New Generation Polar Research Vessel Project Initiated

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Abstract and Key Words

The U.S. National Science Foundation (NSF) has initiated a program to determine science and operational requirements for a new generation Polar Research Vessel (PRV) in the Antarctic. These requirements form the basis to study and investigate vessel characteristics and features that satisfy those requirements. This paper describes some of the results from the initial investigation effort.

Key Words: Research vessel; Antarctic; polar; icebreaker.

Introduction

The National Science Foundation (NSF) is the U.S. Agency responsible for the management of the U.S. Antarctic Research Program (USAP). Support of science is the focus of the USAP. The USAP maintains three permanent research stations: Amundsen-Scott South Pole Station, McMurdo Station and Palmer Station and it maintains two research vessels, the *Nathaniel B. Palmer* (NBP) and the *Laurence M. Gould* (LMG) that operate in the Southern Ocean. A full suite of terrestrial and oceanographic research is conducted at these stations and aboard the two vessels.

The NBP, in addition to being a fully capable research vessel, is classed as an American Bureau of Shipping (ABS) A2 icebreaker. The ship is roughly capable of breaking 0.91 meters of ice at a speed of 3 knots. It came into service in 1992 and is presently on a charter that may be extended until 2012.

Plans for a new generation research vessel are currently being developed by NSF. As described in this paper, the new vessel will incorporate a variety of expanded roles over that of the NBP, most notably increased icebreaking and endurance, an integral shallow water drilling capability and the ability to support Autonomous Underwater Vehicle (AUV) and Remotely Operated Vehicle (ROV) operations in ice. These expanded capabilities have come from guidance and recommendations provided by the scientific community through a series of workshops and the Antarctic Research Vessel Oversight Committee (ARVOC).

To gain a better understanding of the vessel size, characteristics and to examine alternative methods for the ship acquisition, NSF has assembled a team of experts. Raytheon Polar Systems Corporation (RPSC) is the prime contractor to NSF for support of USAP activities. RPSC will develop and issue the contract for the new vessel. The Maritime Administration (MARAD), of the Department of Transportation, has been engaged by NSF to provide naval architectural and ship acquisition expertise. MARAD, in turn, has contracted with Science and Technology Corporation (STC) a naval architectural group with specialized expertise in the design of icebreakers. This team, with considerable input and advice from the scientific community, will guide the process of acquiring this new ship including construction oversight and vessel acceptance.

An artist's rendering of the vessel based on the results from some of the early studies is shown in Figure 1.

Figure 1: Artist rendering of polar research vessel in ice

Science and Operational Requirements

Two science workshops were held in 2002 to establish a preliminary set of operational and science needs for the new Antarctic research vessel. These requirements were to assure an ability to conduct needed investigations in the year-round environment of the southern oceans and to take advantage of new and advanced methods to gather data. The initial findings of the Antarctic Oceanography Planning Workshop and the Antarctic Marine Geology and Geophysics Planning Workshop included the following.

- Acoustic profiling including bottom mapping during icebreaking
- Towing of nets and instruments from the stern during icebreaking
- Conduct Autonomous Underwater Vehicle (AUV) and Remotely Operated Vehicles (ROV) operations from a moon pool
- Geotechnical drilling through a moon pool
- Acoustically quiet
- Compliance with International Maritime Organization (IMO) guidelines for Arctic vessels
- Accommodations for 50 scientists
- 80-day endurance
- Reduced air emissions from diesel engines and incinerator
- Enhanced icebreaking capability
- Provision for a helicopter hangar

These science and operational requirements are being elaborated upon and revised through ARVOC's Scientific Standing Committee (SSC) for the Polar Research Vessel (PRV). This committee comprises approximately 15 members, with additional members to provide expertise in scientific areas as required.

Initial Technical Studies

The polar science community expressed their interest and need for a new research vessel with science and operational capabilities beyond those of the NBP. To achieve these requirements, several special technical studies were performed to better understand the implications of the requirements on the vessel characteristics and cost and are listed below.

