1,252,371.22	Possible water intrusion into CPP system
Propulsion Shaft - Remove and Install (C/L)	$837,002.00	$63.86	40%	$1,284,193.68	Possible water intrusion into CPP system
Controllable Pitch Propelier Overhaul, Stbd-CL-Port	$1,050,000.00		50%	$1,726,062.65	Sub-Contracted to OIW, Possible water intrusion into CPP system
OD Box - Open, Inspect (All)	$169,270.00	$63.86	100%	$371,010.32	Possible water intrusion into CPP system
24302 Shafting and OD Box Items; Procure LLTM	$91,965.00	$59.00		$100,785.62	
Turbine Exhaust Stack Uptakes Inspection	$67,575.00	$63.86		$74,056.31	
Reduction Gear Disconnect Coupling Repairs	$52,253.00	$59.00		$57,264.73	
FUEL VALVES AND MANIFOLD, OVERHAUL	$456,835.00	$63.86	50%	$750,976.98	Stagnant water and fuel in tanks, pipes, manifolds
MISC FUEL OIL VALVES, OVHL	$257,096.00	$63.86	50%	$422,632.19	Stagnant water and fuel in tanks, pipes, manifolds
MDE & SSDG LUBE OIL COOLERS CLEAN, INSPECT & HYDRO	$311,960.00	$63.86	50%	$512,821.43	Diesel Engines were not

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
					properly laid up
Shoretie valves, renew	$52,126.00	$63.86		$57,125.55	
BOILER BLOW-DOWN VALVES OVERHAUL/RENEW	$29,906.00	$63.86		$32,774.37	
Boiler Safety Relief Valves, Overhaul	$76,249.00	$63.86		$83,562.25	
SEA VALVES, OVERHAUL	$323,008.00	$63.86	50%	$530,982.90	Submerged and un-cycled
Sea Strainers (Hayward) Open, Clean & Inspect	$414,581.00	$63.86	50%	$681,516.93	Submerged and un-cycled
FIRE MAIN VALVES, Greater Than 2.5 OVERHAUL 521.002	$621,395.00	$63.86	50%	$1,021,492.09	Stagnant sea water in firemain
Firemain and Saltwater System Valves, Replace	$109,432.00	$63.86	50%	$179,891.89	Stagnant sea water in firemain
BILGE MANIFOLD VALVES, OVERHAUL	$563,606.00	$63.86	50%	$926,494.54	Stagnant water in bilge system
P/W PNEUMATIC TANKS, CLEAN, INSPECT AND HYDRO, TEST AND SET RELIEF VALVES	$36,585.00	$63.86		$40,093.97	
STEAM RELIEF VALVES, OVERHAUL/RENEW	$30,031.00	$63.86		$32,911.36	
MDE & SSDG J/W COOLER, CLEAN , INSPECT & HYDRO	$165,830.00	$63.86	50%	$272,602.83	Diesel Engines were not properly laid up
FIXED CO2 AND HALON SYSTEMS ANNUAL CERTIFICATION	$14,402.00	$63.86		$15,783.34	
HOP clean & inspect	$17,564.00	$63.86		$19,248.61	
STEERING MOTOR CASREP	$20,176.00	$63.86		$22,111.14	
RUDDER STOCKS & LINERS INSPECT & REPAIR	$334,180.00	$63.86	30%	$476,101.78	Submerged and un-cycled
RUDDER STOCK BEARINGS CHECK CLEARANCES	$52,043.00	$63.86		$57,034.59	
RUDDER, INSPECT, REPAIR AND PRESERVE (100%)	$24,371.00	$63.86		$26,708.49	
TOWING BITS, CHOCKS, & FAIR LEADS INSPECT & TEST	$44,059.00	$63.86		$48,284.82	

