Acquisition and Operation of Polar Icebreakers: Fulfilling the Nation's Needs

Letter Report

Division on Earth and Life Studies
and
Transportation Research Board of the
National Academies of Sciences, Engineering, and Medicine

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Transportation Research Board of the
National Academies of Sciences, Engineering, and Medicine
500 Fifth Street, NW
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July 11, 2017

The Honorable John F. Kelly
Secretary of Homeland Security
Washington, D.C. 20528

Dear Secretary Kelly:

In the Coast Guard Authorization Act of 2015,[1] Congress required the Secretary of the Department of Homeland Security to enter into an arrangement with the National Academies of Sciences, Engineering, and Medicine (National Academies) for an assessment of alternative strategies for minimizing the costs incurred by the federal government in procuring and operating heavy polar icebreakers. In response to this requirement, the National Academies formed a committee with expertise in naval architecture, ship construction, polar science, polar ship operations, icebreakers, and maritime finance. Names of committee members and members' biographical statements are shown in Appendix F. The committee's statement of task is given in Appendix A. To fulfill its charge, the committee met four times over a 6-month period and was briefed by multiple stakeholders (see Appendix G for a summary of the committee's information-gathering activities). In view of the breadth of the statement of task and the limited time for the report's completion, the committee and congressional staff agreed that the report should focus on strategies to minimize life-cycle costs of polar icebreaker acquisition and operations. The letter report that follows was reviewed in draft form by a group of independent experts according to the policies and procedures approved by the National Academies' Report Review Committee (see Appendix H for names of the reviewers). The committee's overall findings and recommendations start on page 9, and supporting information is referenced in the appendices that follow. The committee is pleased to provide this letter report to inform the decisions that the administration and Congress must make to ensure the nation's continual access to and presence in the Earth's polar regions.

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[1] See Section 604, Public Law 114–120 (Coast Guard Authorization Act of 2015), dated February 8, 2016. https://www.congress.gov/114/plaws/publ120/PLAW-114publ120.pdf.

Sincerely,

Richard West
Committee Chair

cc: Admiral Paul F. Zukunft, Commandant, U.S. Coast Guard

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LETTER REPORT ON POLAR ICEBREAKER COST ASSESSMENT

INTRODUCTION

The United States has strategic national interests in the polar regions. In the Arctic, the nation must protect its citizens, natural resources, and economic interests; assure sovereignty, defense readiness, and maritime mobility; and engage in discovery and research. In the Antarctic, the United States must maintain an active presence that includes access to its research stations for the peaceful conduct of science and the ability to participate in inspections as specified in the Antarctic Treaty. The committee's charge (see Appendix A) was to advise the U.S. House of Representatives and the U.S. Senate on an assessment of the costs incurred by the federal government in carrying out polar icebreaking missions and on options that could minimize life-cycle costs. The committee's consensus findings and recommendations are presented below. Unless otherwise specified, all estimated costs and prices for the future U.S. icebreakers are expressed in 2019 dollars, since that is the year in which the contracts are scheduled to be made. Supporting material is found in the appendices.

FINDINGS AND RECOMMENDATIONS

1. Finding: The United States has insufficient assets to protect its interests, implement U.S. policy, execute its laws, and meet its obligations in the Arctic and Antarctic because it lacks adequate icebreaking capability.

For more than 30 years, studies have emphasized the need for U.S. icebreakers to maintain presence, sovereignty, leadership, and research capacity—but the nation has failed to respond (see Appendix B). The strong warming and related environmental changes occurring in both the Arctic and the Antarctic have made this failure more critical. In the Arctic, changing sea ice conditions will create greater navigation hazards for much of the year, and expanding human industrial and economic activity will magnify the need for national presence in the region. In the Antarctic, sea ice trends have varied greatly from year to year, but the annual requirements for access into McMurdo Station have not changed. The nation is ill-equipped to protect its interests and maintain leadership in these regions and has fallen behind other Arctic nations, which have mobilized to expand their access to ice-covered regions. The United States now has the opportunity to move forward and acquire the capability to fulfill these needs. Appendix B provides a broader discussion and supporting material concerning U.S. icebreaking needs and the changing polar environment, and Appendix E provides additional information about the icebreaking capability of other nations.

2. Recommendation: The United States Congress should fund the construction of four polar icebreakers of common design that would be owned and operated by the United States Coast Guard (USCG).