- Towing in ice – seismics and nets. Recommend a hull form, stern arrangement, and propulsion system that improves towing in ice.
- Bathymetry in ice – Recommend a hull form and appendages that promote improved ice management and reduce bubble sweep down over the acoustic windows for the multi-beam swath bottom mapping system, sub-bottom profilers, ADCP, fish finding sonars, and other acoustic sensors.
- Geotechnical drilling – Recommend a hull form, propulsion system, thruster system, and drilling arrangement for shallow water drilling in landfast ice and open water.
- Establish requirements for a moon pool to deploy and recover ROVs and AUVs in ice and consider CTD/rosette deployment through the moon pool.
- Evaluate increased icebreaking capability and evaluate one or more propulsion concepts to satisfy mission requirements and develop recommendation.
- Examine compliance with new IMO requirements for Arctic vessels including the provision for no pollutants to be carried directly against the outer shell.
- Investigate and recommend an approach to improve the ship's self-generated noise signature and to improve scientific acoustic sensor performance.
- Analyze and recommend an approach on methods to reduce emissions from diesel engines and the incinerator.

The influence of these studies on the PRV design sprial are shown in Figure 2.

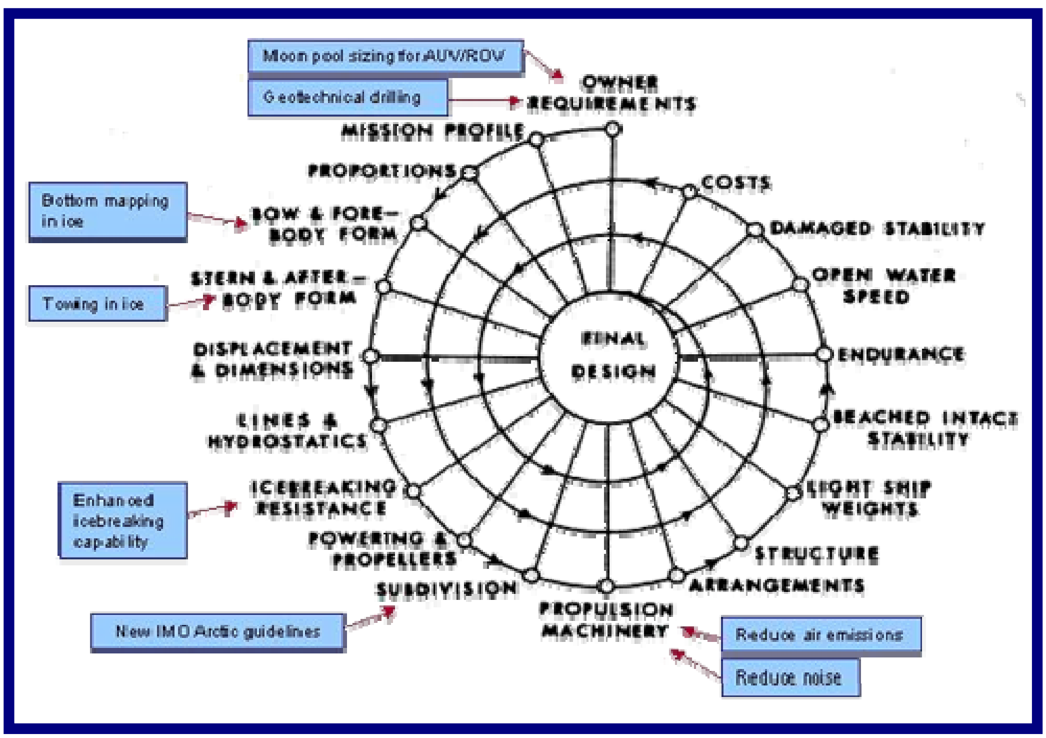

Figure 2. Design spiral showing special technical studies

Description of Several Special Technical Studies

The hull form and propulsion plant for the PRV had to satisfy may objectives including efficient performance in level ice, operation in multiyear ice, good maneuverability in ice, excellent station keeping and sea keeping abilities, low open water resistance. In addition, there was a desire to develop an improved ice-free channel behind the vessel as well as a reduction or elimination of bubble sweep-down over the acoustic array and an ability to acoustically profile during icebreaking operations.