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
SEWAGE TRANSFER PUMPS AND HOLDING TANKS CLEAN & INSPECT, CMP17699	$787,607.00	$63.86	100%	$1,726,297.17	Stagnant sewage in pumps and tanks.
SEWAGE PIPING, CLEAN & FLUSH	$120,040.00	$63.86	100%	$263,106.74	Stagnant sewage in pipes.
TURBINE ROOM BILGE PRESERVATION, CSMP 03020	$294,873.00	$63.86		$323,155.09	
Motor Room Partial Preservation	$168,987.00	$63.86		$185,195.01	
Rudder Trunk, Preserve	$47,146.00	$63.86		$51,667.90	
Cooper Bearing Compartment Preservation	$62,797.00	$63.86		$68,820.04	
CATHODIC PROTECTION / ZINCS CLEAN & INSPECT, CMP17748	$42,428.00	$63.86		$46,497.39	
DRYDOCK CUTTER	$1,036,061.00	$63.86		$1,135,432.50	
Main Motor L.O. Sumps; Drain, Inspect and Fill	$18,685.00	$63.86		$20,477.13	
Steering Gear Flex Hoses & Fittings	$7,915.00	$63.86		$8,674.15	
Shaft Seal Hoses & Fittings	$8,355.00	$63.86		$9,156.35	
Mast Stay Inspection & Pull Test	$48,200.00	$65.00		$52,823.00	
No. 1 Free Turbine & Gas Gen, Replace	$230,387.00	$65.00		$252,484.06	
No. 2 Free Turbine & Gas Gen, Replace	$418,984.00	$65.00		$459,169.92	
No. 3 Free Turbine & Gas Gen, Replace	$200,555.00	$65.00		$219,790.79	
SS & MP Generator, Inspect & Clean (All)	$302,797.00	$65.00		$331,839.11	
F/O Purifier & Ancillary Equip, Clean & Inspect	$33,588.00	$65.00		$36,809.52	
L/O Purifier Sump, Clean & Inspect	$78,303.00	$65.00		$85,813.26	
Navigation Console Foundation Installation	$9,956.00	$65.00		$10,910.91	
Misc Piping Repairs	$51,484.00	$65.00		$56,421.97	
Zones 1 & 2 Flex Hose & Fittings Renewal	$446,749.00	$65.00		$489,597.94	
Air Handler Groom	$224,015.00	$65.00		$245,500.90	
Vent Ducts (Engine & Motor Room, All) Commercial Cleaning	$57,210.00	$65.00		$62,697.17	

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
No 1 & 2 Boiler, Inspect & Test	$229,296.00	$65.00	100%	$502,576.84	Boilers not laid up, drained and dried only.
Steam Reducing Regulating Valves; Overhaul	$74,931.00	$65.00		$82,117.84	
Air Receiver & Relief Valve, Inspect & Test	$35,195.00	$65.00		$38,570.65	
Fixed CO2 & Halon Systems Annual Certification	$4,866.00	$65.00		$5,332.71	
Commissary Hoist Level 2, Inspect & Test	$10,293.00	$65.00		$11,280.23	
Engineer Elevator Level 2, Inspect & Test	$10,216.00	$65.00		$11,195.85	
Anchor Windlass (Gen) Level 2, Inspect & Test	$281,724.00	$65.00		$308,744.94	
Oily Water Separator 5-year Overhaul	$135,387.00	$65.00		$148,372.35	
No 1 and No 2 OWS 5 Year Overhaul; Procure LLTM	$23,473.00	$59.00		$25,724.36	
Exhaust Stack Top Safety Climb Anchor	$19,208.00	$65.00		$21,050.29	
Renewal of Metal Decks	$168,152.00	$65.00		$184,279.93	
03 Level Deck Repairs	$64,590.00	$65.00		$70,785.01	
Chain Locker Clean and Inspect	$75,402.00	$65.00		$82,634.02	
Chain Locker Preservation	$267,585.00	$65.00		$293,249.82	
WT Doors and Scuttles, Inspect and Renew	$261,391.00	$65.00		$286,461.74	
Diver Support for CPP Pitch Calibration	$16,190.00	$65.00		$17,742.83	
Overhaul E-Gen Fuel Oil Cooler Louvers and Actuators	$26,202.00	$65.00		$28,715.11	
Electric Breakers, 400 Hz, Inspect and Test	$19,233.00	$65.00		$21,077.69	
Electric Breakers, 60 Hz, Inspect and Test	$103,888.00	$65.00		$113,852.19	
Salt Water Pumps, Overhaul	$375,956.00	$65.00	50%	$618,022.48	Stagnant salt water in pumps and piping
Flex Hoses and Couplings Renewal, Zone 3	$243,157.00	$65.00		$266,478.87	
Hull Lagging Renewal, Motor Gear Room	$185,082.00	$65.00		$202,833.73	
Vent Fans and Motors, Critical	$203,103.00	$65.00		$222,583.18	

Depot Level Maintenance	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION	
Monitor					
Vent Systems Repairs	$384,058.00	$65.00		$420,894.07	
Preserve and Insulate Vent Ducting (03-49-00-Q Bridge Fan Space)	$79,756.00	$65.00		$87,405.62	
Vent Ducts (All Other) Commercial Cleaning	$90,444.00	$65.00		$99,118.74	
Diesel Room No. 2 Vent Ducting Insulation Renewal	$51,009.00	$65.00		$55,901.42	
CPO Fan Piping Renewal and Ventilation Inspection	$194,394.00	$65.00		$213,038.87	
Flight Deck Drains	$100,694.00	$65.00		$110,351.84	
Evaporators (Gen) Overhaul	$219,374.00	$65.00	50%	$360,622.16	Evaps not properly laid up
Fixed CO2, Inspect and Test	$26,451.00	$65.00		$28,987.99	
Anchor Chains and Ground Tackle Inspect and Repair	$125,721.00	$65.00		$137,779.25	
Warping Capstan (Gen) Level 2 Inspect and Repair	$23,412.00	$65.00		$25,657.51	
Helo Hangar Door and Track (Gen) Overhaul	$168,749.00	$65.00		$184,934.19	
Incinerator, Clean, Inspect, Op-Test	$53,185.00	$65.00		$58,286.12	
CPO Fan Space Bulkhead Renewal	$257,995.00	$65.00		$282,740.02	
Hull Plating, Weather Decks Preserve (All)	$690,565.00	$65.00		$756,799.02	
Hatch Coaming Install	$255,659.00	$65.00		$280,179.97	
Stuffing Tube Renewal	$38,982.00	$65.00		$42,720.87	
Pressure Gauges and Thermometers (Critical), Calibrate	$21,484.00	$65.00		$23,544.59	
Additional Air Conditioning Plant Repairs	$11,148.00	$65.00		$12,217.24	
Total	$22,612,914.00			$30,722,825.65	

