9-1-2012

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DOI

http://dx.doi.org/10.5670/oceanog.2012.96

A NEW US POLAR RESEARCH VESSEL FOR THE TWENTY-FIRST CENTURY

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Scientific and political interests at the poles are significant and rapidly increasing, driven in part by the effects of climate change and emerging geopolitical realities. The polar regions provide important services to global ecosystems and humankind, ranging from food and energy to freshwater and biodiversity. Yet the poles are experiencing changes at rates that far outpace the rest of the planet. Coastal Arctic communities are impacted by climate change through coastal erosion, sea level rise, ice loss, and altered marine food webs, threatening the future of their subsistence lifestyle. Climate change has dramatically increased the melt rate of ice sheets and glaciers at both poles and has the potential to significantly raise sea level worldwide. Oil and gas drilling as well as transportation in the Arctic have reached all-time high levels, in part because of reduced sea ice cover. Tourism is a growing industry at both poles, bringing more than 20,000 tourists each year to the western Antarctic Peninsula alone. The collateral effects of human activities include the potential for pollution of the marine environment, particularly through spills of hydrocarbons. Our ability to understand the effects of such activities and mishaps is limited, particularly in ice-covered areas during winter.

Polar marine research is increasingly interdisciplinary, with many important scientific questions requiring approaches that depend on the careful integration of ideas derived from biology, ecology, Earth science, chemistry, and physics. We expect further blurring of disciplinary boundaries in the decades ahead. As new interdisciplinary fields evolve, the design requirements for polar research vessels are changing. Polar scientists envision using icebreakers in new and different ways as fresh approaches to difficult problems and new technologies emerge. The most important science drivers justifying a US national investment in a new polar research vessel include understanding (1) the rates of processes controlling the extent of sea ice and glacial ice, (2) the outsized role of the polar oceans in the global climate system and the global carbon cycle, and (3) changes in polar marine ecosystems. New technologies are fostering innovative and transformative research in all these areas. Access to a greater portion of the polar seas during more months of the year is required. Such access combined with the need to deploy new technologies plus regulatory changes drive the specifications for a new research icebreaker.

Figure 1. Conceptual drawing of a US next-generation polar research vessel.

Polar research requires specialized logistics and infrastructure, including icebreakers that can support science safely, efficiently, and effectively in the ice-covered waters and rough seas of both the Arctic and Antarctic. For the past 21 years, the US Research Vessel Icebreaker *Nathaniel B. Palmer* has provided the research community with an excellent platform for operations in regions that are within its limited icebreaking capabilities. Scientific discoveries from over 100 *Palmer* cruises have transformed our understanding of the Antarctic oceans and seafloor. Yet the vessel's limited ice capability and layout hampers our ability to build on these successes. High-priority research questions with important ramifications for understanding global environmental change and its impacts remain unanswered. Addressing these issues is becoming increasingly important with the accelerating pace of global climate change and the amplification of its impacts in the high latitudes. Simply put, better access to ice-covered regions with a more capable icebreaker is required to address the most pressing research challenges. A new polar research vessel (PRV) should incorporate enhanced capabilities as articulated by the research community to provide increased year-round access to a greater portion of the ice-covered seas at both poles.

In December 2010, The National Science Foundation (NSF) commissioned the University-National Oceanographic Laboratory System (UNOLS) Program Office to establish a committee to review and update a 2006 Antarctic Research Vessel Oversight Committee (ARVOC) report on needs and requirements for a new US polar research vessel. A 12-member multidisciplinary committee was formed and began meeting on January 7, 2011.