Towing in Ice. A special study of existing non-conventional hull lines and other various technical solutions for clearing ice from the track showed that providing conditions for towing in ice similar to those while operating in open water is very difficult. The most practical way of reducing the ice concentration in a broken channel is the use of an azimuthal propulsion system that can change the wake direction at the stern. The effectiveness of this approach will be limited however by the speed and ice thickness in which the ship is operating. Using special devices or stern arrangements to submerge the towed equipment and minimize their interaction with ice in the ship's track also helps.

Bathymetry. A box keel has been designed for the vessel to ensure the vessel's ability to conduct bottom mapping in open water and during most icebreaking operations. Germany's Alfred Wegener Institute of Polar and Marine Research vessel POLARSTERN has been the most successful ship for swath bathymetry in ice. The design for the PRV therefore used a development of the POLARSTERN box keel with the ends incorporated into the bow ice knife and the stern skeg to avoid bubble sweep down and help clear ice from the bathymetry and other acoustic arrays. Incorporating the ice knife and skeg into the keel will divide the broken pieces sliding down the bow or stern before they get to the box keel proper as shown in Figure 3.

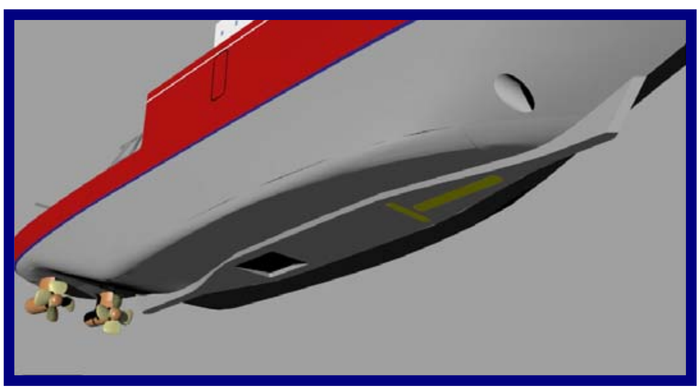

Figure 3. Underwater view of PRV box keel with bottom mapping sensors

The acoustic arrays are positioned as far forward as possible. There is potential for damage to the array during ramming with the arrays in a very forward position but the ice knife should prevent the ship from riding up too high on a pressure ridge and therefore offer some protection for the arrays. The width of the keel was determined from the width of the arrays and the moonpool. Both are of similar width. The other acoustic sensors are positioned in the box keel to port and starboard of the longitudinal array.

The cross-section of the box keel is similar to POLARSTERN with reverse flare on both sides as shown in Figure 4 and the reverse flared sides on the box keel help prevent bubble sweep down from occurring across the face of the sensors. The deep draft of the PRV also serves as an advantage during icebreaking operations.

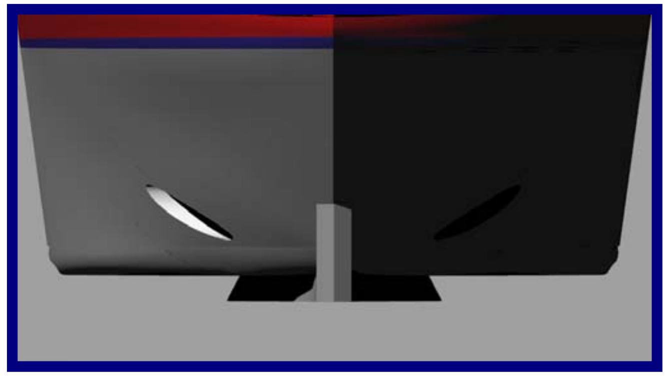

Figure 4. View of box keel with reverse flare on the sides

Geotechnical Drilling. In open water, dynamic positioning will be required to keep the ship on station during drilling operations. The selection of podded propulsors that can be rotated azimuthally was partially based on their good thrusting capability for dynamic positioning. A hull mounted tunnel thruster was incorporated to increase maneuverability for dynamic positioning. The hull mounted unit, instead of the usual thruster mounted in a bow ice knife, moves the thrust opening up and aft causing fewer disturbances from bubble sweep down to the acoustic arrays on the bottom. The thruster will be effective in open water but will fill with ice in heavy pack. Even if cleared of ice, the bow thruster cannot produce enough thrust to be effective in ice. The bow thruster will only be used in open water for dynamic positioning and to assist in maneuvering alongside piers.