Habitability Upgrades	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION
Description	Total Item Cost	Labor Rate		
Reefer & Laundry Flex Hose &	$18,173.00	$63.86		$19,916.02

Habitability Upgrades	POLAR STAR REACTIVATION			POLAR SEA REACTIVATION
Fitting Renewal				
Vent Ducts (Galley & Pantry Room All) Commercial Clean	$21,123.00	$63.86		$23,148.97
Vent Ducts (Laundry Exhaust) Commercial Clean	$9,421.00	$63.86		$10,324.59
Freezer Thaw Chill Compartment	$97,158.00	$63.86		$106,476.69
Crew's Stateroom Rehab	$306,648.00	$63.86		$336,059.47
Self-Help LLTM (Racks/Lockers)	$213,811.00	$63.86		$234,318.21
Comp Key & Lock Renewal	$54,200.00	$63.86		$59,398.47
Crew's Sanitary Spaces Rehab	$238,259.00	$63.86		$261,111.09
Renew Deck Covering, Wardroom Mess	$20,467.00	$65.00		$22,430.05
Renew Deck Covering, Chart Room	$22,160.00	$65.00		$24,285.43
CPO Head Restoration	$263,375.00	$65.00		$288,636.03
Re-hab 1st Class Female Head	$35,887.00	$65.00		$39,329.02
Additional Panel Abatement	$64,423.00	$65.00		$70,601.99
Total	$1,365,105.00			$1,496,036.03

Electronic Systems Upgrades & Grooms	POLAR STAR REACTIVATION	POLAR SEA REACTIVATION
Description	Total Item Cost	Total Item Cost
System Renewals		
PBX Upgrade	$169,573.49	$185,837.76
ECDIS/Vega Install	$180,000.00	$197,264.30
LAN Switch Replacement	$65,000.00	$71,234.33
MILSATCOM Upgrade	$90,000.00	$98,632.15
Iridium Secure Voice	$75,000.00	$82,193.46
Renew all cabling	$300,000.00	$328,773.84
AN/SPS-50	$47,000.00	$51,507.90
HF Install	$300,000.00	$328,773.84
Doppler Speed Log	$100,000.00	$109,591.28
NAVMACS Antenna Group	$100,000.00	$109,591.28
Science GPS Thales NAV ADU 5	$40,000.00	$43,836.51
Science VSAT	$225,000.00	$246,580.38
SWIII Server Upgrade	$35,000.00	$38,356.95
Flight Deck Video System Install	$130,000.00	$142,468.66
Saturn B/Inmarsat	None	None
VHF- AM Transceiver/FM Guard Receive Install	$110,000.00	$120,550.41
Fleet Broad Band	$36,000.00	$39,452.86

Electronic Systems Upgrades & Grooms	POLAR STAR REACTIVATION	POLAR SEA REACTIVATION
KU-Band	$300,000.00	$328,773.84
SIPRNET	$200,000.00	$219,182.56
HFDX Removal	$10,000.00	$10,959.13
DTS Antenna Control Unit(would need entire system)	$200,000.00	$219,182.56
SINS (V)35	$150,000.00	$164,386.92
Mapserver	$100,000.00	$109,591.28
Terrascan	$250,000.00	$273,978.20
VHF-FM	$50,000.00	$54,795.64
AIS	$10,000.00	$10,959.13
HF Coupler Replacement	$385,000.00	$421,926.42
Grooms		
Groom – OE082 Antenna Change-out	$300,000.00	$328,773.84
TV-DTS		
IFF		
Groom – 1MC		
Bathy 2010		
TACAN		
Groom - MILSATCOM		
Groom - ESR		
FCIP (Field Change Improvement Program)		
CCET		
EMC (Electromagnetic Compatibility)		
Total	$3,957,573.49	$4,337,155.41

