National Science Foundation

Office of Polar Programs Advisory Committee

Report of the Ad Hoc Subcommittee on the U.S. Antarctic Program's Research Vessel Procurement

August 14, 2019

Members

Kim S. Bernard, Oregon State University
Amy Leventer, Colgate University
Jonathan Michael Prince, Moss Landing Marine Laboratories, SJSU/CSU
Randy Sliester, British Antarctic Survey
James H. Swift, UCSD Scripps Institution of Oceanography (Chair)
Tom Weingartner (member and OPP/AC liaison)

Tim McGovern, National Science Foundation - OPP liaison

List of Acronyms Used in the Report

2009OCSMR	Ocean Class Science Mission Requirements (SMR) - Table of Requirements, Values, and Priorities; file name: "OCSMR_revision_093009_0.pdf"
2012PRVSMR	University-National Oceanographic Laboratory System (UNOLS) 2012 Polar Research Vessel Science Mission Requirements; file name "PRV_SMR_FinalReport_Feb2012.pdf"
2016OPPRFI	2016 NSF/OPP Antarctic Vessels Request for Information; file name "RFI_Sources_Sought_RVIB_ARSV_FBO_Final.pdf"
2018ASCVSR	2018 ASC-provided Vessel Studies Report; file name "Vessel Studies Report Rev -.pdf"
ABS	American Bureau of Standards
ABS	American Bureau of Shipping
ADA	American Disabilities Act
ADCP	Acoustic Doppler Current Profiler
AGOR	Auxiliary General Oceanographic Research
AHRS	Attitude Heading Reference System
AMAP	Arctic Monitoring and Assessment Program
ARICE	Arctic Research Icebreaker Consortium
ARSV	Antarctic Research and Supply Vessel
ARVOC	Antarctic Research Vessel Oversight Committee
ASC	Antarctic Services Contract
AUV	Autonomous Underwater Vehicle
BAS	British Antarctic Survey
CCTV	Closed-Circuit Television
CMMS	Computerized Maintenance Management System
CTD	Conductivity-Temperature-Depth (instrument)
DMSP	Defense Meteorological Satellite Program
DO	Dissolved Oxygen
DOSECC	Drilling, Observation and Sampling of the Earth's Continental Crust
ECDIS	Electronic Charting and Display System
ECO	Edison-Chouest Offshore
EMI	Electro-Magnetic Interference
GO-SHIP	Global Ocean Ship-Based Hydrographic Investigations Program
HRPT	High Resolution Picture Transmission
HVAC	Heating, Ventilation, and Cooling
ICES	International Council for the Exploration of the Sea
IEEE	Institute of Electrical and Electronics Engineers
IESNA	Illuminating Engineering Society of North America
IMO	International Maritime Organization
LAN	Local Area Network
LARS	Launch and Recovery Systems
LMG	Laurence M. Gould
LRV	Local Research Vessel
MARAD	U.S. Maritime Administration
MARPOL	International Convention for the Prevention of Pollution from Ships

MG&G	Marine Geology and Geophysics
MOCNESS	Multiple Opening and Closing Net and Environmental Sampling System
MREFC	Major Research Equipment and Facilities Construction
NBP	Nathaniel B. Palmer
NEMA	National Electrical Manufacturers Association
NIBS	Navigational Integrated Bridge System
NOAA	National Oceanographic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
OAC	Office of Polar Programs External Advisory Committee
OPP	Office of Polar Programs (NSF)
PRV	Polar Research Vessel
RCRV	Regional Class Research Vessel
RFI	Request For Information
RHIB	Rigid Hull Inflatable Boats
ROV	Remotely Operated Vehicle
RSV	Research and Supply Vessel
RV	Research Vessel
RVIB	Research Vessel Icebreaking
RVTEC	Research Vessel Technical Enhancement Committee (UNOLS)
SAR	Search and Rescue
SDA	RRS Sir David Attenborough
SIO	UCSD Scripps Institution of Oceanography
SLEP	Service Life Extension Program
SMR	Science Mission Requirements
SNAME	Society of Naval Architects and Marine Engineers
SOLAS	International Convention for the Safety of Life at Sea
SOST	National Science and Technology Council's Subcommittee on Ocean Science and Technology
SST	Sea Surface Temperature
STC	MARAD Science and Technology Corporation
TSG	Thermosalinograph
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle
UNOLS	University National Oceanographic Laboratory System
UPS	Uninterruptible Power Supply
URN	Underwater Radiated Noise
USAP	United States Antarctic Program
USBL	Ultra-Short Baseline
USCG	United States Coast Guard
VERTREP	Vertical replenishment
VPR	Video Plankton Recorder
VSAT	Very Small Aperture Satellite
WHOI	Woods Hole Oceanographic Institution
XBT	Expendable Bathythermograph

PART I. Summary

A. Executive Summary

The US National Science Foundation (NSF), which directs and supports the United States Antarctic Program (USAP), is approaching a decision point regarding the ships that support USAP research and Palmer Station resupply. At present there are two USAP ships - ARSV Laurence M. Gould (LMG) and RVIB Nathaniel B. Palmer (NBP) - both of which are operated under charter agreements with Edison-Chouest Offshore (ECO) via the USAP's Antarctic contractor. Both ships are nearing end-of-contract and the NBP in particular is nearing the end of its design service life. Neither USAP ship is up-to-date regarding some regulatory matters, and neither can readily be refit into compliance. Then, too, there is the matter that the operating costs for the USAP ships are increasing (faster than overall inflation), but the USAP operates now and for the conceivable future in a more or less constant-dollar fiscal environment.

For more than ten years, various elements of the US polar research community have addressed the ship support requirements that would be necessary for future USAP research. The National Science Foundation Office of Polar Programs (OPP) external Advisory Committee (OAC) formed a subcommittee to review and assess the science mission requirements and operational capabilities of replacement polar-capable research vessels to support seagoing science in the Southern Ocean and along the Antarctic Peninsula, and to recommend improvement of existing specifications. The Subcommittee examined key reports from prior studies, community advice and their own practical experience to focus on the following assigned objectives:

Science Mission Requirements: Review and verify the continued validity of the University-National Oceanographic Laboratory System (UNOLS) 2012 Polar Research Vessel Science Mission Requirements, the 2016 NSF/OPP Antarctic Vessels Request for Information, and the 2018 ASC-provided Vessel Studies Reports;

Prioritization: Prioritize each proposed vessel's capabilities and operational requirements;

Operational Models: Consider the two-ship operational model of the US Antarctic Program, and evaluate the advantages and disadvantages of moving to a one-ship operating model; and

Community Input: Engage the broader scientific community to ensure vessel capabilities and characteristics are able to meet <u>a majority</u> of anticipated needs for the duration of the 10-year charter, and possibly for the lives of the vessels (~ 30 years).

The major recommendations of this effort include:

1. The RV Subcommittee strongly and unanimously supports a two-ship model to support USAP operations and research in the Southern Ocean.

2. Recognizing that the present USAP ships - ARSV Laurence M. Gould (LMG; constructed 1997) and RVIB Nathaniel B. Palmer (NBP; constructed 1992) - represent a significant existing national resource well in use, the RV Subcommittee recommends retaining them until their replacements are ready for service, meanwhile optimizing their facilities and operational framework while still in use by the USAP.

3. The Laurence M. Gould is already well used, but if it were necessary to broaden the fiscal support base for the ship, the Subcommittee recommends devising and putting into place a new charter agreement for the LMG with an eye to opening opportunities for science and logistics chartering by other nations. (The present charter agreement is soon to expire, and so the timing is appropriate.) The Subcommittee specifically recommends investigating entering into a long-term agreement with UK/BAS (British Antarctic Survey), for example using the LMG to carry out a small number of annual BAS station support visits and/or provide ship support for BAS Peninsula region science missions. If LMG refit activities are scheduled, the RV Subcommittee recommends that upgrades should be carried out only if they are required to meet USAP and BAS marine science and station logistics support needs during the LMG's remaining expected time with the USAP. The RV Subcommittee does not recommend heavy investment in LMG upgrades or in extending its USAP service life.

4. If it is not feasible to design and construct a replacement for the NBP within the next 13 years, the RV Subcommittee recommends that the ship's science support facilities be improved and that the expected service life be lengthened (to 2032). The RV Subcommittee further recommend that a Service Life Extension Program (SLEP) of the NBP be carried out to (a) extend and assure the lifetime of crucial ship's systems, and (b) provide upgrades on a priority basis to the NBP's science support facilities and capabilities. In priority order: The latter should include refurbishment and modernization of the ship's laboratories and climate controlled science spaces, attention to the ship's over-the side handling equipment and winches, relocation of the main CTD winch (or other modifications to improve CTD operations in open seas), improved capabilities for deployment and recovery of AUVs, ROVs, and gliders, and improved workboat operations (not simply a Zodiac). Reducing discharges while on station and in the ice, and increasing the time discharges can be managed, should be investigated. Attention should be given to improving habitability. Consideration could be given to a modest increase in science berthing and increasing real-life mission endurance to 75 days. The SLEP will not change the ship's size or ice capabilities and should be sized and managed to be feasible with minimum loss of ship availability to USAP science, perhaps by incremental work over several years during annual maintenance periods.

5. Future USAP ship operations should employ a two-ship model: (1) one science station support and science ship to support the USAP's (and potentially other entities') Peninsula bases and marine science, and (2) one larger, more capable ship to support wide-ranging science and logistics in the Southern Ocean and that could conceivably also support research in the Arctic and global oceans when not in use in the Antarctic. Technical and fiscal planning for replacement ships should begin approximately 10 years (7 at a minimum) before each new ship enters polar service and involve continual input and oversight from the US polar marine science community throughout planning, design,

construction, testing, and science systems performance verification. However, the RV Subcommittee recommends that a study first be made to assess the overall total cost differential (including design, construction, plus multiple years of operation) of alternatively supporting USAP and other US polar science with two identical polar research and support ships, instead of one larger and one smaller ship as at present.

6. Although not part of the Subcommittee's charge, it is clear that if a two-ship model for USAP continues in the future an effort to define Science Mission Requirements for the LMG replacement is needed. This is especially true if the second ship is expected to support both science and logistics in the region of the Antarctic Peninsula as well as potentially supporting science and logistics for others such as the British Antarctic Survey.

7. If, and only if, it is determined by the support agencies that long-term federal budget restrictions combined with ship operating expenses prohibit extending the present two-ship mode of USAP marine support without serious impacts on polar science support, the Subcommittee recommends the following:

    a. Retire the LMG as a USAP ship at the end of its present contract.

    b. Upon retirement of the LMG, revert to non-USAP ships for support of Palmer Station and a significant share of USAP Peninsula region marine science support. Such ships should be supported via long-term arrangements to aid planning and provide assurance of support. The ships could come from the commercial marketplace, or the US or other nations' marine or polar programs. (The LMG could conceivably be a contender.)

    c. It remains preferred that principal logistics support for Palmer Station be carried out long term via a single ship. This makes it possible to outfit the support ship with sensors (meteorological, ADCP, sea chest measurements), XBT launchers and a basic data system so that the oceanographically-critical Drake Passage crossing time series measurements continue.

    d. If there were to be only one USAP ship, the issue of marine science support for Palmer Station and nearby Antarctic Peninsula areas must be addressed. In particular, the Subcommittee notes there is a regional peak in science support needs during the Austral summer. This coincides with the peak operating season in all other Antarctic waters for the much-wider-ranging NBP (and all other Antarctic ships). Thus, the NBP replacement vessel cannot be considered regularly available at that time in the Peninsula region. The Subcommittee notes, however, that it may be feasible to provide local RV support. Examples include the "Abel J" (mentioned in studies reviewed by the Subcommittee), or a ship similar to the former Academic Research Fleet RV Point Sur, which did once make a trip down to Palmer Station. It would be beneficial if a local RV were ice capable to the point where it could be used in the fall and early winter from Palmer Station. A small ship, even if moderately ice-capable, may need to be evacuated or hauled out during winter. Some enhancements to Palmer Station vessel support facilities may be required, such as increased vessel fuel storage, safety and navigation systems support, local support for qualified mariners, and so forth.

e. The RV Subcommittee recommends that a new committee be formed now to closely examine the needs for marine science support at and near Palmer Station and in the nearby Antarctic Peninsula region, detail the options (with priorities and costs) for the USAP to provide that support, and provide recommendations.

f. The RV Subcommittee unequivocally supports continued operation of a principal USAP polar science ship (presently the NBP) to support Ross Sea and southern-ocean-ranging US marine research, specifically without unduly restricting operations of that ship to the Antarctic Peninsula region at any time of year.

8. The RV Subcommittee reviewed previous documents relating to the science mission requirements for a future Antarctic polar research ship, and also those for ships designed to carry out similar underlying science missions in non-polar waters. The Subcommittee also carried out a community survey regarding related matters. The Subcommittee then prepared an updated list of Science Mission Requirements, including discussion of priorities.

   The Subcommittee focused on two different paths regarding the characteristics of a future polar research ship:

   1. There is enduring science community enthusiasm for design, construction, and operation of a polar research ship with increased ice operation capability, endurance, berthing, storage, and science support facilities over those represented by the Nathaniel B. Palmer. The Subcommittee notes that there would be a significant increase over the NBP in terms of construction and operation costs, especially resulting from providing the desired "PC3" ice operations capability, i.e. "Year-round operation in second-year ice, which may include multi-year ice inclusions".

   2. If it is not feasible for the USA to provide and support a polar research ship with significantly enhanced operational and science capabilities over those represented by the Nathaniel B. Palmer, the Subcommittee supports continued, long-term USAP utilization of a global-ranging NBP-like ship via construction of a new polar research ship meeting as many as feasible of the Science Mission Requirements identified by the Subcommittee, but not with substantially increased ice capability (which is an expensive enhancement with regards to both construction and operation), prioritizing new science capabilities of this ship to meet construction and operation budget realities. Priorities should focus on capabilities that are the most general in terms of applicability and that will have the greatest impact on planned and predicted USAP science and logistics support. These might include, compared to the NBP, improved capabilities for deployment and recovery of AUVs, ROVs, and gliders, improved workboat operations, a functional moon pool, greater scope of biological and geophysical support capabilities, temperature-controlled environmental rooms, improved capability to work in typical Southern Ocean open sea swell for operations over the side and stern, and improved helicopter capabilities. The ice class of the new ship in independent operations should be similar to (or slightly greater than) that of

the NBP, except that hull strength, ice maneuverability, and cold weather safety of the new ship should be sufficient to enable operations with an escort icebreaker in all seasonal Antarctic ice year-round and in multi-year Antarctic ice that is accessible within the operational envelope of a US Coast Guard heavy icebreaker, which might be used as an escort on special deep-ice missions. Any size increases over and above the NBP should be restricted to those required to meet regulatory requirements.

Whichever path is chosen, scientific and technical design of a Nathaniel B. Palmer replacement must be timed so that the new polar research ship is constructed, tested, and ready to enter science service upon the NBP's retirement. With either path, many other considerations must be attended to, such as providing laboratories of various types, an easy to clean uncontaminated seawater line equipped for ready addition of guest instrumentation, and high-speed data processing. The subcommittee notes strong input from the marine geophysical research community urging that compressors for seismic operations be included, as well as the capability for geotechnical drilling. The new ship should be capable of docking at the new Palmer Station pier. The propulsion system should provide increased maneuverability. Hybrid diesel propulsion should be considered for quiet, low pollution operations. Open-ocean performance specifications should be as "sea kindly" as feasible during steaming and on-station work in Southern Ocean waters.

The research and training that the USAP supports require a polar research ship with considerable range and long endurance, able to operate in the Antarctic region year-round, carry a large scientific party and crew, support a very wide range of state-of-the-art science operations, support the helicopters and cargo needed for continental operations, and to do so expeditiously and sustainably, providing a comfortable, safe environment, meeting all regulatory mandates. Some aspects of the science mission requirements are especially significant in terms of their potential impact on ship construction and operating costs. These include, for example, icebreaking capacity, range and endurance, capacity for winter operations, the size of the human complement, and cargo capacity. To provide a ship that meets future science needs and national interests in the Southern Ocean and Antarctica, significant cost hurdles can be expected with regard to nearly every one of these factors. With either of the recommended paths, the result will be a ship that costs more per day to operate than do US Academic Research Fleet global-class open-ocean research ships. One cost savings, of a sort, can potentially come from the icebreaking capacity of a new USAP polar research ship: Increasing icebreaking capability above present NBP performance would add significantly to ship construction and operating costs, but the Subcommittee notes that if a new ship were built to only modestly better icebreaking capability than that of the NBP, it could work as needed with a US Coast Guard or other escort icebreaker to accomplish future science missions requiring more robust icebreaking. Such work with escort icebreakers would benefit from long-term expeditionary planning to make most effective and efficient use of what is viewed as an occasional, though vitally important, opportunity.

Several issues need to be addressed by a more thorough study that weighs the pros and cons of conducting research with an NBP-like vessel (ice class PC4) using an icebreaking escort vessel as opposed to a single "super NBP" vessel (ice class PC3). Such a study would:

i. Determine the operational costs for PC3 versus PC4 vessels.
ii. Determine if a PC4 vessel meeting all the SMRs outlined herein could conduct the same research when operating in conjunction with an ice escort vessel.
iii. Project the demand for research in heavy ice conditions capable of being conducted by a PC3 vessel (number of missions/year, duration and type of missions).

Once these issues have been resolved, assess the cost-benefits of building and operating a PC3 vessel as a stand-alone vessel versus a PC4 operating with an escort icebreaker.

Technical and fiscal planning for replacement ships should begin approximately 10 years (7 at a minimum) before a new ship enters polar service, and involve continual input and oversight from the US polar marine science community throughout planning, design, construction, testing, and science systems performance verification.

The subcommittee recommends that the Leidos Vessel Studies report be paid close attention in future development of operational and design specifications for new USAP polar research and supply ships.

9. The USAP should evaluate alternative operational models for its ships, for example NSF-funded design, construction, and testing, under supervision and then operation by a principal ship-operating academic institution, or a long-term charter agreement aimed at a ship built to specification, with the design construction, and operation contracts overseen by a principal ship-operating academic institution. With either or other models, operating agreements should permit occasional use of the ships for science and support missions by other nations' Antarctic programs when a ship is not in use by US researchers.

10. Design and construct a replacement for the Laurence M. Gould: The future Laurence M. Gould replacement should be designed to optimally support both USAP Antarctic Peninsula science and Palmer Station logistics. In addition, the Subcommittee suggests that the USAP consider providing the future LMG as a chartered support ship for BAS (or other nations as feasible) science and logistics. Careful co-scheduling would allow shared access to this resource. An LMG replacement ship more expensive to charter and operate than the LMG is not envisioned unless the USAP's share of the total costs is less than (or at least no more than) the USAP's present annual cost for the LMG (now paid solely by the USAP). The LMG replacement ship should be ice-strengthened but does not need to be an icebreaker, and it should be outfitted for oceanographic research in a manner similar to the LMG.

    As an alternative to replacing the Laurence M. Gould with another Palmer Station-bound LMG-like ship, the USAP should investigate the advantages of constructing and operating two identical NBP-sized ships. There would be major savings in total design and construction costs, and overall operational costs might be nearly similar, meanwhile adding a huge degree of flexibility and capability to the USAP fleet. Costs to the USAP might be ameliorated by occasional use of one ship for other US research, such as for occupying GO-SHIP transects, or use in marine geophysical research. Another way to reduce costs to the USAP would be to operate the ships via charter agreements that permit chartering to other Antarctic programs when a USAP ship is not needed for USAP or other US research and support.

11. To help offset costs, the USAP should consider operational models for its ships that would permit occasional use of the ships for science and support missions by other nations' Antarctic programs (UK/BAS is specifically noted), when not in use for US research and support missions. The RV Subcommittee supports an approach that develops and maintains greater cooperation and shared resources among Antarctic research programs. A system of cooperative scheduling and barter or charter could serve to provide cost savings, increased flexibility and access to different capabilities in much the same way that the U.S. Academic Research Fleet or the cooperative arrangements in Europe and the Arctic do.

12. The RV Subcommittee recommends that the USAP make expeditionary planning an explicit, routine aspect of an appropriate portion of the available ship time for the NBP (and its replacement) and possibly the LMG (and its replacement). For example, with community guidance, NSF and other polar research support agencies might create long-advance-notice opportunities for unique, specialized science expeditions to regions of special interest, and/or winter and heavy ice operations (such as operations with an escort icebreaker), so that the science community could mobilize (workshops, proposals, etc.) sufficiently in advance. As part of this process, the support agencies should build working relationships with operators of icebreakers which might occasionally be utilized as escort vessels for the USAP principal polar research ship, thus effectively and temporarily increasing its ice classification without the construction and operation expenses attending to a higher ice class polar research ship.

B. Impetus and Approach

B.1 Synopsis of Issues

The US National Science Foundation (NSF), which directs and supports the United States Antarctic Program (USAP), is approaching a decision point regarding the ships which support USAP research and Palmer Station resupply. At present there are two USAP ships - ARSV Laurence M. Gould (LMG) and RVIB Nathaniel B. Palmer (NBP) - both of which are operated under charter agreements with Edison-Chouest Offshore (ECO) via the USAP's Antarctic contractor. The vessels, built in 1992 and 1997, respectively, are approaching the ends of their current contracts (2020 for LMG, 2022 for NBP) and either are at, or are approaching, the end of their nominal 30-year design service lives. Neither USAP ship is up-to-date regarding some regulatory matters, and neither can readily be refit into compliance. Then, too, there is the matter that the operating costs for the USAP ships are increasing (faster than overall inflation), but the USAP operates now and for the conceivable future in a more or less constant-dollar fiscal environment.

For more than ten years, various elements of the US polar research community have addressed in reports and other documents the ship support requirements, which would attend to future USAP research. The National Science Foundation (NSF) initiated the formation and operation of an ad hoc Subcommittee of the NSF Office of Polar Programs (OPP) Advisory Committee on the U.S. Antarctic Program's Research Vessel Procurement. The purpose of the Subcommittee was to review and assess the science mission requirements and operational capabilities of replacement Antarctic research vessels. Outcomes of the assessment were specified to be in the form of a report to the Advisory Committee. The Advisory Committee requested that report specifically state whether or not the Subcommittee feels the vessel specifications as outlined will adequately support sea-going science in the Southern Ocean and along the Antarctic Peninsula. The Advisory Committee noted that the report may include recommendations to NSF for further improvement of the specifications.

An ultimate goal of the study is to help inform development of a new vessel procurement solicitation which will help ensure the Antarctic scientific community continues to be supported with state-of-the-art sea-going facilities designed to operate in these harsh environments. Refurbished or new-build vessels need to be considered. These vessels may operate for the next 10-30 years; therefore, their capabilities must be sufficient to support science in the coming decades.

B.2 Subcommittee Charge and Scope of Activities

The Subcommittee was asked to:

1. Review and verify the continued validity of the University-National Oceanographic Laboratory System (UNOLS) 2012 Polar Research Vessel Science Mission Requirements, the 2016 NSF/OPP Antarctic Vessels Request for Information, and the 2018 ASC-provided Vessel Studies Reports;
2. Prioritize each proposed vessel's capabilities and operational requirements;
3. Consider the two-ship operational model of the US Antarctic Program and evaluate the advantages and disadvantages of moving to a one-ship operating model.
4. Engage the broader scientific community to ensure that vessel capabilities and characteristics are able to meet a majority of anticipated needs for the duration of the 10-year charter, and possibly for the lives of the vessels (~ 30 years). Elements of the recommended prioritized vessel capabilities should be provided in sufficient detail to enable NSF to make subsequent appropriate adjustments in response to available funding.
5. Provide a summary of the outreach efforts and input received from the science community to be included in the final, submitted report.
6. The subcommittee will develop activities to address the elements of the charge.
   The Subcommittee is asked to provide an initial report/response at the April 2018 OAC meeting and its final report by September 2018 for presentation to the AC/OPP, so NSF can consider them in formulating the FY 2020 Budget Request.

B.3 General Approach

The OPP Advisory Committee appointed six persons to the Subcommittee, including four scientists, a marine operations and research ship expert, and an operations manager with the British Antarctic Survey who had extensive prior experience with the USAP ships. One of the scientists was member and Chair of the OPP Advisory Committee and acted as liaison with the host committee. The cognizant NSF Program Officer for USAP ship support provided liaison with NSF.

The Subcommittee met weekly via teleconferences, beginning with a review of the documents as requested, but also including reference to additional related documents known to or brought to the attention of the Subcommittee, for example including reports and other documents from UNOLS efforts related to science mission requirements for research ships. The Subcommittee also designed a community survey which was widely distributed to appropriate persons, with assistance from NSF and UNOLS.

Similarly, other elements of the charge were addressed.

It became immediately apparent to the Subcommittee that a dichotomy existed between the type of polar research ship long envisioned by many in the science community to carry out future research and training, versus today's realistic reach of the National Science Foundation to support such a ship. The Subcommittee determined that it should support the community's expressed needs in the hope of encouraging NSF and Congress to provide funding for a capital polar research ship capable of addressing the widest range feasible of US polar marine science, support, and training needs, but that it was also necessary to move forward with a second option more closely aligned to present and projected NSF ship support capacity.

The Subcommittee was also asked to evaluate the operational model of ship support for the US Antarctic Program. This included evaluation of the present "two ship" mode for USAP ship operations versus a possible "one ship" mode. On that point, a single viewpoint prevailed, although the Subcommittee suggests innovative means to attain its recommended operational model.

The draft report was provided to the OPP Advisory Committee for review and comment. A revised version was sent to the Advisory Committee and adopted by that committee.

B.4 Acknowledgements

The Subcommittee benefited greatly from guidance and much assistance provided by NSF liaison, Tim McGovern, and advice from Kelly Falkner, Director, NSF/OPP. Special thanks to our community colleagues for their time and care in responding to the survey, which would not have been possible without support from Terri Edillon, NSF, and assistance from Annette DeSilva (UNOLS Office) and Timothy Howard (NSF). Thanks to Chris Chuhran, who carefully reviewed the draft science mission requirements, Jerry Kappa, who copy edited the document, and the NSF/OPP Advisory Committee for their review and comments. Additional assistance on a wide range of matters was generously provided by Byron Blomquist, Andrew Bowen, Stephen

Diggs, Joseph Gum, Matt Hawkins, Matt Heintz, Alex Isern, Michael Jakubo, Carl Kaiser, Zoltan Kelety, Luc Lenain, Alison Macdonald, Sabine Mecking, Jon Meyer, Brett Muir, Tim Newberger, Ethan Norris, Catherine Offinger, Mark Rosenberg, Kevin Speer, Lynne Talley, Masako Tominaga, and Kevin Walsh.

C. Relationship of the Analyses to Strategic Science and Logistics Planning

C.1 Strategic planning and future polar science initiatives

Advances in polar science have long and inexorably been linked to advances in polar logistics. Hence the operational knowledge and capability provided via each successive generation of polar-capable ships has enabled research bringing about revolutions in scientific understanding. A long series of community studies points to the continued key importance to research, training, and support provided to the US Antarctic Program by polar-capable research ships, and place these in terms of scientific and national priorities. We review key observations and findings from these studies.

C.1.1 National Science Board 2020 Vision for the National Science Foundation (2005)

In its long-term vision for the National Science Foundation, the National Science Board in 2005 noted:

> The Board recognizes that competing priorities may impose fiscal constraints that limit the Foundation's, and so the Nation's, aspirations. In weighing these competing priorities, the Nation must realize that the challenges we defer today will be faced by our children, and the opportunities we forego today will be charged to their future.
>
> To achieve this 2020 Vision, the Foundation will focus on three Strategic Priorities:
>
> - Strategic Priority 1: Ensure the Nation maintains a position of eminence at the global frontier of fundamental and transformative research, emphasizing areas of greatest scientific opportunity and potential benefit.
> - Strategic Priority 2: Sustain a world-class S&E workforce and foster the scientific literacy of all our citizens.
> - Strategic Priority 3: Build the Nation's basic research capacity through critical investments in infrastructure, including advanced instrumentation, facilities, cyberinfrastructure, and cutting-edge experimental capabilities.

The subcommittee notes that other studies it examined amply demonstrate the alignment of polar marine research with these NSF strategic priorities.

C.1.2 Advancing U.S. Polar Research Through the Acquisition of a New Polar Research Icebreaker, Antarctic Research Vessel Oversight Committee (2006)

The document itself is a pragmatic assessment of the scientific specifications required from a polar research icebreaker in order to achieve key science and training goals mostly outlined in other studies. The document does note:

> [T]hese requirements dictate that the next generation Polar Research Icebreaker will be larger and have a different hull shape than our current polar research vessels. In addition, the layout of decks and lab facilities needs to accommodate a wide variety of existing and new technologies in oceanography.
>
> The scientific rationale leading to these requirements is based in part on the following themes. 1) Understanding Antarctica's role in global change requires access to dynamic areas of the ice sheet margin as well as those areas where heat exchanges between the atmosphere and ocean. Many of these areas are currently inaccessible to the U.S. research community and none of them are accessible year-round. 2) The past history of the ice sheet can inform us about likely scenarios for the future. One of the most useful records of ice shelf and ice sheet activity is preserved in the sediments of Antarctica's continental shelves. These sedimentary archives can be drilled and cored using technologies now in development and from ice-capable vessels adapted for geotechnical sampling. 3) Around the only continent on Earth where there is no terrestrial primary production, the food web and ecosystems of the Southern Ocean emerge as key elements in understanding Antarctica's living marine resources. A process-based understanding requires multidisciplinary and interdisciplinary approaches, both theoretical and in terms of field work. As an example, understanding the controls on primary production requires experts in ocean physics, sea ice formation and melting, the surface atmosphere, the light field, trace element chemistry, potential grazing process, phytoplankton ecology, and cellular biology. Future expeditions to the Southern Ocean will necessarily be more complex and multitasking and will require expanded vessel capabilities.
>
> As we enter the 21st century, the development and application of new instruments and methods in marine science are facilitating novel multidisciplinary approaches for addressing key questions in polar science. As the primary platforms for marine scientific activities in the U.S. Antarctic Program, the vessels used for research must be technologically up-to-date and compatible with a wide range of new research methods. Examples include: geophysical drilling of the seabed, remote sensing using hull-mounted arrays as well as underwater vehicles, micronutrient-sensitive sampling, fisheries surveys, on-board molecular biological assays, etc. The ability to range farther and longer into new and unstudied areas of the Southern Ocean will greatly promote all areas of polar research.

C.1.3 Future Science Opportunities in Antarctica and the Southern Ocean. National Research Council (2011)

The National Research Council in 2011, in an extensive report, outlined future Antarctic and Southern Ocean areas of research. They summarize key important future research in their table S.1:

- FUNDAMENTAL QUESTIONS OF GLOBAL CHANGE
  - How Will Antarctica Contribute to Changes in Global Sea Level?
  - What Is the Role of Antarctica and the Southern Ocean in the Global Climate System?
  - What Is the Response of Antarctic Biota and Ecosystems to Change?
  - What Role Has Antarctica Played in Changing the Planet in the Past?
- FUNDAMENTAL QUESTIONS OF SCIENTIFIC DISCOVERY
  - What Can Antarctica and the Southern Ocean Reveal About Past Climates?
  - How Has Life Adapted to Antarctica and the Southern Ocean Environments?
  - What Can the Antarctic Platform Reveal About the Interaction Between the Earth and the Space Environment?

Addressing most of these fundamental questions for future science will require support from polar research ships. The report specifically noted, (1) "One important area for development is the access to fully and partially ice-covered seas provided by surface ships and, in particular, icebreakers" and (2) "The expansion of physical and biological oceanography research in the Southern Ocean will require research ships that are capable of operating in fully and partially ice-covered seas." While acknowledging logistical requirements the report noted the need to (1) "Increase the flexibility and mobility of the support system to work in a continent-wide and ocean-wide manner, utilizing as much of the year and continent as possible, and fostering innovative 'cutting-edge' science" and (2) "Maintain and enhance the unique logistical assets of the United States, including the research stations, aircraft, and research vessels with increased icebreaking capabilities, and heavy icebreakers for reliable resupply of the U.S. Antarctic Program." Regarding the potential of future research, the report noted, "the next 20 years of Antarctic research have the potential to advance understanding of this planet and beyond."

C.1.4 Critical Infrastructure for Ocean Research and Societal Needs in 2030, National Research Council (2011)

The National Science and Technology Council's Subcommittee on Ocean Science and Technology (SOST) approached the National Research Council "to provide advice and a perspective from the worldwide ocean community on the types of U.S. ocean infrastructure that will facilitate research in 2030, including advice as to what criteria may be most appropriate for setting priorities" and "to ensure that new facilities provide the greatest value, least redundancy, and highest efficiency in terms of operation and flexibility to incorporate new technological advances."

The National Research Council cited 13 questions encompassing issues regarding environmental stewardship:

- How will sea level change on a range of spatial and temporal scales and what are the potential impacts?
- How will climate change influence cycles of primary production?
- How will marine ecosystem structure, biodiversity, and population dynamics be shaped by a changing ocean environment?
- How will marine organisms and ecosystems be affected by ocean acidification?
- How will climate change influence the distribution of chemical elements?
- How do the distributions and fluxes of organic carbon components evolve in an altered ocean?
- How will ocean circulation and the distribution of heat in the ocean and atmosphere respond to natural and anthropogenic drivers?
- How will alterations in the global water cycle influence the ocean?
- How will changes at coastal boundaries alter physical and geochemical processes?
- How will coastal ecosystems and communities respond to multiple stressors?
- What are the critical interactions among ocean, ice, land, and atmosphere in polar regions and how will they influence physical and biological changes?

- What advances will be made in prediction and mitigation of oil spills and industrial accidents in the ocean?
- What are the potential impacts on the ocean from geoengineering?

Specific National Research Council recommendations relating to polar marine support, ships, and icebreakers included:

> To ensure that the United States has the capacity in 2030 to undertake and benefit from knowledge and innovations possible with oceanographic research, the nation should:
>
> - Implement a comprehensive, long-term research fleet plan to retain access to the sea.
> - Recover U.S. capability to access fully and partially ice-covered seas.
> - Facilitate broad community access to infrastructure assets, including mobile and fixed platforms and costly analytical equipment.

The National Research Council noted the decline the polar ocean science infrastructure:

> Infrastructure capabilities that allow study of the high-latitude ocean are waning, although these regions are among the most sensitive to a warming climate due to the amplification of temperature changes nearest the poles. Arctic sea ice is already in decline [reference cited], with implications for ecosystem changes, U.S. jurisdiction interests, national security, and commercial shipping routes. However, the United States is having difficulty ensuring the continued operation of ice-breaking research vessels able to function in multiyear ice. The largest icebreakers, the U.S. Coast Guard's Polar Star and Polar Sea, are over 30 years old and have exceeded their service lives. At the time of writing, the Polar Star has recently been reactivated from caretaker status (where the crew is removed and engines and systems are shut down), and the Polar Sea returned to operations after engine casualties. Newer ice-breaking research vessels such as the U.S. Coast Guard Cutter Healy were designed to operate in multiyear ice only in conjunction with a heavier ship, which would break a path for them to follow. The lack of heavy icebreaker capabilities will cause the nation to be dependent on leasing or operating in collaboration with foreign icebreakers to conduct science missions in high latitudes. Additionally, resupply missions to Antarctic research bases are also dependent upon icebreakers from other countries. The current decrease in U.S. icebreaking capability makes high-latitude research more complex and adds an element of risk because the enabling infrastructure is not within the nation's direct control. In addition, the U.S. Coast Guard is in danger of losing valuable skill sets, as crew from the heavy icebreakers are reassigned to different positions.