Moon pool. Operational requirements for the moon pool include such diverse activities as geotechnical drilling, conduct of AUV and ROV operations, rosettes for water samples and Conductivity, Temperature and Density (CTD) measurements, Ocean Biomass Surveys (OBS), and diving operations. The current size of the moon pool is 6.1 m by 4.9 m, the maximum dimensions were based on the ROV requirements. The moon pool is located on the vessel centerline and longitudinal center of gravity for minimal vessel motion. The entire space is enclosed and provisions have been made for winches, cranes and workshops in the immediate vicinity.

Helicopter Complex. Because of the need for vertical space at the centerline for geotechnical drilling, the traditional arrangement of an aft helicopter landing deck and a forward hangar had to be reconsidered. It appears that the most feasible solution was for the installation of an aft helicopter deck with a flush elevator for helicopter storage below. Sufficient space is provided such that two helicopters can be stored below on the Main Deck. This space is of sufficient size that it offers an excellent inside area for scientific vans when helicopters are not required aboard the vessel.

Icebreaking Capability. Scientific requirements include enhanced icebreaking as compared to that of the NBP. The selected hull form has a modified wedge-shaped bow that is fuller than conventional icebreakers to be a very efficient icebreaker. The shape was shown to be about 25% more efficient than some of the ships in service now.

The moderate side flare decreases resistance in ice, helps with besetment, and improves maneuverability in ice. Increasing flare in the stern portions of the ship allows the hull to break ice while turning quickly with the podded propulsors.

In addition to these features, there is also a need to deploy in landfast ice including old ice found in some bays of Antarctica. These requirements necessitated a hull and propulsion plant capable of operating in multi-year ice. As a result, the PRV will also have the capability to operate in the north polar region. Specifically, the PRV will have an ability for independent operation in Arctic ice along the coastal shelf and into the Arctic Basin in summer. Extended operations in the Central Arctic Basin can be accomplished when escorted by a more capable lead icebreaker.

The only way to accurately predict the impact of icebreaking capability on the ship is to design different ships for each capability. If each design is done by hand, the work quickly becomes a large effort. Instead, a design synthesis model was assembled to tie together the basic parameters of the design so that vessel characteristics could quickly be produced for a given level of capability. The model balances hydrostatics with weights, computes open water speed and fuel capacity to meet endurance. It also employs an icebreaking propeller series and B series regressions to calculate power and towrope pull to meet an icebreaking performance criterion.

Open Water Performance. A smooth hullform reduces open water resistance and improves endurance over hullforms with knuckles below the waterline that may, however, be easier to build. A stepped shear for high bow freeboard and flare above the water improves seakeeping while keeping the working deck aft at reasonable freeboard for the over-the-side operations required of a research vessel.

PRV Machinery and Propulsors. An analysis of the many scientific requirements (moon pool, station keeping, towing of nets, and instruments) and operational requirements (low power open water transit and high power ice-breaking) led to the selection of a diesel-electric propulsion plant with podded propulsors. The diesel-electric propulsion plant consists of four main diesel generator sets, two of 6050 MW and two of 5100 MW with a total brake power of 22 MW. This configuration was selected as it provides greater flexibility as it relates to the physical arrangement on the vessel as well as varying electric power demands. The diesel-electric generators can also be "floated" on isolation mounts for low noise/vibration.

All electrical service loads including propulsors, bow thruster, winches, cranes, light and other general ship service needs are powered from a common bus/integrated electric system. Propulsors on the PRV take the form of two azimuthal propeller pods. Each pod contains a 8.4 MW electric motor driving a pulling propeller. They are independently steerable through 360 degrees and provide superior maneuverability in ice and open water (station keeping) without rudders. Each pod drives one stainless steel four-bladed open fixed-pitch propeller of 5.4 m in diameter. This large propeller rotates at a slow speed and ensures low noise in open water and high thrust for icebreaking.