Pending TCTOs	POLAR STAR REACTIVATION	POLAR SEA REACTIVATION
	Total Item Cost	Total Item Cost
Westinghouse	$ 2,500,000.00	$2,739,781.98
Main Propulsion & SSDG Governor Control Renewal	$ 2,000,000.00	$2,191,825.58
SCBA Scuttle Upgrade	$ 500,000.00	$547,956.40
Reduction Gear Lube Oil Heater Renewal	$ 180,400.00	$197,702.67
Oily Water Separator Renewal	$ 500,000.00	$547,956.40
Turbo Charger Air Filter Install	$ 70,000.00	$76,713.90
Fire Pump Replacement	$ 130,000.00	$142,468.66
Gyro Autopilot Replacement	$ 200,000.00	$219,182.56
Total	**$ 6,080,400.00**	$6,663,588.13

Coast Guard Project Staff				2014	2015	2016	2017	
	Grade	Location	Labor Rate (Off Site)	Planning & Procurement	Industrial Period		Ready For Sea Close Contract	Notes
Port Engineer & Availability Contract COR	LCDR	Seattle		$ 153,008.00	$ 156,068.16	$ 159,189.52	$ 162,373.31	RP Billet to be Requested
Contract Specialist	GS-12	Seattle		$ 141,882.00	$ 144,719.64	$ 147,614.03	$ 150,566.31	RP Billet to be Requested
Port Engineer Support (Contractor)	Eng Level III	Seattle	$ 120.00	$ 249,600.00	$ 254,592.00	$ 259,683.84	$ 264,877.52	
Inspector Mechanical (Contractor)	Eng Level II	Seattle	$ 95.00	$-	$ 201,552.00	$ 205,583.04	$ -	Inspectors only required during industrial period
Inspector Mechanical (Contractor)	Eng Level II	Seattle	$ 95.00	$-	$ 201,552.00	$ 205,583.04	$ -	Inspectors only required during industrial period
Inspector Electrical (Contractor)	Eng Level II	Seattle	$ 95.00	$-	$ 201,552.00	$ 205,583.04	$ -	Inspectors only required during industrial period
Inspector Structural (Contractor)	Eng Level II	Seattle	$ 95.00	$-	$ 201,552.00	$ 205,583.04	$ -	Inspectors only required during industrial period
Financial & Supply Support (Contractor)	Sec & Admin	Seattle	$ 50.00	$ 104,000.00	$ 106,080.00	$ 108,201.60	$ 110,365.63	
CG-45 Project Manager	LCDR	DC	$-	$-	$ -	$-	$ -	General Detail Billet
LRE PL Projects Branch Chief (CDR)	CDR	Oakland	$-	$-	$ -	$-	$ -	General Detail Billet
Business Manager (Contractor)	Fin An II	Oakland	$ 100.00	$ 208,000.00	$ 212,160.00	$ 216,403.20	$ 220,731.26	
Engineering Technical Support; TCTO, MPC, etc. (Contractor)	Eng Level II	Seattle	$ 95.00	$ 197,600.00	$ 201,552.00	$ 205,583.04	$ 209,694.70	
			Total	**$ 1,054,090.00**	**$ 1,881,379.80**	**$ 1,919,007.40**	**$ 1,118,608.74**	
					Project Staff Total		**$ 6,545,981.28**	

Availability Project Support	POLAR STAR REACTIVATION				POLAR SEA REACTIVATION
Description	Total Item Cost	Labor Rate	Phase		Total Item Cost
Shipyard Planning & Project Management					
Basic Planning Work Item (Incl DS/DD PMT)	$ 1,544,877.00	$ 59.00			$ 1,693,050.46
PRODUCTION CONTROL, GANT BAR CHART PROVIDE	$ 43,508.00	$ 63.86	2DS		$ 47,680.97
PRODUCTION CONTROL, GANT BAR CHART PROVIDE	$ 51,768.00	$ 63.86	3DD		$ 56,733.21
STABILITY CONTROL	$ 74,582.00	$ 63.86	3DD		$ 81,735.37
Dockside Project Management	$ 760,732.00	$ 63.86	2DS		$ 833,695.93
Drydock Project Management	$ 1,096,210.00	$ 63.86	3DD		$ 1,201,350.56
Production Control, Gantt Bar Chart Provide	$ 60,083.00	$ 65.00	4DS		$ 65,845.73
Dockside Project Management	$ 1,788,100.00	$ 65.00	4DS		$ 1,959,601.66
Production Control, Gantt Bar Chart Provide	$ 57,530.00	$ 65.00	5DS		$ 63,047.86
Dockside Project Management	$ 1,676,574.00	$ 65.00	5DS		$ 1,837,378.89
Dock /SeaTrials	$ 355,446.00	$ 65.00	5DS		$ 389,537.82
Total	**$ 7,509,410.00**				**$ 8,229,658.47**
Temporary Services					
TEMPORARY SERVICES, PROVIDE	$ 954,986.00	$ 63.86	2DS		$ 1,046,581.37
TEMPORARY SERVICES, PROVIDE (Drydock)	$ 965,786.00	$ 63.86	3DD		$ 1,058,417.23
Temporary Services Provide	$ 1,578,424.00	$ 65.00	4DS		$ 1,729,815.05
Temporary Services, Provide	$ 1,607,570.00	$ 65.00	5DS		$ 1,761,756.53
Total	**$ 5,106,766.00**				**$ 5,596,570.18**
Firewatches					
FIREWATCH, PROVIDE	$ 524,364.00	$ 63.86	2DS		$ 574,657.21
FIREWATCH, PROVIDE	$ 190,470.00	$ 63.86	3DD		$ 208,738.51
Firewatch, Provide	$ 180,350.00	$ 65.00	4DS		$ 197,647.87
Firewatch, Provide	$ 359,673.00	$ 65.00	5DS		$ 394,170.24
Total	**$ 1,254,857.00**				**$ 1,375,213.84**
Transportation					
TRANSPORTATION SERVICES	$ 113,307.00	$ 63.86	2DS		$ 124,174.59
Transportation Services (drydock)	$ 99,686.00	$ 63.86	3DD		$ 109,247.16
Transportation Support	$ 164,099.00	$ 65.00	4DS		$ 179,838.19
Transportation Support	$ 182,718.00	$ 65.00	5DS		$ 200,242.99
Total	**$ 559,810.00**				**$ 613,502.94**
Availability Project Support Grand Total	**$ 14,430,843.00**				**$ 15,814,945.43**