C.1.5 U.S. Antarctic Program Blue Ribbon Panel, More and Better Science in Antarctica through Increased Logistical Effectiveness, July 2012.

The White House Office of Science and Technology Policy and the National Science Foundation in 2011 initiated a special Blue Ribbon Panel "to identify demands placed on the [Antarctic] logistical enterprise if it is to support future scientific effort in the Antarctic region, to discern any mismatches with currently projected capabilities, and to propose appropriate opportunities and corrective actions." The Panel identified "steps that could substantially increase the amount and value of science pursued in the Antarctic region through greater overall effectiveness of the logistics system."

The Panel noted that "U.S. activities in Antarctica are very well managed but suffer from an aging infrastructure, lack of a capital budget, and the effects of operating in an extremely unforgiving environment."

Regarding polar research ships, the Panel made a principal recommendation:

> Aggressively pursue the acquisition of a new polar research vessel with enhanced capabilities to ensure U.S. leadership in pursuing scientific endeavors in the Southern Ocean. Improved capabilities to deploy and recover advanced remote-sensing assets should be a key feature of such a vessel.

C.1.6 National Research Council, Sea Change: 2015-2025 Decadal Survey of Ocean Science (2015).

In its 2015 report, the National Research Council brought together its Committee on Guidance for NSF on National Ocean Science Research Priorities: Decadal Survey of Ocean Sciences, the Ocean Studies Board, and the Division on Earth and Life Studies to address "the strategic investments necessary at NSF to ensure a robust ocean scientific enterprise over the next decade." They identified eight areas of strategic investment with the highest potential payoff:

- What are the rates, mechanisms, impacts, and geographic variability of sea level change?
- How are the coastal and estuarine ocean and their ecosystems influenced by the global hydrologic cycle, land use, and upwelling from the deep ocean?
- How have ocean biogeochemical and physical processes contributed to today's climate and its variability, and how will this system change over the next century?
- What is the role of biodiversity in the resilience of marine ecosystems and how will it be affected by natural and anthropogenic changes?
- How different will marine food webs be at mid-century? In the next 100 years?
- What are the processes that control the formation and evolution of ocean basins?
- How can risk be better characterized and the ability to forecast geohazards like mega-earthquakes, tsunamis, undersea landslides, and volcanic eruptions be improved?
- What is the geophysical, chemical, and biological character of the subseafloor environment and how does it affect global elemental cycles and understanding of the origin and evolution of life?

In discussing the infrastructure necessary to address these priority science questions, the NRC noted:

> Ice-capable ships are requisite for answering a number of questions related to understanding climate change, ocean-ice interactions, and polar marine food webs.

The NRC did not elaborate on a specific plan to provide the required future polar marine infrastructure, other than to note the present composition of the polar-capable ships accessible to the US scientific community:

> Ice-capable ships provide access to polar regions, necessary for many emerging and existing science fields. The newly commissioned *Sikuliaq*, the only ice-strengthened ship in the Academic Research Fleet, can operate in 2.5 ft of ice. Through the Division of Polar Programs, NSF operates two other ice-capable research vessels—*Nathaniel B. Palmer*, a 308-ft-long icebreaker capable of moving through 3 ft of ice, and *Laurence M. Gould*, a 230-ft-long ice-strengthened vessel capable of breaking through 1 ft of ice. These vessels are under charter and their costs, capabilities, and longevity are evaluated by NSF as contracts are considered for renewal. NSF also has access to U.S. Coast Guard vessels for heavy icebreaking (*Polar Star*) and medium icebreaking (*Healy*) that support both science and logistical missions, such as breaking the channel into the Antarctic McMurdo Station for annual resupply and science operations in the high

> Arctic. There has recently been discussion among Congress, the U.S. Coast Guard, and other federal agencies about the rationale and cost to maintain U.S. capabilities for heavy icebreaking as well as the viability of chartering non-U.S. icebreakers for some operations. The polar ships occasionally support lower-latitude research cruises, which can help to avoid long and costly transits for Academic Research Fleet vessels and provide cost efficiencies for both the polar ships and the academic research fleet.

C.1.7 National Research Council (2015) *A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research.*

In 2018 the National Research Council convened a Committee on the Development of a Strategic Vision for the U.S. Antarctic Program which worked with the Polar Research Board, and the Division on Earth and Life Studies to "develop, through widespread community engagement, a decadal-scale vision for NSF's Antarctic and Southern Ocean research," including "priorities for strategic investments in compelling research, and to identify the infrastructure most critical for supporting this research."

The NRC report covered a wide range of critical future research initiatives, many of which would require support from polar research ships and icebreakers, and noted:

> Concerns about ship support for Antarctic and Southern Ocean research were raised repeatedly in our community outreach discussions, and this is a critical need for supporting the Changing Ice Initiative. The United States has very limited heavy icebreaker support for research in Antarctic waters. As discussed later in this chapter, the USCGC Polar Sea is over 40 years old and is tasked primarily with breaking a channel into McMurdo Station. The Nathaniel B. Palmer is approaching the end of its design service life, and in any event, is designed for only limited icebreaking (with a specified capability of breaking through 3 feet of level ice at 3 knots). The NSF recognized the urgency of advance planning for a Palmer replacement more than 12 years ago and has since supported a series of associated science workshops, icebreaker design contracts (with the U.S. Maritime Administration), and mission requirement refresh activities.Yet no significant progress has thus far been made toward the acquisition of a new polar research icebreaker on the funding side.
>
> The potential gap in ship capacity presents a fundamental challenge to U.S. leadership. The only solution at present for U.S. scientists to pursue key research in heavy-ice areas, or along most of the coast during winter, is to work on research icebreakers of other nations. To adequately support the science priorities recommended by this Committee, and to retain a leadership-level role in both Antarctic and Arctic research, NSF will need to prioritize the acquisition of a next-generation research icebreaker. A new MREFC proposal is one possible vehicle that could be explored for advancing this goal. Given the long time horizon for funding, building, and deploying such assets, NSF will meanwhile need to establish stronger ties with foreign research vessel operators to provide critically needed field opportunities for U.S. scientists.

The NRC concluded, regarding ship support:

> This situation limits where U.S. scientists can conduct research and increases dependence on foreign vessels. To support the science priorities recommended by this Committee, and to retain a leadership role in both Antarctic and Arctic research, NSF will need to prioritize the acquisition of a next-generation research icebreaker ... To maintain operations at U.S. Antarctic research stations and support all U.S. research carried out on the continent, progress must be made in acquiring one or more new polar class icebreakers.

The NRC specifically recommended that NSF, "with the assistance of other research partners, design and acquire a next-generation polar research vessel."

C.2 Recommendations from previous US polar research vessel planning

Coming research initiatives hint at an extraordinary future of discovery ahead in polar research, many examples of which include research which can be carried out or supported only from ships. Some of that research can be carried out from ships similar to those operated today in open or moderately ice-covered waters. But some will require new ship capabilities - for example, with respect to increases in icebreaking capacity and geotechnical support and reduced environmental impact - and improvements and new additions in science support facilities.

The science community gained new capabilities for support for a wide range of exciting and influential science upon the initiation of operations of RVIB *Nathaniel B. Palmer* in 1992. Similarly, important breakthroughs in understanding could be expected upon availability to science of a new polar research ship capable of working in a broader range of ice and weather conditions, working closer to the continent, working in a broader range of seasons, and providing enhanced science support facilities. Research ship design and construction requires substantial time and substantial funding. Hence, the community must look ahead. Several studies in the past two decades have examined future ship support for the U.S. Antarctic Program (USAP), with an eye to how the ship needs of future science can most effectively be accommodated. We present synopses of the reports from three of these polar research ship requirements studies - the three documents examined in greatest detail by the subcommittee.

C.2.1 Antarctic Research Vessel Oversight Committee Polar Research Icebreaker Study (2006)

The Antarctic Research Vessel Oversight Committee (ARVOC), which was initiated in 1994, formed a 15-member special standing committee which worked with the USAP's Antarctic contractor (at the time, this was Raytheon Polar Services Corporation, ARVOC's parent organization), the U.S. Maritime Administration (MARAD, Science and Technology Corporation (STC), and NSF on a feasibility level design study and to collect additional science community input on polar research vessel design issues. ARVOC organized a series of “town hall meetings” at large national science congresses and surveyed many additional members of the polar research vessel user community in one-on-one contacts. ARVOC also collected information through a public access website where questions, comments, and opinions about vessel science mission requirements and design are logged and archived. As of May 1, 2006, ARVOC estimated that more than 270 individuals provided opinions, comments, and technical design or engineering information related to the design of a next-generation polar research icebreaker.

Based on this information, in 2006 ARVOC prepared the report "Advancing U.S. Polar Research Through the Acquisition of a New polar Research Icebreaker". The committee concluded:

> While the RVIB *Nathaniel B. Palmer* (NBP) has served the science community well over the past 15 years, there are compelling reasons to plan now for a new research icebreaker to support future U.S. efforts in the Southern Ocean. Specific research requirements that mandate a new vessel for future scientific exploration of the Antarctic seas are as follows:
>
> - Enhanced ice breaking capabilities (4.5 feet level ice at 3 knots)
> - Increased endurance (to 80 days)
> - Increased accommodation and lab space (for 50 scientists)

- Moon pool for geotechnical drilling and access to the water column through a controlled interface (no ice, limited surge and turbulence)
- Ability to tow nets and research instrumentation from the stern during ice-breaking
- Acoustically quiet vessel with hull form designed for installation and operation of remote sensing instruments.

The ARVOC report noted:

> There have been important technical advances in icebreaker design and propulsion/steering systems since the RVIB *Nathaniel B. Palmer* was designed. By incorporating these advances, it will be possible to achieve better performance, in terms of achieving mission goals, at reduced costs. The current design drawings illustrate the current thinking on the desired layout of the ship as well as some of its key science capabilities. These include:
>
> - A vessel 378 feet in length with level ice breaking capability of 4.5 ft at 3 knots (ABS A3), which permits operations in the central Arctic Basin in summer as well as breaking multi-year sea ice. The 4.5 ft capability was the minimum acceptable due to scientific requirements for additional spatial/temporal range of operation (e.g., Figures 1&2).
> - Capable of holding 50 science and science support personnel.
> - Endurance of 80 days /20,000 miles at 12 kt open water speed.
> - Moon pool of 10 ft by 12 ft for geotechnical drilling, and conduct of AUV/ROV and other operations, especially in ice
> - Helicopter hanger

ARVOC also listed initial scientific and operation requirements [quoted verbatim]:

a) The moon pool is currently smaller (10’ x 12’) and relocated to the box keel, i.e., in the center for drilling and dynamic positioning. These changes were possible because geotechnical drilling is not built in. There is a 6 ft space around the moon pool for the drill rig.
b) The jumbo piston coring setup is similar to a design from WHOI, with a capacity for 50 m, up to 80 m.
c) The concept of diesel-electric propulsion, potentially podded, is endorsed due to enhanced station keeping ability, maneuverability in ice and less ambient ship noise. The concept of podded propulsion needs further research on EMI and reliability.
d) The box keel design for transducers gives the ability to survey during ice breaking.
e) The helo deck and hangar are now on the 02 deck.
f) The vessel design promotes reduced emissions, e.g., a ‘greener ship’.
g) The vessel can accommodate 5-6 portable lab containers (2 on 01 deck, 3 to 4 on main deck). g) There is an 8 ft wide passageway on the main deck and inter-deck elevator.
h) 2 microscope rooms.
i) 2 environmental rooms.
j) There is a walk-in science freezer with a minimum footprint of 200 ft2. k) Designed for easy handling of and access to containers in hold.
k) 2-point winch system for large otter trawl.

C.2.2 A New U.S. Polar Research Vessel (PRV): Science Drivers and Vessel Requirements (2012)

[Note: Some of the text following is quoted directly from the 2012 SMR document.]

In December 2010, The National Science Foundation (NSF) tasked and funded the University-National Oceanographic Laboratory System (UNOLS) program office to establish a committee to review and update the 2006 Antarctic Research Vessel Oversight Committee (ARVOC) report on needs and requirements for a new U.S. polar research vessel.

Committee charges were to:

- Update the science questions and review/modify the vessel science mission requirements defined in an ARVOC study conducted between 2002 and 2006.
- Articulate and evaluate emerging new science drivers.
- Utilize the UNOLS model for developing science mission requirements based on inclusive science community input
- Submit a report to NSF in two stages, with an interim report due in August 2011 and a final report due in early 2012.

The committee's work included a community survey, which received 163 responses. The committee report included a list of 23 "Essential PRV Capabilities", quoted verbatim below:

1) A new PRV must be able to approach modern ice sheet grounding zones, regardless of typical sea ice conditions, i.e., capable of navigating 50 km transects through moderately heavy sea ice (up to 1.5 m).
2) Similarly, a new PRV must be able to transit independently through winter pack ice to reach coastal polynyas (requiring longer transects through ice up to 1.5 m thick) and be able to operate in both polar regions year-round. The committee notes that solo winter access to the central Arctic area will require greater icebreaking capability than we envision for this PRV.
3) The vessel must 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 must be able to host and deploy/recover Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV), both with a wide variety of capabilities. Most likely, such operations will take place in ice covered seas and hence vehicles will need to be deployed through a moon pool or over the side after ice clearing.
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 and ship's crew.
6) Multiple large laboratories designed to support advanced biological and chemical analyses and experiments, including clean sites for genomics and trace organic and metals analysis and sample preparation, and to accommodate modern analytical instrumentation. Space should also be allocated for temperature-controlled environmental rooms.
7) The vessel must be equipped to acquire long stratigraphic sections (50 m via a jumbo piston core or other long core system) and be capable of accommodating temporarily-installed geotechnical drilling to 100 m below sea floor, at water depths of up to 1200 m.
8) The vessel must 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 must be able to operate seismic gear, including towing long multi-channel 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 reliable, well-known multibeam swath mapping echo sounders installed behind ice protection windows. Given the expected range of water depths this will require both a deep-sea multibeam such as a Kongsberg EM122™ and a shallow water system such as an EM710™ for high quality data collection on continental shelves and upper slopes. Supporting

equipment for the multibeam systems will include primary and backup attitude, position, and heading reference providers, such as the Applanix POS/MV™ .

11) The vessel should be equipped with a reliable, ice-protected, hull mounted sub-bottom profiler operating in the 3.5 kHz range. Typical systems are either FM-modulated (CHIRP) such as a Knudsen 3260™ , parametric (narrow beam) system such as an Atlas Parasound™ or Kongsberg Topas™ . The sub- bottom may be integrated with the multibeam, e.g. Kongsberg SBP120™ .
12) Significant efforts should be directed towards making the ship as acoustically quiet as practical. Significant and detailed technical compromises are necessary to achieve a reasonable balance between the performance of ships' acoustic systems and the power and strength necessary to be an efficient icebreaker.
13) 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 3 passengers and 1200 lbs. of cargo. The PRV should be capable of landing a single medium-lift helicopter such as a Bell 412, Sikorsky S-70, or landing a (USCG) HH60.
14) The vessel should be capable of launching small drone aircraft for ice survey and reconnaissance (remotely or autonomously operated).
15) 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.
16) Built-in climate-controlled workspaces.
17) Built-in reefer/freezers.
18) A flow-through science sea water system: ~10-20 liters/minute maximum, for instrumentation (TSG, fluorometers, nitrogen analyzer, flow-through mass spectrometers, DO, pCO_2 etc.) only, not for sampling. This system will be driven by a separate pump (and spare) from the sampling, incubator cooling water and washing water.
19) Incubator/washing water: 400 liters (~100 gallons) per-minute delivered to the location of the incubators. Also delivers water to science sinks, vans sites, science working deck areas.
20) Capability of storing instruments and sampling gear, washing nets, and processing benthic samples in a warm environment during winter operations.
21) Capable of supporting "UNOLS standard" lab vans.
22) Capable of high-speed internet for shipboard scientists and crew.
23) Science winches: CTD (0.322" conductor), multipurpose (e.g., camera, nets, benthic grabs) (3/8" wire rope), trawl/core (9/16" wire rope), deep tow (0.681" FO/EM).

The committee further noted that changes in requirements since the 2006 study included:

- Renewed emphasis on a moon pool that is at least 4m x 4m in size and that opens into an interior space to allow sheltered science operations during polar winter conditions. The 2006 report included a smaller moon pool.
- Extension of endurance from 80 days to 90 days.
- Addition of an instrumented foremast for atmospheric studies combined with a deckhouse design that further enhances the ability of the vessel atmospheric sensors to sample undisturbed air.
- Use of the latest in "green" technology for the vessel's systems to ensure an environmentally clean and operationally cost effective vessel.
- Limited compliance with ADA guidance.

C.2.3 Research Vessel Placement Program Vessel Studies Report (2018)

On behalf of the USAP Antarctic Support Contract, Leidos was contracted to provide information regarding potential new chartered ships to replace RVIB *Nathaniel B. Palmer* and ARSV *Laurence M. Gould*, including construction cost estimates, charter rates, program schedules and vessel descriptions for two new vessels - an icebreaking research vessel and an ice capable supply vessel - each based on NSF requirements. Initial parameters included a 2014

Request for Information developed by NSF and reports from the Polar Research Vessel (PRV) program that existed from 2002 to 2012 [the reports summarized in Sections C.3.2 and C.3.3.]. The PRV SMR Refresh Committee Report (2012) was used as the guiding document for many design aspects of new vessels that were not addressed in the RFI. Another important document for the Leidos study was a Service Life Extension Feasibility Assessment developed by JMS Naval Architects for NSF in 2015. That report established some areas of improvement on *Nathaniel B. Palmer* that can be relevant to new vessel requirements definition.

Key vessel characteristics for both an ice breaking research vessel (IBRV) and an ice capable supply vessel were summarized in the report's Table 8 (verbatim):

	IBRV	**ICSV**
Registry	US Flag	US Flag
Classification	46 CFR, Ch. I Subch. U; IMO Polar Code, ABS HAB+, ABS DP – 0 or DP – 1	46 CFR, Ch. I Subch. U; IMO Polar Code, ABS HAB+,
Speed	> 11 kts in ice-free waters	> 10 kts in ice-free waters
Ice Breaking	> 3 – 4.5 ft at > 3 kts	> 1 – 1.5 ft at > 3 kts
	IBRV	**ICSV**
Polar Class	PC 4 or PC 5	PC 5
Size	LOA: ~328 ft B: ~64 ft	LOA: ~250 ft B: ~60 ft
Endurance and Range	70 – 90 days / 17,000 nm	70 – 85 days / 15,000 nm
Underwater Radiated Noise	DN-GL Silent (A) with modified criteria	No Requirement
Cargo Capacity	> 15 20 ft containers in hold and on deck;	> 9 20 ft containers in hold and on deck;
Propulsion Plant	Integrated Diesel Electric with Hybrid Battery	Integrated Diesel Electric with Hybrid Battery
Propulsors	Azimuthing Z-Drives or Controlled Pitch	Azimuthing Z-Drives or Controlled Pitch
Helicopter Operations	Deck and Hangar supporting two (2) light or one (1) medium	None
Complement	45 – 55 science and technical	28 – 40 science and technical
Working Deck Area	4,500 – 5,500 sq ft	3,600 – 4,000 sq ft
Science Lab Areas	5,700 – 6500 sq ft	2,900 – 3,500 sq ft

The report is highly detailed. Although the subcommittee paid close attention to this report, the report discussed many important aspects of polar research ship design that were outside the immediate scope of the subcommittee's work. Hence, the subcommittee recommends that the Leidos Vessel Studies report be paid close attention in future development of operational and design specifications for new USAP polar research and supply ships.

C.3 Polar research ships recently in service or under construction

Several nations have recently constructed polar research ships, some of which double as resupply ships. Each represents a view of advances in design, operations, and research support optimized for the needs of a national polar research program. We present information about four of these.

C.3.1 Statement of Requirements for the Procurement of the New Polar Research Vessel Sir David Attenborough (2015)

RRS *Sir David Attenborough* (SDA) is a polar research vessel constructed for the UK Natural Environment Research Council, to be operated by the British Antarctic Survey for the purposes of both research and logistic support. The ship is replacing a pair of existing vessels, RRS *James Clark Ross* and RRS *Ernest Shackleton*. The £200M commitment represents the UK Government's largest investment in polar science since the 1980s.

Technical features include:

- Length: 129 meters (423 feet); beam: 24 meters (79 feet)
- Large scientific cargo volume (≈ 900 m^3)
- Endurance of up to 60 days (in polar regions)
- Range: 19,000 nm at 13 knots cruising speed
- Ice breaking capability of up to 1m thick at 3 knots
- Bow and stern thrusters for excellent dynamic positioning in challenging conditions
- Launch and recovery of aerial and ocean robotic systems
- Crew: approx. 30
- Accommodation for up to 60 scientists and support staff
- Expected reduced environmental impact and cost savings over the ships replaced.

The ship has been designed to incorporate the following key features:

- Scientific winch system with a proven robust design.
- Efficient hull form optimized to minimize underwater radiated noise, minimize bubble sweepdown, reduce propulsive power at service speed, and provide good seakeeping performance.
- Minimum surface area for ice accretion.
- Environmental protection of equipment.
- De-icing facilities where necessary.
- Ease of mobilization and demobilization.
- Self Sufficient craneage.
- Flexible cargo holds with tween decks configured for efficient stowage of containers and cargo.
- Dynamic positioning.

- Flexible working spaces.
- Scientific Moonpool, with closing doors top and bottom.
- Helicopter capable, including the provision of hangar and refueling.
- Maximum protection of working areas.
- Reliability and redundancy in propulsion and essential safety systems.
- Minimum maintenance.
- Efficient use of energy.
- Speed and economy in transit.
- Minimum environmental impact. Including provision for compliance with NOx requirements and Environmental requirements of the POLAR code and the Antarctic Treaty.

Some key features of RRS *Sir David Attenborough* (table reduced from original):

Feature	**Considerations**
Ice Capability	PC4 ice breaking capability (up to 1m thick at 3 knots).
Accommodation block	Comfort is the primary consideration. Crew and scientists cabins to be separate from public areas. Efficient arrangement of catering spaces, provisions stores and waste management.
Heli-deck	Position to be adjacent to the helicopter hangar. (Obstruction free and with infrequent use.)
Helicopter hangar	To accommodate two small helicopters, Eurocopter AS365 N3 or similar. Secondary use for containerized laboratories / light cargo / stores.
Cargo hold space	In reach of the main ship's crane. Easy access for movement of cargo to the heli-deck. Stowage of aviation fuel in drums including fire detection & extinguishing arrangements. Flexible internal handling systems for cargo in the hold spaces.
Working deck	Direct access for working over the stern, over the side or through the moonpool, using common transfer systems.
Deck cargo	In reach of the ship's cargo crane.
Dynamic Positioning	DP2 (DP(AA)) capable.
Cargo Tender	The cargo tender will be located in a suitable position that will allow safe deployment and recovery. The Cargo Tender will carry a 20ft ISO container and have space to open the doors for discharge to the shore.
Starboard side "A" Frame	To allow deployment and recovery of scientific packages from the hangar and over the side.
Starboard side CTD gantry	To allow deployment and recovery of scientific packages from the hangar and over the side.

Survey towing winch/A frame	Arranged for over the stern deployment.
Rescue boats	Fast rescue boat required port and starboard.
Laboratories	Direct access to the scientific hangar.
Subsea survey	Transducers / transceivers mounted behind titanium plate “ice windows” flush with the shell plating in optimum position to minimize bubble sweep-down effects and prevent ice damage to the sensors.
Scientific Moonpool	Close to midships to minimize motion to allow enhanced operability.
HVAC	Air conditioning systems will be required to handle the extremes of both the Antarctic and tropical conditions in transit. Redundancy will be incorporated into the system.

C.3.2 RV *Kronprins Haakon*

[information from web sites]

RV *Kronprins Haakon* is a Norwegian icebreaking polar research vessel jointly owned by the University of Tromsø, Norwegian Polar Institute and Norwegian Institute of Marine Research, built in Italy and delivered in 2018. *Kronprins Haakon* is the largest Norwegian icebreaker ever built. The research vessel has accommodation for 55 personnel in 38 cabins, including a crew of 15–17. She is equipped with a hanger for two small- to medium-sized helicopters, but the helipad in the bow is strengthened also for heavier helicopters.

Kronprins Haakon has a diesel-electric propulsion system. Her power plant consists of two 3,500 kW and two 5,000 kW medium-speed diesel engines that produce power for two 5.5 MW azimuth thrusters and two 1.1 MW bow thrusters. The propulsion system also gives her Dynamic Positioning Class 1 station keeping capability. In open water, she has a maximum cruising range of 15,000 nautical miles (28,000 km) and endurance of 65 days at cruising speed.

Kronprins Haakon is strengthened for operation in winter ice with pressure ridges and multi-year ice, and in ambient temperatures of −35°C (−31°F). She is designed according to International Association of Classification Societies (IACS) Unified Requirements for Polar Class Ships and her ice class, Polar Class 3, is intended for vessels designed for "year-round operation in second-year ice which may include multi-year ice inclusions". A capable icebreaker, *Kronprins Haakon* can break 1 metre (3 ft) thick ice at a continuous speed of 5 knots (9.3 km/h; 5.8 mph) and maintain a speed of 12 knots (22 km/h; 14 mph) in 0.4 metres (16 in) thick ice.

As a research vessel, *Kronprins Haakon* has an extensive scientific outfit for oceanography, marine biology and geology. The main deck is largely dedicated to scientific activities with 15 fixed and three container laboratories, refrigerated storage rooms, large working deck with cranes and an A-frame for trawling, and a hangar and 3-by-4-metre (10 by 13 ft) moon pool for sampling as well as AUV and ROV operations. Underwater acoustics instrumentation is fitted in two drop keels as well as special "arctic tanks" for operations in ice-covered seas.

Tonnage:	9,145 GT
Length:	100.382 m (329 ft)
Beam:	21 m (69 ft)
Draught:	8.666 m (28 ft)
Depth:	10.408 m (34 ft)
Ice class:	Polar Class 3
Installed power:	(2 × 3,500 kW) + (2 × 5,000 kW) [ca. 22,800 HP total]
Propulsion:	two azimuth thrusters (2 × 5.5 MW) (14,750 HP)
Two bow thrusters	(2 × 1.1 MW)
Range:	15,000 nautical miles (28,000 kmi)
Endurance:	65 days at cruising speed
Capacity:	Accommodation for 35 scientists and 15-17 crew in 38 cabins 1,180 m^3 cargo hold 20 containers
Crew:	15–17
Aviation facilities:	Helipad and hangar

C.3.3 Australian Antarctic science and resupply ship, RSV *Nuyina*

The Australian Antarctic science and resupply ship, RSV *Nuyina*, presently under construction for operations beginning in 2020, is a large polar research and supply ship built to meet the resupply and personnel support needs of the nation's on-Continent Antarctic program as well as their polar marine research program in ice-bound waters. (Their new open-ocean ship RV *Investigator* supports Australia's marine research in ice-free waters.) RSV *Nuyina* is a large ship, handling significant freight, fuel, and personnel as well as on-ship polar research. RSV *Nuyina* can:

- break 1.65 m thick ice at a continuous speed of 3 knots
- cruise efficiently at 12 knots, with a maximum speed of 16 knots
- handle sea state 9 (waves over 14 m)
- handle Beaufort 12 winds (hurricane)
- cope with air temperatures as low as -30°C and up to 45°C
- support voyages of up to 90 days

Features:

- 96 containers plus large amount bulk cargo
- 117 passengers plus 32 crew
- 2 controllable pitch propellers; 3 bow and 3 stern thrusters for manoeuvring

- 2 diesel engines (19 200 kW total) for icebreaking and two electric motors (7400 kW total) powered by diesel generators for silent operations
- Moon pool
- Retractable boom for instruments to measure snow and ice thickness
- Two drop keels with acoustic instruments
- Wet well to process seawater containing krill
- ‘Silent R’ acoustic rating at 8 knots
- Dynamic positioning system maintains ship’s position ±20 m in sea state 4 (moderate seas)
- minimises noise from the engines and ‘Silent R’ acoustic rating at 8 knots
- minimises noise from the engines and bubbles sweeping around the hull
- Meteorological instruments

Heavy Lifting:

- 1200 tonne (t) capacity below decks in up to 96 20-foot shipping containers
- 60 20-foot containers above deck for cargo and labs
- Cranes: 2 x 55t on bow; 1 x 15t side loader; 1 x 15t aft; and smaller cranes on science work deck
- Helicopters: 4 small (B3s) or 2 medium (S92s)
- Tenders: 3 ship + 1 science
- Barges: 2 x 45t capacity

The icebreaker will be able to handle:

- waves up to sea state 9 (14 metres plus significant wave height)
- wind speed up to Beaufort 12 (hurricane)
- air temperature ranging from –30° Celsius to 45° Celsius, and
- water temperatures ranging from –2° Celsius to 32° Celsius.

It will have the capability to:

- travel at an efficient cruising speed of 12 knots, with a maximum sustained speed of 16 knots in open water
- break ice at a continuous 3 knots in ice of 1.65 metre thickness
- transfer personnel and cargo from the icebreaker to the stations using a range of means over water, over ice and by air, including the capability to operate and support four light helicopters or two medium helicopters
- handle, stow and transport up to 1200 tonnes of solid cargo consisting primarily of containers and break-bulk cargo, including large items of plant and equipment using the ships own cargo cranes, and
- handle, stow and transport up to 1,900,000 litres of bulk liquid cargo (Special Antarctic Blend diesel used for station operations)
- ·support voyages for up to 90 days, which includes the ability to remain within the Antarctic area for up to 80 days
- accommodate 117 personnel with modern services including a specialised medical facility, and
- ensure a high standard of environmental compliance.

The vessel will be able to sustain multidisciplinary and concurrent science operations, and support numerous sample and data collection systems, including for sea-floor, sea-ice, sea life and atmospheric research. It will have the capability to deploy, operate and with location precision recover a range of equipment and instruments in a range of conditions including:

- drop keels and a moon pool to support a wide range of scientific research operations and modes
- a multi-beam bathymetric echo sounder for mapping the sea floor at full ocean depth
- sub-bottom profiler to analyse the physical properties of the sea floor
- scientific echo-sounders for biomass assessment and fisheries sonar systems, and
- hydrophones and underwater cameras.

It will have a dynamic range of fixed and portable work spaces, facilities and services to support experimentation and analysis and the capability to deploy a specialized marine tender.

Length overall:	160.3 metres
Maximum beam:	25.6 metres
Maximum draught:	9.3 metres
Displacement:	25,500 tonnes
Icebreaking:	1.65 metres at 3 knots
Speed:	12 knots economical, 16+ knots maximum
Range:	> 16,000 nautical miles
Endurance:	90 days
Cargo fuel capacity:	1,900,000 litres / 1671 tonnes
Container capacity:	96 TEU
Cargo weight:	1200 tonnes
Passengers:	117
Crew:	32

C.3.4 Chinese polar research vessel, *XueLong 2*

The People's Republic of China completed construction of the *XueLong 2,* a polar research and supply vessel in September 2018, with its first mission anticipated in 2019. The hull form was designed with good seakeeping characteristics and low open water resistance. A special box keel provides a disturbance-free flow environment for bottom-mounted scientific instruments in both open water and ice. The diesel-electric power plant and propulsion system, which consists of four main generating sets, two 7.5 MW azimuth propulsion units and two transverse bow thrusters, provides the vessel with redundant DP2 class station keeping capability.

Type:	Research Vessel
Displacement:	14,300 tons
Length:	402 feet (122.5m)
Beam:	73 feet (22.3 m)
Draught:	26 feet (7.9 m) design, 27 feet (8.3 m) maximum
Depth:	39 feet (11.8 m)
Ice class:	PC3 (1.5 m thick ice at 2-3 kts ahead and astern)
Installed power:	2 × Wärtsilä 16V32 and 2 × Wärtsilä 12V32
Propulsion:	Diesel-electric; two ABB Azipod units (2x7.5MW) and 2 bow thrusters
Speed:	12 knots (1 engine), 15 knots (2 engines), 2-3 knots icebreaking
Capacity:	90 crew and scientists
Aviation:	Helideck and hangar for 2 helicopters.
Range:	20,000 nm
Endurance:	60 days
Operating temp:	-30°C

The scientific outfit includes both wet and dry laboratories, a large aft working deck served by several cranes and winches, and a moon pool with scientific hangar that allows for the deployment of scientific instruments in ice-covered seas. The large forward cargo hold, heavy crane and cargo fuel tanks allow the vessel to carry out resupply missions to scientific research stations. The *Xuelong 2* is larger than the 15,300-ton Ukraine-built icebreaker *Xuelong* which is currently in service and which was built in 1993. China is developing another icebreaker capable of breaking 3-m thick ice and operating in temperatures as low as -45°C.

PART II. Analysis, Discussion, and Detailed Recommendations

D. USAP Polar Research Ship Science Mission Requirements

D.1 Overview

A primary focus of the subcommittee was on science mission requirements (SMRs) applicable to USAP polar research and support ships. The subcommittee was directed to "Review and verify the continued validity of the University-National Oceanographic Laboratory System (UNOLS) 2012 Polar Research Vessel Science Mission Requirements, the 2016 NSF/OPP Antarctic Vessels Request for Information, and the 2018 ASC-provided Vessel Studies Report" (from Leidos). The file names used by the subcommittee were:

- "PRV_SMR_FinalReport_Feb2012.pdf",
- "RFI_Sources_Sought_RVIB_ARSV_FBO_Final.pdf", and
- "Vessel Studies Report Rev -.pdf", respectively.

Disparities between the documents were identified and investigated. The subcommittee also considered the document "Ocean Class Science Mission Requirements (SMR) - Table of Requirements, Values, and Priorities" (file name "OCSMR_revision_093009_0.pdf"), finding this to be a useful example of contents and organization of an SMR document at an appropriate level of detail. The results, along with input from the community survey, professional opinions, and practical experiences, were used by the subcommittee to produce an updated set of SMRs, along with general priorities.

[The document names are abbreviated in the remainder of section D of this report as

"2012PRVSMR", "2016OPPRFI", "2018ASCVSR", and "2009OCSMR".]

The committee also had access to selected ship specifications or ship specification documents from polar research ships constructed by other nations, including RRS *Sir David Attenborough* (British Antarctic Survey), RSV *Nuyina* (Australian Antarctic Division), and RV *Kronprins Haakon* (University of Tromsø, Norwegian Polar Institute, and Norwegian Institute of Marine Research). Where these are mentioned in Section D, the ship is referred to by name.

D.2 Science Mission Requirements, Updates

The subcommittee worked from a list of science mission requirement categories, identifying text from the primary reference documents applicable to each SMR category. In each of the following report sections, the Subcommittee's updated SMR appears first, then materials from the reference documents are quoted in italics, and these are followed by discussion summarizing the subcommittee's analysis. The SMRs recommended by the subcommittee are summarized in Appendix 2.

D.2.1 Size and general requirements

Updated SMR

The size and power of a new icebreaking research vessel for the Antarctic is dependent on available funds and driven by those requirements considered the highest priority. At a minimum, the vessel should be at least as large and capable as the NBP. However, to achieve many of the research and support requirements described in this document it will need to be larger and more powerful. Maximum draft should be constrained by the need to service particular ports/stations such as Palmer Station with a 30-foot maximum draft nominally required.