Low Diesel Exhaust Emissions. Diesel engines aboard existing U.S. research vessels, such as the NBP, were not subject to any emissions regulations when they were built. However, the new engines to be installed on the PRV must comply with recent U.S. regulatory requirements of the Environmental Protection Agency that limits exhaust emissions, particularly lower Nitrogen Oxides (NOx). In addition, optional emission reduction equipment can be installed to reduce emissions further.

These technologies can be divided into two broad categories. The first category affects the basic combustion process and prevents the formation of undesirable air emissions in the engine. These technologies include fuel selection or treatment, electronic control of fuel injection and valve timing, ceramic coating of combustion parts, exhaust gas recirculation, and the injection of water into the combustion chamber, to name a few. The second category focuses on the removal of undesirable emissions from the exhaust after they form in the engine. These include the use of catalyzed reaction and filtration processes including selective catalytic reduction, diesel oxidation catalysts, and particulate traps.

Emission estimates were made for diesel engines based on various technologies and treatments for NOx, Total Hydrocarbons (THC), and Particulate Matter (PM). These estimates are for the "off-the-shelf" regulatory compliant engine after 2007, for the 2007 engine with currently available, year 2003, optional technology and finally for 2007 engine with optional technology that may be available in 2007. These levels are all compared with the likely emission levels from engines on vessels of the *NBP* vintage. Table 1 provides a listing of emission rates.

Table 1: Comparison of emission estimates

Emission Estimates for Various Engine Configurations	NOx + THC (g/kW-hr)	PM (g/kW-hr)
NBP-1990 engines	20	0.50
PRV-2007 engines without optional treatment	9	0.50
PRV-2007 engines with 2003 optional technology	4	0.06
PRV-2007 engines with 2007 optional technology	2	0.03

In summary, it is clear that the new generation PRV provides an opportunity to significantly reduce diesel engine emissions – the technology is available.

Principal Characteristics

Science and operational requirements previously defined were translated to vessel design criteria such that the vessel size and characteristics could be determined. An artist rendering of the vessel is shown in Figure 5 and the principal characteristics are shown in Table 2.

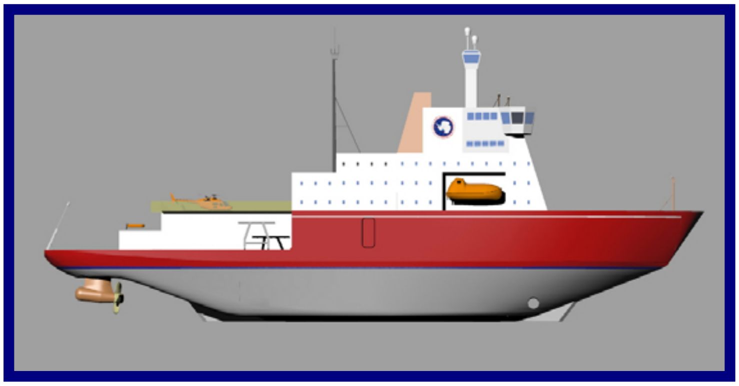

Figure 5. Outboard profile of the PRV showing dual podded propulsors

Table 2. PRV Principal Characteristics

Length, Overall	115.3 m
Length, Waterline	103.9 m
Beam	22.7 m
Draft	9.0 m
Displacement	11,200 MT
Twin Podded Propulsors	8.4 MW each

Acquisition Plans

Although detailed acquisition plans for the vessel must still be developed, a likely scenario is for a long-term lease similar to that presently used for the NBP and the LMG. The terms of the lease would have to be determined, but it is recognized that the longer the lease period, the less the risk to the bidder and thus the greater the competition and the lower the daily charter rate. A lease-versus-buy study would have to be performed before such a decision could be made.

Additionally, and prior to release of a request for proposal to build the ship, the NSF, RPSC and MARAD will begin a series of meetings with prospective bidders (charterers) in order to stimulate interest and thus competition. It would also enable industry to provide suggestions on methods to construct the vessel more economically and thus more cost-effective for the government.