POLAR STAR OUTFIT RESTORATION COST BY DIVISION				
Division	**Priority 1**	**Priority 2**	**Priority 3**	**Division Totals**
AUX	$ 66,500.00	$ 127,250.00	$ 125,500.00	$ 319,250.00
DCK	$ 128,500.00	$ 22,000.00	$ 159,000.00	$ 309,500.00
EDC	$ 117,825.00	$ 113,535.00	$ 24,473.00	$ 255,833.00
EEM	$ 52,350.00	$ 42,000.00	$ 45,725.00	$ 140,075.00
EET	$ 74,300.00	$ 32,000.00	$ 58,000.00	$ 164,300.00
FS	$-	$ 23,500.00	$ 7,500.00	$ 31,000.00
MAA	$ 41,000.00	$ 38,009.00	$ 44,000.00	$ 123,009.00
MED	$-	$ 3,500.00	$-	$ 3,500.00
MPA	$ 89,500.00	$ 340,500.00	$-	$ 430,000.00
MST	$ -	$ 48,000.00	$-	$ 48,000.00
SSK_YN	$ 60,000.00	$ 192,000.00	$-	$ 252,000.00
Totals	**$ 629,975.00**	**$ 982,294.00**	**$ 464,198.00**	**$ 2,076,467.00**
POLAR SEA OUTFIT RESTORATION COST (inflation indexed)				**$ 2,275,626.75**
POLAR SEA OBRP RESTORATION COST (based on TAV extract)				**$ 1,139,778.41**
POLAR CLASS SPARE PROPELLER BLADES, 1EA RH & 1EA LH				**$ 800,000.00**
Total for OBRP & Outfit				**$ 4,215,405.16**

Appendix C: NAVSEA Independent Review

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
1333 ISAAC HULL AVENUE
WASHINGTON NAVY YARD DC 20376-0001

IN REPLY
REFER TO

9200
Ser 05D/343
10 Jul 13

FOR OFFICIAL USE ONLY

From: Commander Naval Sea Systems Command (SEA 05D)
To: Commandant, U.S. Coast Guard, CG-751)

Subj: NAVSEA COMMENTS ON USCG BUSINESS CASE ANALYSIS REGARDING THE REACTIVATION OF THE USCG POLAR SEA

Ref: (a) MIPR HSCG85-13-X-P30J10/ P30J24, CGC Polar Sea BCA support
(b) CGC POLAR SEA Business Case Analysis 2013 Report to Congress
(c) Memorandum of Agreement between US Coast Guard, (CG-4, CG-9) and Naval Sea Systems Command (SEA 05) A NAVSEA Lead Systems Engineer to coordinate engineering support provided to the USCG - February 2008

Encl: (1) NAVSEA POLAR SEA Inspection Notes

1. Reference (a) provided tasking and funding for NAVSEA to conduct a site visit to the POLAR SEA to "Provide feedback and an overall assessment of the work package and make recommendations for additional items to be accomplished as part of the overhaul and reactivation."

NAVSEA did not participate in the development of reference (b) but did conduct a limited independent Condition Assessment of the POLAR SEA's and some general assessment of planned Work Items and reactivation costs as outlined in reference (b). A two day walk-through inspection of the POLAR SEA and POLAR STAR (for comparison) and some interviews with former POLAR SEA crewmembers and shore side support personnel was conducted. During the inspection, no equipment was operated and no tanks or voids were opened.

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2. **Condition Assessment**. Overall, POLAR SEA was in remarkably good condition. Prior to deactivation many systems had received major depot level maintenance and the ship was being prepared to remain in service for many years into the future. It appeared that regular maintenance, upkeep and preservation was taking place right up to the time the cutter was removed from service in November of 2011.