The current Department of Homeland Security (DHS) Mission Need Statement (DHS 2013) contemplates a combination of medium and heavy icebreakers. The committee's recommendation is for a single class of polar icebreaker with heavy icebreaking capability. Proceeding with a single class means that only one design will be needed, which will provide cost savings. The committee has found that the fourth heavy icebreaker could be built for a lower cost than the lead ship of a medium icebreaker class (see Appendix D, Table D-10).

The DHS Mission Need Statement contemplated a total fleet of "potentially" up to six ships of two classes—three heavy and three medium icebreakers. Details appear in the *High Latitude Mission Analysis Report*. The Mission Need Statement indicated that to fulfill its statutory missions, USCG required three heavy and three medium icebreakers; each vessel would have a single crew and would homeport in Seattle. The committee's analysis indicated that four heavy icebreakers will meet the statutory mission needs gap identified by DHS for the lowest cost. Three of the ships would allow continuous presence in the Arctic, and one would service the Antarctic.

As noted in the *High Latitude Report*, USCG's employment standard is 185 days away from home port (DAFHP) for a single crew. Three heavy icebreakers in the Arctic provide 555 DAFHP, sufficient for continuous presence. In addition, the medium icebreaker USCG Cutter *Healy*'s design service life runs through 2030. If greater capacity is required, USCG could consider operating three ships with four crews, which would provide 740 DAFHP. The use of multiple crews in the Arctic could require fewer ships while providing a comparable number of DAFHP. For example, two ships (instead of the recommended three) operating in the Arctic with multiple crews could provide a similar number of annual operating days at a lower cost, but such an arrangement may not permit simultaneous operations in both polar regions and may not provide adequate redundancy in capability. More important, an arrangement under which fewer boats are operated more often would require more major maintenance during shorter time in port, often at increasing cost. In addition, if further military presence is desired in the Arctic, USCG could consider ice-strengthening the ninth national security cutter.

One heavy icebreaker servicing the Antarctic provides for the McMurdo breakout and international treaty verification. The availability of the vessel could be extended by homeporting in the Southern Hemisphere. If the single vessel dedicated to the Antarctic is rendered inoperable, USCG could redirect an icebreaker from the Arctic, or it could rely on support from other nations. The committee considers both options to be viable and believes it difficult to justify a standby (fifth) vessel for the Antarctic mission when the total acquisition and lifetime operating costs of a single icebreaker are projected to exceed $1.6 billion. Once the four new icebreakers are operational, USCG can reasonably be expected to plan for more distant time horizons. USCG could assess the performance of the early ships once they are operational and determine whether additional capacity is needed.

USCG is the only agency of the U.S. government that is simultaneously a military service, a law enforcement agency, a marine safety and rescue agency, and an environmental protection agency. All of these roles are required in the mission need statement for a polar icebreaker. USCG, in contrast to a civilian company, has the authorities, mandates, and competencies to conduct the missions contemplated for the polar icebreakers. Having one agency with a multimission capability performing the range of services needed would be more efficient than potentially duplicating effort by splitting polar icebreaker operations among other agencies. The requirement for national presence is best accomplished with a military vessel. In addition, USCG is fully interoperable with the U.S. Navy and the nation's North Atlantic Treaty Organization partners. USCG is already mandated to operate the

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nation's domestic and polar icebreakers. Continuing to focus this expertise in one agency remains the logical approach (see Appendix B).

Government ownership of new polar icebreakers would be less costly than the use of lease financing (see Appendix C). The government has a lower borrowing cost than any U.S.-based leasing firm or lessor. In addition, the lessor would use higher-cost equity (on which it would expect to make a profit) to cover a portion of the lease financing. The committee's analysis shows that direct purchase by the government would cost, at a minimum, 19 percent less than leasing on a net present value basis (after tax). There is also the risk of the lessor going bankrupt and compromising the availability of the polar icebreaker to USCG. For its analysis, the committee not only relied on its extensive experience with leveraged lease financing but also reviewed available Government Accountability Office reports and Office of Management and Budget rules, examined commercial leasing economics and current interest rates, and validated its analysis by consulting an outside expert on the issue (see Appendix C).

Chartering (an operating lease) is not a viable option (see Appendix C). The availability of polar icebreakers on the open market is extremely limited. (The committee is aware of the sale of only one heavy icebreaker since 2010.) U.S. experience with chartering a polar icebreaker for the McMurdo resupply mission has been problematic on two prior charter attempts. Chartering is workable only if the need is short term and mission specific. The committee notes that chartering may preclude USCG from performing its multiple missions (see Appendix B and Appendix C).