Special Features that will impact overall size and power: Icebreaking capability with Polar Code P4 or even P3 along with an endurance of 70 to 90 days will have the biggest impact on size and power. Other driving features include the berthing capacity, a box keel, 4m x 4m interior moon pool, lab van capacity (4 or 5), helicopter support, 24/7 internet, small boat operations, design for flexible use of both starboard and port rails for instrument deployment, capacity to carry >15 standard 20-foot intermodal containers in the hold and on decks; size of wastewater holding tanks; all vessel underway discharge must be consolidated to one side of the vessel providing a "clean working side"; capacity to transport, deliver and pump >60,000 gallons of various grades of diesel such as Antarctic Grade diesel, to Antarctic research stations; ability to fully operate in water temperatures 28°F to 90°F and air temperatures of -40°F to 100°F and wind speeds of 100 knots; ability to conform to IMO Polar Code regulations, as required.

Previous Requirement Language

2012PRVSMR:

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, 4m x 4m interior moon pool, lab van capable (4 or 5), helicopter support, 24/7 internet, small boat operations, designed for flexible use of both starboard and port rails for instrument deployment*

2016OPPRFI:

Length Overall:	*(not specified)*
Beam:	*(not specified)*
Draft:	*30 feet maximum*
Displacement:	*(not specified)*
Propulsion Horsepower:	*(not specified)*
Special Features:	*[partial listing] capacity to carry >15 standard 20-foot intermodal containers in the hold and on decks; all vessel underway discharge must be consolidated to one side of the vessel providing a "clean working side"; capacity to transport, deliver and pump >60,000 gallons of various grades of diesel such as Antarctic Grade diesel, to Antarctic research stations; ability to fully operate in water temperatures 28°F to 90°F and air temperatures of -40F° to 100°F and wind speeds of 100 knots; ability to conform to IMO Polar Code regulations, as required.*

2018ASCVSR:

Length Overall:	*≈328 feet*
Beam:	*≈64 feet*
Draft:	*vessel draft requirements will be based upon the new pier.*
Displacement:	*(not specified)*
Propulsion Horsepower:	*(not specified, but Integrated Diesel Electric with Hybrid Battery)*
Special Features:	[many, similar to RFI]

Discussion:

The polar science community anticipates an increasing demand for interdisciplinary cruises in Antarctic waters. There is growing demand for more research cruises occurring during the shoulder seasons and in winter (in both ice and open water) and the capability of working in heavier ice concentrations than heretofore possible. There is also community interest in working in relatively unexplored Antarctic waters, which argues for greater vessel endurance. Interdisciplinary cruises usually entail a large scientific complement and more specialized gear. Consequently, such cruises require more storage, deck, and lab spaces, including an increase in the diversity of lab types (including the temporary use of lab vans). New technologies offer unprecedented sampling capabilities involving suites of acoustical devices, AUVs, ROVs, and UAVs, geotechnical drilling and seismic operations. Additional sampling requirements will necessitate the use of more physically robust workboats with an increased sampling capacity and greater endurance than now possible. There is also increased interest in working on and in the ice, which requires both helicopters and the ability to safely and efficiently transport people from the vessel to the adjacent ice. In aggregate, these interests require a vessel whose size and endurance are greater than the NPB.

D.2.2 Accommodations and habitability

D.2.2.1 Accommodations/Berths

Updated SMR

Berthing and support facilities for >45 science and technical personnel (threshold) and >55 science and technical personnel (objective).

Priorities: Threshold requirements rated as "must have, as is";
Objective requirements rated as "nice but not necessary"

Previous Requirement Language

2012PRVSMR: *Crew and marine technicians plus 45 scientists.*

2016OPPRFI: *Support of >45 science and technical personnel (threshold) / >55 science and technical personnel (objective).*

2018ASCVSR: *Scientific complement: 45 (threshold) and 55 (objective).*

Discussion:

Fifty-seven percent of the survey respondents were satisfied with the number of berths for scientists and staff on the NBP, currently at 39. Numbers for increased berths ranged as high as 80 (1 respondent), however increasing to either 45 (5 respondents) or 50 (4 respondents) were more common suggestions.

One respondent noted that "The issue tends not to be "number of berths" but rather how those berths are managed, with unfortunately the momentum building in recent years to favor the contractor as opposed to the science. However, overall, the demand on vessel support is increasing and will no doubt continue in the future, so any plan for new vessels should default to increasing the number of available berths. Regarding question 14 specifically, the LMG is currently inadequate and the NBP borderline adequate."

One respondent noted that space "should increase proportionally with an increase in berths."

We concur with the 2012PRVSMR recommendation that a new PRV should be designed with labs and berthing to accommodate up to 45 scientists in addition to the on-board technical support and ship's crew.

D.2.2.2 Habitability

Updated SMR

Accommodations and personnel spaces shall be designed to maximize comfort and reduce fatigue and to meet and/or exceed industry standards for acceptable noise and vibrations levels. All areas on the vessel, including lab and living areas, must meet American Bureau of Shipping HAB+ (WB) notation for habitability standards.

Common areas (non-working spaces) include gym, sauna, lounges, conference rooms and galley. The gym is considered quite important and should be adequately sized for a variety of exercise methods, some of which require open spaces for movement. Fitness equipment should be ample and located in one or more dedicated spaces noise-isolated from staterooms. Conference rooms need to be designed to consider noise and ability to conduct remote conference (video and audio). Separate and smaller learning centers to support linked programs with universities are needed to allow conference meetings to occur concurrently. Additional considerations include provisions for maintenance of interior temperature standards during Antarctic winter conditions, provision of spaces to store and change into polar clothing, a large and comfortable lounge (as in the NBP), and isolation of living, dining, and lounge spaces from ship, equipment, and icebreaking noise. The "hotel" area of a polar RV is a 24/7 quiet zone and thus should be as isolated as feasible from other areas of the ship such as main passageways, equipment rooms (such as thrusters, engines, winches and fans), exterior hatches, and main ladderways. Multiple places to work or relax (such as on the NBP) are desirable. The galley should be equipped and staffed to serve four meals per day (i.e., to include hot food at mid-rats).

HVAC - Temperature ranges and environmental conditions:

Maintain temperatures in normally occupied spaces (A/C spaces) of at least 70°F in the heating season and 75°F or lower in the cooling season. Other spaces can have relaxed requirements based on the use of the space. Use SNAME Technical and Research Bulletin No. 4-16 for guidance. Environmental conditions range from a minimum air temperature of -40°F or less and seawater temperature of 28°F in winter and a maximum dry bulb air temperature of 100°F (82°F wet bulb) and seawater temperature of 90°F. (Objective/desired: Same as minimum with wider range of environmental conditions and/or additional capacity for heating and cooling.)

HVAC - Relative Humidity percentages:

Laboratories require a non-condensing environment and shall have a relative humidity of 50% relative or lower. Other A/C spaces shall have a relative humidity of 55% or lower.

HVAC - rate of air changes: Use SNAME T&R Bulletin No. 4-16 for guidance.

Airborne noise in ship compartments and at deck stations shall be specified such that the weighted sound pressure levels meet or exceed the requirements of the ABS Hab + (WB) notation as an objective and ABS Hab (WB) as the threshold. Laboratories and other normally occupied spaces shall meet the standards for offices (60 dB or lower). Working Decks should meet the requirements of Machinery Control Rooms (70 to 75 dB). Staterooms shall be sound insulated to limit noise between cabins as much as possible for privacy. Airborne noise specifications should be developed using an experienced shipboard noise consultant.

The ship and all ship components shall be free from excessive vibration. Vibration is excessive when it results in damage or danger of damage to ship structure, machinery, equipment or systems, or when it interferes with the proper operation of the ship and all ship components. Vibration is also considered excessive when it interferes with the safety, comfort or proficiency of personnel, or with scientific operations. In particular, vibration should be at a minimum in areas where microscope work or other sensitive scientific equipment is in operation. The following criteria should be used: Vibration in normally occupied spaces shall be limited to a maximum allowable velocity of 160 mils/sec (4 mm/sec) in maximum repetitive amplitude terms for a frequency range of 1 to 100 Hz in accordance with revisions to ISO 6954 recommended by SNAME T&R Bulletin 2-29A.

The vibration of the masts and other structures supporting vibration-sensitive equipment shall be limited to that level acceptable to the manufacturers of mast-mounted equipment, or ±0.1g over the frequency range of 1 to 100 Hz, whichever is less.

The vibratory response of the propulsion system over its entire power range and speed range through 115 percent of maximum shaft RPM shall be limited according to manufacturer's recommendations and so as not to harm installed machinery.

Lighting levels shall generally exceed by 30% the values given in IESNA RP-12-97, Marine Lighting, Table 3. Laboratories shall have 100 foot-candles of light, staging bays and working decks shall have 70 foot-candles of light. In the laboratories, individual lights or groups of lights shall have independent switches to allow them to be controlled separately to provide varying light levels. Navigation spaces shall be equipped with red illumination in addition to the normal lighting.

Enhanced Habitability: The productivity of all personnel sailing in these vessels can be enhanced by providing comfortable, aesthetically pleasing spaces, and by including, to the extent possible, areas for off-hour activities other than staterooms and workspaces such as a library, lounge, or conference room with tables, good lighting, video capability, etc. Equipment and appropriate space for exercise should be provided. Human engineering principles should be applied in the design of workspaces. As an example, the distance from the deck to the underside of the finished overhead should be 7.5 to 8 feet. Headroom space and room for the installation of tall equipment should be maximized while balancing the need for cable trays, adequately sized ventilation ducts, lighting, etc.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *Accommodations and personnel spaces shall be designed to maximize comfort and reduce fatigue and to meet and/or exceed industry standards for acceptable noise and vibrations levels.*

2016OPPRFI: *All areas on the vessel, including lab and living areas, must meet American Bureau of Shipping HAB+ habitability standards.*

2018ASCVSR*:* *…ABS HAB+ ... would improve living conditions on the new vessels in regards to noise control as compared to the existing vessels. ... the NBP and LMG meet or exceed most space and layout considerations for habitability, therefore HAB + would maintain standards in terms of living layouts but not improve them.*

Also: *Common areas (non-working spaces) include gym, sauna, lounges, conference rooms and galley. The gym is considered quite important ... and should be adequately sized for a variety of exercise methods, some of which require open spaces for movement. …Conference rooms need to be designed to consider noise and ability to conduct remote conference (video and audio). Separate and smaller learning centers to support linked programs with universities are needed to allow conference meetings to occur concurrently.*

Discussion:

With long cruises in polar ocean regions frequented by heavy seas, polar research ships benefit from special focus on habitability issues. Indeed, 38% of survey respondents selected habitability as their top choice from a list of six key needs for USAP ships.

The UNOLS ocean-class SMRs included extensive habitability specifications, including temperature, humidity, air exchange, noise, vibration, lighting, and enhanced habitability. The resulting ships (RVs *Neil Armstrong* and *Sally Ride*) are renowned for their comfortable, low vibration, quiet staterooms with excellent air temperature control, although storage for personal gear is limited, and the ships were constructed without spaces dedicated to fitness equipment and activities.

The ocean-class habitability SMRs [lightly edited]:

> HVAC - Temperature ranges and environmental conditions:
>
> Maintain temperatures in normally occupied spaces (A/C spaces) of at least 70°F in the heating season and 75°F or lower in the cooling season. Other spaces can have relaxed requirements based on the use of the space. Use SNAME Technical and Research Bulletin No. 4-16 for guidance. Environmental conditions range from a minimum air temperature of 0°F and seawater temperature of 28°F in winter and a maximum dry bulb air temperature of 95°F (82°F wet bulb) and seawater temperature of 90°F. (Objective/desired: Same as minimum with wider range of environmental conditions and/or additional capacity for heating and cooling.)

HVAC - Relative Humidity percentages:

Laboratories require a non-condensing environment and shall have a relative humidity of 50% relative or lower. Other A/C spaces shall have a relative humidity of 55% or lower.

HVAC - rate of air changes:

4-minute rate of change of air in air conditioned areas and 6 minute rate of change in ventilated spaces.

Airborne noise in ship compartments and at deck stations shall be specified such that the weighted sound pressure levels are 60 dB or lower in staterooms and lounges, 65 dB or less in other occupied spaces and passageways, 70 to 75 dB or less on working decks, bridge wings and the Main Control Station, and no more than 110 dB in machinery spaces. Spaces not listed shall have a noise level limit similar to a listed space with similar function or be in accordance with NVIC No. 12-82 and IMO Resolution A.468(XII), "Code on Noise Levels On Board Ships." Staterooms shall be sound insulated for privacy. Airborne noise specifications should be developed using an experienced shipboard noise consultant.

The ship and all ship components shall be free from excessive vibration. Vibration is excessive when it results in damage or danger of damage to ship structure, machinery, equipment or systems, or when it interferes with the proper operation of the ship and all ship components. Vibration is also considered excessive when it interferes with personnel safety, comfort or proficiency, or with scientific operations. In particular vibration should be at a minimum in areas where microscope work or other sensitive scientific equipment is in operation. The following criteria should be used: Vibration in normally occupied spaces shall be limited to a maximum allowable velocity of 160 mils/sec (4 mm/sec) in maximum repetitive amplitude terms for a frequency range of 1 to 100 Hz in accordance with revisions to ISO 6954 recommended by SNAME T&R Bulletin 2-29.

The vibration of the masts and other structures supporting vibration-sensitive equipment shall be limited to that level acceptable to the manufacturers of mast-mounted equipment, or ±0.1g over the frequency range of 1 to 100 Hz, whichever is less.

The vibratory response of the propulsion system over its entire power range and speed range through 115 percent of maximum shaft RPM shall be limited according to manufacturer’s recommendations and so as not to harm installed machinery.

Lighting levels shall generally exceed by 30% the values given in IESNA RP-12-97, Marine Lighting, Table 3. Laboratories shall have 100 foot-candles of light, staging bays and working decks shall have 70 foot-candles of light. In the laboratories, individual lights or groups of lights shall have independent switches to allow them to be controlled separately to provide varying light levels. Navigation spaces shall be equipped with red illumination in addition to the normal lighting.

Enhanced Habitability:

The productivity of all personnel sailing in these vessels can be enhanced by providing comfortable, aesthetically pleasing spaces, and by including, to the extent possible, areas for off-hour activities other than staterooms and workspaces such as a library, lounge, or conference room with tables, good lighting, video capability, etc. Equipment and appropriate space for exercise should be provided. Human engineering principals should be applied in the design of workspaces. As an example, the distance from the deck to the underside of the finished overhead should be 7.5 to 8 feet. Headroom space and room for the installation of tall equipment should be maximized while balancing the need for cable trays, adequately sized ventilation ducts, lighting, etc.

The statements in 2018ASCVSR and the Ocean-class SMRs regarding habitability are a reasonable starting point for the polar RV SMRs regarding habitability. Additional considerations include provisions for maintenance of interior temperature standards at Antarctic winter conditions, provision of space(s) to store and change into polar clothing, a large and comfortable lounge (as in the NBP), and isolation of living, dining, and lounge spaces from ship, equipment, and icebreaking noise. The "hotel" area of a polar RV is a 24/7 quiet zone and thus should be as isolated as feasible from other areas of the ship such as main passageways, equipment rooms (such as winches and fans), exterior hatches, and main ladderways. Multiple places to work or relax (such as on the NBP) are desirable. Fitness equipment should be ample and located in one or more dedicated spaces noise-isolated from staterooms. The galley should be equipped and staffed to serve four meals per day (i.e., to include hot food at mid-rats).

D.2.3 Operational characteristics

D.2.3.1 Icebreaking

<u>Updated SMR</u>

The new vessel should have icebreaking capability that exceeds that of the existing RV *Nathaniel B. Palmer*. For this reason, the Objective SMR goal is the priority and under no circumstances would it be acceptable to end up with icebreaking capabilities less than PC 4 or less than the *Palmer*.

Objective: >4.5 feet with 12 inches of snow at a continuous speed >3 knots. Polar Code: PC 3 - year-round operation in second-year ice which could include multi-year ice inclusions.

Threshold: Capability of independently breaking sea ice with a thickness >3 feet. Polar Code: PC 4 - year-round operation in thick first-year ice, which may include old ice inclusions.

As per the recommendations in the ASC Vessel Studies Report, the ice performance requirements should incorporate the following design criteria:

- Ice flexural strength = 500 kPa
- Average speed in thin (0.5 m or less) ice = 5 to 6 knots
- Level ice astern = 1.4 m (4.5 ft), same as ahead
- Maneuvering characteristics (turning radius, turning out of an existing channel, starturn, etc.)
  - Maximum turning diameter of 3×LWL to 4×LWL in 1.4 m (4.5 ft) level ice ahead
  - Maximum turning diameter of 2×LWL to 3×LWL in 0.7 m (2.3 ft) level ice
  - Ability to break out of its own channel in 1.4 m (4.5 ft) level ice

Design issues to be resolved include the ability to penetrate ice ridges (e.g., the typical ridge size to be transited, backing and ramming ability). We note that Antarctic sea ice tends to be less prone to ridging than Arctic sea ice, so ridge penetration requirements for a vessel primarily operating in the Arctic do not necessarily apply to operations in the Antarctic. Consideration needs to be given to vessel performance in compressive ice and in old ice (noting that the Antarctic tends to have more first-year ice than the Arctic. Antarctic sea ice tends to be covered with thicker snow than Arctic sea ice so the design criteria should consider these differences .

Priorities: Objective and Threshold requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *Icebreaking Capability 4.5ft at 3 knots, which is classified by the International Association of Classification Societies (IACS)as a PC-3 vessel. The vessel should be capable of 50km transects through moderately heavy sea-ice (up to 4.5 ft thick) to include operations in both polar regions year-round, although this classification does not include the central Arctic area. The U.S. requires a research icebreaker that can approach ice sheet grounding zones and penetrate much of the polar sea ice pack during winter. The icebreaking capability includes the ability to transit 4.5 ft of sea ice at a speed of 3 kts (ice class PC3).*

2016OPPRFI: *Capability of independently breaking sea ice with a thickness >3 feet (threshold) / >4.5 feet (objective) at a continuous speed >3 knots, with a minimum transit speed of 11 knots in ice-free waters.*

2018ASCVSR: *>3 feet (threshold) / >4.5 feet (objective) at 3 knots. Polar Code: PC 4 (threshold), PC 3 (objective).*

Discussion:

The NBP is classified as a PC4 or 5 with an endurance of 75 days. It is not feasible in practical terms, to upgrade the NBP to ice class PC3: the reviewed documents describe significant costs and many unknowns in any attempted upgrade of that nature. A modified NBP or a new polar RV with similar or only slightly improved ice class could, however, potentially operate in heavier ice than its capacity by utilizing the services of an escort icebreaker. This might permit considerable savings in construction and operating costs for the science ship because icebreaking capability is a key cost driver. This approach would permit at least occasional science operations in areas and ice conditions otherwise off limits to the ship.

We note, however, that the costs for icebreaker escorts are quite variable and imprecisely known for specific missions. For example, the *Oden*, used as an escort vessel, has an endurance of 100 days (50,000 km in open seas) and an ice-breaking capability of 4.6 ft of level ice at 3 knots.

According to the Swedish Polar Research Secretariat report (*Inquiry into how to best fulfill the state's need for a research vessel with icebreaker capacity intended for scientific expeditions in the polar regions Final report (26 p.), 2016-12-30, Dnr 2016-74*), the daily operating cost of the *Oden* is \$85K - \$200K. The *USCGC Healy* is designed to break 4.9 ft of ice continuously at 3kts or 10 ft thick ice by backing/ramming with an endurance of 60-150 days (depending upon ice). The cost of the *Healy* to NSF is subject to negotiation between the USCG, NSF, and Congress. The rates may range from ~\$25K/day if shared with the USCG or ~\$100K/day if NSF shoulders the full cost of the effort.

Two recently built polar research vessels are the *Kronprins Haakon* and the *Sir David Attenborough*. However, neither vessel meets the endurance and/or berthing capacity of the SMRs outlined here. The construction costs for the *Kronprins Haakon* was $172M in 2015. Although a PC3, it differs from the vessel considered herein in supporting a crew of 15-17 and only 35 scientists as opposed to the threshold requirement of 45 scientists. In addition, the *Kronprins Haakon* has an endurance of 65 days as opposed to an endurance of 70 days (threshold) and 90 days (objective) called for in these SMRs.

The *Sir David Attenborough*, built at a cost of $203M, is PC4 (3 knots in 3.5 ft of ice) with an endurance of, 35,000 nm at 13 knots and 60 days, with a berthing capacity of 28 crew, 60 scientists and support of 1 helicopter.

The Challenges and Science Questions pertaining to Southern Ocean and Antarctic science raised in the SMR document provide clear support for a research vessel with a PC3 classification and with the stated endurance. The science community survey reflects a clear demand to work in heavy ice concentrations and in open water in all seasons in the Southern Ocean/Antarctic seas. In addition to being a more scientifically-capable vessel, the PC3, to the extent that it does not require icebreaker escorts for missions, should provide NSF and the science community greater flexibility in terms of mission scheduling. The community has also expressed concerns that without a PC3 capability, U.S. polar research will be significantly hamstrung in the future as research becomes more focused on regions with heavier ice concentrations. This will require U.S. investigators to seek accommodation on foreign vessels or await the availability of an icebreaker escort. The fear is that the U.S. will not be able to maintain cutting-edge research endeavors in polar waters.

Several issues need to be addressed by a more thorough study that weighs the pros and cons of conducting research with a PC4 vessel using an icebreaking escort vessel as opposed to a single PC3 classified vessel. Such a study would:

1. Determine the operational costs for PC3 versus a PC4 vessels.
2. Determine if a PC4 vessel meeting all the SMRs outlined herein could conduct the same research when operating in conjunction with an ice escort vessel.
3. Project the demand for research in heavy ice conditions capable of being conducted by a PC3 vessel (number of missions/year, duration and type of missions).
4. Once these issues have been resolved assess the cost-benefits of building and operating a PC3 vessel as a stand-alone vessel versus a PC4 operating with an escort icebreaker.

D.2.3.2 Endurance & Range

<u>*Updated SMR*</u>

Endurance of >70 days (threshold) / >90 days (objective) underway and 17,000nm without replenishment. Average annual operational tempo of 250-300 days.

Priorities: Threshold requirements rated as “must have, as is”; Objective requirements rated as “could manage with something less stringent”

Previous Requirement Language

2012PRVSMR: *90-day endurance with full complement. 25,000 nm range (assumes 90 days @ 12 kts)*

2016OPPRFI: *Endurance of >70 days (threshold) / >90 days (objective) underway and 17,000nm without replenishment.*

2018ASCVSR: The document discusses 70-day and 90-day mission profiles (shown below as 70/90 days):

open water @ 12kts - 7/14

icebreaking @ full power - 10/12

in ice leads @ 7 kts - 4/6

on station - 26/35

transit between stations @ 10 kts - 8/8

hotel only - 15/15

Discussion:

An endurance of 90 days would permit a ship to reach presently unexplored polar regions, to carry out very long projects, and to carry out additional cruise legs without resupply (making only personnel transfers). A long range (between refueling) is an essential companion requirement. A downside of such a long endurance is that the ship would need to be larger to accommodate the fuel, supplies, etc. required. Leidos noted in its report that an icebreaker RV would have an endurance of ≥70 days (threshold) / ≥90 days underway and 17,000 nm without replenishment. Leidos further reported that determining fuel efficiency for icebreakers requires further study.

D.2.3.3 Speed

Updated SMR

Minimum transit speed of 11 to 12 knots in ice-free waters.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *12 kt in open water.*

2016OPPRFI: *minimum transit speed of 11 knots in ice-free waters.*

2018ASCVSR: *≥ 11 kts in ice-free waters*; *NSF RFI specifies speed … at 11 knots. However … additional definitions are required to fully define ship's propulsion needs. Understanding tow loads, operations in various sea states, icebreaking, operations in ice concentrations and dynamic positioning all affect sizing of propulsors and thrusters.*

Discussion:

Open water speed is just one factor determining installed power. Hull efficiency and icebreaking capability will most likely have a much bigger impact on the amount of installed power required.

The subcommittee recommends that open water speed be used as a threshold to stay above, but not to use this to restrict or determine installed power or hull design.

D.2.3.4 Sea keeping

<u>Updated SMR</u>

Sea-keeping capabilities should permit work in rough seas of the Polar Regions and sufficient environmental control to allow year-round work in the polar seas. The vessel must also operate in the heavy seas of the open polar ocean as well as within sea ice.

The vessel should be fully operable in SS4 and for most routine operations in SS5. Vessel motions should be minimized through hull design, weight control and the use of passive or active anti-roll devices such that personnel can safely work in the SS6 or greater.

Safety of equipment operation and deployments should also be taken into account.

Suggested targets for maximum motions in SS5 are as follows subject to further study:

Limit maximum vertical accelerations to less than 0.15 g (rms)
Limit maximum lateral accelerations to less than 0.05 g (rms) at lab deck level.
Limit maximum roll to less than 3 degrees (rms)
Limit maximum pitch to less than 2 degrees (rms)

Priorities: Requirements rated as "must have, as is"

<u>Previous Requirement Language</u>

2012PRVSMR: *Must have sea-keeping capabilities that permit work in rough seas of the polar regions and sufficient environmental control to allow year-round* *work in the polar seas*. Also: *The vessel must also operate in the heavy seas of the open polar ocean as well as within sea ice*.

2016OPPRFI: (not specified)

2018ASCVSR: *Ability to operate in difficult sea states*. With note: *"Need more specific[s] here*."

Discussion:

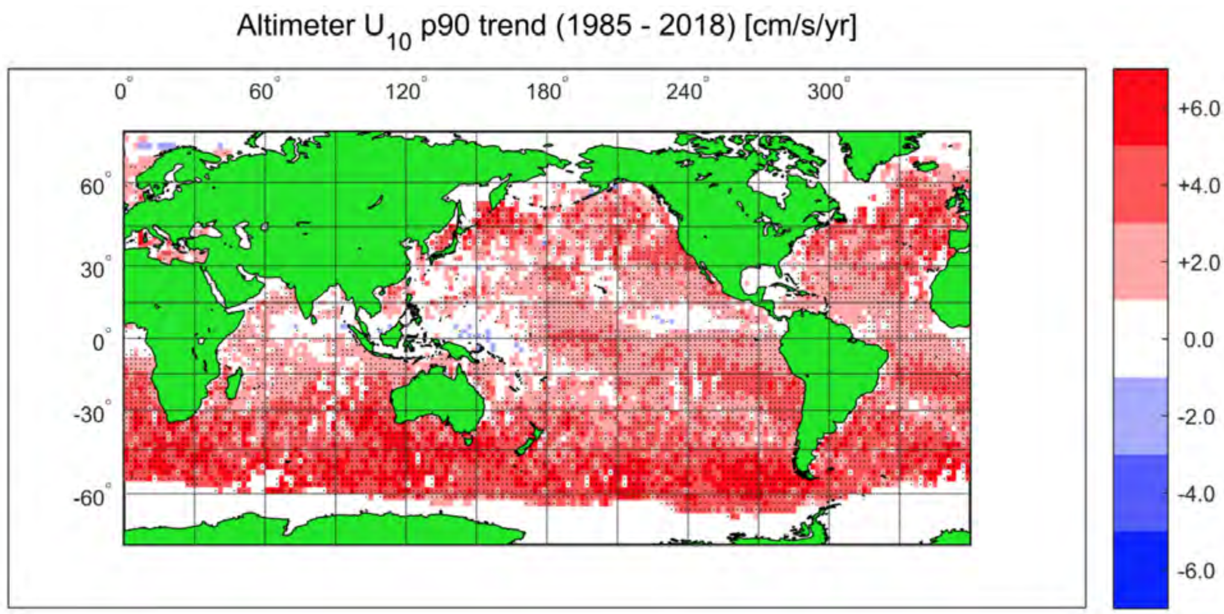
Sea keeping ordinarily refers to the motions and loads on ships moving with forward speed. Here we also include ship motion during research operations (for example while a ship is on station) and its effects on those operations.

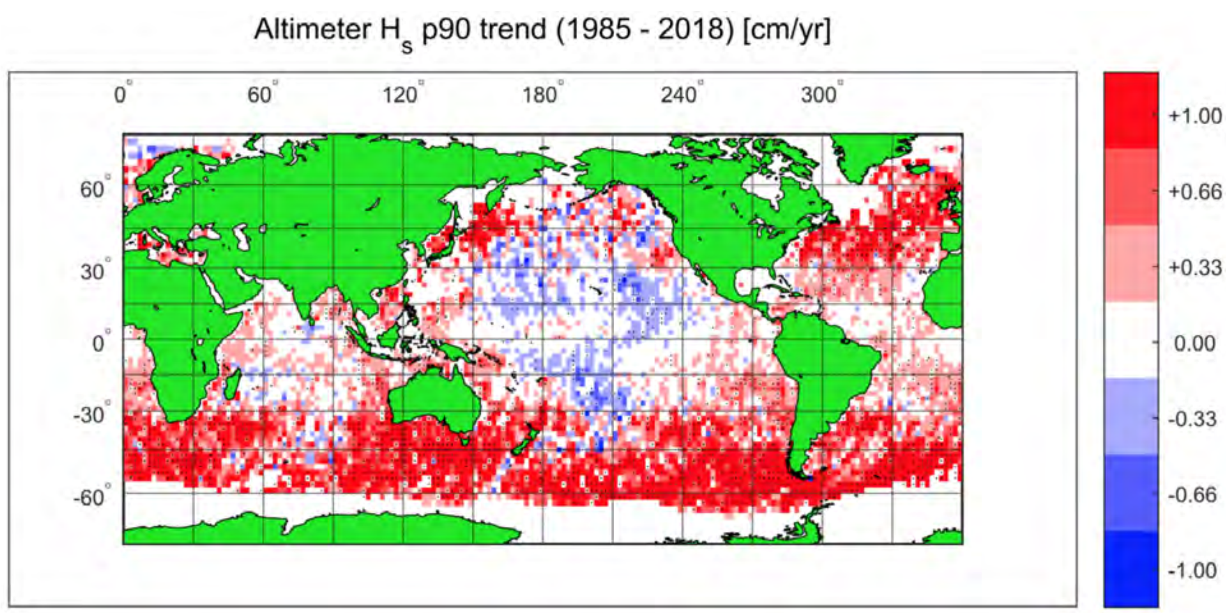
The LMG's sea keeping performance, and overall performance in heavier seas, whether underway or on station, was consistently criticized by survey respondents. For example, a respondent noted that "passenger safety in the staterooms/bunks needs to be improved … people were wedging themselves into their bunks with life jackets to prevent ejection from their bunk while they slept." Other LMG notes include it "is not a pleasant ship to work off", "has very poor performance in heavy seas", and "has issues in regards to maneuverability for over-the-side operations … when the sea is not calm, many over-the-side operations (fish traps retrieval, CTD casts) are not possible on the LMG". An LMG summary was in effect provided by one respondent: "very poor performance in heavy seas …[and] it's sea ice capabilities are virtually non-existent".

The NBP's sea keeping performance was not discussed by most survey respondents. There was more focus on the NBP's dynamic positioning. But additional community comments on this topic were received outside of the survey. These focused on transit speeds frequently slowed by weather and seas (to a greater extent than expected), and on interruptions in on-station operations from the NBP's Baltic Room and work deck when the ship was operating in seas workable from Academic Research Fleet global-class ships. This was viewed as a high priority item for improvement.

Research ship operations in the Southern Ocean and Antarctic waters are frequently affected by adverse weather. Therefore, it is expected during any research cruise in these waters that, compared to operations in temperate regions, more time will be taken up in operational delays and slower ship speeds due to high winds and seas. That said, it is clear to those who have worked in these waters that some ships steam "easier" in heavy seas than do others.

A recent analysis of an extensive database obtained from 31 satellite missions comprising three types of instruments - altimeters, radiometers, and scatterometers - shows small increases in mean wind speed and significant wave height over the 33-year period from 1985 to 2018 period, with larger increases in extreme conditions (90th percentiles) [Young and Ribal, 2019]. The largest increases occurred in the Southern Ocean, as illustrated in the figures below, copied from the cited article.





Figures: (top) The trend in extreme wind speed and (bottom) the trend in extreme wave height, 1985-2018. Copied from Figures 1A and 1B in Young and Ribal (2019). Values that are statistically significant are marked with a black dot.

Effects of these increasing winds and seas - and stronger increases in storminess - in the Southern Ocean are amplified to a degree by the very long transits from ports typical of many NBP cruises.

Another issue is the effect of winds and seas on the ability to work from the ship on station, during towing, or launching packages while underway slowly, which is another aspect of sea-keeping. It can be difficult to set well onto station in the Southern Ocean. Winds are high, the large ships have a significant "sail" area, seas and swells are routinely larger than in most other ocean areas, and wind and swell are often not aligned. As a result, setting the ship on station to minimize vertical motion at a sheave - a requirement for CTD work for example - can be challenging. With a typical set on station, seas may traverse fore-to-aft down the starboard side of a ship and then break into a Baltic Room or onto the aft work deck. This is a common problem but is exacerbated on the NBP by the relatively short distance to water and the placement of the CTD winch operator (and winch) on the deck of the Baltic Room. The operator is not protected from seas (which can enter the Baltic Room in force) and also cannot see the wire where it enters the water. This requires an extra person to constantly watch the CTD wire and, when seas are up, cancels CTD work sooner than would be the case for on-deck CTD work from the Academic Research Fleet global-class research ships.

Specifically, the NBP is clearly not as operationally capable in open waters as are the Academic Research Fleet Global-class *Thomas G. Thompson* (AGOR-23), *Roger Revelle* (AGOR-24), and *Atlantis* (AGOR-25), in terms of both steaming and over-the-side operations. The NBP is well outfitted and does have long endurance, making it a desirable ship choice for open ocean work - USAP and non-USAP cruises - in the remote far south. And partly due to shrinking of the academic research fleet, the NBP is increasingly being used for open ocean cruises in more temperate latitudes. But significant time is lost to weather and seas on those cruises, beyond what would have likely transpired on the same cruise if carried out from one of the UNOLS global-class AGORs. Extra time can sometimes (but not always) be added by the agencies and schedulers to compensate. But each extra "weather" day of NBP time may be adding ≈ $100k in ship and science team costs. Another matter of concern is that there are indications that Southern Ocean winds and seas are increasing in intensity as part of global climate changes. Hence: (1) if the NBP is refit, attention must be paid to ameliorating these crucial aspects of ship performance, and (2) if a new polar RV is designed and built, the aspects of design and performance related to steaming and carrying out science operations in heavy Southern Ocean seas should rise to high priority. With regards to #1, at the very least, problems attending to Baltic Room operations in heavier seas must be addressed, with high priority given to reducing the impact of heavier seas on the NBP's open deck aft of the Baltic Room, where pre- and post-cast activities take place following over-the-side operations not involving the Baltic Room.

The Ocean-class SMRs note: "Maximize ability to work in sea states 5 (2.5 to 4 m wave heights) and higher." Then, in further discussion: "Sea-keeping is the ability to carry out the mission of the vessel while maintaining crew comfort and safety and maintaining equipment operability. It is an important design criterion to maximize the sea-kindliness of these vessels and maximize their ability to work in sea states five (2.5 – 4 m wave heights) and higher within the constraints of their overall size. It is desirable for these vessels to operate 75% of the time in the winter in the Pacific Northwest and in the North Atlantic. Bilge keels, anti-roll tanks or other methods to reduce the motions of these vessels should be used to enhance sea- keeping.

> In sea state four (1.25 – 2.5 m wave heights) the vessel should be fully operational for all but the most demanding deployments and recoveries.