In general, the overall Condition Assessment portion of Reference (b) appears to be accurate. The following areas are noted as somewhat better than what is stated in Reference (b)

a) **Structural**. The Shell Plating is listed as FAIR, where the NAVSEA assessment was that it should be EXCELLENT. Framing and longitudinals, bilges, decks, deck covering, interior bulkheads and habitability were all listed as FAIR. The NAVSEA assessment is that they are GOOD. There was only limited and minor wastage and material loss noted where frames and stiffener meet the deck which is typically where the onset of corrosion begins.

b) **Habitability**. Most staterooms, living spaces, food service spaces were in GOOD condition and could easily be reconstituted with little effort.

c) **Auxiliary**. Ventilation systems, distributed systems, fan rooms, electrical distribution system are listed as FAIR. The NAVSEA assessment is that they are GOOD.

Enclosure (1) outlines the in greater detail the NAVSEA assessment including recommendations for additional items to be considered.

3. **Cost Estimate**. In general, the methodology used in reference (b) to determine the reactivation costs for the POLAR SEA represents a reasonable estimating approach. Utilizing the costs from the recent reactivation of the POLAR STAR leverages a similar work package including recent labor and material costs from the same geographic area. The following comments should be considered when attempting to determine a more refined reactivation cost estimate:

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a) **Major Sy tem Upgrade** . All of the Major System Upgrades seem to have a direct inflation factor applied but it is not clear what benefits or offsets are being taken for the reduction in non-recurring engineering costs and the learning curve, both from the Coast Guard and the Industrial Base. Many system upgrades (engine overhauls and replacements, crane replacement, machinery plant and gas turbine control system upgrades) can benefit from the recent effort aboard POLAR STAR.

Accordingly, the estimated Major System Upgrades costs outlined in Reference (b) likely represent the upper limit and the actual costs would likely be lower once the non-recurring engineering and learning-curve cost savings are introduced.

b) **acklog Depot Level Maintenance. The POLAR SEA** reactivation BCA assumes that nearly all depot maintenance is due or will be completed during a reactivation period and that there would be no significant Depot level maintenance due at the time of reactivation. Normally maintenance comes due either from the passing of time (calendar based) or the accumulation of operating time on equipment (hours based). Since the POLAR SEA has been inactive for several years, a broad assessment that all Depot maintenance is required likely overestimates the reactivation costs. The "scaling growth factor" applied to many depot level items over and above the POLAR STAR reactivation costs needs to be re-examined. It is unclear why this is being applied. The cost estimate for Depot Maintenance backlog likely represents the upper bound of any cost estimate.

c) **Habitability Upgrade** . The estimate to complete this work is likely on the high side as most habitability spaces are in good condition and can easily be reconstituted. Additionally, whole-sale replacement of asbestos panels is likely not required as POLAR SEA has already completed some of this work.

d) **Electronic Upgrade** . Nearly all the communications, navigation and other C4ISR systems have been removed. It is not clear if these were installed on the POLAR STAR, allocated as spares or placed in shore-side storage. Part of any decision to reactivate the POLAR SEA should include

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a more in-depth assessment of the cost to reconstitute these systems.

Part of any decision to reactivate the Polar Sea should include an assessment of the cost to reconstitute these systems to a configuration similar to the POLAR STAR or develop a C4I suite based on a newer, more supportable configuration baseline possibly based on systems fielded on other cutter classes.Any estimate to reactivate the Polar Sea should also include a significant cost to reconstitute a good portion of the C4I cable plant. It is clear that many of the cables were cut during removal of the topside and interior rack mounted equipment. Discussions with prior Polar STAR/SEA Electronics Technicians reaffirmed that this would be the biggest challenge to reactivation. Without knowing the disposition or condition of the removed equipment or the extent to which the cabling replacement is required, there is a high likelihood that the estimate in this area is inaccurate.

e) **OBRP-Outfit Restoration.** Stores, storerooms items, consumables, outfit and furnishings and spare parts are nearly all removed. A significant effort will be required to reconstitute the onboard repair parts as part of a reactivation. The transfer of spare parts, outfitting items and, in some cases, the wholesale cannibalization of installed equipment coupled with a lack of an accurate inventory would indicate that there is a high likelihood that the estimate in this area is inaccurate and likely underestimates what the actual cost would be.

4. **Recommendation:** The Polar Sea was a fully mission ready cutter that has only been deactivated for a short time. Despite the limited lay-up and preservation that was completed, the ship has not yet reached the "tipping point" where the impact of remaining idle will start to significantly impact the reactivation costs. **Accordingly, if the decision is made to reactivate the Polar Sea, or if the decision to reactivate is going to be delayed, it would be prudent to invest in properly laying up and preserving the cutter while these decisions are being made before the long term impacts of remaining idle start to take hold on the ship and systems.**

5. The Condition Assessment is generally accurate and the

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methodology used to develop the Reactivation Cost Estimate portions of reference (b) represents a sound and reasonable approach. Utilizing the costs from the recent reactivation of the POLAR STAR leverages a similar work package including recent labor and material costs from the same geographic area.