In the committee's judgment, an enlarged icebreaker fleet will provide opportunities for USCG to strengthen its icebreaking program and mission. Although the number of billets that require an expert is small compared with the overall number of billets assigned to these icebreakers, more people performing this mission will increase the pool of experienced candidates. This will provide personnel assignment officers with a larger pool of candidates when the more senior positions aboard icebreakers are designated, which will make icebreaking more attractive as a career path and increase the overall level of icebreaking expertise within USCG. Importantly, the commonality of design of the four recommended heavy icebreakers will reduce operating and maintenance costs over the service life of these vessels through efficiencies in supporting and crewing them. Having vessels of common design will likely improve continuity of service, build icebreaking competency, improve operational effectiveness, and be more cost-efficient (see also Appendix C and Appendix D).[2]

3. Recommendation: USCG should follow an acquisition strategy that includes block buy contracting with a fixed price incentive fee contract and take other measures to ensure best value for investment of public funds.

Icebreaker design and construction costs can be clearly defined, and a fixed price incentive fee construction contract is the most reliable mechanism for controlling costs for a program of this complexity. This technique is widely used by the U.S. Navy. To help ensure best long-term value, the criteria for evaluating shipyard proposals should incorporate explicitly defined life-cycle cost metrics (see Appendix D).

A block buy authority for this program will need to contain specific language for economic order quantity purchases for materials, advanced design, and construction activities. A block buy

[2] VADM F. Midgette, USCG, briefing to the committee, April 13, 2017.

contracting program[3] with economic order quantity purchases enables series construction, motivates competitive bidding, and allows for volume purchase and for the timely acquisition of material with long lead times. It would enable continuous production, give the program the maximum benefit from the learning curve, and thus reduce labor hours on subsequent vessels.

The acquisition strategy would incorporate (*a*) technology transfer from icebreaker designers and builders with recent experience, including international expertise in design, construction, and equipment manufacture; (*b*) a design that maximizes use of commercial off-the-shelf (COTS) equipment, applies Polar Codes and international standards, and only applies military specifications (MIL-SPEC) to the armament, aviation, communications, and navigation equipment; (*c*) reduction of any "buy American" provisions to allow the sourcing of the most suitable and reliable machinery available on the market; and (*d*) a program schedule that allows for completion of design and planning before the start of construction. These strategies will allow for optimization of design, reduce construction costs, and enhance reliability and maintainability (see Appendix D).

4. Finding: In developing its independent concept designs and cost estimates, the committee determined that the costs estimated by USCG for the heavy icebreaker are reasonable. However, the committee believes that the costs of medium icebreakers identified in the *High Latitude Mission Analysis Report* are significantly underestimated.

The committee estimates the rough order-of-magnitude (ROM) cost of the first heavy icebreaker to be $983 million. (See Appendix D, Table D-6.) Of these all-in costs, 75 to 80 percent are shipyard design and construction costs; the remaining 20 to 25 percent cover government-incurred costs such as government-furnished equipment and government-incurred program expenses. If advantage is taken of learning and quantity discounts available through the recommended block buy contracting acquisition strategy, the average cost per heavy icebreaker is approximately $791 million, on the basis of the acquisition of four ships. The committee's analysis of the ship size to incorporate the required components (stack-up length) suggests an overall length of 132 meters (433 feet) and a beam of 27 meters (89 feet). This is consistent with USCG concepts for the vessel.

Costs can be significantly reduced by following the committee's recommendations. Reduction of MIL-SPEC requirements can lower costs by up to $100 million per ship with no loss of mission capability (see Appendix D, Table D-12). The other recommended acquisition, design, and construction strategies will control possible cost overruns and provide significant savings in overall life-cycle costs for the program.

Although USCG has not yet developed the operational requirements document for a medium polar icebreaker, the committee was able to apply the known principal characteristics of the USCG Cutter *Healy* to estimate the scope of work and cost of a similar medium icebreaker. The committee estimates that a first-of-class medium icebreaker will cost approximately $786 million. The fourth ship of the heavy icebreaker series is estimated to cost $692 million. Designing a medium-class polar icebreaker in a second shipyard would incur the estimated engineering, design, and planning costs of $126 million and would forgo learning from the first three ships; the learning curve would be restarted with the first medium design. Costs of building the fourth heavy icebreaker would be less than the costs of designing and building a first-of-class medium icebreaker (see Appendix D, Table D-10). In developing its ROM cost estimate, the committee agreed on a common notional design and

[3] See O'Rourke and Schwartz 2017 for an overview of the advantages and limitations of block buy contracting and multiyear procurement.

basic assumptions (see Tables D-2, D-3, D-4, and D-5). Two committee members then independently developed cost estimating models, which were validated internally by other committee members. These analyses were then used to establish the committee's primary cost estimate. Uncertainties of the cost estimate are identified and discussed further in Appendix D.