The authors of this article constituted the committee, with Rob Dunbar as chair and Jon Alberts representing the UNOLS Office. The committee was charged with:

- Updating the science questions and reviewing/modifying the vessel science mission requirements defined in an ARVOC study conducted between 2002 and 2006
- Articulating and evaluating emerging new science drivers
- Employing the UNOLS model for developing science mission requirements based on inclusive science community input

The UNOLS Science Mission Requirement (SMR) process includes a survey designed to capture the community's vision of future scientific questions and associated ship requirements. Survey results were used to thoughtfully develop design features and parameters for use as guidelines during vessel design. Specific ship systems are integrated into the vessel design to support envisioned science missions. The SMR process provides a science capability framework for the steps between community input, vessel concept design, and final construction. Although mission requirements and technology change with time, the SMR study represents community consensus on vessel requirements.

One hundred and sixty-three written survey responses from the polar scientific and vessel logistics community were supplemented by additional and more nuanced contributions from a UNOLS PRV workshop held at NSF headquarters in Arlington, VA, on February 28 and March 1, 2011. Sixty-six participants discussed science drivers for both Arctic and Antarctic research. Participants were asked to think across disciplines and 30 years into the future, the approximate lifespan of a new icebreaker. The PRV committee met again May 5–6, 2011, at Stanford University. After substantial committee review, an interim report was released publicly and to NSF for comment in August 2011. The PRV SMR committee met a final time

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Table 1. Basic PRV conceptual specifications

Characteristics	Specification
Icebreaking Capability	Continuous transit through 1.5 m (4.9 ft) sea ice at 3 knots (ice classification PC 3)
Accommodations	Crew and marine technicians plus 45 scientists
Length Overall	~ 115 m (380 ft)
Beam	~ 23 m (75 ft)
Draft	~ 9 m (30 ft)
Displacement	~ 11,000 LT (11,200 MT)
Propulsion Horsepower	~ 16.8 MW (22,400 HP)
Special features	Box keel, 4 m x 4 m interior moon pool

at NSF headquarters on December 1–2, 2011, to discuss and incorporate comments and ideas received in response to the interim report. An updated interim report was posted at the UNOLS website on December 5, 2011, along with a final request for public comments. A final report was released to NSF on February 10, 2012, and is publicly available at: http://www.unols.org/committees/fic/smr/PRV/document.html. The full report describes polar marine science drivers and challenges for the decades ahead. Here, we focus on the translation of science drivers to vessel requirements.

A careful review of science drivers and mission requirements leads to the following fundamental ship specification. The United States needs a research icebreaker that can approach ice sheet grounding zones and penetrate much of the polar sea ice pack during winter[1]. These conditions translate to a capability of transiting 1.5 m of sea ice at a speed of 3 kts (ice class PC 3). This specification alone leads to minimum ship dimensions and propulsion requirements that then permit the incorporation of nearly all other required design features. The PRV committee recommends that the vessel have an endurance of 90 days, a range of 25,000 km, and an effective transit speed of 12 kts. The vessel should support up to 45 scientists in addition to crew and technical support staff, and be capable of supporting science in the heavy seas of the open polar ocean as well as within sea ice. The ship design should include a large moon pool and the ability to support geotechnical drilling. Helicopter capability should be built in as well as design features for the use of marine and airborne autonomous vehicles.

A new US PRV will provide improved access to the polar regions of the world. The ability to reach further into ice-covered waters on a year-round basis will significantly advance our understanding of global environmental change and the oceanographic processes that impact long-term stability of polar ice sheets and ecosystems. Improved understanding of the polar regions will also affect political sovereignty. The new ship will carry scientific teams to study the impacts of climate change on polar physical and biological systems. The ship will ensure that the United States achieves and maintains a global leadership role in polar marine science as well as in setting the polar research agenda.

SUMMARY OF ESSENTIAL PRV CAPABILITIES

1. A new PRV should be able to approach modern ice sheet grounding zones, regardless of typical sea ice conditions (i.e., be capable of navigating 50 km transects through moderately heavy sea ice, up to 1.5 m).
2. Similarly, a new PRV should be able to transit independently through winter pack ice to reach coastal polynyas, which requires longer transects through ice up to 1.5 m thick, and be able to operate in both polar regions year-round (excluding solo winter access to the central Arctic, which requires significantly greater icebreaking capability).
3. The vessel should have sea-keeping capabilities that permit work in the rough seas of the Southern Ocean and sufficient environmental control to allow year-round work in polar seas.
4. A new PRV should be able to host and deploy/recover remotely operated vehicles and autonomous underwater vehicles, both with a wide variety of capabilities. Such operations will frequently take place in ice-covered seas and hence vehicles will be needed to be deployed through a moon pool or over the side/stern after ice clearing.