6. My Point of Contact for this issue is the NAVSEA Lead Systems Engineer (LSE) for Coast Guard Technical Assistance, Mr. Abe Boughner. Mr. Boughner can be reached at 215 897 1814, or abe.boughner@navy.mil.

ROBIN P. WHITE
By direction

Copy to:
CG-45, (Ibrahim)
SEA 05
SEA 05D, SEA 05D4 (Cable),
NSWC-CD, 915 (Boughner)

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Appendix D: Personnel Rates and Ranks

Table C1: CG SPC FY2013 Rates

RANK	AFC01 R	AFC20 R	AFC20 NR	AFC08 R
*Officers				
O-8	$ 206,094	$ 9,678	$ 14,314	
O-7	$ 200,332	$ 9,822	$ 14,526	
O-6	$ 168,906	$ 7,215	$ 10,671	
O-5	$ 149,257	$ 7,855	$ 11,618	
O-4	$ 127,309	$ 7,258	$ 10,734	
O-3	$ 107,049	$ 5,736	$ 8,483	
O-2	$ 84,914	$ 4,192	$ 6,200	
O-1	$ 64,138	$ 3,447	$ 5,098	
CAD	$ 15,259	$ 1,614	$ 2,386	
W-4	$ 117,025	$ 4,715	$ 6,973	
*Enlisted				
E-9	$ 115,313	$ 5,591	$ 8,268	
E-8	$ 97,181	$ 6,050	$ 8,947	
E-7	$ 86,378	$ 5,667	$ 8,381	
E-6	$ 73,792	$ 4,959	$ 7,334	
E-5	$ 62,518	$ 3,772	$ 5,578	
E-4	$ 51,507	$ 2,638	$ 3,901	
E-3	$ 38,519	$ 1,359	$ 2,010	
E-2	$ 33,989	$ 815	$ 1,205	
E-1	$ 19,089	$ 775	$ 1,146	
*Civilian				
GS-15				$ 187,100
GS-14				$ 160,600
GS-13				$ 135,800
GS-12				$ 112,500
GS-11				$ 95,400
GS-10				$ 93,400
GS-09				$ 78,400
GS-08				$ 76,300
GS-07				$ 67,000
GS-06				$ 60,200
GS-05				$ 55,600
GS-04				$ 50,500
GS-03				$ 37,700

	AFC30 R	AFC56 R	AFC56 NR	AFC57 R
Officers	$ 6,230	$ 3,167	$ 2,343	$ 8,914
Warrant Officers	$ 6,230	$ 2,384	$ 1,478	$ 8,914
Enlisted Personnel	$ 5,865	$ 1,857	$ 1,398	$ 8,914
Civilian	$ 5,354	$ 598		

Table D2: POLAR SEA Operational Crew # of Billets by Rank

Operational Crew	
Rank	Polar Sea
O6	1
O5	1
O4	2
O3	1
O2	4
O1	2
W4	4
E9	4
E8	1
E7	10
E6	13
E5	12
E4	33
E3	29
E2	17
Total	134

Table D3: POLAR SEA Government Unit Maintenance Support # of Billets by Rank

Rank	Polar Sea
O-4	1
O-3	0.9
CWO3	0
CWO2	0.6
E-9	0.3
E-8	0.3
E-7	0.8
E-6	4.1
E-5	4
E-4	1
E-3	0.6
E-2	0.2
GS-13	0.2
GS-12	2.4
GS-11	4.4
GS-7	0.2
TOTAL	21

Appendix E: Risk Elements

Table E1: Risk Elements

Variable or WBS Elements	Distribution Type	Parameter 1	Parameter 2	Parameter 3	Data Source(s)
Number of Year Crew Assembled Prior to Delivery for POLAR SEA	Triangular	Low = 1	ML = 2	High = 2	Engineering Judgment
Shore Support Personnel	Triangular	Low (% of PE) = 95	ML(PE) = 100	High (% of PE) = 105	Engineering Judgment
Fuel Price ($ per gallon)	Triangular	Skew = Center	CV = .30	N/A	DESC Fuel Prices (Feb2009-October 2012)
Average Annual O&D Level Maintenance Cost	Triangular	Low = 4069	ML = PE	High = 22991	FLS Historical Data(FY2000-FY2010)
Average Annual Electronic Support Cost	Triangular	Low (% of PE) = 95	ML(PE) = 100	High (% of PE) = 105	Engineering Judgment
Average cost per student	Triangular	Low (% of PE) = 95	ML(PE) = 100	High (% of PE) = 105	Engineering Judgment
Average cost per instructor	Triangular	Low (% of PE) = 95	ML(PE) = 100	High (% of PE) = 105	Engineering Judgment
Average of HEALY and POLAR SEA Recap Spent	Triangular	Low = 500	ML = PE	High = 6140	POLAR SEA Historical Data (FY2000-FY2010)
GLIB Shore Facilities Upgrades Budget Analogy	Triangular	Low (% of PE) = 95	ML(PE) = 100	High (% of PE) = 105	Engineering Judgment
Tow Vessel Cost	Triangular	Low = 500	ML = PE	High = 1000	Engineering Judgment

IX.