5. Finding: Operating costs of new polar icebreakers are expected to be lower than those of the vessels they replace.

The committee expects the operating costs for the new heavy polar icebreakers to be lower than those of USCG's *Polar Star*. While USCG's previous experience is that operating costs of new cutters are significantly higher than those of the vessels they replace, the committee does not believe this historical experience applies in this case. There is good reason to believe that operating costs for new ships using commercially available modern technology will be lower than costs for existing ships (see Appendix D). The more efficient hull forms and modern engines will reduce fuel consumption, and a well-designed automation plant will require fewer operation and maintenance personnel, which will allow manning to be reduced or freed up for alternative tasks. The use of COTS technology and the minimization of MIL-SPEC, as recommended, will also reduce long-term maintenance costs, since use of customized equipment to meet MIL-SPEC requirements can reduce reliability and increase costs. A new vessel, especially over the first 10 years, typically has significantly reduced major repair and overhaul costs, particularly during dry-dock periods, compared with existing icebreakers—such as the *Polar Star*—that are near or at the end of their service life (see Appendix D). The *Polar Star* has many age-related issues that require it to be extensively repaired at an annual dry-docking. These issues will be avoided in the early years of a new ship. However, the committee recognizes that new ship operating costs can be higher than those of older ships if the new ship has more complexity to afford more capabilities. Therefore, any direct comparisons of operating costs of newer versus older ships would need to take into account the benefits of the additional capabilities provided by the newer ship.

USCG will have an opportunity to evaluate the manning levels of the icebreaker in light of the benefits of modern technology to identify reductions that can be made in operating costs (see Appendix C).

6. Recommendation: USCG should ensure that the common polar icebreaker design is science-ready and that one of the ships has full science capability.

All four proposed ships would be designed as "science-ready," which will be more cost-effective when one of the four ships—most likely the fourth—is made fully science capable. Including science readiness in the common polar icebreaker design is the most cost-effective way of fulfilling both the USCG's polar missions and the nation's scientific research polar icebreaker needs (see Appendix D). The incremental costs of a science-ready design for each of the four ships ($10 million to $20 million per ship) and of full science capability for one of the ships at the initial build (an additional $20 million to $30 million) are less than the independent design and build cost of a dedicated research medium icebreaker (see Appendix D, p. 103). In briefings at its first meeting, the committee learned that the National Science Foundation and other agencies do not have budgets to support full-time heavy icebreaker access or the incremental cost of design, even though their science programs may require this capability. Given the small incremental cost, the committee believes that the science capability cited above should be included in the acquisition costs.

Science-ready design includes critical elements that cannot be retrofitted cost-effectively into an existing ship and that should be incorporated in the initial design and build. Among these elements are structural supports, appropriate interior and exterior spaces, flexible accommodation spaces that can embark up to 50 science personnel, a hull design that accommodates multiple transducers and minimizes bubble sweep while optimizing icebreaking capability, machinery arrangements and noise dampening to mitigate interference with sonar transducers, and weight and stability latitudes to allow installation of scientific equipment. Such a design will enable any of the ships to be retrofitted for full science capability in the future, if necessary (see Appendix D, p. 103).

Within the time frame of the recommended build sequence, the United States will require a science-capable polar icebreaker to replace the science capabilities of the *Healy* upon her retirement. To fulfill this need, one of the heavy polar icebreakers would be procured at the initial build with *full* science capability; the ability to fulfill other USCG missions would be retained. The ship would be outfitted with oceanographic overboarding equipment and instrumentation and facilities comparable with those of modern oceanographic research vessels. Some basic scientific capability, such as hydrographic mapping sonar, should be acquired at the time of the build of each ship so that environmental data that are essential in fulfilling USCG polar missions can be collected.

7. Finding: The nation is at risk of losing its heavy polar icebreaking capability—experiencing a critical capacity gap—as the *Polar Star* approaches the end of its extended service life, currently estimated at 3 to 7 years.

The *Polar Star*, built in 1976, is well past its 30-year design life. Its reliability will continue to decline, and its maintenance costs will continue to escalate. Although the ship went through an extensive life-extending refit in 2011–2012, the *Polar Star*'s useful life is estimated to end between 2020 and 2024. As USCG has recognized, the evaluation of alternative arrangements to secure polar icebreaking capacity is important, given the growing risks of the *Polar Star* losing its capability to fulfill its mission (see Appendix B).