In sea state five these vessels should be able to:
Maintain underway science operations at 9 knots
Maintain on station operations 80% of the time, including:

- CTD operations 90% of the time
- Mooring deployments 75% of the time
- Coring operations 50% of the time
- ROV or other sensitive deployment operations 50% of the time

Limit maximum vertical accelerations to less than 0.15 g (rms)
Limit maximum lateral accelerations to less than 0.05 g (rms) at lab deck level.
Limit maximum roll to less than 3 degrees (rms)
Limit maximum pitch to less than 2 degrees (rms)

At sea state six (4 – 6 m wave heights) these vessels should maintain 7 knots and be capable of station operations 50% of the time.

At sea state seven and greater (> 6 m wave heights), these vessels should be able to operate safely while hove to.

These motion criteria specifications should be verified as adequate and achievable during the earliest concept design phase. Otherwise, other motion criteria that result in ship motions that allow personnel and equipment to work effectively can be utilized during the concept design phase as long as the intent of the above sea keeping specifications is not sacrificed. Tables showing sea state and the practical effects of ship motion are included as appendices V and VI.

Vessel motions should be minimized through hull design, weight control and the use of passive or active anti-roll devices such that personnel can safely work in the SS6 or greater. Safety of equipment operation and deployments should also be taken into account.

D.2.3.5 Station keeping and dynamic positioning

<u>*Updated SMR*</u>

Dynamic Positioning System > ABS DPS-0 (threshold) / ABS DPS-1 (objective).

Dynamic positioning relative to a fixed position in 35-knot wind, sea state 5, and 2 knot current. The maximum excursion allowed should be ± 5 meters (equal to navigation accuracy) from a fixed location for operations such as bore hole re-entry through sea state 4 at best heading and up to ± 20 meters at best heading through sea state 5. DP system design and operation should minimize noise, vibration, and adverse effects on the operation of acoustic systems as much as possible, and these issues should be evaluated early in the design process. The DP system should have outputs for interfacing with science systems.

Performance is more important that ABS certification.

Priorities: Threshold requirements rated as “must have, as is”; Objective requirements rated as “nice but not necessary”

<u>Previous Requirement Language</u>

2012PRVSMR: *Dynamic Positioning capability to meet the requirements of over-the-side sampling is required.*

2016OPPRFI: *Dynamic Positioning System > ABS DPS-0 (threshold) / ABS DPS-1 (objective).*

2018ASCVSR: Mentions use of batteries for power on station to reduce noise during dynamic positioning. Mentions "*Dynamic positioning and precision trackline capabilities*" without further specification. "*ABS DPS-0*" is listed as threshold criteria and "*ABS DPS-2*" is listed as objective criteria for dynamic positioning.

Discussion:

Station keeping and dynamic positioning are vital functions for research ships.

Community survey responses were of mixed opinions on the NBP's station keeping performance, and overall performance in heavier seas and sea ice (whether underway or on station). For example, "the NB Palmer dynamic positioning is fine in average conditions, but not strong enough in heavy sea ice or strong winds." A response looking for improvement noted that "Ability to hold station in more ice (which I guess means more thruster capability) would certainly increase what we are able to do in our current programs." A specific comment regarding desired performance: "Seabed drill rigs, despite being connected to the ship by a flexible umbilical cable, require quite limited vessel movement during drilling. The exact radius limit depends on water depth and the drilling system but may be as little as 10 m or less over a period of up to two days." The NBP is the USAP ship for in-ice (and on-ice) work. Yet, "sea ice operations have been challenging with the NBP - yet this will be a critical demand for research programs going forward. Design a ship that is sea ice capable and that is designed to get science access to sea ice floes". Although a respondent noted "need improved capability to maintain station, particularly during coring and drilling", another noted "the NBP was able to move a couple of meters at a time in any requested direction for our benthic camera operations." However, not all the problems cited by respondents related to the ships themselves, with lack of officer experience and crew training for work in the ice on some cruises a limiting factor.

The Ocean-class SMRs contain this specification: "Dynamic positioning relative to a fixed position in 35 knot wind, sea state 5, and 2 knot current. The maximum excursion allowed should be ± 5 meters (equal to navigation accuracy) from a fixed location for operations such as bore hole re-entry through sea state 4 at best heading and up to ± 20 meters at best heading through sea state 5. DP system design and operation should minimize noise, vibration, and adverse effects on the operation of acoustic systems as much as possible, and these issues should be evaluated early in the design process. The DP system should have outputs for interfacing with science systems."

A comment serving as a general summary was provided by one respondent: "precise dynamic positioning is needed".

D.2.3.6 Track line following

Updated SMR

The vessel should maintain a track line while conducting underway surveys for spatial sampling and geophysical surveys within ± 5 meters of intended track and with a heading deviation (crab angle) of less than 45 degrees with 30 knots of wind, up to sea state 5 (2.5 – 4 m wave heights) and 2 knots "beam" current. This target may be required for ship speeds as low as 2 knots. Straight track segments shall be maintained without large and/or frequent heading changes.

Priorities: Requirements rated as "could manage with something less stringent"

Previous Requirement Language

2012PRVSMR:	(not specified)
2016OPPRFI:	(not specified)
2018ASCVSR:	Mentions only that the polar RV should have *precision trackline capabilities*.

Discussion:

Regarding the related issue of track line following, the Ocean-class SMRs note:

> The vessel should maintain a track line while conducting underway surveys for spatial sampling and geophysical surveys within ± 5 meters of intended track and with a heading deviation (crab angle) of less than 45 degrees with 30 knots of wind, up to sea state 5 (2.5 – 4 m wave heights) and 2 knots "beam" current. This target may be required for ship speeds as low as 2 knots. Straight track segments shall be maintained without large and/or frequent heading changes.

The subcommittee noted as a general comment that the Ocean-class track line following SMR could be adopted for the polar RV SMR, with possible allowance for the larger ship size and the Southern Ocean operating area.

D.2.3.7 Ship and winch control

Updated SMR

Ship control and control of major deck machinery should be designed and specified with an integrated approach that maximizes visibility, communications, safety and efficiency of operations during over-the-side deployments, cargo operations, small boat operations and recovery of instrumentation from the sea and air. Control of major deck machinery includes winches, frames, cranes, Launch and Recovery Systems (LARS), drilling systems, seismic systems, moon pool systems, helicopter operations and other similar systems. Good visibility requires clear sightlines to aft working deck and starboard side working deck deployment areas from the ship control and winch control stations to the greatest extent possible. This can be augmented if needed with video cameras, especially to areas blocked from view such as the moon pool. If a separate aft control station is necessary to accomplish the visibility requirements careful consideration should be given to the amount of ship control to include in addition to winch and handling system control. Communications and video monitoring requirements are critical in the design of an aft control station.

Priorities: Requirements rated as "must have, as is"

<u>Previous Requirement Language</u>

2012PRVSMR:	*Vessel shall have an aft conning and aft winch control station to facilitate over-the-operations and vessel maneuvering.*
2016OPPRFI:	(not specified)
2018ASCVSR:	*Aft control station ... contain[s] controls for winches, a-frames, dynamic positioning joystick, audio/video network connections. Clear sightlines to aft working deck and starboard side working deck.*

Discussion:

There is not a lot of discussion in previous documents about this other than the SMR requirement. That approach is too narrow and does not address the real requirements. Visibility from control stations is a continual problem, especially with larger vessels with lots of equipment on the upper decks aft of the pilot house.

An SMR should specify requirements for an integrated design of operational control of the vessel and major deck machinery that maximizes visibility, communications, safety and efficiency of operations during over-the-side deployments, cargo operations, small boat operations and recovery of instrumentation from the sea and air. The Vessel Studies Report does this with regards to an Aft Control Station.

D.2.3.8 Underwater radiated noise

<u>Updated SMR</u>

Significant efforts should be directed towards making the ship as acoustically quiet as practical without negatively impacting icebreaking capabilities. Significant and detailed technical compromises are necessary to achieve a reasonable balance between the performance of ships' acoustic systems and the power and strength necessary to be an efficient icebreaker.

Special consideration should be given to machinery noise isolation, including heating and ventilation. Propeller(s) are to be designed for minimal cavitation, and hull form should attempt to minimize bubble sweep down. Airborne noise levels during normal operations at sustained speed or during over-the-side operations using dynamic positioning shall conform to standards in USCG NVIC No. 12--82 and IMO Resolution A.468(XII), “Code On Noise Levels On Board Ships." Sonar self-noise should meet or exceed manufacturer's requirements. The use of a drop keel or retractable centerboard could be considered to improve acoustic system performance.

Underwater radiated noise and airborne noise specifications should be developed using an experienced shipboard noise consultant. Underwater radiated noise criteria that are less stringent than ICES 2009, such as those used for the Ocean Class AGORs or the RV *Sikuliaq*, should be considered as a target.

Priorities: Requirements rated as “could manage with something less stringent”

Previous Requirement Language

2012PRVSMR: *Significant efforts should be directed towards making the ship as acoustically quiet as practical. Significant and detailed technical compromises are necessary to achieve a reasonable balance between the performance of ships’ acoustic systems and the power and strength necessary to be an efficient icebreaker.*

Special consideration should be given to machinery noise isolation, including heating and ventilation. Propeller(s) are to be designed for minimal cavitation, and hull form should attempt to minimize bubble sweep down. Airborne noise levels during normal operations at sustained speed or during over-the-side operations using dynamic positioning shall conform to standards in USCG NVIC No. 12---82 and IMO Resolution A.468(XII), "Code On Noise Levels On Board Ships". Sonar self noise should meet or exceed manufacturer's requirements.

Underwater radiated noise and airborne noise specifications should be developed using an experienced shipboard noise consultant.

Further, the SMR views an *“acoustically quiet ship with minimal underwater radiated noise”* as an *“additional cost dependent on exact specifications”*.

2016OPPRFI: *Low underwater radiated noise at vessel speeds <8 knots (not required, objective only). Targeting ICES 209 standards at <8 knots versus 12 knots.*

2018ASCVSR: (not specified)

Discussion:

According to the Glosten report (Appendix B of the Leidos report)

> For underwater radiated noise (URN) requirements, there is a direct correlation between the stringency of the requirements and the initial capital cost. This holds for life-cycle cost as well, as the isolation systems' maintenance requirements increase. We recommended that URN requirements be based on the true scientific need for the vessel missions. Attempting to meet ICES 209 at 8 knots or DNV-GL Silent(R) requirements will add significant cost to the vessel.

Regarding this issue, the Leidos report states the following:

> Leidos concurs with Appendix B and does not recommend specifying ICES 209 or DNV Silent(R) requirements. Although the USAP vessels do conduct some level of fisheries research, it is understood that criteria imposed by ICES 209 is designed to ensure accurate measurements of fish population vice examination of fish species. Costs to meet ICES 209 type criteria seems to far outweigh the needs of the types of science done under USAP. This recommendation appears to be in keeping with the acoustic requirements defined in the PVR SMR refresh report as well.

The NSF OPP RFI specified that the ICES 209 must be met under 8 knots, but this requirement seems to have been developed for fisheries acoustic research, which is not typically done in Antarctica. Acoustic surveys are, however, conducted on Antarctic krill. A study on the URN produced by the RRS *James Clark Ross* did not result in ship avoidance by Antarctic krill (Brierley et al., 2003, Fisheries Research 60: 569-576). The Glosten report (Appendix B of Leidos report) provides some recommendations on URN.

Regarding radiated noise one might examine the radiated noise aspects (abatement, goals, etc.) for the NSF/UNOLS RCRV program, which may be aiming for lower radiated noise than the ICES standards. See http://blogs.oregonstate.edu/rcrv/2017/10/20/sound-silence-cutting-noise/ for more information.] One of the main causes of URN is the propulsion system. It seems that the quietest propulsion systems, although the cheapest, have reduced maneuvering capability in ice. Also, low-noise propellers are not efficient and could reduce vessel endurance. Since endurance and sea-keeping capabilities are listed as fundamental and major requirements in the PRV SMR, respectively, URN requirements that negatively affect either should be carefully considered.

In conclusion, the specifications in the Leidos report are appropriate.

D.2.3.9 Helicopter support

Updated SMR

Ship operations in remote areas of both polar regions necessitate helicopter capability to support transfer of personnel, vessel logistics, ice reconnaissance, expanded scientific reach with the vessel as a mobile science base, and emergency medical evacuations. The ship shall be capable of landing and supporting two helicopters that each are able to make 150 nm round trip with 3 passengers and 1200 lbs. of cargo (for example, Bell 214, Sikorsky S-70, or landing a (USCG) HH60). The flight deck shall be structurally capable of landing a larger single rotor helicopter.

The hangar shall be sized to house the two smaller helicopters with the rotors folded and the necessary storage/shop capability. On board aviation fuel capacity shall be adequate to support two helicopters for up to the endurance of the ship, based on flying one helicopter for four hours for 1/3 of the underway days. Accommodations for the helicopter crew and technicians would come out of the science berths.

The following describes a range of aviation capabilities that should be considered:

- Helicopter-deck for landing of helicopters for cargo and personnel transfers or Unmanned Aerial Vehicles (UAV) in support of ice navigation or scientific operations including the capability of housing or servicing of the helicopters or UAVs
- Helicopter-deck able to support the landing/takeoff and re-fueling by helicopters of a maximum takeoff weight of 13 tons. This is for Search and Rescue (SAR) or transfer operations by a larger helicopter, not the ship based aircraft
- Helicopter-deck and hanger suitable for the operation of two mid-size aircraft of up to 5 tons maximum weight each and based on board the vessel.
- Jet A1 (aviation) fuel in permanent or portable storage tanks.
- Helicopter re-fueling equipment capable of operation in the Polar environment.
- De-fueling capability of the aircraft whilst aboard.
- Access to Helicopter-deck to allow safe transfer of cargo from slung loads for VERTREP (vertical replenishment) operations with an assumed weight of 1500kg operations
- Suitable deck tie points for up to two aircraft.
- The Helicopter-deck is to comply with all international requirements such as CAP 437 and ICS guide to helicopter/ship operations.

Priorities: Requirements rated as "could manage with something less stringent"

<u>Previous Requirement Language</u>

2012PRVSMR: *Ship operations in remote areas of both polar regions necessitates helicopter capability to support transfer of personnel, vessel logistics, ice reconnaissance, expanded scientific reach with the vessel as a mobile science base, and emergency medical evacuations. The ship shall be capable of landing and supporting two helicopters and to be able to make 150 nm round trip with 3 passengers and 1200 lbs. of cargo (e.g. Bell 214, Sikorsky S-70, or landing a (USCG) HH60). The flight deck shall be structurally capable of landing a larger single rotor helicopter.*

The hangar shall be sized to house the two smaller helicopters with the rotors folded and the necessary storage/shop capability. On board aviation fuel capacity shall be adequate to support two helicopters for up to the endurance of the ship, based on flying one helicopter for four hours for 1/3 of the underway days. Accommodations for the helicopter crew and technicians would come out of the science berths.

2016OPPRFI: *Helicopter deck and hangar capable of supporting two light helicopters or one medium helicopter.*

2018ASCVSR: *Per the PRV SMR refresh report, a single medium-lift helicopter such as a Bell 412, Sikorsky S-70 or USCG HH60 should be considered.*

Discussion:

Although only 20% of respondents had specific comments regarding helicopter support, most indicated a critical need for air support, and suggested that the costly nature of operations makes it difficult to get funding for projects that require helicopter support. One respondent noted that "if helicopter support was available from both ships it would allow for a greater scope of work and capabilities of collecting information and surveying that is not currently available. This would be greatly appreciated for long-term planning." Respondents noted that helicopters "are a potentially irreplaceable means of access to ice-free areas in remote coastal locations that are not otherwise accessible," "may provide the only possible access for many interesting research sites" including coastal locations where access by ship is limited by sea ice, and are critical for glacier-ocean studies. Finally, it was noted that helicopter support can facilitate navigation as well as science.

Several recommendations for helicopter operations were made. In general, respondents suggested that helicopter support needs to be simplified; this might be easier if helicopters are used more routinely. Current helicopter size was deemed too small, and operations had "limited ability to operate in anything but perfect, cloud-free, weather conditions. Greater ability to work in partial cloud cover would allow more flight days." Several respondents noted the impact that helicopter support had on space – "Without hanger and extra berthing, helos are mostly a non-starter," and "ice work often requires extra vans to be placed on the NBP and this often constrains the use of helos."

The following is an example of helicopter support considerations for Antarctic operations:
Heli deck

- A Range of aviation facilities are required
- VERTREP (vertical replenishment – slung cargo) with an assumed weight of 1500kg
- Heli-deck, landing of a helicopters and or UHVs for cargo and or personnel transfers. Or UHV operations in support of ice navigation or scientific operations
- Heli-deck and Hanger for the landing, housing or servicing of helicopters and or UHVs
- Heli-deck able to support for the use of landing/take-off and refueling by helicopters of a maximum take-off weight of 13t. This is for SAR operations only not ship based aircraft
- Heli-deck and hanger suitable for the operation of two mid-size aircraft of up to 5t maximum weight each and based on board the vessel
- Jet A1 (aviation) fuel portable storage tanks
- Helicopter refueling equipment capable of operation in the Polar environment
- De-fueling capability of the aircraft whilst aboard
- Access to Heli-deck to allow safe transfer of cargo from slung loads for VERTREP operations

- Suitable deck tie points for up to two aircraft
- The heli deck is to comply with all international requirements CAP 437 and ICS guide to helicopter/ship operations

Helicopter hanger

- A helicopter hanger to accommodate two aircraft shall be provided either adjacent to or below (accessed via a lift) to the helideck. The dimension of the hanger are to allow access for maintenance of the aircraft when both are in the hanger. The aircraft type will be of commercial specification and not have folding tail sections.
- Hanger dimensions should be at least 13.6m L 9.5m W and 5.25m height to accommodate two midsize aircraft Dauphin, Astar or similar aircraft.
- The hanger shall have adequate lighting and climate control so as to allow routine maintenance to be undertaken.
- The hanger shall be such that it is multipurpose in design, this shall allow portable laboratories/cargo /science equipment storage. Means to transfer and secure portable laboratories and cargo in the helicopter hanger will require special consideration.
- An overhead multi-purpose gantry crane is required for overhaul purposes.
- The hanger shall be capable of accommodating up to four standard 20ft ISO portable containerized laboratories/scientific stores. The hanger area is to be equipped with plug and play connections for services.

The Hanger shall be outfitted to include the following as standard fit

- Permanent securing point in the deck for aircraft
- Permanent securing point in the deck for containerized laboratories
- Permanent securing points for cargo/scientific equipment
- Services to support helicopter servicing/maintenance. Power/compressed air/gas bottle rack
- Services to support laboratories
- Helicopter parts storage
- Helicopter maintenance workshop (Clean)
- Hanger door(s) or hatch suitable for the adverse environment and helicopter down draft
- Portable science laboratory transfer system (maximum weight 8t)
- Able to maintain climate in working space.

D.2.3.10 Off Vessel Support for Field Work and Logistics

Updated SMR

The vessel must be capable of support for field work off vessel on the ice, in boats, on islands and other land based field camps and stations. It must also be capable of supporting transport of personnel, supplies and equipment to stations and field camps. Requirements that support these activities are contained in SMR elements for Cranes (including accommodation ladder for rapid deployment to and from the ice), Vans, Storage, Work Boats, Helicopters and inherent in many others such as endurance, icebreaking, dynamic positioning, sea-keeping, etc.

In developing the operational profile and design specifications the support for these activities off the ship should be carefully considered.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

This is a new SMR element.

D.2.4 Over-the-side and weight handling

D.2.4.1 Over the side handling

Updated SMR

An integrated approach to design and specification of weight handling and over-the-side equipment based on required science performance requirements is required. Take into account current advances in technology and tension member (wire/cable) developments including the use of synthetic cables. Plan for the use of temporarily installed systems for some requirements such as large ROV systems, longer length coring, drilling, etc. Design should support flexibility and safe/efficient operation. Create arrangements that will protect winches from the weather, allow for use to multiple locations such as over the stern and the side or to the moon pool. Consider innovative designs for deployment of systems in ice and very cold conditions. For example, some recent research icebreaker designs include a "side pool" system that creates a protected ice-free area alongside the ship's starboard side CTD launching area. The use of an over-the-side handling system single source vendor or system integrator should be considered.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR:	*(Not directly addressed in the PRV SMR document)*
2016OPPRFI:	*Ability to have stern facing deep sea research winch ... with stern deployment system (A-Frame); ability to have "clean working side" facing deep sea winching and deployment system capable ...*
2018ASCVSR:	*A stern frame capable of supporting towing, piston coring, ROV/AUV operations and other activities will be required ... [question whether] an 80 ft jumbo piston core [capability is needed]. Piston coring must also take the route to indoor coolers into account as these long segments can*

be impossible to move around tight corners and narrow passageways… frames lowered onto the deck …for rigging and maintenance.

An A-Frame or other device to starboard is needed for both cargo and science missions. ... desire to tow from the starboard side, away from the propeller stream …could possibly be accomplished by the ship's crane or the starboard A-frame.

... staging bay / hangar located on the same working deck as the stern frame for AUV deployments.

Vessel must be capable of loading and unloading all cargo using its own handling equipment, including UNOLS Vans

Discussion:

All recent research vessel design and construction efforts have called for an integrated approach for the over-the-side and weight handling equipment. Often, construction contracts call for a system integrator for the winch, frame, crane systems. This approach, implemented early in the design and then in the construction process results in systems that are designed to be controlled and function well together, address operational concerns for safety and flexibility as well as maintainability.

Additionally, these systems are designed and specified based on the intended science functions the vessel is expected to support. For example, GO-SHIP CTD casts to full ocean depth up to sea state 5 or 30 m Jumbo Piston Cores in ice or in up to sea state five from the starboard side as close to the pivot point as possible. For cranes, the ability to load and unload 20 ft containers weighing up to 20,000 lbs while at the dock and the ability to deploy equipment weighing up to 10,000 lbs at sea at least 12 feet beyond the side of the ship in sea state 4. These are just examples of describing performance as opposed to specifying a specific wire/winch/crane.

D.2.4.2 Winches & Wire

<u>Updated SMR</u>

These vessels should be designed to operate with a new generation of oceanographic winch systems that are an integral part of the equipment handling and deployment system. The winches should provide fine control (0.1 m/min under full load); maximum winch speeds should be at least 100 meters/min; and constant tensioning and other parameters, such as speed of wire, should be easily programmable while at the same time responsive manual control must be retained and immediately available at any time. Manual intervention of winch control should be available instantly for emergency stop and override of automatic controls. Wire monitoring systems with inputs to laboratory panels and shipboard recording systems should be included. Wire monitoring systems should be integrated with wire maintenance, management, and safe working load programs. Local and remote winch controls should be available. Remote control stations should be co-located with ship control stations and should be located for optimum operator visibility with reliable communications to laboratories and ship control stations. Winch control and power system design should be integrated with other components of over-the-side handling systems to maximize safety and protection of equipment in heavy weather operation and to maximize service life of installed wires. Adequate provisions for connecting slip rings and ship's power and data network to the E-M and F-O cables should be included in the design. Electric drives and motors should be used whenever possible.

Two hydrographic-type winches capable of handling up to 10,000 meters of wire rope, electromechanical or fiber-optic cables having diameters from 1/4" to 1/2" should normally be installed. Winches should be readily adaptable to new wire designs with sizes within a range appropriate to the overall size of the winch. At least one winch should be capable of supporting both over the side and moon pool operations.

A heavy winch complex capable of handling 12,000 meters of 9/16" wire/synthetic wire rope and/or 10,000 meters of 0.68" electromechanical cable (up to 10 KVA power transmission) or 0.681 fiber optics cable should be permanently installed. This complex is envisioned as one or two winches with the possibility of multiple storage drums that could be interchanged in port. Alternately this could be a traction winch with two or more storage drums that can be used interchangeably. Winches should be adaptable to new wire/cable designs including synthetics within a range appropriate to the overall size of the winch. At least one winch should be capable of supporting operations over the stern and starboard side and one should also be capable of supporting operations through the moon-pool.

Winches handling fiber-optic cable should normally be traction winches that allow storage of the cable under lower tension unless new technologies in wire construction allow otherwise. This includes winches for both 0.681" and smaller cables.

Additional special-purpose winches (e.g., clean sampling, pumping, multi-conductor) may be installed temporarily at various locations along working decks. Winch sizes and power requirements should be considered during the design phase in order to establish reasonable limits based on the vessel size.

Permanently installed winches should be out of the weather where feasible to reduce maintenance and increase service life. The trawl/tow winch should be below the main deck, but smaller winches may be located in semi-protected areas of upper decks to allow for better fairlead.

Wire fairleads, sheave size, and wire train details need to be integrated with the general arrangement as early in the design process as possible in order to increase the possibility of limiting wire bends and overly complicated wire train. Sheave sizes, number, and locations should be designed to maximize wire life and safe working load. Requirements in 46 CFR 189.35 - "Weight Handling Gear" and in the UNOLS Research Vessel Safety Standards should be adhered to. It should be possible to fairlead wires from permanent winches over the side or over the stern.

Details of winch location should include provisions for easily changing wire drums, spooling on new cable, and changing from one storage drum to another, and for major overhaul of winches so that these operations can take place with minimum time and effort in port. Some operations, such as re-reeving wires through fairlead blocks or switching the wire being used through a frame or with a traction winch, should be factored into designs so that the operations can be performed at sea safely and efficiently.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *Hydrographic winches, (2) capable of 10,000m of 0.322 E-M and/or 3/8" wire rope. Trawling/coring winch, (1) capable of handling 10,000m of 9/16" wire rope and 1 deep-tow winch capable of handling 10,000m of 0.681 F-O cable.*

2016OPPRFI: *…winch able to handle 9/16" mechanical and /or .680" electromechanical cable… [winch] capable of .322" electromechanical cable.*

2018ASCVSR: *Winch function can be multiplied by the use of double drum winches, replaceable drums, rotating pedestals and change in line direction.*

Dedicated CTD Winch – 10,000 m of 0.322 electro-mechanical cable. Electric drive with active heave compensation. Located in Baltic Room.

10,0000 m of 9/16" mechanical wire to stern. Electric drive with auto rendering. Located inside the ship.

10,000 m of 0.680" coaxial electro- mechanical cable to stern. Electric drive with auto rendering. Located inside the ship.

10,000 m of 5/16" wire to starboard. Electric driven. Prefer located inside ship.

10,000 m of 0.322" electro-mechanical cable to starboard. Electric drive. Prefer located inside ship.

Discussion:

Leidos has reviewed the requirement for a two-drum traction winch with 9/16" cable on one drum and 0.680" electromechanical cable on the other. The NBP does not have a traction winch and operators have not had any operational difficulties. Leidos interviewed both Rapp Hydema and Markey Machinery during this effort and neither company feels a traction winch is required for research vessel applications unless a fiber application is to be considered. Leidos believes the cost and space impact of adding a traction system to the stern facing winch on an IBRV is not commensurate to the value, unless NSF expects to someday use 0.681" electromagnetic cable for ROV operations. This could be an important cost savings measure but must be weighed against expected future operations.

Leidos is also aware of the desire to use synthetic rope in lieu of wire rope in some applications. NSF input on wire selection is requested.

There is a bit of a disconnect between the PRV SMR document and the Leidos Vessel Studies Report and even a disconnect between the Leidos recommendations and the Glosten recommendations in Appendix B of the Vessel Studies report. The issue is related to whether or not the vessels (IBRV) should carry 0.681 Fiber Optic Cable as one of the installed cables. Generally, with the F/O cables such as the 0.681 need to be deployed with a traction winch so that they are not stored under tension. The PRV SMR states that one of the cables needed is 0.681 FO for the deep tow winch. The Glosten recommendation for a traction winch is based on this and the other advantages a traction winch with two or more storage drums provides in terms of flexibility. Leidos on the other hand indicates a traction winch in not required for the 9/16" wire rope and EM cable and that single drum direct pull winches would save money, weight and space UNLESS NSF determines that 0.681 FO cable will be needed in the future. The NSF RFI calls out 0.680" EM cable (not FO) that could be supported by a direct pull winch. [*Ability to have stern facing deep sea research winch able to handle 9/16"mechanical and /or .680" electromechanical cable with stern deployment system*.] However, since the SMR's specifically call out the FO cable and it has become more of a standard on larger Academic Research Fleet vessels, it seems that a traction winch might be more appropriate.

The SMR calls out 9/16" wire rope as the other deep tow winch wire for coring, dredging, trawls, etc. The SMR's call out the requirement for 50 m piston cores. If these are the same diameter as the 20 m and 30 m piston coring systems used on Academic Research Fleet vessels, then 9/16" wire rope may not be sufficient. The pull out loads for even 20 m cores often stretch the limits of safe working load for this cable. If the winch systems on these vessels are going to be expected to support 50 m or even 40 m coring operations, dredging and larger net tows, then a stronger wire rope or the use of synthetic cables needs to be made a requirement. In general, if a traction winch is specified, it should be capable of being adapted to different diameters of wire rope, EM cable and synthetic ropes within some reasonable range.

There should probably be a dedicated CTD winch paired with a CTD launch and recovery system that is hands free and probably semi-automated for systems such as those used for the GO-SHIPS programs. The winches should be electric drive with motion compensation and have render/recover capabilities. The CTD LARS should facilitate landing or moving the CTD to and from a weather protected, temperature-controlled space. Ideally, a second hydro winch is available as a back-up to the dedicated CTD winch and for other operations requiring a small diameter EM cable.

The ability to support portable winches including trace metal clean winch systems should be included in the design.

Recommendations for specifications derived from the SMR's:

- Determine and articulate safe working load, conductivity, data requirements for wires and cables. This will lead to winch type, size and power.
- Determine and articulate special requirements for winch control, operating conditions, automation and location of operations on the ship (starboard side, Baltic room, moon pool, stern, etc.) This will lead to design of things like winch support for moon pool, CTD handling systems that are hands-free, motion compensated and automated.
- Determine and articulate the extent redundancy and multiple operations are needed, which will lead to the number and type of winches.
- Specify an integrated approach to the design, procurement, installation, and system control for the winches, cranes and over-the-side handling devices including those in the moon pool or those that would be installed on a temporary basis.

D.2.4.3 Cranes, Frames and Handling Devices

Updated SMR

Onboard cranes capable of reaching all areas of the working deck including the flight deck to move cargo, science equipment, and capable of moving loaded 20-foot intermodal containers on and off the vessel. A suite of modern cranes should be provided to handle the required cargo loads, scientific equipment deployments in the cold weather conditions of the intended operating area and should be integrated with the entire over-the-side handling system. The main heavy lift cranes should be considered at a minimum, that of the NBP the Main, FWD 20,000 lbs @ 40ft and Main, AFT 50,000 lbs. @ 60ft. The highest rated crane needs to have the capacity and reach to service a Geotechnical drilling rig. One or two cranes that provide the capability to reach all working deck areas and that are capable of offloading vans and equipment weighing up to 20,000 lbs. to a pier or vehicle in port is desirable. This will generally mean being able to reach approximately 20 feet beyond one side of the ship (usually starboard) with the design weight. At least one crane should be able to deploy buoys and other heavy equipment weighing up to 10,000 lbs. up to 12 feet over the starboard side at sea in sea state 4 or 5 if possible. At least one crane should be articulating in order to keep the load close to the crane head.

One or two smaller cranes, articulated for work with weights up to 4,000 lbs. at deck level and at the sea surface, with installation locations forward, amidships, and aft should be provided. They would also be usable with relocatable crutches as an over- the-side, cable fairlead for vertical work and light towing. If the design includes the need to store and launch boats or to deploy equipment from the foredeck, then design for cranes or weight handling should accommodate those needs. Cranes may need to have servo controls, motion compensation or damping as part of the integrated over the side handling systems. The ship should be capable of installing and carrying portable cranes for specialized purposes.

At a minimum one crane should have a man riding certified whip. This will allow for placement of personnel via man basket over the side of the vessel, onto the sea ice, small craft or ice shelf. Additionally, a readily deployable gangway or accommodation ladder should be provided for efficient deployment to and from the ice or shore.

A Stern A-Frame and handling devices on the Starboard and possibly Port side should be included to properly handle intended instrument deployments with wires and cables fairlead from installed and temporary winches. Design specifications and safe working loads should be based on the breaking strength of the intended wires and cables in accordance with 46 CFR 189.35 and the UNOLS Research Vessel Safety Standards.

Stern A-Frame dimensions and range of motion should accommodate intended instrument and equipment deployments. The size and safe working load should be greater than or equal to that on *Palmer* or the Global Class AGOR 23 Class vessels. As a minimum the stern frame should be designed for a dynamic safe working load of 30,000 lbs. through its full range of motion, and it must be structurally engineered to handle 1.5 times the breaking strength of cables up to one inch, such as the tether for large ROV systems (up to 120,000 lbs. breaking strength). The stern frame should have a 15-ft minimum horizontal and 25-ft vertical clearance from the attachment point for the block to the deck. At least a 12-ft inboard and outboard reach is required. Consideration should be given to an A-Frame design that incorporates a forward maintenance position to facilitate changing blocks and wire leads as well as an outboard position parallel to the sea surface or near to it for deployments in ice similar to the A-Frame on *Sikuliaq*.

A launch and recover system coupled to one or both of the hydro-winches to function as a CTD Handling System over the starboard side near mid-ship or from a Baltic room or the moon pool should be designed to allow safe and efficient hands free deployment of a large GO-SHIP CTD system in ice or in open waters of sea state five or greater.

Additional Starboard side handling devices and moon pool devices should be designed for safe and efficient deployment of nets, towed devices, coring devices, small ROVs, etc. At least one Starboard side device should be capable of supporting wires or cables fairlead from the heavy winch complex.

Cranes or handling systems for rescue boats and work boats should meet regulatory requirements and be designed and located for efficient, rapid and safe deployment of the boats in sea state four or greater. The ability to load cargo, equipment and personnel safely should be included in the arrangements for boat handling systems.

Priorities: Requirements rated as "must have, as is"

<u>Previous Requirement Language</u>

2012PRVSMR: *Cranes capable of reaching all areas of the working deck including the flight deck to move cargo, science equipment, including vans.*

2016OPPRFI: *On board cranes capable of moving loaded 20-foot intermodal containers on off vessel.*

2018ASCVSR: *Articulating cranes are much more conducive to research vessel operations that require lifting work at sea and also in consideration to the high wind environment experienced in most port calls in the region. Cranes must be designed to meet the low temperature requirements of the* *region and should be rated to lift personnel as well cargo. Crane location is important to be able to reach all working areas of the decks and necessary reach over the side to the pier or sea. However, location typically competes with lines of visibility desired from the pilot house and aft control station. Additional details describing the lift capacity and operable sea state need to be determined. Cranes will also be specified as personnel rated, which requires additional safety design considerations.*

Discussion:

The Leidos report has a little more about the functionality of the cranes including the need to use articulated cranes in order to have better control over the location of the load, especially when moving it at sea. They also address the need for cold weather operation and indicate the need to specify lift capacity and reach and what the operable sea-state would be. Also important is crane locations and that they may need to be rated for lifting personnel.

The Glosten Addendum to the Leidos report further specifies the need to load and off-load 20-ft containers but does not specify a weight limit. They also address the need to support towing over the side without a crutch for the hydro wires. They recommend sea state 5 for the at sea crane ratings.

A-Frames, Side Frames, etc. are not really spelled out in the SMR's, but are addressed by Leidos in the vessel studies report. Mostly this is about accommodating functions such as coring and for towing on the starboard side. Nothing about capacity, sea state and type of operational control is described. They do mention the benefit of a maintenance position such as on the newer Academic Research Fleet vessels. Leidos also mentions integrating winches, cranes and handling systems under the vessel procurement section.