Appendix F: Acronym Listing

Ao	Operational Availability
AC	Air Conditioning
AC&I	Acquisition, Construction, and Improvement
ACEIT	Automated Cost Estimating Integrated Tools
AFC	Allotment Fund Code
AFFF	Aqueous Film Forming Foam
ATON	Aids to Navigation
BCA	Business Case Analysis
BTR	Below Threshold Reprogramming
BY	Base Year
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
C4IT	Command, Control, Communications, Computers, and Information Technology
CART	Cutter Assessment of Readiness and Training
CES	Cost Element Structure
CHS	Central Hydraulic System
CIP	Capital Investment Plan
CL	Confidence Level
CMP	Class Maintenance Plan
CPIF	Cost-Plus Incentive Fee
CPP	Controllable Pitch Propeller
CSMP	Current Ship's Maintenance Project
DC	Direct Current
DESC	Defense Energy Support Center
DFCS	Digital Fuel Control System
DHS	Department of Homeland Security
DLA	Defense Logistics Agency
DOD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Material, Leadership, Personnel, and Facilities
DR	Defense Readiness
EDG	Emergency Diesel Generator
ELA	Electrical Load Analysis
ELEX	Electronic
ESR	Equipment Supportability Review
F	Fahrenheit
FFP	Firm Fixed Price
FLS	Fleet Logistics System
FOUO	For Official Use Only
FY	Fiscal Year
GFE	Government Furnished Equipment
GLIB	Great Lakes Icebreaker
HLMAR	High Latitude Mission Analysis Report
HM&E	Hull, Mechanical and Electrical
HP	Horsepower
HPU	Hydraulic Pump Unit
HSPD	Homeland Security Presidential Directive

IMO	International Maritime Organization
IO	Ice Operations
LCCE	Life Cycle Cost Estimate
LHS	Latin Hypercube Sampling
LLTM	Long Lead Time Material
LMR	Living Marine Resources
LRE	Long Range Enforcer
MARAD	Maritime Administration
MCAMS	Machinery Control and Monitoring System
MDE	Main Diesel Engine
MEP	Marine Environmental Protection
MGT	Main Gas Turbine
MPCMS	Machinery Plant Control and Monitoring System
MS	Marine Safety
MSMO	Multi-Ship, Multi-Option
MSU	Major System Upgrade
MTBF	Mean Time Between Failures
MTL	Master Training List
NAVSEA	Naval Sea Systems Command
NDRF	National Defense Reserve Fleet
NSF	National Science Foundation
NSPD	National Security Presidential Directive
NSTM	Naval Ships Technical Manual
NSWC	Naval Surface Warfare Center
O&D	Organizational and Depot
O&M	Operation and Maintenance
O&S	Operation and Support
OEM	Original Equipment Manufacturer
OFCO	Operational Facilities Change Order
OLE	Other Law Enforcement
OM&S	Operating Materials and Supply
OPC	Offshore Patrol Cutter
OPRB	On-Board Repair Parts
PAL	Personnel Allowance List
PC	Polar Class
PCAMS	Propulsion Control and Monitoring System
PL	Product Line
POE	Projected Operating Environment
POL	Petroleum, Oil, and Lubricants
PRV	Polar Research Vessel
PSU	Polar Science Upgrades
PWCS	Ports, Waterways, and Coastal Security
RCFA	Root Cause Failure Analysis
RIP	Reliability Improvement Project
ROC	Required Operational Capability
ROM	Rough Order of Magnitude
SAR	Search and Rescue
SCIF	Sensitive Compartmented Information Facility

SES1	Systems and Equipment Section 1
SFLC	Surface Forces Logistics Center
SLEP	Service Life Extension Project
SME	Subject Matter Expert
SORS	Spilled Oil Recovery System
SPC	Standard Personnel Costs
SSDG	Ships Service Diesel Generator
SSMEB	Ship Structure and Machinery Evaluation Board
SUP1	Supply Section 1
TCTO	Time Compliance Technical Order
TONO	Travel Order Number
TSTA	Tailored Ships Training Availability
TY	Then Year
UNOLS	University-National Oceanographic Laboratory System
UAS	Unmanned Aircraft System
US	United States
USC	United States Code
USCG	United States Coast Guard
USCGC	United States Coast Guard Cutter
WAGB	Coast Guard Polar Icebreaker
WBS	Work Breakdown Structure
WHEC	Coast Guard High Endurance Cutter
WMEC	Coast Guard Medium Endurance Cutter
WMSL	Coast Guard National Security Cutter
WLB	Coast Guard Seagoing Buoy Tender