8. Recommendation: USCG should keep the *Polar Star* operational by implementing an enhanced maintenance program (EMP) until at least two new polar icebreakers are commissioned.

Even if the committee's notional schedule for new polar icebreakers is met, the second polar icebreaker would not be ready until July 2025 (see Appendix D, Figure D-2). The committee's proposed EMP could be designed with planned—and targeted—upgrades that allow the *Polar Star* to operate every year for its Antarctic mission. The necessary repairs could be performed in conjunction with the ship's current yearly dry-docking schedule within existing annual expenditures, estimated to average $5 million. In particular, the EMP would require improvements in the ship's operating systems, sanitary system, evaporators, main propulsion systems, and controllable pitch propellers. In the committee's judgment, the EMP could be accomplished within USCG's average annual repair expenditures for the *Polar Star*, which currently range between $2 million and $9 million (see Appendix B).

References

Abbreviation

DHS Department of Homeland Security

DHS. 2013. *Polar Icebreaker Recapitalization Project Mission Need Statement Version 1.0.* Washington, D.C.

O'Rourke, R., and M. Schwartz. 2017. *Multiyear Procurement (MYP) and Block Buy Contracting in Defense Acquisition: Background and Issues for Congress*. Congressional Research Service, Washington, D.C., June 2. https://fas.org/sgp/crs/natsec/R41909.pdf.

Committee on Polar Icebreaker Cost Assessment: Members and Biographical Information

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Committee on Polar Icebreaker Cost Assessment:

Statement of Task

SEC. 604. NATIONAL ACADEMY OF SCIENCES COST ASSESSMENT.

(a) Cost Assessment.—The Secretary of the department in which the Coast Guard is operating shall seek to enter into an arrangement with the National Academy of Sciences under which the Academy, by no later than 365 days after the date of the enactment of this Act, shall submit to the Committee on Transportation and Infrastructure and the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate an assessment of the costs incurred by the Federal Government to carry out polar icebreaking missions.

An ad hoc committee shall:

(1) describe current and emerging requirements for the Coast Guard's polar icebreaking capabilities, taking into account the rapidly changing ice cover in the Arctic environment, national security considerations, and expanding commercial activities in the Arctic and Antarctic, including marine transportation, energy development, fishing, and tourism;

(2) identify potential design, procurement, leasing, service contracts, crewing, and technology options that could minimize life-cycle costs and optimize efficiency and reliability of Coast Guard polar icebreaker operations in the Arctic and Antarctic; and

(3) examine:

(A) Coast Guard estimates of the procurement and operating costs of a Polar icebreaker capable of carrying out Coast Guard maritime safety, national security, and stewardship responsibilities including:

(i) economies of scale that might be achieved for construction of multiple vessels; and

(ii) costs of renovating existing polar class icebreakers to operate for a period of no less than 10 years.

(B) the incremental cost to augment the design of such an icebreaker for multiuse capabilities for scientific missions;

(C) the potential to offset such incremental cost through cost-sharing agreements with other Federal departments and agencies; and

(D) United States polar icebreaking capability in comparison with that of other Arctic nations, and with nations that conduct research and other activities in the Arctic.

(b) Included Costs: For purposes of subsection (a), the assessment shall include costs incurred by the Federal Government for:

(1) the lease or operation and maintenance of the vessel or vessels concerned;

(2) disposal of such vessels at the end of the useful life of the vessels;

(3) retirement and other benefits for Federal employees who operate such vessels; and

(4) interest payments assumed to be incurred for Federal capital expenditures.

(c) Assumptions: For purposes of comparing the costs of such alternatives, the Academy shall assume that:

(1) each vessel under consideration is

(A) capable of breaking out McMurdo Station and conducting Coast Guard missions in the Antarctic, and in the United States territory in the Arctic (as that term is defined in section 112 of the Arctic Research and Policy Act of 1984 (15 U.S.C. 4111)); and

(B) operated for a period of 30 years;

(2) the acquisition of services and the operation of each vessel begins on the same date; and

(3) the periods for conducting Coast Guard missions in the Arctic are of equal lengths.

(d) Use of Information.—In formulating cost pursuant to subsection (a), the National Academy of Sciences may utilize information from other Coast Guard reports, assessments, or analyses regarding existing Coast Guard Polar class icebreakers or for the acquisition of a polar icebreaker for the Federal Government.