There needs to be at least one man-riding certified crane in order to meet legal requirements. This will allow people to be lifted on the sea ice in a man basket or lift a small boat into the water with an operator aboard. Also, if this ship is to support logistics requirements and potentially move equipment to an ice shelf, then the current maximum capacity should be at 50 tons. The NBP main 10 ton crane was inadequate to support the SHALDRILL project. The NBP needed to have the current 50 ton crane added.

Recommendations for design specifications:

- Specify requirement for the crane to be man-rated.
- Specify design weight of containers and desired reach over the side (at sea and in port).
- Specify recommendations regarding location, type and number of cranes needed.
- Specify sea-state for at sea operations.
- Specify requirements for towing, side load and other over the side operations that might use the cranes.
- Specify size, operating loads, configurations for other over-the-side handling devices such as frames, booms and moon-pool devices. Include requirements for sea-state, side loads, maintenance positions, and removability.

- Include requirements for workboat and rescue boat launch and recovery in handling system specifications.

D.2.4.4 Towing/Trawls/ice-clearing stern

Updated SMR

The ship should be capable of towing large scientific packages up to 10,000 lbs. tension at 6 knots, and 25,000 lbs. at 4 knots. Winch control should allow for fine control (± 0.1 meters/min) at full load and all speeds. Winches should be capable of sustaining towing operations continuously for days at a time. Towing operations include mid- to low-load operations with mid-water equipment such as towed undulating profilers, single and multiple net systems, and biological mapping systems. Other systems may involve larger loads and spike loads such as deep towed mapping systems, bottom trawls, benthic grabs, camera sleds, and dredges.

The vessel should be capable of towing multi-channel seismic streamers and air guns. Icebreaking design should consider the capability of creating sufficient ice-free area astern to allow the towing of nets and other equipment astern while icebreaking.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *Ability to tow nets and instruments from the stern during ice-breaking.*

2016OPPRFI: *Ability to tow a multi-channel seismic streamer ...*

2018ASCVSR: *Ability to tow nets and other science gear during ice breaking.*

2009OCSMR: *Science Mission Requirements – Ocean Class Research Vessel*

The ship should be capable of towing large scientific packages up to 10,000 lbs tension at 6 knots, and 25,000 lbs at 4 knots. Winch control should allow for fine control (± 0.1 meters/min) at full load and all speeds. Winches should be capable of sustaining towing operations continuously for days at a time. Towing operations include mid- to low-load operations with mid-water equipment such as towed undulating profilers, single and multiple net systems, and biological mapping systems. Other systems may involve larger loads and spike loads such as deep towed mapping systems, bottom trawls, camera sleds, and dredges.

Discussion:

The primary concern is maintaining waters at the stern that are sufficiently ice-free such that gear (nets, trawls, seismic guns and streamers, underway CTD) can be towed safely. While this can be accomplished under heavier ice conditions via a two ship operation, with the lead ship clearing a path, and sometimes accomplished with a single ship doubling back on its path, greater efficiencies could be achieved if a ship design could optimize maintenance of an open water lane. Only a few respondents discussed this issue, specifically with regard to trawling and towing seismic gear. Marine geophysicists also asked that consideration be given to ship design to facilitate 3-D seismic operations. This entails towing a short, lightweight streamer on each side of the ship, in addition to instruments towed from the stern. This requires that the ship have the capability to tow off both sides, so there needs to be open space on deck to mount small temporary cranes with booms to get the streamers off to the side.

We concur with the 2009 Science Mission Requirements for Ocean Class Research Vessels. We add the necessity for towing seismic gear, and addressing capabilities of towing in ice.

D.2.4.5 ROV support

Updated SMR

The ship must be able to host and deploy/recover Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV), both with a wide variety of capabilities. Provision for operations in ice-covered seas needs to be made, such as the possibility of deployment through a moon pool or over the side after ice clearing, with a capable handling system. Adequate deck space for up to four ROV support vans and dedicated launch and recovery systems along with sufficient deck and tie down hardware strength to accommodate the loads created with ROV/AUV systems will be required for the largest currently available systems. A hanger bay with climate control for staging ROV/AUV operations will not only facilitate these operations but many others as well. The capability to support JASON operations can be used as a guiding example; the US National Deep Submergence Facility provides up-to-date documents with support requirements for these systems. Other considerations include how and where cables should go over the side, how and where free-swimming vehicles should be recovered (e.g. moon pool, cable dock, open water maintained by the ship), and how subsea vehicles will be navigated. For AUV/ROV operations the stern frame should be designed for a dynamic safe working load of 30,000 lbs. through its full range of motion, and it must be structurally engineered to handle 1.5 times the breaking strength of cables up to one inch, such as the tether for large ROV systems (up to 120,000 lbs. breaking strength). The stern frame should have a 15-ft minimum horizontal and 25-ft vertical clearance from the attachment point from the block to the deck. At least a 12-ft inboard and outboard reach is required.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *A new PRV must be able to host and deploy/recover Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV), both with a wide variety of capabilities. Most likely, such operations will take place in* *ice covered seas and hence vehicles will be needed to be deployed through a moon pool or over the side after ice clearing with a capable handling system.*

2016OPPRFI: (not discussed)

2018ASCVSR: *A stern frame capable of supporting towing, piston coring, ROV/AUV operations and other activities will be required…", on page 131/261 there is mention of adequate work deck area to accommodate ROV operations, and on page 148/261 there is mention of use of the staging bay for ROV operations.*

Discussion:

There has been and will likely continue to be an increase in launch and recovery of autonomous instrumentation for ocean and ice measurements - such as a μCTD, glider, AUV, and automatic ice cameras - along with ROV operations. Survey respondents who mentioned support for ROV operations principally focused on the need to provide support for the ROVs, for example in terms of adequate available deck space, and the power required by the systems. As noted above, the capability to support JASON operations was cited as a guiding example. The US National Deep Submergence Facility provides up to date documents with support requirements for systems. Support considerations also include how and whether AUV/ROV vehicles can moved inside between dives, and if not, how to allow regular maintenance activities on deck, how and where cables should go over the side, how and where free-swimming vehicles should be recovered - moon pool, cable dock, open water maintained by the ship - and how should subsea vehicles be navigated (assuming constraints on ship motion). The community recommends that the stern frame should be designed for a dynamic safe working load of 30,000 lb. through its full range of motion, and it must structurally engineered to handle 1.5 times the breaking strength of cables up to one inch, such as the tether for large ROV systems (up to 120,000 lbs. breaking strength). The stern A-frame should have a 15-ft minimum horizontal and 25-ft vertical clearance from the attachment point for the block to the deck. At least a 12-ft inboard and outboard reach is required. There is also a note regarding providing for the significant deck loads of some ROV systems (e.g. JASON with all of its support gear).

Some respondents felt that due to logistical and cost issues, the ship itself should be equipped with an ROV cable and control room, with inferences that the USAP have an Antarctic-designated ROV available to investigators, noting "can do this now but logistically the cost blows proposals out of the water".

D.2.4.6 Unmanned Aerial Systems (UAS) support

<u>Updated SMR</u>

The vessel should be capable of launching and recovering small unmanned aircraft for multiple science surveys, ice survey and reconnaissance (remotely or autonomously operated).

The design of the next generation polar research ship should meet the basic needs of UAS shipboard requirements, including:

- communication (air band radios),
- sufficient “real-estate” to install system antennas (omni and directional),
- sufficient physical clearance for take-off and landing (generally not an issue),
- crew training on basic UAS ship-based operations, and
- sufficient internet bandwidth to access remote sensing and aviation forecast products needed for flight planning.

In some instances, rapid response via small boat (e.g. Zodiac) will be necessary to retrieve a UAS (e.g. drone) that malfunctions. Drones are designed to return to launch GPS coordinates when batteries die or if any malfunction occurs. At sea, this may be problematic if the ship has drifted and will result in the drone crash-landing into the ocean.

Priorities: Requirements rated as “must have, as is”

Previous Requirement Language

2012PRVSMR: *The vessel should be capable of launching small unmanned aircraft for multiple science surveys, ice survey and reconnaissance (remotely or autonomously operated).*

2016OPPRFI: (not discussed)

2018ASCVSR: Mentions use of NBP helo deck *as a launching/landing location for unmanned aerial systems (UAS).*

Discussion:

UAS operations are increasingly part of research at sea. Science foci, among others, include physical oceanography, atmospheric studies, electromagnetic studies, sea-ice studies, biological studies, and various forms of scientific mapping. Outreach activities also increasingly use UAS support. For polar ships, there is demand for UAS support for ice reconnaissance, navigation, and ice station planning, although there are operational hazards such as icing that pose challenges for UAS operations at low temperatures.

Improved UAS technologies such as smarter navigation and control systems, automatic take off and landing with sensing capability for obstacle avoidance (e.g. A-frame, ship superstructure) are maturing rapidly. Ship-based UAS operations are anticipated to become a routine component of research operations conducted from US research ships.

D.2.5 Science working spaces

D.2.5.1 Working deck area

Updated SMR

Working deck(s) area of >4,500 ft2 (threshold) / 5,500 ft2 (objective).

Deck loading should meet the current ABS rules (i.e. designed for a 12-foot head or 767 lbs/sq ft). The total aggregate load on the main working deck should be maximized within the constraints of deck size, variable science load and stability. An aggregate total deck load of 100 Tons is required to maintain the capability of the existing vessel. Point loading for some specific large items (such as vans and winches) should be evaluated in the deck design since these may generate loads of 1,500 lbs/sq ft or higher.

All working areas should provide 1”-8NC (SAE National Coarse Thread) threaded inserts on two-foot centers with a tolerance of ± 1/16” on center. The bolt down pattern should be referenced to an identifiable and relevant location on the deck to facilitate the design of equipment foundations. The inserts should be installed and tied to the deck structure to provide maximum holding strength (rated strength should be tested and certified). Tie down points should be provided for any clear deck space that might be used for the installation of equipment including the foredeck, 0-1 deck, bridge, and flying bridge and should extend as close to the sides and stern as possible.

Stern deck area should be as clear as possible and highly flexible to accommodate large and heavy temporary equipment. Bulwarks should be removable and all deck- mounted gear (winches, cranes, a-frames, etc.) should be removable to a flush deck as much as possible to provide flexible re-configuration.

The design should provide a dry working deck with provisions for allowing safe access for deployment and recovery of free-floating equipment to and from the water. Traditionally low freeboard and stern ramps have been provided as means to accomplish this goal. The use of stern ramps has been limited and should be included in new designs only if required by specific planned operations. Low freeboard facilitates launch and recovery operations but results in wetter decks and less reserve buoyancy. The use of innovative design features to facilitate safe and effective equipment launch and recovery while maintaining dry and safe weather decks should be carefully considered. Removable bulwarks with hinged freeing ports to provide dry deck conditions in beam or quartering seas have proved effective. The use of a moon pool can be considered.

A clear foredeck area should be capable of accommodating small, specialized towers, booms, and other sampling equipment as much as possible. Providing tie down sockets, power, water, and data connections will facilitate flexible use of this space.

Additional deck areas should be provided with the means for flexible and effective installation of incubators, vans, workboats, and temporary equipment. (See relevant SMRs below for details.)

All working decks should be equipped with easily accessible power, fresh and seawater, air, data ports, and voice communication systems. Adequate flow of ambient temperature seawater for incubators should be available on decks supporting the installation of incubators.

All working decks need to be covered by direct visibility and/or television monitors from the bridge. Gear deployment areas should maximize direct clear visibility.

The main exterior working deck should be equipped with means to keep key working areas ice free, for example via boilers to circulate a water/antifreeze mixture under the deck.

Priorities: These requirements are rated as “must have, as is”, except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as “must have, as is”, with the Objective requirements rated as “could manage with something less stringent”.

Previous Requirement Language

2012PRVSMR: *[No directly related SMR language]*

2016OPPRFI: *Working deck(s) area of >4,500 ft2 (threshold) / 5,500 ft2 (objective).*

2018ASCVSR: *Working deck area 4500-5,500 sq ft. (NBP is 4,400 sq ft)*

Discussion:

From the survey:

General comments: Many respondents directed their comments toward deck space. Comments focused on the need for improved deck space appropriate for launch and recovery of small boats, unmanned aircraft and AUVs. Others noted a need for “Space that is specifically designed for deck incubations, with easy/adjacent lab space.” One respondent noted that “the deck area should include enough room for seabed drilling vans, or any vans associated with drilling activities” and as well, the space should accommodate sediment sampling. In terms of accommodating drilling, “Sea bed drill rigs require a lot of deck space - e.g. for the British Geological Survey Rock-Drill2 (RD2), 7 x 20ft containers, ~ 100,000 kg, as well as space for the launch system and winch. The German MeBo drill rig requires use of a substantial A-frame and has a similar deck space requirement. A moonpool type deployment would be preferable, being close to the center of motion and protected from sea ice. But such sea bed drilling systems are designed for a back deck or over-the-side deployment, and I’m not sure they would fit through a 4x4m moon pool. Ability to deploy a geotechnical rig through the moonpool would partly address the same need.”

NBP specific comments:

Scientists noted a shortage of deck space (and storage space and space in wet labs) when multiple science parties, or complex projects, multi-disciplinary share the ship. Respondents noted, “Accommodating multiple containers on deck and still having clear space for crane operations was a problem.” And “The forward deck space on NBP is currently unusable so long cable runs or sampling tubes are required for clean air sampling off the front deck. Undisturbed ice sampling (remotely by lidar or em) is currently not doable on the NBP as there is no bow crane and instrument cables need to be shorter than the current long run back to warm lab space. Provision of wireless connections, ethernet ports and/or instrument vans or shelters on the foredeck are needed. On the rear deck, current access to the ice is limited to the starboard side which precludes oceanographic (CTD) sampling using the Baltic room or starboard A-frame.”

D.2.5.2 Laboratories

Updated SMR

Scientific laboratory space of >5,700ft2 (threshold) / 6,500ft2 (objective) to accommodate up to 45 scientists. Walk in refrigerators and freezers for scientific work and sample storage (-20° to 10°C) for science samples. Lab spaces (with approximate square footage) should include the following:

- Aft Dry Lab (~1100)
- Forward Dry Lab (~1100)
- Wet Lab (~900)
- Hydro Lab (~750)
- Baltic Room/Staging Area (~700)
- Electronics Lab/Computer Lab (~700)
- Climate Controlled Spaces
    - Environmentally Controlled Lab (~100) [used for Autosal on *Palmer*]
    - Built-in climate-controlled workspaces. Built-in refrigerators/freezers. At least 2 rooms must be included. Cooled independently. Seawater drops in each room. Humidity controls in each room. High quality fixtures, corrosion resistant. Deck bolts and drains. Temp range 15°F to 50°F with variance of +/- 2°F (-10°C to 10°C with variance of +/- 1°C).
- Bio Lab (~400)
- Aquarium Room, with flowing seawater (~400)
- Marine Technician Shop (~150)
- Electronic Technician Shop/Electronic Equipment Room, with separation of computing facilities with climate control and limited vibration (~100)
- Microscope Room (~20)
- Changing/Mud Room (~100)
- Hazardous material storage lockers

The design should also accommodate these functions as much as possible as separate spaces, within other lab spaces or with space for dedicated lab vans:

- Gravitometer room
- Gimbaled platform
- Electrophoresis equipment
- Trace Metal Clean lab

- Core Processing Facilities

Priorities: These requirements are rated as "must have, as is", except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as "must have, as is", with the Objective requirements rated as "could manage with something less stringent"

Previous Requirement Language

2012PRVSMR: *Labs to accommodate up to 45 scientists.*
To include:
Main Lab
Wet-Lab
Computer Lab with separation of computing facilities with climate control and limited vibration
Dry Lab
Hydrolab
Refrigerated Lab (2ea.)
Microscope Lab (2ea.)
Gimbaled platform
Electrophoresis equipment
Trace Metal Clean lab
Core Processing Facilities
Built-in climate-controlled workspaces. Built-in refrigerators/freezers.
Aquariums- with flowing seawater
Electronic Technician Shop
Marine Technician Shop
Conference room
Exercise Room

2016OPPRFI: *Scientific laboratory space of >5,700ft^2 (threshold) / 6,500ft^2 (objective). Walk in refrigerators and freezers for scientific work and sample storage (-20°to 10°C) for science samples.*

2018ASCVSR:

2300	*Dry Lab(s)*
870	*Wet Lab*
750	*Hydro Lab*
500	*Electronics Lab*
160	*Science Freezer/Chiller*
400	*Analytical/Clean Lab*
710	*Bio Lab*
100	*Enviro Lab*
50	*Microscope Room*
5840	*Total* (NBP total is 4381)

...also aquariums, workshops, hazardous material storage lockers, gravitometer room, and scientific storage

Discussion:

From survey, general comments:

Many respondents noted problems with space, with regard to a variety of work spaces on the ships. They noted that this is particularly significant when multiple projects are using the ship at once, even though these larger bio-geo-chemical-mooring cruises may be rare.

Respondents noted that spaces can be cramped, and suggested more wet lab space, more easily configurable spaces, more general work space for setting up laptop computers for scientists and students, and space for spreading out and testing field gear. Problems noted included a need for larger aquarium space (inside and outside and deck) to conduct experiments with live organisms under appropriate environmental conditions and to hold fish during fishing operations, more storage space in the -80 Freezers, more storage space for ice samples, and more than one instrument platform high up, capable to carry 200+lbs, ideally 360° field of view. Respondents requested more chemical fume hoods and clean labs that are contamination free with respect to trace metals and also other contaminants. Increasing interest in doing molecular analysis in real time in the field, in order to inform further sampling, for example, requires lab space which can be kept sufficiently clean and isolated for this kind of work to be conducted. Scientists suggested that more environmentally controlled rooms or vans would be very useful. Several noted that "both ships need more space for core processing" and that "modern laboratory and computational researcher space is needed, including connection to flat screen for the visualization of complex data sets."

LMG specific comments:

Respondents also noted that some of the labs and their arrangement is not as functional as necessary. For example, "the wet lab can only be accessed weather permitting. I have lost experiments because we were not allowed outside during bad weather. All science lab spaces should have safe inside access." "The aquarium facility on the LMG is substandard …. It needs to be accessible without going out on deck and configurable for more than huge fish holding tanks." "Chemical storage could be better integrated with other spaces on the LMG."

NBP specific comments:

Many respondents had positive comments regarding the NBP, noting that the "labs are largely sufficient and can be adapted to many different projects." One respondent noted that "the NBP is close but try visiting one of the many vessels recently built for ocean research by other nations and you'll get the picture. The US is WAY behind in terms of providing modern, well-functioning labs and over-the-side research capabilities in the polar regions."

One respondent noted that "NBP labs are good (and are well maintained) and spacious but could be better. More care is needed to have more nearly complete assortment of power types, compressed air, seawater, etc., etc. in more of the labs. Not sure if there is a full-out climate-controlled lab (well below to well above freezing, with unistrut, lights, full range of hook-ups, etc. - actually there should be two of them). Don't think the NBP has a lab on one of the higher decks for the teams doing air/sky work." Other respondents noted limited fume hood space and the need for better climate control, particularly in the main labs. The importance of well-functioning environmentally controlled rooms for seawater processing and experimental work was also noted.

D.2.5.2.1 Layout & construction

Updated SMR

Flexibility and support for different types of science operations within limited space are the important design criteria for these vessels. Benches and cabinetry should be flexible and reconfigurable (e.g. SIO erector set and/or Unistrut™). Bench and shelving heights should be variable to allow for installation and use of various types of equipment. Bench tops should be constructed of materials that will allow equipment to be tied down or secured easily and that can be cleaned and replaced as necessary. The ability to easily install or remove cabinets and drawers as needed should be included. Provisions for large, flat chart/map tables including a light table should be incorporated in the lab design.

- There must be high quality benches and cupboards installed in all lab areas.
- Countertops should be chemical resistant (chemtrek, etc.).
- Countertops could have brass inserts for eyebolts in a grid pattern, every 2 feet.
- Overhead cupboards should be high quality and have LED adjustable task lighting available.

Refer to the section on habitability for guidance on the importance of lighting and air circulation. Include natural lighting in most labs, with the ability to black out portholes. Light levels in labs should meet UNOLS standards, 100 foot candles.

Labs should be fabricated using materials that are uncontaminated and easily cleaned. Furnishings, HVAC, doors, hatches, cable runs, and fittings must be planned to facilitate maintaining maximum lab cleanliness. Spaces and materials that may trap chemical spills should be avoided.

Static dissipative deck coatings to reduce static damage to electronics should be required in the "ET" shop and computer/electronics spaces and recommended in other lab spaces. Deck coatings should protect the ship's structure, be easily cleanable, easily repairable, and resistant to damage from chemical spills. Deck materials or padding should provide safe footing and minimize fatigue to working personnel that need to stand for long periods.

The distance from the deck to the underside of the finished overhead should be 7.5 to 8 feet. Headroom space and room for the installation of tall equipment should be maximized while balancing the need for cable trays, adequately sized ventilation ducts, lighting, etc.

Through the design process, minimize the incursion of "ship stuff" (e.g., air handlers, gear lockers, electrical panels and transformers not related to the labs, sounding tubes, valve controls, food freezers and etc.) into the lab space.

Labs should have bolt downs (1/2"-13NC on two-foot centers) in the deck in addition to Unistrut™ on the bulkheads and in the overhead. Fiberglass Unistrut™ should be considered as an alternative to galvanized steel. Deck bolt downs on one-foot centers should be considered for some areas.

Locations for two fume hoods with explosion proof motors in the main lab and one in the wet lab should be included in the laboratory layouts. Exhaust ducting, electrical connections, and sink connections should be permanently installed in place to allow for easy installation and removal of fume hoods. Fume hood locations should accommodate hoods at least four feet wide. Snorkel system with removable snorkels must be present in all labs. 1-4 snorkels per lab. Fume hoods and snorkels must not recirculate into ship and shall exhaust safely to atmosphere away from personnel.

Sinks should allow for flexible installation, removal, and additional sinks when needed. At least two locations in the wet lab and four locations in the main lab (some of which are located with the fume hoods discussed above) should be provided with stubbed out plumbing at convenient locations. More locations can be provided if possible. At least one large sink with a sediment trap that is easily accessible for cleaning should be included. Drains should be designed to work at all times, taking into account operating conditions that create various trim and list conditions, rolling, etc. Drains should be capable of being diverted over the port side, into holding tanks, or to the normal waste system, and should allow for continuous discharge of running water. Sinks should be large enough to accommodate five-gallon buckets and the cleaning of other equipment.

Work with radioactive materials should be restricted to radiation lab vans that remain isolated from the interior of the vessel.

Other design criteria to consider and include as much as possible include:

- Clean sites for genomics and trace organic and metals analysis and sample preparation.
- Bulkhead pass throughs to adjacent labs and spaces in all labs with approved watertight and fire boundary ratings. Allow for growth in the number of cables.
- Ships compressed air drop available on ceilings in each lab. Ships compressed air must be sufficiently clean to support a liquid nitrogen plant 30-40 psi.
- Installed gas bottle racks in all labs, removable, 5 bottles each.
- Oldham MX43 gas detector or equivalent installed in all labs.
- Specific laboratory HVAC requirements to be carefully designed and installed. To include independent temperature control for each space, filtered to provide high quality air with the intakes located away from contaminating sources, minimum 8 - 10 air changes per hour.
- Fresh water, hot and cold must be available in all labs. 1-3 sinks per lab. Salt water from the uncontaminated seawater system must be available in each lab. Seawater must be available in copious quantity in an aquarium room and an outside area to support incubations.
- Lights must be controllable in the aquarium room to darken space.
- There must be filtered emergency eyewashes on all sinks, emergency showers in each lab. There should be drains under all showers. Emergency showers at least 20 GPM. Eye washes at least 0.4 GPM.

- Microscope Room [should be] quiet, low vibration, [with] space reservation for anti-vibration table, compressed air connections, water and sink, no window required.
- Clean Lab [will have] high flow HEPA hood and laminar flow hood. Laminar flow at the door. Trace metal clean (no metals inside of this lab).
- Small flammables cabinet. Located near exterior door where TMC CTDs are done.
- Small anteroom for clothes changing preferred.
- Ice makers required in 1 or 2 labs.
- Deionized (DI) water required in 2 or 3 labs.
- Capability of storing instruments and sampling gear, washing nets, and processing benthic samples in a warm environment during winter operations.
- Doors must be wide enough for cargo.
- Laboratory spaces shall be located on Main Deck, adjacent to each other and the working deck area as much as possible.

Priorities: Requirements rated as “must have, as is”

Previous Requirement Language *Updated SMR*

2012PRVSMR: (not specified)

2016OPPRFI: (not specified)

2018ASCVSR: *Laboratories shall be as flexible as possible with the capability to be reconfigured, and adapted to various uses. Clean sites for genomics and trace organic and metals analysis and sample preparation. Labs must be constructed of materials that are uncontaminating and easily cleaned. Items not directly related to laboratory services and science operations such as valve controls, breaker panels (non-laboratory service), and other equipment shall not be located in labs. Natural lighting in most labs, with the ability to black out portholes. Light levels in labs should meet UNOLS standards, 100 foot candles. Pass throughs through bulkheads on all walls in the lab. Ships compressed air drop available on ceilings in each lab. Ships compressed air must be sufficiently clean to support a liquid nitrogen plant.30-40 psi. Installed gas bottle racks in all labs, removable, 5 bottles each. Unistrut on walls for securing items, deck sockets on floors. Fume hoods required in all labs. Snorkel system with removable snorkels must be present in all labs. 1-4 snorkels per lab. Fume hoods and snorkels must not recirculate into ship and shall exhaust safely to atmosphere away from personnel. Oldham MX43 gas detector installed in all labs. Specific laboratory HVAC requirements TBD. To include independent temperature control for each space, filtered to provide high quality air with intakes located away from contaminating sources, minimum 8 - 10 air changes per hour. Fresh water, hot and cold must be available in all labs. 1-3 sinks* *per lab. Salt water from the uncontaminated seawater system must be available in each lab. Seawater must be available in copious quantity in an aquarium room and an outside area to support incubations. Lights must be controllable in the aquarium room to darken space. There must be filtered emergency eyewashes on all sinks, emergency showers in each lab. There should be drains under all showers. Emergency showers at least 20 GPM. Eye washes at least 0.4 GPM. There must be high quality benches and cupboards installed in all lab areas. countertops should be chemical resistant (chemtrek, etc.). countertops need to have brass inserts for eyebolts in a grid pattern, every 2 feet. Overhead cupboards should be high quality and have LED adjustable task lighting available. Flooring should be chemical resistant, spark resistant, and replaceable. Microscope Room [should be] quiet, low vibration, [with] space reservation for anti-vibration table, compressed air connections, water and sink, no window required. Clean Lab [will have] high flow HEPA hood and laminar flow hood. Laminar flow at the door. Trace metal clean (no metals inside of this lab). Small flamms cabinet. Located near exterior door where TMC CTDs are done. Fiberglass* Unistrut™ *on bulkheads. Small anteroom for clothes changing preferred. Ice makers required in 1 or 2 labs. Deionized (DI) water required in 2 or 3 labs. Built-In climate-controlled spaces. At least 2 rooms must be included. Cooled independently. Seawater drops in each room. Humidity controls in each room. High quality fixtures, corrosion resistant. Deck bolts and drains. Temp range 15°F to 50°F with variance of +/- 2°F. Capability of storing instruments and sampling gear, washing nets, and processing benthic samples in a warm environment during winter operations. Doors must be wide enough for cargo. [Laboratory spaces} shall be located on Main Deck, adjacent to each other and the working deck area.*

Discussion:

These SMR recommendations mirror the SMRs for Ocean Class and Regional Class research vessels with some additions particular to the PRV and from the survey results.

D.2.5.2.2 Electrical

<u>Updated SMR</u>

Each lab area is to have a separate electrical circuit on a clean bus and continuous ‘household’ quality power. The electrical system capacity and design should take into account provisions for the cruise variable connection of systems with large electrical motors or power demands. Provision for multiple simultaneous connections should be possible for 480V 3-phase, 208 – 230V 3-phase and single phase, and 110V single phase with 50 to 200 amps service for vans, laboratories, and on deck. Final design specifications should take into consideration common electrical requirements for currently used and planned equipment, and excess capacity should be designed in to the maximum extent possible. Uninterruptible power should be available throughout all laboratory spaces, bridge/chart room, and science staterooms. The use of modular UPS design can be considered. Separate circuits should be available for tools and other equipment that will not interfere with clean power circuits. Use current IEEE 45 or equivalent standards for shipboard power and wiring and current IEEE standard for UPS and clean power specifications.

Electrical service for the labs should include:

- 110 VAC, single phase 75-100 amps service for each lab
- 208/230 VAC, 3-phase, 50 amps, “readily available” (i.e., in the panel, or 1-2 outlets)
- 480VAC, 3-phase available “on demand” (for example, run into the lab from auxiliary outlets on deck).

Examples of lab and science support electrical requirements include the following:

- 120VAC Ship Power - Ship power system servicing all lab and computer spaces with at least 8 x 20 Amp circuits per lab in addition to the UPS service. Lab Receptacles - Two 120 volt, single-phase receptacle strips, each fed by a 20 amp circuit breaker, shall be provided for every 6 linear feet of bulkhead and shall be installed at a height of approximately 42 inches above the finished deck. Each strip shall have six standard NEMA 5-20R receptacles.
- Foreign Equipment Power Capability - 2x 20 Amp per lab and computer space at 220V 50Hz.
- Weather Deck Power Service - 2x 100 Amp 3-Phase 208V, 4x 60 Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering deck containers and portable equipment. Some systems may need as much as 200A of 440V 3-phase AC power.
- Container Hold Power Service - 2x 100 Amp 3-Phase 208V, 4x 60 Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering container hold containers and portable equipment.
- 120VAC 30 Amp Power Service - Each Lab, Computer Space, Science Workshop,
- Staging Area and Aquarium Space shall have at least one 30 Amp 120V 60Hz circuit provided in addition to normal 20 Amp service.
- For van hook-ups - Electrical connections for 20 amps 440 VAC 3-phase, 40 amps 230 VAC 3-phase, and 40 – 50 amps 208 VAC single phase should be provided. 30 amps 110 VAC single phase may also need to be provided, but usually can be provided by panels in the van from step down transformers. There may occasionally be a possible need to supply electrical power to cargo vans being carried en route to science stations.

Scientific wire ways must be considered throughout the ship connecting relevant scientific work spaces. These wire ways must be accessible for frequent change out of cabling to support various scientific missions. Double-tiered wire trays, with one tray above hidden ceilings for long term cable placement and one tray below the ceiling for rapid cable routing are required. Science wireway routing will be defined between various laboratories and include other working areas including the pilot house, main and forward mast, staging bay and aft working deck. Science wire ways should be separated from power and other signal cables. Transitions through watertight bulkheads and decks will be appropriately protected with approved pass through systems. Where applicable, conduit piping to connect scientific work spaces on different ship levels shall be used.

The quality of the electrical power supplied to science systems is also important. Electrical power quality specifications should be implemented and met (e.g., a specified maximum percent total harmonic distortion at a common reference point, along with voltage, stability, phase, and power quality rating specifications). Experience shows clean power reduces undue temperature rise in electrical equipment and systems, lengthens equipment life, reduces failures, and reduces noise in circuits

The design should include a specific electrical power plan for each laboratory or other designated science space, including locations designed to support science vans, climate-controlled chambers, and so forth. The power plan should follow, and if needed improve on, the guidelines of the Leidos and Ocean-class SMRs for voltages, outlets, wire ways, etc. The electrical power specifications in the science design should also be specific in terms of power quality. Consideration should be given to the feasibility of using software-defined power systems.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: (not discussed in document)

2016OPPRFI: (not discussed in document)

2018ASCVSR: *Scientific wire ways must be considered throughout the ship connecting relevant scientific work spaces. These wire ways must be accessible for frequent change out of cabling to support various scientific missions. Double-tiered wire trays, with one tray above hidden ceilings for long term cable placement and one tray below the ceiling for rapid cable routing are required. Science wireway routing will be defined between various laboratories and include other working areas including the pilot house, main and forward mast, staging bay and aft working deck. Transitions through watertight bulkheads and decks will be appropriately protected. Where applicable, conduit piping to connect scientific work spaces on different ship levels shall be used.*

110v electrical service every 8 feet in lab. Installed on all permanent islands, and receptacles on ceiling in all labs; 220V electrical in all labs. 1-2 receptacles on walls, 1-2 receptacles on ceilings, depending on the size of the lab; Electrical connections must be single point neutral grounded; UPS system required. Receptacles required 1-5 in each lab;

120VAC Ship Power - Ship power system servicing all lab and computer spaces with at least 8 x 20 Amp circuits per lab in addition to the UPS service. Lab Receptacles - Two 120 volt, single-phase receptacle strips, each fed by a 20 amp circuit breaker, shall be provided for every 6 linear feet of bulkhead and shall be installed at a height of approximately 42 inches above the finished deck. Each strip shall have six standard NEMA 5-20R receptacles. Foreign Equipment Power Capability - 2x 20 Amp per lab and computer space at 220V 50Hz. Weather Deck Power Service - 2x 100 Amp 3-Phase 208V, 4x 60 Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering deck containers and portable equipment. Container Hold Power Service - 2x 100 Amp 3-Phase 208V, 4x 60 Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering container hold containers and portable equipment. 120VAC 30 Amp Power Service - Each Lab, Computer Space, Science Workshop, Staging Area and Aquarium Space shall have at least one 30A mp 120V 60Hz circuit provided in addition to normal 20 Amp service. 340 VAC 30 Amp Power Service - 240 VAC service for all lab and computer spaces 10 x 30A spare circuit breakers total. Lab Receptacles - Two 240 volt, single-phase receptacles, each fed by a 30 amp circuit breaker, shall be provided for every lab and computer space, as well as in the container hold and workshops.

Discussion:

Although laboratory and other science space electrical supply was not discussed in the earlier SMR document, this is an important aspect of research ship design and outfitting, as seen for example in the details in the contractor-provided Vessel Studies Report (from Leidos). The Ocean-class SMRs state the needs more generally:

> Each lab area is to have a separate electrical circuit on a clean bus and continuous 'household' quality power. There should be two 110V outlets per linear foot of bulkhead. Delivery capability of at least 40-volt amperes per square foot of lab deck area is required (the amount of power needed will be verified at the time of design)." "The electrical system capacity and design should take into account provisions for the cruise variable connection of systems with large electrical motors or power demands. Provision for multiple simultaneous connections should be possible for 480V 3-phase, 208 – 230V 3-phase and single phase, and 110V single phase with up to 50 amps service for vans, laboratories, and on deck. Final design specifications should take into consideration common electrical requirements for currently used and planned equipment, and excess capacity should be designed in to the maximum extent possible." "Each lab area is to have a separate electrical circuit on a clean bus with continuous 'household' quality power. There should be two 110V outlets per linear foot of bulkhead. Delivery capability of at least 40-volt amperes per square foot of lab deck area is required (the amount of power needed will be verified at the time of design). Uninterruptible power should be available throughout all laboratory spaces, bridge/chart room, and science staterooms. The use of modular UPS design can be considered. Separate circuits should be available for tools and other equipment that will not interfere with clean power circuits. Use current IEEE 45 or equivalent standards for shipboard power and wiring and current IEEE standard for UPS and clean power specifications.
>
> Electrical service for the labs should include:
>
> - 110 VAC, single phase 75-100 amps service for each lab;
> - 208/230 VAC, 3-phase, 50 amps, "readily available" (i.e., in the panel, or 1-2 outlets); and

- 480VAC, 3-phase available "on demand" (for example, run into the lab from auxiliary outlets on deck).