Web Page for Communication

Purpose

The PRV web forum will provide an open means to solicit, gather and incorporate input from the broad community of potential ship users: scientists, technicians, operators, managers and all who have a vested interest in the new ship. In effect, this forum will be a project management tool for developing, collecting and organizing PRV science and technical requirements. After project completion, the forum will be maintained as a public history of the project. The web forum can be found at http://www.polar.org/science/marine/prv/index.htm

Web Page Contents

The web page continues to be under development and consists of four sections: Background and Current Efforts, Conceptual Design Specifications, Science Community Participation, and a Multimedia Gallery. The most dynamic section is Community Participation, which allows for free-form comments or commenting directly on specifications under development.

Comments will be reviewed by a team consisting of MARAD, STC and Raytheon Polar Services Company. The team will routinely review feedback from the Science Capability Feedback Forum, town meetings, phone calls and e-mails. The product of the review meetings will be feedback that is culled for feasible improvements to the design. That product will then be fed back into the Conceptual Design Specifications.

The Multimedia Gallery will consist of presentation posters for conferences, videos and pictures from other icebreakers and field reports, and vessel drawings. The gallery will serve the dual purpose of additional documentation using graphics, and sparking community interest through the use of videos and pictures.

From a yeoman's perspective, the web forum will partially, and we hope significantly, become a superior substitute for the hundreds of undocumented phone calls and e-mails that would otherwise accumulate over the lifetime of the project. Archiving all comments on the web will assure all participants that their voice and expertise has been recognized and included in the overall effort. Openly and permanently archiving all comments will also serve as a clear record for use in discussions with potential bidders and the winning bidder. A history of the web forum, and its success or failure, will also be open for other marine institutions to observe, and to use or avoid as they wish, employing features that are efficient for them, and ignoring ones that are cumbersome or irrelevant to their project.

Vessel Specifications and Drawings

Vessel specifications are found under Conceptual Design Specifications, under the current N. B. Palmer Spec's link and the Conceptual PRV Performance Spec's link. Drawings are linked to the Multimedia Gallery.

Drawings are provided to help visitors to the site provide more informed feedback regarding the layout and design of the lab spaces for the new vessel. Drawings are in .pdf and .jpg file format only. There is no intent that the drawings on the web site are to be controlled drawings for the construction of the vessel.

Controlled Access for Changes and Comments

Access to the site, and the ability to enter comments, are open to all. Access to make changes to all sections and functionality of the site is controlled.

Background/Current Efforts Technical Studies PRV Timeline (PDF format)	Newsletters September 2003 June 2003
Conceptual Design Specifications Current NBP Specs Conceptual PRV Performance Specs PRV Workshop Reports	Multimedia Gallery PRV Draft Feasibility Poster (3 x 4 feet) PowerPoint (4.4 MB) | JPG (880 KB) Page Size PowerPoint (3.3 MB) | PDF (1.2 MB)
Community Participation PRV Science Capability Feedback Form PRV Science Capability Working Groups	Videos (MPG format) BOTNICA Icebreaking in Baltic ODEN Icebreaking in Baltic

Next Phase of Vessel Design

The initial series of technical studies has resulted in an approximation of vessel size and characteristics based upon two science workshops that established mission requirements. The results are now being reviewed and discussed within the scientific community for possible changes to requirements. These changes are in part due to a better understanding of the implications of certain mission requirements on the vessel characteristics and costs. In addition, there are a number of naval architectural studies that need to be performed to refine and possibly change some of the conclusions made in the initial effort.

Accordingly, there are three primary technical areas requiring future study in the coming year. These include geotechnical drilling, sizing and arrangement of the moon pool and machinery and propulsor equipment. These efforts will be conducted in concert with ARVOC's Science Standing Committee through a number of workshops and meetings. The results will include a refined vessel with new arrangement drawings, the layout for a standard two-person cabin for scientists, vessel weight estimates, hydrostatics, stability calculations, a revised cost estimate and an initial set of vessel technical specifications for use in the acquisition process.

Summary

The NSF has begun the process of conducting a series of technical studies to provide guidance for the acquisition of a new generation Polar Research Vessel. Mission requirements of the vessel are based on an expanded set of scientific and operational requirements from the American science community. Some of these requirements are in response to the national need to expand global warming studies in the Polar Regions as global climate change models point to the southern ocean as a critical component for developing forecasts. The PRV is intended to serve as a national platform for future decades of research.