[1] Although sea ice may be retreating in many places, this situation will not obviate the need for an enhanced icebreaking capability over the next several decades.

5. A new PRV should be designed with labs and berthing to accommodate up to 45 scientists in addition to the on-board technical support staff and ship's crew.
6. A new PRV should have multiple large laboratories designed to support advanced biological and chemical analyses and experiments, including clean spaces for genomics and trace organic and metals analysis and sample preparation.
7. The vessel should be equipped to acquire long stratigraphic sections (50 m of sediment via a jumbo piston core or other long core system) and be capable of accommodating temporarily installed geotechnical drilling to 100 m below seafloor, at water depths of up to 1,200 m.
8. The vessel should be able to core sedimentary sections in ice-covered seas and should be able to support drilling operations as allowed by sea ice movement and available ice-clearing assistance.
9. A new PRV should be able to operate seismic gear, including towing long multichannel streamers and a moderate source array, while underway at speeds of 3.5 to 4.5 kts in moderate (three to four tenths) sea ice cover.
10. The new vessel should be equipped with multibeam swath mapping echosounders installed behind ice protection windows. Given the expected range of water depths, both deep-sea and shallow multibeam systems are required. Supporting equipment for the multibeam systems includes primary and backup attitude, position, and heading reference sources.
11. The vessel should be equipped with a reliable, ice-protected, hull-mounted subbottom profiler operating in the 3.5 kHz range. Typical candidate profilers are either FM-modulated (Chirp) or parametric (narrow-beam) systems. Significant efforts should be directed toward making the ship as acoustically quiet as practical. Major, detailed technical compromises are likely to be necessary to achieve a reasonable balance between the performance of the ship's acoustic systems and the power and strength necessary to be an efficient icebreaker.
12. A new PRV should have the capability of supporting two helicopters. The minimum acceptable aircraft should be able to make 150 nm round trips with three passengers and 1,200 lbs. (~ 544 kg) of cargo. The PRV should be capable of landing a single medium-lift helicopter.
13. The vessel should be capable of launching small, unmanned drone aircraft for ice survey and reconnaissance as well as aerial science missions.
14. A new PRV should be equipped with high-speed data processing facilities capable of handling large data sets for rapid processing, display, evaluation, and archiving. Typical data sets might include LiDAR elevation surveys from glaciologists, seismic imaging, and multibeam swath map output.
15. The vessel should have built-in climate-controlled workspaces and built-in reefer/freezers.
16. The vessel should have a flow-through science seawater system: ~ 10–20 liters per minute maximum for instrumentation only (e.g., thermosalinograph, fluorometer, nitrogen analyzer, flow-through mass spectrometer, dissolved oxygen, pCO_2), not for sampling. A pump (and spare) separate from the sampling equipment, incubator cooling water, and washing water could drive the system.
17. In terms of incubator/washing water, the vessel should permit 400 liters per minute delivered to the location of the incubators and to science sinks, vans sites, and science working deck areas.
18. A new PRV should be designed to easily support small vessel operations (e.g., rubber inflatables).
19. A new PRV should accommodate up to four or five "UNOLS standard" lab vans.
20. A new PRV should be capable of high-speed Internet connectivity for shipboard scientists and crew.
21. The vessel should have a variety of science winches for deploying different equipment: CTD (0.322" conductor), multipurpose (e.g., 3/8" wire rope for cameras, nets, benthic grabs), trawl/core (9/16" wire rope), and deep tow (0.681" fiber optic/electromagnetic).