There should be dedicated science wire-ways with dedicated transits to all science and instrumentation locations, including locations at the bow, at the seawater intake locations, and at winches. There should be two color-coded science wire-ways; one is for permanent science equipment and the other for temporary science equipment. Science wire ways should be separated from power and other signal cables. There should also be non-energized wiring installed and dedicated to supporting project science systems (appropriate gauge and number of conductors determined during design phase). Provisions for easy installation and removal of temporary wiring should be made.

For van hookups the Ocean-class SMRs state: *"Electrical connections for 20 amps 480 VAC 3-phase, 40 amps 230 VAC 3-phase, and 40 – 50 amps 208 VAC single phase should be provided. 110 VAC single phase may also need to be provided, but usually can be provided by panels in the van from step down transformers."* We note there may occasionally be a need to supply electrical power to cargo vans being carried en route to science stations.

The quality of the electrical power supplied to science systems is also important. For example, if electrical power quality specifications are implemented and met (e.g., a specified maximum percent total harmonic distortion at a common reference point, along with voltage, stability, phase, and power quality rating specifications), experience shows this will reduce undue temperature rise in electrical equipment and systems, lengthen equipment life, reduce failures, and reduce noise in circuits. Most methods used at the time of this study to improve power quality come at a cost in terms of energy, heat, and efficiency. But there is new (in 2018) technology for software-defined shipboard power systems, which in effect build a very high-quality power stream at sub-microsecond intervals from the supplied power. Such systems are expensive now (ca. $100k), though with huge power quality advantages covering nearly all aspects of power. But these may be much cheaper by the time the next polar research ships are designed and constructed.

Recommendations:

We recommend that the science design include a specific electrical power plan for each laboratory or other designated science space, including locations designed to support science vans, climate controlled chambers, and so forth. The power plan should follow, and if needed improve on, the guidelines of the Leidos and Ocean-class SMRs for voltages, outlets, wire ways, etc. The electrical power specifications in the science design should also be specific in terms of power quality. Consideration should be given to the feasibility of using software-defined power systems.

D.2.5.3 Vans

Updated SMR

Space is needed for carrying at least 7 "UNOLS Standard" lab vans or equivalent on the main aft deck plus the aft areas of decks above the main deck. For example, these vans might include specialized lab space (such as for working with radioisotopes, under contamination free and trace metal free conditions and/or other environmentally controlled conditions), or operator-supplied support vans for specialized ROVs, coring, or drilling equipment. Space is also needed in an area forward of the pilot house - sited to provide the best feasible degree of protection from heavy seas - for up to two additional “UNOLS Standard” lab vans.

In addition, capacity to carry at least 4 (Threshold) or 8 (Objective) standard containers (including, for example, laboratory, berthing, or frequently-accessed storage vans) in an accessible and human habitable working area below decks is needed.

All container tie-down locations intended to support laboratory vans should be supplied 20 amps 440 VAC 3-phase, 40 amps 230 VAC 3-phase, and 40 – 50 amps 208 VAC single phase should be provided. 30 amps 110 VAC single phase may also need to be provided, but usually can be provided by panels in the van from step down transformers; non-freezing fresh water and seawater lines; non-freezing grey water line; compressed air, and data and communications hook-ups, including for the ship’s emergency notification system.

Additional spaces should be provided for standard 20-foot intermodal containers being carried in transit to/from Antarctic research sites, containing equipment for other marine expedition legs, or to carry stored wastes, emergency supplies, or other items. Spaces intended for such vans do not require the full range of hook-ups for laboratory vans, but at a minimum must have 120/240 volt power available, plus data and communication hookups.

The total count of supported vans in all spaces should be at least 20 (Threshold), with ≥24 preferred (Objective).

Priorities:

These requirements are rated as “must have, as is”, except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as “must have, as is”, with the Objective requirements rated as “could manage with something less stringent.”

Previous Requirement Language

2012PRVSMR:	*[Space to carry 5-6, science vans- ISO standard 8 foot x 20 foot portable deck vans ("UNOLS Standard" lab vans).]*
2016OPPRFI:	*Capacity to carry >15 standard 20-foot intermodal containers in the hold and on decks.*
2018ASCVSR:	*≥15 standard 20-foot containers to be stowed on deck and in holds.*

Discussion:

Support for laboratory, cargo, and other vans - mostly but not always standard 20-foot containers - is an integral aspect of all research ships. Such support is even more important for polar ships, where supplies and wastes are carried between ports and temporary and permanent science stations, and multiple cruise legs must be supported between visits to ports. Scientist's experience with planning NBP cruises is that the ship's cargo capacity often comes into question. A related issue is that some science facilities or specialized requirements are best met via vans. Although not specifically queried about vans, respondents requested that the ships have clean labs that are contamination free with respect to, trace metals, and also other contaminants. Increasing interest in doing molecular analysis in real time in the field, in order to inform further sampling, for example, requires lab space which can be kept sufficiently clean and isolated for this kind of work to be conducted. Several noted that "both ships need more space for core processing" which might be accommodated by van space. Scientists suggested that more environmentally controlled rooms or vans would be very useful. While not entirely, these requirements might be met, partially, through the use of vans. In addition, one respondent noted that "the deck area should include enough room for seabed drilling vans or any vans associated with drilling activities" and as well, the space should accommodate sediment sampling. In terms of accommodating drilling, "Sea bed drill rigs require a lot of deck space - e.g. for the British Geological Survey Rock-Drill2 (RD2), 7 x 20ft containers, ~ 100,000 kg, as well as space for the launch system and winch."

Survey respondents were not queried about cargo van needs. Experience from the US and other national Antarctic programs, plus results from previous SMR exercises provided guidance. Some polar research ships have significant science storage capabilities in the form of capacity to carry a large number of standard 20-foot cargo containers, with some or all vans protected from seas and weather. One means to augment the storage capacity of a new US polar RV - above that provided at present by the NBP - would be additional capacity to carry vans in protected spaces.

D.2.5.4 Storage

Updated SMR

Storage spaces should be provided in all classes represented by those presently on the Nathaniel B. Palmer, with at least that ship's present capacities except: (1) Increased capacity, above that of the NBP, is needed for hazardous items storage, including in the laboratories, and also for chemical wastes. (2) Significantly increased storage is needed for scientific cargo for other expedition legs and delivery to scientific sites, partially via increased capacity to carry standard 20-foot cargo containers protected from weather and seas, but also for bulk cargo. Also, climate-controlled storage spaces (at least two, with temperatures individually selected from at least -20°C to +10°C) should be larger than those on the NBP and outfitted for optional use as climate-controlled laboratories.

These storage spaces will include:

- storage for resident technician deck and rigging equipment and spares
- storage for resident technician shop equipment and spares
- storage for resident computer technician equipment, supplies, and spares
- reagent and hazardous materials storage
- storage for spares for ship's science gear
- storage for specialized outdoor/weather clothing
- storage for spares and boxes for scientist-provided science gear

- climate-controlled storage (at least two, with temperatures individually selected from at least -20°C to +10°C), able to accommodate 10-foot long cores, sited to permit an access path for the cores from the aft working deck
- storage for compressed gas cylinders from the science teams
- storage for chemical and other scientific wastes
- storage for helicopter parts, spares, and flight suits
- storage for bulk cargo items to be delivered to Antarctic sites

In most of the classes noted above this would include support for the storage needs of multiple cruise legs. The basic scientific cargo storage space should be at least twice that (Threshold) or ≥3-4 times that (Objective) of the Academic Research Fleet global-class research vessels.

Priorities:

These requirements are rated as "must have, as is", except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as "must have, as is", with the Objective requirements rated as "could manage with something less stringent".

Previous Requirement Language

2012PRVSMR:	Little mention, other than "*Frozen Science Storage space*" and "*Science Storage*".
2016OPPRFI:	"*Walk in refrigerators and freezers for scientific work and sample storage (-20° to 10°C) for science samples*."
2018ASCVSR:	*Need segregations for scientific equipment, workshop raw materials (non-hazardous) and cargo to station. Locations to be considerate of workflow and cargo off load/on load. Volumes and number of segregations TBD. Sufficient planned/segregated hazmat storage area for MLTs with similar segregated space in labs. Dedicated to science, not shared with crew. Safe access when at sea to transfer haz waste from labs to external storage sites. … Removable hazmat lockers shall be provided in certain lab spaces for daily use. … Marine Tech shop/science rigging storage[with] direct access to main deck, ~450 sq. ft, overhead rail, lista cabinets etc*. And: *storage of spares for small boats*.

Discussion:

Scientific storage needs were not covered in the community survey, and survey responses did not mention this issue. Science-related storage on a polar RV is, however, a significant aspect of specification and design, dealing with a multitude of needs and spaces. A research ship operating far from access to commercial ports must be prepared to store significant amounts of scientific cargo - in many classes - for multiple cruise legs. This alone could at least double or triple the science support storage space needs above those recommended for a UNOLS global-class research ship, not including storage for items to be delivered to Antarctic sites, such as Palmer Station or temporary science camps, or for wastes and other materials returned from Antarctic sites. The size requirements are, however, not yet specified in existing documents. [The Ocean-class SMR specification ("approximately 5000 cubic of storage space that could also be used as shop or workspace when needed would be desirable") is not applicable to a large polar RV.] Specifications for the British Antarctic Survey's RRS *Sir David Attenborough* call for ≈ 900 m^3 scientific cargo volume, for the Norwegian Polar Institute's *Kronprins Haakon* a 1,180 m3 cargo hold, and for the Australian Antarctic Division's RSV *Nuyina* 6,500m^3 of solid cargo space (which is the equivalent of carrying 96 containers!). These numbers, aside from being large, do not provide the descriptive detail and specification needed for a USAP polar research (and supply) ship. It may be necessary to carry out further study in order to provide appropriate specifications.

D.2.5.5 Science load

Updated SMR

Sufficient variable science load should be included in weight, draft, stability calculations taking into account the required variable scientific equipment and systems, science storage, vans, helicopters, additional work boats and deck load.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: (not discussed in document)

2016OPPRFI: (not discussed in document)

2018ASCVSR: (not discussed in document)

Discussion:

Service life growth should be included in the calculations.

D.2.5.6 Workboats

Updated SMR

There are two needs for small boats in addition to the requirement for a rescue boat:

1) Transfer of scientists and their gear from ship-to-shore and ship-to-ice to make measurements, install instruments, and collect samples
2) Conduct supplemental research activities that are made away from the mothership.

The research vessel should be equipped with two 20-to-30-ft rigid hull inflatable boats (RHIBs) or the equivalent to address the first need. There are alternatives to the RHIB that are under development, which may be more suitable for operation in the rough and cold seas surrounding Antarctica. These alternatives should be given equivalent consideration. The RHIB (or alternative) location on the research vessel should facilitate safe, easy and efficient launching and recovery.

The research vessel should also include a scientific workboat (~30 ft LOA) specifically fitted out for supplemental operations at sea including data/sample collecting, instrumentation, and wide-angle seismic measurements. The workboat should have 12-hour endurance and include both manned and automated operation and clean construction.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

Recommendations: The research vessel should be equipped with two 20-to-30-ft rigid hull inflatable boats (RHIBs) or the equivalent to address the first need. (The committee notes that there are alternatives to the RHIB that are under development, which may be more suitable for operation in the rough and cold seas surrounding Antarctica. These alternatives should be given equivalent consideration.) The RHIB (or alternative) location on the research vessel should facilitate easy launching and recovery. The research vessel should also include a scientific workboat (~30 ft LOA) specifically fitted out for supplemental operations at sea including data/sample collecting, instrumentation, and wide-angle seismic measurements. The workboat should have 12-hour endurance and include both manned and automated operation and clean construction.

Priority: Must have as specified

2012PRVSMR: *The vessel shall be equipped with sea-worthy boats for scientific sampling.*

2016OPPRFI: (not discussed)

2018ASCVSR: *Space reservations for a zodiac will be required. A launching system for the zodiacs could be specified or improved ability could be added with the recommended articulating crane. … Clear deck area for storage of up to two zodiacs capable of being reached by crane. Can be stored on top of 20 ft storage container.*

Discussion:

There are two needs of small workboats: 1) transfer of scientists and their gear from ship-to-shore and ship-to-ice to make measurements, install instruments, and collect samples and 2) conduct supplemental research activities that are made away from the mothership. There is frequent and continued need to support small boat operations in Antarctic research. A growing need, for example, is for agile, efficient small boat operations in support of autonomous devices deployed from or recovered by a ship. This requires adequate space, siting, and facilities to support safe, quick, functional launch and recovery. Efficiencies count: small boat operations can be limited due to involvement of crew and technicians needed for other concurrent operations. Yet programs relying upon work with autonomous vehicles can sometimes benefit from having more than one boat in the water. Furthermore, Antarctic conditions for small boat operations are frequently faced with challenging conditions. A survey respondent recommended that the "NSF/USAP [should] consider the design of Icelandic small boat called Rafnar, which is considered by the Navy to operate better (significantly better) in rough seas due to unique hull design. See: https://rafnar.is/pages/about-us". Zodiacs were seen to be better for small boat operations than the NBP's "Cajun Cruncher", though adequate space must be provided. However, Zodiacs and other small boats used by the USAP are small and have limited capabilities in sea ice and may not be suitable for shallow-water surveys, very close to shore.

D.2.5.7 Masts

Updated SMR

The ship shall have a permanently mounted foremast that is equipped with an instrument platform for permanently mounted atmospheric and meteorological sensors. The instrument platform shall also be capable of temporarily mounting additional sensors with preinstalled cableways for routing power and data cables. Access to the instrument platform shall be built into the foremast to allow at sea servicing and installation of sensors. The foremast shall be wired by 2 x 20 Amp circuits in a waterproof junction box and include an accessible wireway linking the foremast with interior scientific wireways. Provisions for the installation of ice lights if required should be included in the design of the foremast. The foremast should have at least 3 inlet ports for air sampling. Each port should be connected to ¼" Teflon tubing that run from the foremast through a conduit to the foredeck and into the compartment below the foredeck. The ability to close off the inlet tubes to prevent water seepage when not in use is important. The ability to blow compressed air into the tubing to expel liquid water during sampling is also required. The foredeck should include space for an air-sampling van with clean science power (110V and 220V) available to the van. Similarly, the below deck compartment should have the same power supplies available. Both locations should have access to the science Ethernet. The foredeck van should also be able to incorporate additional inlet tubes and sampling ports that feed directly into the van. Care should be taken that sewage line vents are not located near the van or foremast.

The main mast shall be provided with yardarms capable of supporting five scientific packages each weighing 100 pounds and measuring 2 feet wide by 2 feet long by 3 feet high. This mast should have a clear view of the sky and able to support multiple GPS antennas, meteorological and optical instrumentation. This mast shall have a top working platform of at least 3'x10' in size for servicing instruments, be wired by 4x20 Amp circuits in a waterproof junction box and include an accessible wireway linking the midships mast with interior scientific wireways.

The foredeck should also include a standard deck bolt pattern that easily allows the installation of a temporary (secondary) mast, davit, or crane. The davit or crane would facilitate the mission-specific bow deployments of a temperature/conductivity (or other sensor) chain to sample the undisturbed upper ocean.

There should be the capability to install temporarily larger and heavier atmospheric instruments (e.g., aerosol filter samplers, lidars, and upward looking radiometers, vertically pointing cloud radars) on the deck atop the bridge or other suitable place where there is an unobstructed view of the sky. There should be the ability to secure these instruments to the deck plates or the rails, with unobstructed views of the sky, adequate power, and the ability to connect to the interior scientific wireways.

Because the vessel will often be operating in sea ice, scientists will need to be able to map sea ice and sea ice drift in the regions in which the vessel is operating. This can be facilitated by having the ship's X-band radar data made available in near real time to the science team. Provision should be made to do so.

Mast and Flying Bridge design and layout must consider the mounting and location of Satellite communications systems that allow for unobstructed view of communications satellites.

Priorities: Requirements rated as "must have, as is"

<u>Previous Requirement Language</u>

2012PRVSMR: *The main mast shall be provided with yardarms capable of supporting five scientific packages each weighing 100 pounds and measuring 2 feet wide by 2 feet long by 3 feet high.*

The ship design will incorporate a location with good to excellent full-sky visibility for mounting navigation and attitude antennas. Additionally, the area should be easy and safe to access to mount antennas with easy cable runs to the labs.

A second lightweight and removable mast shall be provided on the foredeck. The secondary mast shall be located as far forward on the bow as possible in a region where airflow is as little disturbed as possible by the ship's structure. The secondary mast shall be designed for easy servicing of installed scientific packages and instruments.

The secondary mast shall be provided with yardarms capable of supporting 5 scientific packages weighing 25 lbs. each and measuring 1 foot wide by 1 foot long by 2 feet high. The secondary mast shall be of adequate height and stiffness to properly support the scientific packages in a region of undisturbed airflow. The secondary mast shall be provided with means (ex. hand-winch) for raising and lowering to allow servicing of installed *sensors in one hour or less. The cranes or oceanographic winches shall not be used for raising or lowering.*

2016OPPRFI: (not discussed)

2018ASCVSR: *A forward instrumented (e.g., foremast) for atmospheric studies combined with a deckhouse design that further enhances the ability of the vessel atmospheric sensors to sample undisturbed air. This will be highly dependent upon deckhouse structure and relative distance to stacks. Mast shall be wired by 2 x 20 Amp circuits in a waterproof junction box. There shall be an accessible wireway linking the foremast with interior scientific wireways. Midships' mast with clear view of the sky for multiple GPS antennas, meteorological and optical instrumentation Mast shall have a top working platform for servicing instruments of at least 3'x10' in size. Mast shall be wired by 4x 20 Amp circuits in a waterproof junction box. There shall be an accessible wireway linking the midships mast with interior scientific wireways.*

Discussion:

The NBP mast is aft of the bridge, which is useless for making air-sea flux measurements. It is unclear if a foremast of the type recommended can be included in an NBP retrofit, although this should be considered. If not, then it may be feasible to make provisions for a removable/portable bow mast (along the lines of the secondary mast discussed above).

The ability to mount a variety of instruments on a permanent foremast and the main mast (as opposed to a temporary or secondary bowmast) should be given highest priority. Users also stressed the desire to include bolting patterns on the foredeck and the masts to facilitate sensor installation and temporary masts and/or davits and cranes. The latter springs from the increasing desire to conduct air-sea interaction studies that would include air-sampling and upper ocean measurements from sensor chains. Lattice-type tower structures should be avoided as these more easily accrete ice, which may become a safety issue for personnel engaged in installation and maintenance of instruments. Several commenters felt that the type of bow mast on the RV *Sikuliaq* is superb and works very well under both icing and heavy weather conditions.

The atmospheric measurement capabilities outlined in the SMR updates respond to the main science questions that motivate this review and the ever-increasing need for air-sea interaction studies. In addition, these updated SMRs would allow scientists to more readily examine:

1. the sources of oceanic and biogenic aerosols and how they impact high-latitude precipitation, clouds, and the atmospheric energy budget, and
2. the dependence of air-sea exchanges on oceanic mesoscale phenomena.

D.2.5.8 Geotechnical Coring and Drilling

Updated SMR

The vessel must 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. Drilling in Antarctic waters typically requires at least one additional ship to reposition icebergs that threaten the drilling ship when engaged in operations.

The vessel must be equipped to acquire long stratigraphic sections (40 - 50 m via a jumbo piston core or other long core system) and be capable of accommodating temporarily-installed geotechnical drilling to 300-400 m below sea floor, at water depths of up to 1250 m in ice covered areas.

Improvement in sediment coring capabilities is linked to adequate laboratory and storage space for initial core analysis and cold storage.

Priorities: Requirements rated as "must have, as is"

<u>Previous Requirement Language</u>

2012PRVSMR: *The vessel must be equipped to acquire long stratigraphic sections (50 m via a jumbo piston core or other long core system and be capable of accommodating temporarily-installed geotechnical drilling to 100 m below sea floor, at water depths of up to 1200 m in ice covered areas. The vessel must be able to core sedimentary sections in ice-covered sea and should be able to support drilling operations as allowed by sea ice movement and available ice-clearing assistance.*

2016OPPRFI: (not discussed)

2018ASCVSR: *...drilling capability ... to penetrate 100 m below the sea floor at up to 1200 m water depth. [Drilling in Antarctic waters typically requires at least one additional ship to reposition icebergs that threaten the drilling ship when engaged in operations.] Notes that: NBP has as 72 inch diameter moon pool located on starboard working deck. The moon pool was added after construction was complete, to accommodate drilling operations. Operations with this moon have been limited in icy waters as the moon pool often gets fouled with ice that is trapped from underneath. Moon pool designs on recent research vessels include a hull closure device that can be operated at sea and a steam de-icing system.*

Discussion:

The MG&G scientific community places a high priority on geotechnical drilling around the Antarctic margin, as drilling is an essential supplement to coring, and is required to tackle the most critical questions facing the marine geologic community. See reports for example, from the 2009 INVEST White paper: proposal for future Antarctic margin paleoclimate scientific drilling under the IODP (https://www.scar.org/library/science-4/research-programmes/pais/3591-ace-antarctic-invest-white-paper/file/); 2012 Antarctic and Southern Ocean Future Drilling Workshop (https://www.scar.org/scar-library/search/science-4/research-programmes/pais/3592-antarctic-drilling-workshop-2012-report/file/) and the 2016 workshop, Antarctica's Cenozoic ice and climate history: new science and new challenges of drilling in Antarctic waters (https://usoceandiscovery.org/wp-content/uploads/2017/04/USSSP_AntarcticCenozoicPaleoclimateWorkshop_FinalReport-Web.pdf).

In conversations with MG&G scientists, several suggested aiming for drilling to 300-400 m below sea floor, an increase over the 100 m in the SMR Refresh and LEIDOS reports. Drilling capabilities and choice of drilling technology impact ship design in terms of space for pipe storage and drilling fluid volume, location and size of a moonpool, and overhead clearance height.

Two primary types of drilling are possible from a new ship – seabed drilling, that is, deployment of a drill rig at the sea floor, or drilling via a more classic mining style rig, top-side. Each style of drilling has its advantages and disadvantages, however seabed drilling, using a system such as MeBo, is not yet a proven technology in terms of core recovery, while top-side drilling, as done for example, with the IODP, has a long history of success. In addition, deployment of a large underwater rig is riskier in terms of loss of equipment at the sea floor. Both types of systems will place similar demands on cold storage space and laboratory facilities, so this text focuses on the two types of drilling options, with the overall recommendation that given the complexities of drilling and the requirements it places on ship design, this is a topic that should be addressed more fully by a group with greater depth and breadth of expertise.

If MeBo70 or MeBo200, or a future version of seabed drilling is utilized, this requires space for up to seven 20-ft containers on deck and space for the hydraulics for seabed drilling, and places specific demands on an A-frame safe working load. The MeBo system can be deployed off the stern or side of the ship but deployment through a moonpool is not recommended because the legs fold down and retract up against the sides. This means that if for any reason the legs fail to retract it would not be possible to get it back through a moonpool. In contrast the legs on the British Geological Survey RD2 are designed differently and it is intended that this should be deployable through a moonpool, as on the RRS *Sir David Attenborough*. One survey respondent noted that "A moon pool type deployment would be preferable, being close to the center of motion and protected from sea ice. But such sea bed drilling systems are designed for a back deck or over-the-side deployment, and I'm not sure they would fit through a 4 x 4m moon pool."

Details regarding operational requirement for MeBo70 and the second generation MeBo200 can be found at:

https://www.marum.de/en/Infrastructure/Sea-floor-drill-rig-MARUM-MeBo70.html
https://www.marum.de/en/Infrastructure/MeBo200.html

Details regarding the RD2 drill can be found at:

https://www.bgs.ac.uk/scienceFacilities/marine_operations/15m_rockdrill.html

Seabed drill rigs, despite being connected to the ship by a flexible umbilical cable, require quite limited vessel movement during drilling. The exact radius limit depends on water depth and the drilling system but may be as little as 10 m or less over a period of up to two days. So, seabed drilling may require improved DP and potentially a need for passive heave compensation. Also, for seabed drill rig operations, the ship will require open water conditions, both for station-keeping and for a back-deck deployment and protection of the umbilical.

Two respondents commented on the space requirements for seabed drilling - that "Seabed drill rigs require a lot of deck space - e.g. for the British Geological Survey Rock-Drill2 (RD2), 7 x 20ft containers, ~ 100,000 kg, as well as space for the launch system and winch. The German MeBo drill rig requires use of a substantial A-frame and has a similar deck space requirement."

While seabed drilling is a possible choice for the new USAP ship, given that this appears to be the path for drilling from the RRS *Sir David Attenborough*, and the long history of successful drilling and high core recovery using the more classic mining style rig, we suggest that USAP strongly consider this second option. Several styles/models of drilling rigs are currently available and described by DOSECC ("a geoscience-driven, engineering and core drilling services firm with 30 years' experience completing projects around the globe"; http://dosecc.com/services/systems/); other options and designs are also possible. Creative solutions for top-side drilling are a priority here. Specifics that will impact ship design include the minimum size of a moonpool, overhead clearance height rig access (at more than one level), overall footprint and weight, and the need for heave compensation. (This suggests provision for a science hangar with a sliding roof over the moonpool so there is the option of installing a drill rig over it. Such a sliding roof could form part of a helideck in normal use, providing it can be made strong enough. This was a concept developed for the Polarstern 2 design.) The closer the weight of a rig is to the center of the ship, the safer the drilling operations, so this places limits on the position of the moonpool. To accommodate rig height, perhaps the rig could be situated such that it could be at least partially enclosed by temporary shelter, rather than permanent ship structure. This could be facilitated by an overhead closing, sealable "door".

With any style of added drilling capability, other considerations for ship design include the need flexible and large lab spaces for working on cores, with space available for splitting cores, describing cores, automated non-destructive characterization, and sampling of cores. One scientist noted the need for space appropriate for geochemical analysis, including hoods that can be used with HF. Core storage refrigerated space at + 4°C should be large enough to store cores and contain racks to hold the cores safely.

Finally, several respondents discussed a need for "longer" coring, with that number as either 30 meters or 40 meters. The limit on the NBP is 25 meters, with the limit a function of the free space on the starboard rail. Longer coring operations would require addressing the winch and A-frame systems, which are not adequate on either vessel. One respondent also noted a preference to switch to synthetic line.

Given the complexities regarding choice and design of geotechnical drilling capabilities for a new polar research vessel, and the implications of this choice on ship design, this committee recommends more comprehensive analysis.

D.2.5.9 Moon pool operations

<u>*Updated SMR*</u>

The vessel shall be designed with a moon pool that meets the following requirements:

- 4 meters by 4 meters in size, with sufficient internal overhead clearance for Jason, Ropos, Mebo, to allow temporary installation of drilling rigs (see Geotechnical Drilling above).
- The moon pool must be closed to the sea when not in use. Capable of being pumped down free of water and ice when the bottom door(s) for the pool are closed.
- Include a system to clear ice when in use.
- Accessible from an environmentally controlled compartment with sufficient space and support systems to enable the deployment of scientific gear including CTDs, ROVs, VPRs, nets, drilling systems, portable ADCPs, etc.
- Shall be supported by the same oceanographic winches that support over the side operations.
- Located as close to the center of motion of the ship as is practicable so as to minimize the impact of the ship's motion.

Priorities: Requirements rated as "must have, as is".

<u>Previous Requirement Language</u>

2012PRVSMR: *The moon pool shall meet the following requirements:*

4 meters X 4 meters in size, with sufficient internal overhead clearance for Jason, Ropos, Mebo, to allow temporary installation of drilling rigs (see Geotechnical Drilling above).

The moon pool must be closed to the sea when not in use. Capable of being pumped down free of water and ice when the bottom door(s) for the pool are closed.

Accessible from an environmentally controlled compartment with sufficient space and support systems to enable the deployment of scientific gear including CTDs, ROVs, VPRs, nets, drilling systems, portable ADCPs, etc.

Shall be supported by the same oceanographic winches that support over the side operations.

Located as close to the center of motion of the ship as is practicable so as to minimize the impact of the ship's motion.

2016OPPRFI: (not discussed)

2018ASCVSR: *The moon pool requirement was not included in the RFI. Therefore, Leidos is not specifying a moon pool in new vessel specifications.* But in the specs. there is this note: *4m x 4m moon pool for ROV/AUV Launch & Recovery, with bottom closure and ability to be pumped dry when not in use. Situated to be served by secondary .322 overboarding system.*

Discussion:

Please see preceding discussion of geotechnical drilling. A moon pool is considered a requirement for this to be accomplished. As noted in section D.2.5.8. (Geotechnical Coring and Drilling), in order to maintain the potential for geotechnical drilling via a topside "mining style" rig, overhead opening doors for the moonpool into an open space is needed, located as close to the center of motion of the ship as is practicable so as to minimize the impact of the ship's motion.

D.2.5.10 On deck incubations

Updated SMR

Deck incubator positions (unshaded by structure) with a means for securing to the vessel shall be provided. Seawater delivery to each incubator with a flow capacity of 50 gallons/min is required. The total number of incubators to be serviced at one time should be determined taking into account available deck space and input from science users and will determine total pump capacity required. It should be possible that at least two deck incubators can be used simultaneously side-by-side. Plumbing should include valves that can be fine-tuned to adjust flow rates. Incubator seawater should be within 1°C of ambient seawater temperature. Outflow drainage will be required, the bigger the drainage hole the better. Design criteria must take into account operations in freezing weather, particularly when air temperatures are well below seawater temperatures causing drain lines and water discharged on decks to freeze. Heat tape right at the outflow can be useful in preventing freezing. Deck space designated for incubators should preferably be located on the same deck as the CTD station such that researchers conducting experiments that make use of large amounts of seawater collected from the CTD do not have to hand-carry heavy buckets of seawater up stairwells, which increases the risk of falling and injury.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR:

2016OPPRFI: (not discussed)

2018ASCVSR: *Deck Incubator Positions (unshaded by structure). Seawater delivery to unshaded deck area for Incubators (currently 4 ea. supply/return). Incubator/washing water; 400 liters/min on deck, science sinks, van sites.*

Discussion:

The committee as well as survey respondents noted the fundamental need for dedicated and well-engineered deck incubators with flowing ambient seawater. One respondent suggested that "the system would be even better if temperature/ light/ ocean acidification control systems could be engineered into it." Specific concerns and design criteria are addressed above.

D.2.5.11 Marine mammal & bird observations

Updated SMR

Design of the pilothouse area and/or flying bridge should include provisions for making weather-protected, heated, and obstruction free (at least a combined 180 degrees forward of the beam) observations by two to three scientific personnel. Bird and mammal observers will be on watch continuously during daylight hours and observation locations should include secured, but removable chairs, access to the navigation/data network, and a protected location for portable computers and/or logbooks. Mounting locations for big eyes or similar devices may be required for some observers. Observer locations should be free from radiation hazards generated by radars and other communication equipment.

Provision of an icebridge proving these capabilities could also be considered.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: (not discussed)

2016OPPRFI: (not discussed)

2018ASCVSR: *Icebridge or marine mammal observation area to be determined. Is ice bridge desired by scientists?*

Discussion:

The SMR recommendations given here are consistent with the ocean and regional class research vessel SMRs pertaining to marine mammal and bird observations

D.2.6 Science and shipboard systems

D.2.6.1 Navigation

Updated SMR

Best available navigation (real-time kinematics, differential, P-code, and 3-axis GPS) capability shall be provided with appropriate interfaces to data systems and ship control processors for geo-referencing of all data, dynamic positioning, and automatic computer steering and speed control. Backups and redundant systems should be provided to ensure continuous coverage. Best available electronic charting (e.g., ECDIS) and bridge management system shall be provided. GPS aided attitude heading reference system (AHRS) and/or other available systems for determining ship heading, speed, pitch, roll, yaw, etc. as accurately as possible should be installed and integrated into ship and science systems.

Bridge navigation, management, and safety systems will meet all regulatory requirements and facilitate effective science operations with minimal manning. Systems should be designed so that any changes to bridge navigational display and control systems will not have any effect on science data collection processes. Communication of waypoint information between science and bridge system should be an integral part of the system. Specification, purchase, and installation of systems should take place as close to delivery as possible to ensure the most up-to-date systems. Provisions for temporary installation of short or ultra-short baseline acoustic systems and other navigations systems when necessary should be included so that they can be integrated with existing systems.

ABS Requirements for Notation NIBS (Navigational Integrated Bridge System) should be considered as a design and construction requirement.

Priorities: Requirements rated as “must have, as is”

Previous Requirement Language

2012PRVSMR:

2016OPPRFI: (not discussed)

2018ASCVSR: *Redundant navigational equipment; normal navigation equipment/requirements.*

Discussion:

Bridge Navigation Systems for most recent Research Vessels have been integrated systems often designed according to the ABS Navigational Bridge Systems Notation (NIBS). This supports safe vessel navigation, science cruise planning and operational data access.

D.2.6.2 Data network, onboard computing, and data processing

<u>*Updated SMR*</u>

High-speed data processing facilities capable of handling large data sets for rapid processing, display, evaluation, and archiving are needed. Typical data sets might include: LiDAR elevation surveys from glaciologists, seismic imaging and multibeam swath map output. It should also include receiving real-time updates of the ship's navigation data and disposition of the X-band radar data for analysis by the science party.

A split IT network with dedicated USAP servers and other equipment separate from any crew IT network is necessary. Four network drops per stateroom are required (2 - person owned computers, 1 - smart tv, 1 - IP phone). 1 network drop per common area, lab and others to be defined for WIFI (WAP). 2 drops per station in all computer / dry lab areas. 4 network drops in IT / ET workshop. CCTV must be available in every lab. A central command station for all operations must be available, this includes a radio and CCTV at hand, and room for a number of monitors. GPS strings must be available in every lab. All labs should have WIFI access and LAN drops, at least every 4 bench feet.

Data processing-related comments from the user survey included the need for the addition of "remote access to instrumentation control and data, and video presence". One respondent stated that "quality of the data, the data coverage and the accessibility of data coming off the ships" is sometimes less than clear. This person was referring to meteorological data, underway seawater measurements, XBT transects during crossings, and ADCP data.

A data presence system shall be capable of local (ship-based) data processing and further visualization of real-time data with the potential for a shore-side component. The shore-side component may not be as important in the new Antarctic vessel/s, but if it is something of interest then the limiting factor is always going to be bandwidth, so this should be kept in mind.

When dealing with large datasets there are important considerations that need to be made. For example, for the multibeam, data processing tools are required, as is an added level of expertise to run the software. Having these systems already installed on the ship will enable PIs to efficiently plug-and-play the instrument they need and visualize data in real-time. Therefore, it is recommended that user input be sought by the NSF to identify key data-intensive instruments needed by a wide user group and to have these and the support systems they require set-up on the vessels.

Finally, in terms of facilities necessary, it is essential that there be a lab dedicated to servers, etc. that has adequate space for racks and other DAS equipment.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *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.*

2016OPPRFI: *LAN, voice and CCTV connections throughout laboratories and living spaces, preferably via fiber-optics running throughout vessel.*

2018ASCVSR: *A split IT network with dedicated USAP servers and other equipment separate from any crew IT network. Network Drops - 4 drops per stateroom (2 - person owned computers, 1 - smart tv, 1 - IP phone). 1 drop per common area, lab and others to be defined for WIFI (WAP). 2 drops per station in all computer / dry lab areas. 4 network drops in IT / ET workshop. CCTV must be available in every lab. central command station for ops must be available, radio must be near, CCTV near, room for many monitors. GPS strings must be available in every lab. All labs should have WIFI access and LAN drops, at least every 4 bench feet.*

Discussion:

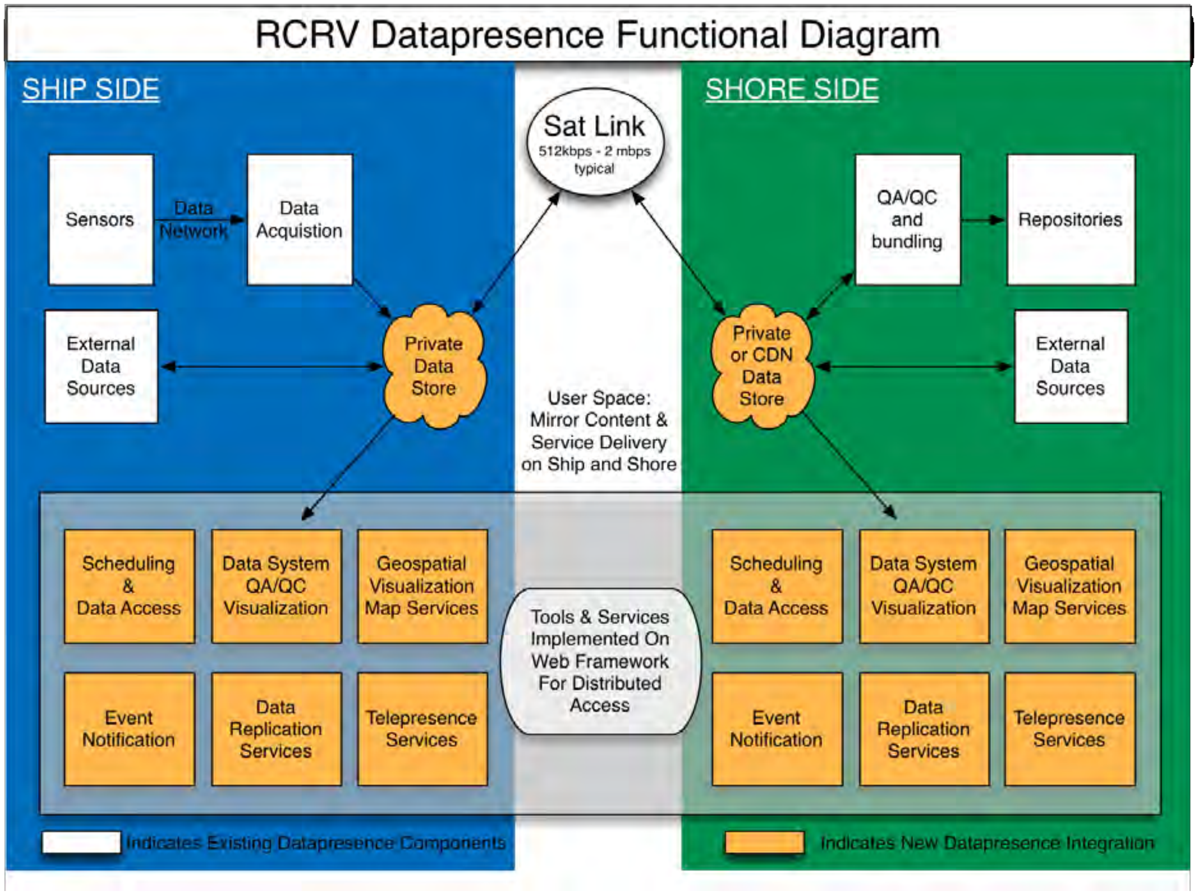
A number of respondents emphasized the need for more bandwidth and greater internet connectivity on the USAP vessels. They stated that the "restrictive internet access made science difficult at times." Specifically, downloading relevant papers and software, and transmitting data from the ship to shore-based PIs and researchers. Some respondents need the ability to "receive high-resolution remote sensing data", noting that the current "bandwidth is not generally sufficient to handle downloads of real-time large volume datasets." One respondent noted that the "recent upgrades to internet services and capacity are much better than they have been in the past".

Other data processing-related comments revolved around the addition of "remote access to instrumentation control and data, and video presence". Another respondent stated that "quality of the data, the data coverage and the accessibility of data coming off the ships" is sometimes less than clear. This person was referring to meteorological data, underway seawater measurements, XBT transects during crossings, and ADCP data.

The Leidos report had no clear specifications on data processing.

What follows is information received from a member of the RCRV Datapresence team, Katie Watkins-Brandt.

Below is a functional diagram of the datapresence system for RCRV.



This illustrates the flow of how the Datapresence team on the RCRV have designed the system to be capable of the local (ship-based) data processing and further visualization of real time data, the other side of this is the shore-side component. The shore-side component may not be as important in the new Antarctic vessel/s, but if it is something of interest then the limiting factor is always going to be bandwidth, so this should be kept in mind.

The above poster, although slightly out dated from RVTEC of 2016, outlines all of the major component layers of the RCRV datapresence system. The Service Layer is the one that is likely to be most pertinent with regards to data processing on the new polar vessel/s. The idea is to have different levels of data to access and a fair amount of processing that occurs on the ship for local, real-time visualization. For the RCRV, much of the QA/QC will occur on shore by a team there. A system like this will not succeed without proper support. Computer technicians assigned to Antarctic research cruises will be invaluable for this support. With a computer technician the running of the system is covered but there is still QA/QC component that should be addressed. Also, some instruments require specialized data processing skills.

D.2.6.3 Real time data acquisition system

Updated SMR

A well designed "system" is required for real-time collection of data from permanently installed sensors and equipment as well as from temporarily installed sensors and equipment that allows for archiving, display, distribution, and application of the data for a variety of scientific and ship-board purposes. This system should be designed and specified by a group of knowledgeable science users and operators. Further, this system should be integrated with the data network and other onboard systems with access to data and displays available in staterooms and all working spaces. It should include real-time updates of the ship's navigation data and disposition of the X-band radar data for analysis by the science party. While planning for this system should begin at early stages to ensure that it is integrated into the ship's infrastructure, the actual specification of hardware and operating system should be made as close to the delivery of the vessel as possible to ensure an up-to-date system.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: (not discussed)

2016OPPRFI: (not discussed)

2018ASCVSR: (not discussed)

Discussion: (The recommendation is self-explanatory.)

D.2.6.4 Communications – internal

Updated SMR

Internal communications includes phones, PA, entertainment systems, ship alarms, some bridge comms, via LAN, voice and CCTV connections throughout laboratories and living spaces, preferably via fiber-optics running throughout vessel.

Internal communication system providing high quality voice communications throughout all science spaces, working, berthing areas should be provided, and be available to all inhabited vans. Point to point and all-call capabilities are required such as 21mc and 1mc systems. A sound powered phone emergency system should be included.

All staterooms should have phones for internal communications. A primary and backup (spare) telephone switch capable of providing one voice line to every space on the ship and access to off-ship services such as INMARSAT or equivalent equipment should be provided. Voice telephone wiring to all spaces on the vessel should be installed.

Consideration should be given to including installed equipment to support pagers, mobile phone/radio (UHF) communications, or other versatile methods for contacting personnel.

Alarm and information panels should be installed in key workspaces, common areas, and all staterooms. The alarm system and information panels should connect to vans seamlessly.

The ability to install closed circuit television monitoring and recording of working areas should be provided to improve operations and safety. There should be CCTV outlets in all science spaces and staterooms, with channels available in those locations to monitor science operations and environmental conditions. The ability to install monitors (flat screen) for all ship control, environmental parameters, science and over the side equipment performance should be available in all, or most, science spaces, common areas, and staterooms.

Infrastructure for internal communications and data networks should adhere to IEEE 45 standards (or current guidelines) for keeping signal and power wiring separate and other safe reliable design considerations.

While planning for this system should begin at early stages to ensure that it is integrated into the ship's infrastructure, the actual specification of hardware and operating system should be made as close to the delivery of the vessel as possible to ensure an up-to-date system.

Priorities: These requirements are rated as "must have, as is".

Previous Requirement Language

2012PRVSMR:	*no specifics*
2016OPPRFI:	*no specifics*
2018ASCVSR:	*Includes phones, PA, entertainment systems, Ship Alarms, some bridge comms.*

Discussion: (The recommendation is self explanatory.)

D.2.6.5 Communications – external

Updated SMR

Primary high-speed Internet access will be provided by a Very Small Aperture Satellite (VSAT) system. A location for installing a 2 to 3 meter VSAT or similar actively stabilized antenna will be provided in the design with a full-sky view. Above 70 degrees Latitude Internet connectivity will be provided by ganged (load equalized) systems via Low Earth Orbit (LEO) satellite systems such as Iridium Pilot, or one of several emerging LEO offerings that may provide more bandwidth than Iridium over the poles. A flat panel phased array antenna should be considered.

The operating area and schedule of the ship will probably require it to be outside of VSAT footprints often and therefore a location for an Inmarsat™ antenna such as a Fleet Broad Band™ will also be required. Goal should be a radio uptime requirement of 99% uptime for satellite radios, either by dual radome or some other means

Ship-based weather satellite receivers (e.g. Terascan™ and Dartcom) provide real- time visual and infrared imagery from NOAA HRPT and DMSP satellites with no delay. The PRV design will have a suitable mounting location for a 1.5m dynamic antenna to support direct satellite reception.

A split IT network with dedicated USAP servers and other equipment separate from any crew IT network is recommended. Due to limited top deck space, it is likely that satellite antennas will need to be shared between the ship and USAP IT networks.

The technical specifications for external communications should be re-evaluated at final design time to take into account recent technical developments. The actual specification of hardware and operating system should be made as close to the delivery of the vessel as possible to ensure an up-to-date system.

Priorities: These requirements are rated as “must have, as is”.

<u>Previous Requirement Language</u>

2012PRVSMR: *Primary high-speed Internet access will be provided by a Very Small Aperture Satellite (VSAT) system. A location for installing a 2 to 3 meter VSAT or similar actively stabilized antenna will be provided in the design with a full-sky view. Above 80 degrees Internet connectivity will be provided by ganged (load equalized) systems via Low Earth Orbit (LEO) satellite systems such as Iridium Openport™ . The operating area and schedule of the ship will probably require it to be outside of VSAT footprints often and therefore a location for an Inmarsat™ antenna such as a Fleet Broad Band™ will also be required.*

Ship-based weather satellite receivers (e.g. Terascan™ and Dartcom™) provide real- time visual and infrared imagery from NOAA HRPT and DMSP satellites with no delay. The PRV design will have a suitable mounting location for a 1.5m dynamic antenna to support direct satellite reception.

2016OPPRFI: (not discussed)

2018ASCVSR: We recommend a split IT network with dedicated USAP servers and other equipment separate from any crew IT network. Due to limited top deck space, it is likely that satellite antennas will need to be shared between the *ship and USAP IT networks. ...Primary high-speed internet access will be provided by Very Small Aperture Satellite (VSAT) or similar actively stabilized antennas. The vessel will have a secondary unique system to provide redundancy with an auto-failover capability to maintain continuous internet connection. These antenna systems will include internet service to a minimum of 70 degrees latitude and have a bandwidth greater than 3Mbps bidirectional with options to increase bandwidth as needed. Above 70 degrees, the vessel will have a Low Earth Orbit (LEO) system such as Iridium OpenPort or similar system to provide global internet access.*

Discussion: (The recommendation is self-explanatory.)

D.2.6.6 Scientific Seawater System

<u>Updated SMR</u>

Flow-through scientific seawater system capable of delivering >40 liters/minute (threshold) / 100 liters/minute (objective) to all laboratory spaces. Include an alarming system for seawater if it over pressurizes or shuts off. Anti-icing: develop requirements to deal with de-icing that does not affect seawater requirements. Piping material should be corrosion resistant and as chemically neutral as possible within the limits of regulatory requirements.

The underway seawater sampling system should consist of an intake near the bow and the surface to provide uncontaminated seawater, resistant to ice-clogging, while the ship is underway and/or stationary. Careful attention to system design for operations in ice is necessary to minimize and mitigate ice-clogging drawing on lessons learned from other ice capable research vessels. A secondary intake location for use if the primary intake is compromised by heavy seas or ice clogging.

This system will support a suite of standard sensors (temperature, conductivity, depth, and fluorescence), but also be flexible enough to include multiple ports for additional sensors. The system should be designed to optimize flexibility and maintenance. A minimal lag time between intake and arrival at the sensor packages and the lab sinks with an objective of less than 2 minutes is desired.

Final location of intakes for underway seawater sampling should be determined following final hull design to minimize thermal contamination, bubbles, intake blockage, and to maximize water flow.

The underway system should be designed with the following criteria:

1. Minimize the time lag between intake and sampling location (sensor suite and/or lab sinks). If more than one intake is installed ensure that the intake being used is flagged in the data stream.

2. Provide underway seawater taps at least 4 sinks in lab-accessible spaces (although the more access points the better should be the rule). This will allow users to configure to either continuous or discrete sampling of underway seawater according to their needs. Additional access points should be provided in sinks in other labs (chem. labs, trace metal labs, wet lab, and ability to access underway seawater from labs in vans on deck). While these sinks will not be used exclusively for underway seawater sampling this arrangement provides the option for cruises that will utilize underway flows extensively for a variety of sampling. User-supplied sensors that would be installed near sinks include flow cytometers, LISST (laser-based particle imaging), and cavity ring down systems for measuring gases (CH_4 and N_2O) and pCO_2. However, all of these could be installed next to a sink with seawater access. It is important to minimize the time between water intake and delivery of the intake to the sink.
3. The underway system should be designed so that any additional sensors (user-supplied or ship-supplied and not requiring a sink) can be mounted in close proximity to the ship's 'standard' CTD-fluorometer package. The likely suite of additional sensors would include optical sensors (backscatter, transmissometer, additional fluorescence sensors), nitrate (suna or ISUS), pH (Seabird), O_2 (SBE 43 or optode-based). Although these additional sensors could be standalone with their own datalogging, the underway system should be designed to allow the voltage output to be recorded and merged with the ship's underway data feed. It is important to minimize the time between water intake and delivery to the sensors.
4. The foredeck should have a standard deck bolt pattern that easily allows the installation of a davit or crane that would facilitate the mission-specific bow deployments of a temperature/conductivity (or other sensor) chain to sample the undisturbed upper ocean.
5. The underway sampling system should include an infrared sensor installed at the bow for measuring sea surface skin temperature.
6. Maintenance of the underway sampling system is critical for obtaining high-quality data. The system should be designed to conduct periodic (approximately daily) back-flushes with freshwater or a dilute bleach rinse, to prevent accumulation of growth/biofilms in the underway plumbing. The system should have the ability to access coarse strainers for conducting daily rinses. This can be done by bifurcating the inflow so that one side can be taken out of line for cleaning.
7. The foremast should include ducting so that underway air-sampling can be undertaken with the air ducted through the ship to and accessible via ports in the main, wet and chemistry labs.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *A flow-through science sea water system: ~10-20 liters/minute maximum, for instrumentation (TSG, fluorometers, nitrogen analyzer, flow-through mass spectrometers, DO, pCO_2 etc.) only, not for sampling. This system* *will be driven by a separate pump (and spare) from the sampling, incubator cooling water and washing water.*

2016OPPRFI: *Flow-through scientific seawater system capable of delivering >40 liters/minute (threshold) / 100 liters/minute (objective) to all laboratory spaces.*

2018ASCVSR: *40 lpm to all lab spaces (threshold); 100 lpm to all lab spaces (objective). Must be seawater system drops to accommodate "seawater wall" in at least 2 labs. Primary and backup. Include an alarming system for seawater if it over-pressurizes and shuts off. Anti-icing: develop requirements to deal with de-icing that does not affect seawater requirements.*

Discussion:

The underway sampling system should consist of an intake near the bow and the surface to provide uncontaminated seawater, resistant to ice-clogging, while the ship is underway and/or stationary. This system will support a suite of standard sensors (temperature, conductivity, depth, and fluorescence), but also be flexible enough to include multiple ports for additional sensors. The system should be designed to optimize flexibility and maintenance. Users want a minimal lag time between intake and arrival at the sensor packages and the lab sinks. The range in lag times is as long as 9 minutes on the Healy and less than 2 minutes on the *Sikuliaq*. Users seem happy with the latter but not with the former.

The Subcommittee received a report on the NBP's scientific seawater system performance, written by the underway pCO_2 scientific team for the NBP (Appendix 4). Here we summarize key points:

- There are two inlets for the underway water sampling system on the NBP: The so called "Stern thruster tunnel" inlet is the primary one and the alternate inlet is located in the "moon pool". Intake is selected manually: the intake is switched to the moon pool inlet when the stern thruster is used or when heavy ice prevents a good flow of water to the pumps. Due to persistent problems with ice in the moon pool, that option is rarely used.
- The shipboard data system flags the inlet for seawater, which is important for assessment of water sample quality.
- The two water inlets are located close to each other, and the pipes from the inlets are joined to the common piping system in a very short distance. A remote temperature probe is located at a short distance from the pipe junction. Salinity of the pumped water is measured by a TSG unit located in the hydro lab after the water is passed through a degasser.

- The performance of the science seawater system on the Palmer in ice fields, evaluated using temperature data, was evaluated as stable (0.2 ± 0.05°C). This indicates that the underway pumping system supplies a steady stream of seawater in a sufficient rate for scientific studies in ice fields.
- The quality of pumped water samples, evaluated based on the underway pCO_2 values obtained during transits through ice field waters, indicates uniformity of chemical properties of pumped water in time. When SST and salinity fluctuated suggesting small-scale variations of waters, the pCO_2 values suggested corresponding changes in chemical properties.
- Small ice particles are sometimes transported through the pumping system into the equilibration chamber of air CO_2 with seawater sample. In extremely heavy pack ice conditions, ice particles accumulate in the pCO_2 equilibrator, and have to be drained periodically by the technicians on board. This indicates uncertainty in the pCO_2 measurements (and associated temperature and salinity data) in sea ice fields. Although the uncertainty may be small, a detailed study has yet to be made.

The report shows that the performance of the NBP's present system is satisfactory in some ways. But discussions with the community showed that performance improvements in polar research vessel underway seawater systems, relative to that of the NBP, are needed. This is reflected in the SMRs and their high priority.

D.2.6.7 Acoustic systems (including deep and shallow multibeam, echosounder, sub-bottom profiling; ADCP)

Updated SMR

The hull design and structure for transducer installation should support the installation and operation of the following systems:

- Deep Ocean multibeam bathymetric mapping system
- Shallow Water multibeam bathymetric mapping system
- 38 kHz and 75 kHz Acoustic Doppler Current Profilers, and if space permits, a 150 kHz or 300 kHz system for use in shallow water.
- 3.5 kHz Sub-Bottom Profiler, CHIRP or Parametric Narrow Beam
- 12 kHz Echosounder
- Bioacoustic Sonars – 38, 120 and 200 kHz transducers as a minimum, 18 and 70 kHz desired in addition.
- Ultra-short baseline (USBL) underwater systems positioning transponder
- 12 kHz Acoustic Release transponder
- Hydrophones and Hull-mounted Underwater Cameras
- Other Requirements:
    - At sea transducer maintenance capability wherever possible.
    - A drop down keel in order to minimize effects from bubble sweepdown and provide additional science capability for the installation of mission specific equipment without need of a dry dock should also be considered carefully.
    - Hull design or features designed to minimize bubble sweepdown

- ○ Noise and vibration treatments to minimize SONAR self-noise

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *Multibeam - Deep: Reliable, well-known deep water multibeam swath mapping echo sounders with a 1° x 2° array or 1° x 1° array installed behind ice protection windows (eg Kongsberg EM122 add trademark). Supporting equipment for the multibeam systems will include primary and backup attitude, position, and heading reference providers, such as the Applanix POS/MVTM.*

Multibeam - Shallow: Reliable, well-known deep water multibeam swath mapping echo sounders installed behind ice protection windows (eg EM710TM) for high quality data collection on continental shelves and upper slopes. Supporting equipment for the multibeam systems will include primary and backup attitude, position, and heading reference providers, such as the Applanix POS/MVTM.

Echosounder: Reliable, ice-protected, hull mounted sub-bottom profiler operating in the 3.5 kHz range. Typical systems are either FM-modulated (CHIRP) such as a Knudsen 3260, parametric (narrow beam) system such as the Atlas Parasound or Kongsberg Topas. The sub- bottom may be integrated with the multibeam, e.g. Kongsberg SBP120TM.

Sub-bottom Profiler: A number of science objectives require routine operation of a sub- bottom profiler. The vessel should be equipped with a reliable, ice- protected, hull mounted sub-bottom profiler operating in the 3.5 kHz range. Typical systems are either FM-modulated (CHIRP) such as a Knudsen 3260TM, parametric (narrow beam) system such as an Atlas Parasound™ or Kongsberg Topas™ . The sub- bottom may be integrated with the multibeam, e.g. Kongsberg SBP120TM.

Acoustic-Doppler Current Profiler (ADCP): Acoustic-Doppler Current Profilers to meet low and high frequency surveys is required. Typical systems are the Ocean-Surveyor 38 and the Ocean Surveyor 150 kHz systems.

2016OPPRFI: *Deep ocean multibeam bathymetric mapping system (threshold); Deep ocean and mid-level multibeam systems (objective).*

2018ASCVSR: *Deep Ocean multibeam bathymetric mapping system*

Shallow Water multibeam bathymetric mapping system

38 kHz and 75 kHz Acoustic Doppler Current Profilers, and if space permits, a 150 kHz or 300 kHz system for use in shallow water.

3.5 kHz and 12 kHz Sub-Bottom Profiler (Echosounder)

Bioacoustic Sonars – 38, 120 and 200 kHz transducers

Ultra-short baseline (USBL) underwater systems positioning transponder

12 kHz Acoustic Release transponder

Hydrophones and Hull-mounted Underwater Cameras

Also: *...at sea transducer maintenance capability* .. and … *drop down keel in order to minimize effects from bubble sweepdown and provide additional science capability for the installation of mission specific equipment without need of a dry dock.*

Discussion:

Consideration should be given to including a retractable centerboard as installed on the Sikuliaq. The centerboard appears to minimize effects from bubble sweepdown and provides additional science capabilities via the installation of mission specific equipment without need of a dry dock. It may also permit easily adding other acoustic devices to the vessel for testing and/or mission specific requirements.

D.2.6.8 Seismics

<u>Updated SMR</u>

The science objectives require periodic use of a broad range of marine seismic sources for reflection and/or refraction studies. The vessel should have the power and infrastructure to deploy seismic gear, including towed multichannel streamers at speeds of 3.5-4.5 kts in moderate (3/10-4/10) sea ice cover.

Recommend the continued inclusion of onboard compressors for seismic operations. The compressors currently on the NBP, Seismic Air Compressors (Borsig-LMF) 1,200 scfm at 2,000 psi, are adequate.

Priorities: Requirements rated as "must have, as is"

<u>Previous Requirement Language</u>

2012PRVSMR: *The science objectives require periodic use of a broad range of marine seismic sources for reflection and/or refraction studies require substantial infrastructure including large volume (100 SCFM to 1,000 SCFM), high* *pressure (3,000 PSI) air compressors. At a minimum the vessel should be designed to accommodate operating a range of compressor sizes in protected space near the fantail. A careful technical and cost analysis of the total cost of ownership (TCO) over 20 or 30 years may lead to a decision that the optimum solution would be to build the compressors into the ship and carry their maintenance as part of normal operation.*

2016OPPRFI: *Ability to tow a multi-channel seismic streamer and provide compressed air supply.*

2018ASCVSR: *Compressed air needed for seismic and other lab needs; Seismic gear, including towed multichannel streamers at speeds of 3.5-4.5 kts in moderate (3/10-4/10) sea ice cover.* The ASC report indicates that seismic operations on NBP utilize government furnished air compressors that are installed below decks.

ASC believes that future seismic operations can be supported by skid mounted systems located on the working deck and no compressors will be specified. With new technology and regulations, smaller seismic compressors would provide adequate air volume and could be leased based on the frequency of use and the upkeep required. Further investigation can be done if desired. Necessary power requirements would need to be specified to support skid mounted gear on the deck. However, compressors could be specified as an optional requirement and some operators may choose to outfit their vessels as such to enhance their bid. Leidos requests confirmation on this requirement.

Follow-on action: Confirm if seismic compressors are to be specified on new vessels.

Discussion:

While only 20% of respondents noted that seismic capabilities were critical to their research, these respondents expressed that we “absolutely need seismic capability for NSF polar research to drive our knowledge of ice proximal records particularly and to set us up for piston coring or drilling.” One respondent asked for a “consensus statement about the importance of supporting marine geologic operations, including geotechnical drilling, due to the need for data model integration for future ice sheet predictions.” Further, they stated, “There should also be a consensus statement about the need for shipboard compressors and support for marine seismic and site survey activities, given the need for additional drilling and coring activities in the Southern Ocean and Antarctica's shelves.”

The MG&G community prefers built in compressors, although having the compressors located within containers has two advantages – (1) allows for greater access for routine maintenance and (2) the container(s) could be used on multiple platforms.

Rentals are the least preferred option. While you can rent a seismic compressor and technicians to run it, the long transits and duration of cruises will make such rentals very expensive. These rentals are paid from the moment the compressor vans leave the company's door to the moment it arrives back and the technicians are similarly so funded. Respondents worried that "if no built-in compressors were available portable systems requiring full size compressors would become fiscally untenable. Note such compressors are needed for anything from multiple GI guns through regular airguns. Only very high res systems can be run with portable compressors of the type academic institutions own (e.g. 25 scfm or smaller). Given these arguments I would see we absolutely want at least one of our polar vessels to have onboard compressors and capable of supporting GI gun or larger operations. Additionally, the size of this vessel should be such that the same vessel can do piston coring as combined seismic-piston coring expeditions can be very efficient use of NSF resources."

Finally, one respondent suggested that NSF consider more capable small boat operations to conduct coastal work. They noted "something that is 20-30 feet long with an a-frame or heavy-duty davit capable of towing equipment (shallow seismic, fish nets, etc.) that could be deployed in a faraway fjord from a research vessel might be a real addition to the USAP capabilities."

One additional request from marine geophysics community is that the ship has the capability of conducting limited 3-D seismic operations. This is addressed in section D.2.4.4. Towing.

D.2.6.9 Project science system installation and power

Updated SMR

The Science Mission Requirements in general are designed to support the provisions required for installing equipment that is brought on board occasionally such as SeaSoar, MOCNESS, MR1, Deep Tow, towed sonars, portable seismic reflection systems, gravimeters, and specialized ADCPs. Taut and slack tether ROVs, AUVs, remotely piloted aircraft, and other systems should also be readily accommodated. A very wide variety of scientist-supplied sampling and laboratory equipment must be accommodated, in a variety of locations on the ship, including, but not limited to, all laboratories, all science decks, and access points on the scientific seawater system, including near the intake. The types of equipment will need to be defined during concept and preliminary design cycles, and as much flexibility as possible should be designed. Generally providing power sources, deck space, mounting locations, and data connections will accommodate most needs, however, in some cases it may be necessary to provide fuel, hydraulic power or other services.

The electrical system capacity and design should take into account provisions for the cruise variable connection of systems with large electrical motors or power demands. Provision for multiple simultaneous connections should be possible for 480V 3-phase, 208 – 230V 3-phase and single phase, and 110V single phase with up to 50 amps service for vans, laboratories, and on deck. Final design specifications should take into consideration common electrical requirements for currently used and planned equipment, and excess capacity should be designed in to the maximum extent possible.

Priorities:

These requirements are rated as "must have, as is", except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as "must have, as is", with the Objective requirements rated as "could manage with something less stringent".

Previous Requirement Language

2012PRVSMR: *nothing specific*

2016OPPRFI: *nothing specific*

2018ASCVSR (copied from Table in the ASCVSR report Appendix C, Group 3):

- *120VAC Ship Power - Ship power system servicing all lab and computer spaces with at least 8 x 20Amp circuits per lab in addition to the UPS service*
- *Lab Receptacles - Two 120 volt, single-phase receptacle strips, each fed by a 20 amp circuit breaker, shall be provided for every 6 linear feet of bulkhead and shall be installed at a height of approximately 42 inches above the finished deck. Each strip shall have six standard NEMA 5-20R receptacles*
- *Foreign Equipment Power Capability - 2x 20Amp per lab and computer space at 220V 50Hz*
- *Weather Deck Power Service - 2x 100Amp 3-Phase 208V, 4x60Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering deck containers and portable equipment*
- *Container Hold Power Service - 2x 100Amp 3-Phase 208V, 4x60Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering container hold containers and portable equipment.*
- *120VAC 30 Amp Power Service - Each Lab, Computer Space, Science Workshop, Staging Area and Aquarium Space shall have at least one 30Amp 120V 60Hz circuit provided in addition to normal 20 Amp service.*
- *340 VAC 30 Amp Power Service - 240 VAC service for all lab and computer spaces 10 x 30A spare circuit breakers total.*

- *Lab Receptacles - Two 240 volt, single-phase receptacles, each fed by a 30 amp circuit breaker, shall be provided for every lab and computer space, as well as in the container hold and workshops*
- *Mid-Level multibeam bathymetric mapping system*

Discussion: (The recommendation is self-explanatory.)

D.2.6.10 Discharges

Updated SMR

Compliance with new environmental regulations, such as emissions and discharges, is required. All vessel underway discharge must be consolidated to one side of the vessel (normally port side) providing a "clean working side". The PRV will need to adhere to MARPOL and IMO Polar Code regulation with respect to discharges of wastewater and solid waste. MARPOL regulations dictate that the waste must be held in holding tanks until the vessel is in ice-free waters. Generally treated wastewater discharges can be made in areas having ice concentrations >0.1. Untreated water discharges must be 12 nmi. from land or ice and/or shore. In addition, there can be no discharge of food wastes onto ice.

The desired holding times of all sewage could possibly be increased beyond minimum regulatory requirements to meet scientific needs for time alongside ice. Some recent research icebreaker designs have demonstrated a hold time of 20 days for black water and 60 days for gray water, far exceeding current NBP or LMG capacity. A careful evaluation of daily waste water generation and holding time requirements should be made as part of the design once crew complement and as waste treatment and holding tank specifications are developed. As a minimum, a holding period of at least 4 days is required for other vessels, but should be greater for a vessel working in ice-covered areas.

Priorities: Requirements rated as "must have, as is"

Previous Requirement Language

2012PRVSMR: *Compliance with new environmental regulations, such as emissions and discharges, is required.*

2016OPPRFI: *All vessel underway discharge must be consolidated to one side of the vessel providing a "clean working side".*

2018ASCVSR: *The PRV will adhere to MARPOL and IMO Polar Code regulation with respect to discharges of wastewater and solid waste. All wastewater discharges must be on the port side of the vessel in order to minimize contamination of samples. This is consistent with the SMRs for the Ocean* *and Regional Class UNOLS vessels. MARPOL regulations dictate that the waste must be held in holding tanks until the vessel is in ice-free waters. Generally treated wastewater discharges can be made in areas having ice concentration >0.1. Untreated water discharges must be 12 nmi. from land or ice and/or shore. In addition, there can be no discharges of food wastes onto ice. More details can be found in the report.*

ASC notes that desired holding times of all sewage could possibly be increased beyond minimum regulatory requirements to meet scientific needs for time alongside ice. Leidos recommends NSF determine preferred holding times on ice to meet expected scientific needs.

Discussion:

A review of the RV Kronsprins Haakon design demonstrated a hold time of 20 days for black water and 60 days for gray water, far exceeding current NBP or LMG capacity. This increased hold time seems sensible when considering how long a science team may want to operate in ice where such discharges are restricted. The following table provides a sense of the daily wastewater production rates, and holding and tank capacities for the NBP and LMG as well as possible new vessel configurations. ASC assumes a wastewater generation rate of 33 gal/day/person.

Sewage capacity comparisons for NBP, LMG, and various PRV options. (Table 10 in the ASCVSR.)

	NBP	***LMG***	***IBRV (Goal)***	***ICRV (Goal)***	***IBRV (StretchGoal)***	***ICRV (StretchGoal)***
Complement	*61*	*45*	*67*	*45*	*77*	*57*
WW prod (g/dy)	*2,013*	*1,485*	*2,211*	*1,485*	*2,541*	*1,881*
Holding capacity (days)	*2.5*	*5.4*	*4*	*4*	*4*	*4*
Tank capacity (gal)	*5200*	*8390*	*9309*	*6253*	*10669*	*7920*

For perspective a 10,000 gallon cylindrical holding tank has a diameter of 10’ and height of 17’, so 8 to 12 days of in-ice work will require a substantial volume for holding tanks. The ultimate size of the holding tanks will depend upon the size of the ship’s complement and the maximum or typical number of continuous days the vessel will be working in ice with concentrations >0.1. The ASC report’s recommendations should be followed once these criteria have been established.

D.2.7 Construction, operation & maintenance

D.2.7.1 Green ship

Updated SMR

Environmental, sustainable ship design features should be incorporated in vessel design, but in use must not interfere substantively with critical mission performance criteria such as icebreaking capacity, endurance, and range. These features might include incorporation of recycled materials, non-polluting equipment and instrumentation and fuel efficient or alternative fuel technologies to make these vessels as environmentally friendly and cost effective as possible. Based on best research ship practices at the time of design and construction, specific equipment and materials should be specified. Green ship technologies might include use of reflective exterior paints and electrochromic glass to reduce HVAC loads, use of devices which provide improved oil-water separation, improved marine sanitation devices, design for use of environmentally safe oils, use of software-defined shipboard electrical power systems, and use of selective catalytic reduction (SCR) for emissions control.

A hybrid battery system should be considered as a potential addition to a diesel-electric configuration, with a goal of being able to provide zero emission periods for air sampling and quiet ship operations. Unless there is substantial improvement in battery technology, it is not envisioned that extended underway propulsion would be supported under battery power, but instead that on or near station battery operation periods of approximately 4 (Threshold) to 12 (Objective) hours be feasible.

Priorities:

These requirements are rated as "must have, as is", except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as "must have, as is", with the Objective requirements rated as "could manage with something less stringent".

Previous Requirement Language

2012PRVSMR: *Environmental, sustainable ship design features must be incorporated in vessel design. Every effort should be made to incorporate recycled materials, non-polluting equipment and instrumentation and fuel efficient or alternative fuel technologies to make these vessels as environmentally friendly and cost effective as possible.*

2016OPPRFI: (not discussed)

2018ASCVSR: *The vessel specification and charter can be used to encourage or mandate environmentally friendly practices in excess of the minimum requirements* *defined by class or flag. This can be accomplished by requiring optional class certification which impacts design and operation. Otherwise, specific equipment and materials can be specified and operations can be governed in the charter.*

Also: *A hybrid battery system is described as an additional option that could be added to a diesel electric configuration. ... There are many variations to examine based on what is expected from the battery. Zero emission periods for air sampling will require a definition of duration and frequency during voyage. Zero emission stationing while pier side at Palmer may be defined on a basis of affordability and space impact to the ship design. There may be other science missions where zero emission operations is preferred … .*

Discussion:

Green ship technologies help to promote both environmental sustainability in construction, operation, and maintenance of research ships and also environmental awareness in the operators, scientists, and the public. In addition, some aspects of 'green' technologies can provide substantial scientific benefit. The UNOLS "Greening the Fleet Initiative", begun in 2012, targets port sustainability, emerging technologies, propulsion and fuel, energy monitoring and conservation, ship design, recycling, certification, compliance, and noise pollution. UNOLS holds biennial workshops in support of this initiative.

During the design process for the Academic Research Fleet Regional Class Research Vessels (RCRVs), the Glosten Corporation evaluated relevant green ship technologies and approaches (Madsen, 2014). Their tables 1 and 2, copied below verbatim, summarize issues and approaches relevant to those ships at that time:

Table 1. Green ship incorporated alternatives ["incorporated" into the RCRV design] (Madsen, 2014)

Green Ship Alternative	Benefit/Rationale
Hull	
Hull form optimization	15% reduction in resistance
Hull coating-hard coating with frequent in water cleaning	No biocide toxin release
Propulsion	
Variable speed generators	Estimated 5-15% reduction in fuel consumption

Permanent magnet alternators and motors	Increased motor efficiency
Wake adapted propellers	Increased propeller efficiency, decreased underwater radiated noise
Twin propeller pods	Increased propulsive efficiency
Electrical System	
VFD pumps and fans	Electrical savings, possible noise attenuation concern
Premium efficiency motors	3-10% electrical savings
LED Lighting	Lower energy use, higher upfront cost
Auxiliary Systems	
Waste heat recovery	Provides heat for HVAC, water makers, and domestic hot water. ~350 kW electrical savings
Climate control – waste heat heating	Can replace electric heat for large heaters, 70+ kW electrical savings
Novec 1230 fire suppression	Minimum application of greenhouse gas
Non-ozone depleting refrigerants	Minimize environmental damage
Pollution Control	
Biologic MSD	Clean effluent 5 PPM OWS
Minimize oil discharge	
Fuel overflow system	Minimize risk of accidental fuel oil discharge
Environmentally acceptable lubricants	Minimize impact of accidental oil discharge
Minimize underwater radiated noise	Minimize noise pollution
Ballast water treatment system	Required, reduces spread of invasive species
EPA Tier 4 engines	Reduce engine air emissions
Solid waste storage No incinerator air emissions	
Outfitting 3" minimum insulation	Reduce heat loss/gain
Sustainably sourced, environmentally friendly materials	Minimize environmental impact

Table 2. Green ship alternatives - not recommended for incorporation [“not recommended” for the RCRV design] (Madsen, 2014)

Green Ship Alternative	Benefit/Rationale
Propulsion	
Battery hybrid	Minimal benefit with variable speed generators. Adds cost & weight.
Alternative fuels, LNG	Integration of LNG system incompatible with vessel design
Electrical System	
Solar system	Minimal benefit with available installation area
Auxiliary Systems	
Climate control – air/air heat exchangers	Impractical due to space constraints, may offer benefit if feasible
Climate control – heat pump	Less efficient than waste heat heating, equivalent to chiller A/C

The science system and design specifications for new US polar research ships could take advantage of what has been learned from UNOLS workshops and experience with "green" implementation on other ships, such as the RCRV program, and any including other research ships and ice-operating ships. For example, hybrid power is being implemented on some ships for some operational models, reflective exterior paints are being used to lower HVAC demands, and electrochromic glass reduces HVAC loads. Also, practical lessons in "greening" are being learned via the mid-life refits of the AGOR-23 ships (Thompson, Revelle, Atlantis), which are resulting in improved fuel efficiency, improved oil-water separation, and improved marine sanitation devices.

Green ship technologies also assist with meeting existing and proposed marine regulations, including US federal regulations, compliance with the international Antarctic Treaty (for which the US Antarctic Conservation Act implements environmental protocols), and the International Code for Ships Operating in Polar Waters (aka Polar Code). For new polar ships, considerations include holding waste water (in certain areas and during sensitive operations), fuel efficiency, fuel tank isolation from hull, air emissions, and use of environmentally safe oils.

Nearly all ship and science systems may benefit from attention to efficiency and environmental impacts. For example, if electrical power quality specifications are implemented and met (e.g., a specified maximum percent total harmonic distortion at a common reference point, along with voltage, stability, phase, and power quality rating specifications), experience shows this will reduce undue temperature rise in electrical equipment and systems, lengthen equipment life, reduce failures, and reduce noise in circuits. Most methods used at the time of this study to improve power quality come at a cost in terms of energy, heat, and efficiency. But there is new (in 2018) technology for software-defined shipboard power systems. These are expensive now (at least $100k, and that may be for smaller-load systems), though with huge power quality advantages covering nearly all aspects of power and also saving fuel). These or equivalent may be much less expensive or at least cost effective over a reasonable period by the time the next global and polar ships are constructed.

Another "greening" aspect could arise from consideration of utilizing improved technologies for the ship's power/drive systems. Newer integrated diesel electric systems and hybrid power systems for research ships bring about savings in low speed operations, which are much more fuel efficient than with the older systems. These new systems are DC and hence can be used with batteries for hybrid operation with all-electric for noise sensitive and emission free operations, with the side benefit of a built-in safety power back-up. [DC drives also have smaller net mechanical footprint, although adding batteries for a hybrid system currently takes up all or more of the space savings.]

If emissions control becomes an issue, selective catalytic reduction (SCR) for emissions control is being installed on the RCRVs, and their experience with these systems could be studied. These are closed-loop systems that adjust automatically to engine load, exhaust temperature, etc.

To be sustained, the human side of "greening" and environmental compliance must be addressed, to help shift the overall culture from "what a pain" to "we can do this".

D.2.7.2 ADA compliance

Updated SMR

Implement ADA Guidelines as *feasible to accommodate disabilities that meet USAP qualifications for participation,* within the budget and size constraints for the vessel. Reference: ADA Guidelines for UNOLS Vessels_Final_Feb08.pdf.

Priorities: Requirements rated as “could manage with something less stringent”

Previous Requirement Language

2012PRVSMR: *Implement as many of the ADA Guidelines as possible within the budget and size constraints for the vessel. ADA Guidelines for UNOLS Vessels_Final_Feb08.pdf*

2016OPPRFI: *(not discussed)*

2018ASCVSR: *It is assumed that compliance with the Americans with Disabilities Act (ADA) is not required. Limited compliance with ADA guidance. Need* *more specific here, unsure what requirements to apply considering med quals required before anyone can transit to Antarctica.*

Discussion:

It is necessary to determine what types of disabilities would permit disabled individuals to comply with the medical qualifications required for transiting to and working in Antarctic Seas. If the criteria indicate that certain disabilities meet these qualifications, then limited compliance with ADA may be possible. To the extent possible the implementation of ADA guidelines should not impact vessel size.

D.2.7.3 Maintainability

Starting with the earliest elements of the design cycle, the ability to maintain, repair, and overhaul these vessels, and the installed machinery and systems efficiently and effectively with a small crew should be a high priority. This ability is a science mission requirement in the sense that increased reliability and fewer resources and man-hours devoted to maintenance and repair means more time and personnel support for science. Ship layout should include adequate space for ship repair and maintenance functions such as workshops with proper tools, spare parts storage, and accommodations for an adequate number of crew. Design specifications should include provisions for reliable equipment (including adequate backups and spares) that are protected from the elements to the maximum extent possible. Equipment monitoring systems and planned maintenance systems combined with configurations that provide for reasonable access by repair and maintenance personnel will help ensure that equipment remains in the best possible condition. Specifications for equipment should require all equipment vendors to provide parts lists, manuals, and maintenance procedures in electronic form for integration with a Computerized Maintenance Management System (CMMS). This will all reduce the overall cost and effort for maintaining a reliable research vessel.

D.2.7.4 Operability

Design should ensure that the vessel could be effectively and safely operated in support of science by a well-trained, but relatively small crew complement. The remote Southern Ocean and Antarctic conditions, available ports, and shore side services should be considered during the design process. The impact of draft, sail area, layout, and other features of the design on the ability to operate the vessel during normal science operations should be evaluated by experienced operators, technicians, scientists, and crewmembers.

D.2.7.5 Life cycle costs

A thorough evaluation of construction costs, outfitting costs, annual operating costs, and long-term maintenance costs should be conducted during the design cycle in order to determine the impact of design features on the total life cycle costs.

E. US Antarctic Program Ship Support Options

E.1 Perspective

The US Antarctic Program (USAP) is approaching a decision point regarding the ships which support USAP research and Palmer Station resupply. At present there are two USAP ships - ARSV *Laurence M. Gould* (LMG) and RVIB *Nathaniel B. Palmer* (NBP) - both of which are operated under charter agreements with Edison-Chouest Offshore (ECO) via the USAP's Antarctic contractor. Both ships are nearing end-of-contract and the NBP in particular is nearing the end of its design service life. Neither USAP ship is up-to-date regarding some regulatory matters, and neither can readily be refit into compliance. Then, too, there is the matter that the operating costs for research ships are increasing (faster than overall inflation, due largely to fuel cost increases), yet there is a possibility that the USAP may operate for the conceivable future in a more or less constant-dollar fiscal environment.

Meanwhile, as noted in report section C, the US scientific community has been continually engaged in strategic planning regarding future polar research priorities and, through various initiatives extending over more than 10 years with broad community participation, has investigated the science mission requirements attending to the ships needed to support the marine aspects of future US polar research. The Subcommittee's assessment of science mission requirements (report section D) amply demonstrates that to provide the needed ship support, the overall specifications call for a polar research ship with greater capabilities than those represented by the NBP. There is also a continued need for a research and supply ship which would support the USAP's Palmer Station and Antarctic Peninsula region science.

The Subcommittee reviewed the missions of ARSV *Laurence M. Gould* (LMG) and RVIB *Nathaniel B. Palmer* (NBP) over recent years to provide a perspective on present use of the ships (Section E.2), examined issues related to USAP Palmer station resupply and regional science support (Section E.3), examined British Antarctic Survey (BAS) experience regarding ship support for their Antarctic bases and regional research (Section E.4), and examined options for refit of the NBP (section E.5). The committee took these matters into consideration in its discussion of the "one ship versus two ships" issue facing the USAP (Section E.6). The committee also discussed operations models for the USAP ships (Section E.7).

E.2 USAP ship use in recent years

The Subcommittee examined whether or not the USAP was optimally utilizing the two ships it operates. The number of days comprising a "full optimal year" schedule of operations of a research ship is dependent upon many factors, allowing for maintenance and repairs, non-science transits, regulatory and other inspections, and so forth. To compile a year by year count of the annual operating days of the USAP ships, we used methodology compatible with that used by UNOLS, insofar as feasible, so that our estimates may be most readily compared to those of similar class (but not ice strengthened) Academic Research Fleet research ships (formerly sometimes called the "UNOLS Fleet"). For UNOLS' calculations, "Ship operating days are all days away from homeport in an operating status supporting the scientific mission. This includes transit time, days in ports for the purpose of fueling, changing personnel and renewing scientific teams and equipment, and the day of arrival and day of departure from homeport." Operating days include all days operating at sea. It also includes mob/demob days, test or training cruises, outreach days (such as an open house at a dock), days spent on transits to science ports (but not days spent in transit to shipyards), and most short periods of down time at a dock away from home port. [Through 2018, days in homeport were not considered charge days and were not operating days. In 2019, at the direction of the agency reps, the homeport mob/demob days became operational/charge days for the Academic Research Fleet.]

In general terms, the full optimal year of operations for an Academic Research Fleet global-class research ship is traditionally estimated to be approximately 270 to 300 scheduled days, though for this class of ship in particular, due to heavy demand, and long cruise durations (more time for at-sea maintenance activities), over 300 annual operating days sometimes can be supported. The intermediate- or ocean-class ships typically have more frequent, shorter missions, and operate more often from their home port. Before 2018, the ocean-class full optimal year was estimated to be approximately 250-275 operating days. Now that home port mob/demob days are included, that number may be adjusted somewhat higher. (The NBP would be classed as a global-class ship. The LMG would probably be an “intermediate” - or now, “ocean”- class ship.) A caveat is that polar ships traditionally work in areas where marine operations are uncommon or not feasible at certain times of year and this will affect the setting of their “full optimal year”. We have not, however, made full optimal year adjustments for the USAP ships based on seasonal considerations.

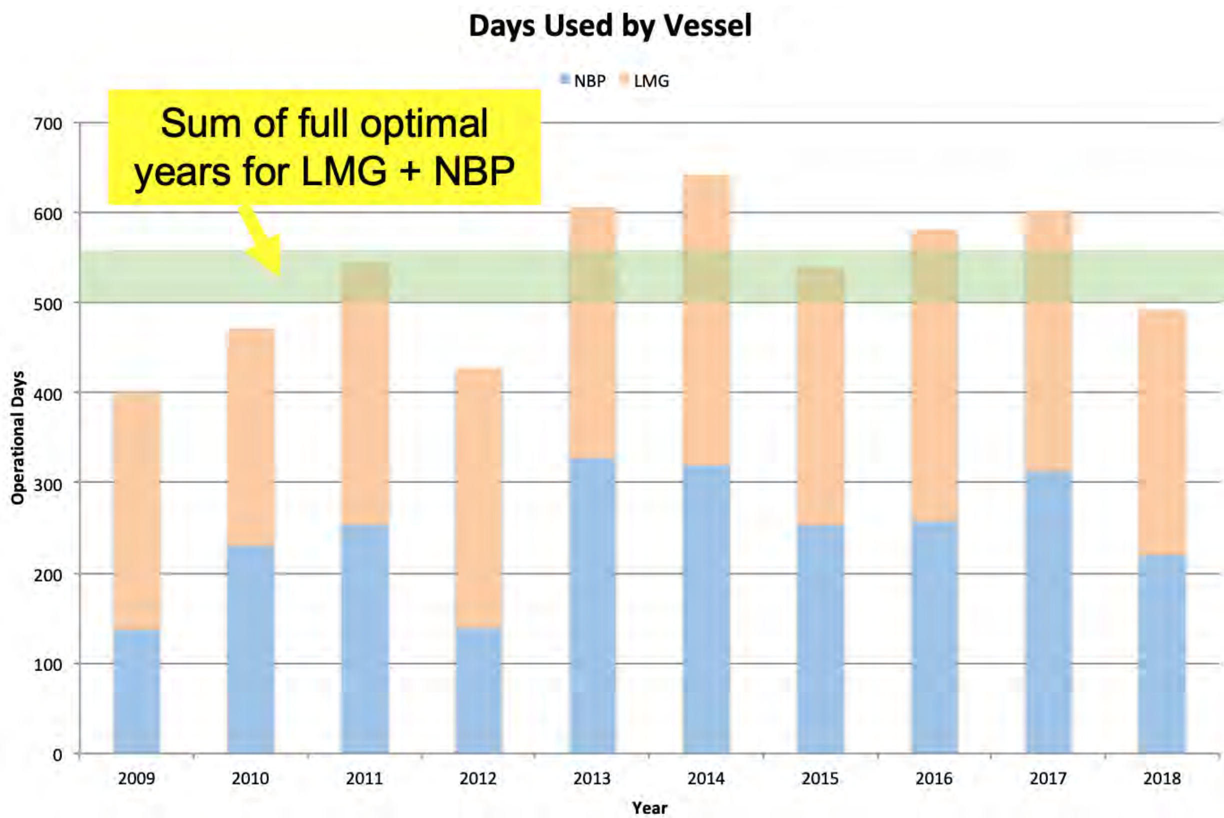
We combed through on-line records from 2009-2018 for the USAP ships Laurence M. Gould and Nathaniel B. Palmer. The primary sources of information were the USAP files "nbp_history.pdf" and "lmg_history.pdf", with additional information gleaned from the UNOLS Shiptime Request System. In some cases it was not feasible to reconcile information between the USAP and UNOLS sites. For example, the year 2011 for the LMG contained different information on the two sites. The USAP site, which appeared to be more nearly accurate, though less complete in some respects, was then given priority. Although we recognize that the USAP operates a field year centered on the southern hemisphere summer, we broke the USAP information into calendar years to maintain maximum compatibility with UNOLS figures. The UNOLS historical ship schedule reports do not include the NBP prior to 2012 or the LMG prior to 2011. Estimates were thus needed for the earlier years and some other years for mob/demob days (not part of the USAP files; gleaned from the UNOLS tables). The estimates were based on figures from comparable cruises in more recent years. Due to these and other uncertainties, we cannot defend our "USAP operational days" calculations as absolutely correct, but we believe we have captured the information needed with accuracy appropriate to be useful to our study.

An examination of the ten most recent past years of ship use (table below) shows that from 2011 the LMG has operated every year at least the equivalent of a full optimal year (using the suggested revised "270" day figure adjusted for home port mob/demob days). During most of the 10-year period, the NBP's annual operating days were a little below the UNOLS optimum use figure, though this could be affected partly by seasonal considerations. The NBP figures for 2014 and 2017 would have been lower had not US GO-SHIP transects (in non-polar waters) been placed on the NBP those years.

In particular we note that a single ship could not meet the total annual days at sea scheduled by the USAP for these two ships. Hence, if the USAP reverted to a single ship operation, without additional support from non-USAP ships, a major reduction in USAP marine science and/or logistical support would ensue.

Table. Total annual operating days (using UNOLS definitions) by calendar year for the USAP-chartered ships Laurence M. Gould (LMG) and Nathaniel B. Palmer (NBP). US GO-SHIP cruises on the NBP (included in the "NBP" and "total" columns) are noted. The GO-SHIP cruises in 2011 and 2018 were requested for the NBP, and required operations in ice-covered waters. The GO-SHIP cruises in 2014 and 2017 took place in open waters and had been requested for a UNOLS global-class research ship.

Year	**LMG**	**LMG legs science (plus logistics)**	**LMG legs station logistics only**	**NBP**	**Total**	**GO-SHIP**
2009	262	4	2	138	400	
2010	241	4	2	231	472	
2011	290	6	4	254	544	[69]
2012	287	9	2	140	427	
2013	279	8	2	327	606	
2014	323	6	3	319	642	50
2015	285	6	4	254	539	
2016	324	6	4	257	581	
2017	289	8	3	313	602	97
2018	271	6	3	221	492	[72]



Most of the LMG's missions include transits between the home port in Chile and the USAP Palmer Station. We noted which LMG missions had a designated chief scientist and which did not, taking the former to have a distinct science support component in addition to station logistics support, and the latter to be principally for logistics support. Using that criterion, 63 out of 92 LMG legs included science (and station logistics support in all but a few cases) and 29 were for logistics support only. Note, however, that LMG "resupply" ship days include operation of the ship's underway science systems, which contribute to several valuable long-term science programs. Science systems operated during Drake Passage crossings include: ocean temperature sections via XBT probes at ca. 10 km spacing (six times per year), ocean currents via Acoustic Doppler Current Profiling (150 and 38 kHz), ocean-atmosphere partial pressure of CO_2, surface seawater characteristics (temperature, salinity, fluorescence, and transmissivity), and meteorological data (air temperature, wind speed and wind direction).

USAP ships have been operating in all seasons in recent years. It is not clear, however, to what extent some of these winter operations involve working in Antarctic winter weather, or, instead, involve operations in the winter season away from the Continent.

E.3 USAP Palmer Station Science Support and Resupply

Support of the USAP Palmer Station - local and regional science support, resupply, and personnel transfers - has been an important ongoing function, carried out largely by the USAP Antarctic Research and Supply Vessel Laurence M. Gould, following the ship's introduction into service in 1998. The Gould is 230 feet long and is capable of breaking one foot of level ice with continuous forward motion. The Gould can accommodate 26 scientists. The Gould acts as a resupply ship and does research in the Drake Passage and the Antarctic Peninsula region, shuttling between Punta Arenas, Chile and Palmer Station, averaging 285 operating days per calendar year (using UNOLS definitions) during 2009-2018, partly supporting marine research and partly supporting logistics. She replaced the RV Polar Duke as the main supply ship to Palmer Station.

USAP Palmer Station logistics were examined in a 2010 study by Martin, Ottaway, van Hemmen and Dolan, Inc, "Re-supply and Science Support Evaluation of Palmer Station and the Antarctic Peninsula Region", on behalf of the National Science Foundation and the US Army Corps of Engineers ERDC Cold Regions Research and Engineering Laboratory. The study report contains results of a multidisciplinary engineering analysis to review the then-current operating procedures and infrastructure used to support the re-supply and activities of Palmer Station and Antarctic Peninsula area science. This project involved multi-level analysis of the existing and potential logistics options for Palmer Station fuel supply, cargo supply and research support. The purpose was to provide NSF with options and recommendations of how these activities could be achieved more efficiently and effectively in the future. Conclusions and recommendations from that report relevant to the RV Subcommittee's examination include:

- *There is no need for Palmer Station resupply to be based upon 20-foot containers (over break bulk handling or the use of smaller and lighter cargo containers).*

  [The subcommittee notes that based on recent experiences at Palmer Station, resupply and science cargo support is better maintained with the ability to handle 20-foot containers. Hence, any new support vessels should be capable of loading and off-loading fully loaded 20-foot containers at Palmer Station.]

- *There are more advantageous options than the LMG for support of Palmer Station.* [Those options were not defined in the report.]

- *The Palmer pier will continue to be the most effective main supply point at Palmer Station. There are water depth issues at the present* [2010] *berth that prevent larger vessels* (NBP) *from coming alongside. [The study proposed solutions which might effectively avoid the need to remove bottom material].*

- *Use of commercial passenger ships for Palmer Station passenger and resupply, though presenting policy issues for the resupply functions in particular, provides some inherent features (greater public outreach, inherent low environmental impact, potential significant cost savings, training opportunities for all stakeholders, a cooperative tool for other Antarctic stakeholders, and increased overall fuel efficiency) that could serve the larger NSF OPP mission.*

- *The use of an "ABEL J" (105 feet) sized local research vessel (LRV) in conjunction with a larger research vessel is the single most significant factor in increasing the efficiency of the research performed at Palmer Station. The relatively small annual cost of such a vessel (US$1.5 million per year) is one of the most effective investments that can be made at Palmer with regard to research. This smaller vessel also increases the logistics* *efficiencies and flexibility of personnel delivery by allowing transfer of personnel through nearby airfields, and will allow greater levels of safety redundancy.*

- *The cost of fuel and cargo logistics support for Palmer is a small fraction of the overall cost of the LMG. The analysis indicates that the supply of fuel and cargo can be effectively performed for under 20% of the 2009/2010 annual cost of the LMG via independent commercial operators as a standalone function. Alternatively NSF OPP could choose a method where they have a higher level of involvement through their operations contractor.*

- *The present research at Palmer Station requires the availability of a research vessel that has research capabilities comparable to the LMG. If the replacement vessel is not required to provide fuel and cargo logistics, the replacement of the LMG will be a pure research vessel with significant passenger capacity for personnel transfer functions. The design of the LMG replacement will require great discipline with regard to fuel and overall efficiency in order to maintain, and improve on, present overall system efficiencies in conjunction with optimal use of the NBP and the "ABEL J" (LRV) type vessel.* [The RV Subcommittee notes that the 2010 Palmer Station logistics report envisioned a three-ship USAP fleet: the LMG replacement, the Palmer area LRV, and the NBP or equivalent.]

- *An airlink for personnel transfer support could be worthwhile. Air delivery of personnel as close as possible to Palmer Station tends to reduce the amount of fuel needed for each person delivered to Palmer Station. For example, use of airstrips at Rothera and KGI would be effective in reducing fuel use and the study recommended that a significant effort be made in further developing the ability to transfer personnel through these airstrips and subsequent transfer of personnel to Palmer Station by boat or alternate means.*

We note regarding the Palmer Station pier (the third bullet above) that in August 2018 NSF announced that it would rebuild the pier, making a "transformative" upgrade. The approved design (see https://future.usap.gov/palmer-pier-planning-advances/) will form the basis for final design and construction plans. The new pier will increase the pier area from approximately 1800 square feet and 18 feet of water depth to 8,000 square feet and 34 feet of water depth. This project will thus facilitate Palmer Station resupply and personnel transfers from ships larger than the LMG, including the NBP or similar sized ships.

We note, regarding the use of a local area research vessel (LRV; considered in the fifth bullet above), that some enhancements to Palmer Station vessel support facilities may be required, such as a crane suitable to move a RHIB from shore to sea and vice versa, increased vessel fuel storage, safety and navigation systems support, local support for qualified mariners, and so forth.

The subcommittee did not examine Palmer Station resupply and personnel transfers in further detail, other than to note, regarding future USAP ships, that reports such as the one from the 2010 study show that it may be feasible to carry out most future resupply and personnel transfers from non-USAP ships, should the LMG or other USAP ship not be available. Some Palmer Station regional science missions could conceivably be carried out by RHIB or local research vessels, though this would likely leave a block of regional science now supported by the LMG to be carried out by another ship (such as a next-generation "NBP replacement" USAP polar research ship), an Academic Research Fleet ship, or a research ship operated by another nation. But there are significant unresolved issues in how those science missions could realistically be carried out. For example, the Palmer Long-Term Ecological Research (LTER) project conducts annual summer surveys from Palmer Station down the length of the Peninsula. The LTER work coincides with a typical maximum demand period for *all* ships serving the Antarctic region, including the NBP. Thus it is not at all clear how continued annual/seasonal LTER-like work in the Antarctic Peninsula region could be supported by the USAP in the absence of the LMG. Using the NBP for summer-specific science support in the Peninsula region could have major impact on the wider-region USAP studies now supported by the NBP. If another ship is used, there is also the matter that the underway measurements routinely carried out by the LMG during Drake Passage crossings have provided unique records valuable to ocean climate research. If the LMG were replaced by a commercial "resupply-only" ship not equipped for science, this important time series could come to an end. To prevent the cessation of these climate time series, consideration should be given to developing a program in which the chartered re-supply vessel is outfitted with marine and atmospheric instruments. Successful precedence for such efforts includes the Gulf Stream Oleandar Project and the University of Miami - Royal Caribbean International cruise lines. Vessels involved in these programs are outfitted with hull-mounted Acoustic Doppler Current Profilers (38 and 150 kHz). Other sensor packages include an Autonomous eXpendible Instrument System (AXIS; which launches XBT probes automatically at programmable spatial intervals and without the need for intervention by the crew) and a variety of atmospheric instruments. In addition, the vessel should incorporate a seawater sampling system tied to a thermosalinograph (TSG), fluorometer, pCO_2 sensor and one that is flexible enough to incorporate additional sensors as deemed desirable.

The subcommittee notes that USAP Peninsula-area activities carried out by the LMG overlap substantially with those carried out on behalf of the British Antarctic Survey by BAS ships (formerly RRS Ernest Shackleton and RRS James Clark Ross; now being replaced by RRS Sir David Attenborough). There almost certainly exist areas of shared interest between the USAP and the BAS, and the Subcommittee urges that these be explored. But the possibility to share ship resources between these or other Antarctic entities must take into account the fact that maximum demand for science and resupply activities takes place at about the same time for all nations' Antarctic programs.

E.4 British Antarctic Survey recent experience with the "one ship versus two ship" issue

The British Government funded NERC/BAS to invest in a replacement polar research/logistics vessel, to replace the current two aging ships. If the current vessels were to be retained they would end up costing BAS approximately 25% of the annual operating budget for all of BAS operations. The decision was made to build a single larger polar classed vessel, able to carry the equivalent, combined cargo capacity as the current vessels. This new vessel is to have double the science compliment capacity as the RRS *James Clark Ross*, with a longer endurance too. The operating model will require chartering in logistics capacity to offset the lost capacity of the RRS

Ernest Shackleton. Even with chartering in logistics capacity BAS will not be able to equal the amount of marine science days currently enjoyed with a two-ship operation. BAS will have limited capacity in reacting to changes to the annual program plan.

E.5 Nathaniel B. Palmer Continued Service to ca. 2032 (with note about the Laurence M. Gould)

The *Nathaniel B. Palmer* (NBP) is well maintained, is in good operating condition, and is carrying out USAP and other US science with mostly favorable user reviews regarding the ship and its science outfitting. Continuing the NBP in service for a total 40-year operational life (to ca. 2032) is probably feasible with a relatively modest engineering and science/technical mid-life refit, although the ship would not be current regarding some regulatory issues.

A more aggressive mid-life refit has been investigated, with an eye to addressing updated polar RV science mission requirements. For example, consider statements from, "RVIB *Nathaniel B. Palmer* Service Life Extension Program Feasibility Assessment (2015):

> [Begin extract.] In early 2011, a panel of scientific and technical experts gathered to "refresh" the Science Mission Requirements (SMRs) for a new Polar Research Vessel (PRV). The final report containing a list of recommended capabilities for the new vessel was delivered to NSF in January 2012. A series of cost analyses were performed by both internal and external working groups which looked at the overall construction and operating costs of a vessel as described in the SMR's. In general, costs of both a government-built/operated, or a contractor-built/operated, were prohibitive, particularly in the current budget climate and considering competing priorities for research funding.
>
> In consideration of the funding climate currently affecting all Federal research investments, NSF's Division of Polar Programs (PLR) is reviewing the desired capabilities of a new PRV against the potential enhancements of the NBP that could meet the needs of the research community. Given the overall good condition of the vessel and its current age (23 years), NSF is exploring whether a service life extension of the NBP, with incorporation of enhanced capabilities would serve research community's needs.
>
> The National Science Foundation is seeking to determine the feasibility of the NBP entering a SLEP, to extend the operational life of the vessel as well as incorporate modifications to increase the capabilities of the vessel over its current abilities. Potential improvements include:
>
> 1. Increase science berthing from 39 to up to 55 science and technical personnel
> 2. Increase lab space by 15-20%
> 3. Increase deck space by 10-15%
> 4. Increase endurance from ~55 days up to 90 days
> 5. Increase acoustic "quietness" as much as practical/economical
> 6. Increase icebreaking capability from A2 up to PC3
> 7. Extend total service life to 40+ years (2032 or beyond)
>
> One concept for achieving many of these objectives is to design and build a mid-body insert. The mid body insert has the benefit of providing increased berthing, lab space, deck space and endurance (by increased storage space, fuel tankage, potable water tankage and sewage capacity). However, there are significant structural, machinery and regulatory challenges to address. … … The entire vessel [may then need to] meet all standards (USCG, SOLAS, MARPOL, IMO and possibly Polar Code) in effect at the date of a major conversion resulting in significant secondary effects. It is believed that due to the structural, machinery and regulatory challenges, a mid-body insert approach poses a significant cost risk and is prohibitively complex and expensive. As a result, solutions to each of the 7 objectives were looked at individually. [End extract.]

> [Begin new extract (the report summary, verbatim:] The RVIB NATHANIEL B PALMER is being maintained in a condition which meets or exceeds the standards typically expected of a research vessel of this size and service. Recommended improvements to existing scientific equipment, including winches, cranes, frames, laboratory facilities and network infrastructure, as well as the vessel in general, are contained in the report. However, the vessel is in very good condition overall, and there are many feasible and cost-effective options to enhance the science capabilities and extend the service life to 2032 or beyond.
>
> It is believed that due to the significant structural, machinery and regulatory challenges, a mid-body insert approach to address many of the objectives poses a significant cost risk and is prohibitively complex and expensive. As a result, solutions to each of the 7 objectives were looked at individually. Of the 7 objectives assessed, only #6, Increase icebreaking capability from A2 up to PC3 was considered infeasible. It is believed that increasing the ice capability poses a significant risk and is prohibitively complex and expensive. Increasing the vessel's endurance to the stated goal of 90 days may not be reasonably achievable but there are several options for proving some level of increase. There are many options for increasing berthing and lab space, not all of which need to be implemented in order to achieve the desired goals. Many of the work items presented here are not "all or nothing" options and could be descoped or phased in over time as determined by a final prioritization of objectives and available budget. [End extract.]

The Subcommittee notes from the report that the 2015 "Rough Order of Magnitude" cost for item #7 ("extend total service life to 40+ years (2032 or beyond)") was ≈ $9.4M. We thus regard an expenditure of ca. $10M in 2015 dollars (perhaps significantly more, based on typical experiences with mid-life refits for other large US ships) as the minimum investment in the NBP to extend its service life to 40+ years. Adding the costs of the other five refit categories thought to be feasible (in order, in 2015 millions: 4.2, 0.6, 0.6, 0.5, 2.2) comes to $17.5M (or ≈ $20M), not a prohibitive or unusual sum, though experience with other US ships has shown that escalating costs are likely - even doubling of early-estimated refit costs is not unrealistic.

In recent decades mid-life refits have been undertaken successfully for all academic research fleet global class ships (when they are due), though typically at greater costs and with changed scope than forecast ahead of each refit. The Subcommittee notes that if a "moderate" refit were to be carried out on the NBP, this should probably be done as soon as feasible in order to receive maximum benefit to science over the remaining operational life of the ship.

The Subcommittee did not explicitly evaluate the aspects of LMG performance which might be addressed during a mid-life refit. It is important, however, that the future operational model for that ship be well understood, and that it be taken into account in refit goals and specifications. In fact, there remains a question regarding whether the needs now supported by the LMG might evolve to the point where they would feasibly be better carried out by a different ship. Hence it is probably wise to refrain from significant further material investment in the LMG, unless it is clearly the best option for the future.

E.6 Operational models for USAP ship support

A plausible fiscal future faced by the USAP is shared by NSF as a whole: annual budgets at more or less constant dollars, with occasional possible nudges up, but not keeping up with average inflation. Meanwhile, present experience in the Academic Research Fleet (formerly sometimes termed the "UNOLS fleet") is that the overall cost to operate a given ship tends to increase faster than average inflation. [This is due principally to rising fuel costs, but other factors include the introduction of new security requirements, new international safety standards, new pollution control measures, garbage disposal costs, rising costs of shipyard work, and the rising cost of health care coverage.] In NSF Geoscience's Ocean Sciences Division, due to the risk of increasing support costs impacting core science funding, a decision has been made and implemented to keep costs of the major infrastructure programs to comprise no more than 40-50% of the total annual program budget. This has contributed to a decline in total annual operating days of the academic research fleet, and a reduction in the size of that fleet from 28 ships in 2001 to 18 ships in 2019.

Because there are multiple Academic Research Fleet ships in each of the local, regional, ocean/intermediate, and global categories, it has been possible to "right size" the academic research fleet to help maintain full operating schedules for each active ship, thus leading to more efficient ship use on a cost-per-operating-day basis. The planning that underlies "right-sizing" the academic fleet anticipates the amount of investment the federal agencies can reasonably make to maintain the academic research fleet.

The ship support situation faced by the USAP is more stark than that of the UNOLS example. To keep the total of its rising ship expenses from unduly impacting science budgets in an approximately constant USAP total budget environment, a fiscally obvious method to achieve this would be to follow suit with NSF Ocean Sciences and, in the end, decrease the total number of ships it supports. Unfortunately, for the USAP that means going from two ships to one, which would have a significantly greater proportional impact on science than does a reduction in one Academic Research Fleet ship.

To examine aspects of that impact, the Subcommittee examined the USAP on-line files "nbp_history.pdf" and "lmg_history.pdf" with an eye to determining peak-use periods of each USAP ship over the 10 austral summers from 2008-2009 to 2017-2018. Dates were extracted for the longest continuous stretch of science cruises - uninterrupted by logistics runs or open periods in ports, allowing only for between-cruise mobilization and demobilization. The NBP has few logistics-only runs and tends to be scheduled each year with a long run of successive cruises. The LMG is a busy ship (see section E.2), with science legs (the definition used: cruise legs with named chief scientists) interspersed with logistics runs. Many of the LMG science cruises likely had logistics components, but the Subcommittee took the longest stretch each austral summer of continuous LMG science legs to represent the period the ship was in the greatest demand for science. The results are shown in the figure.

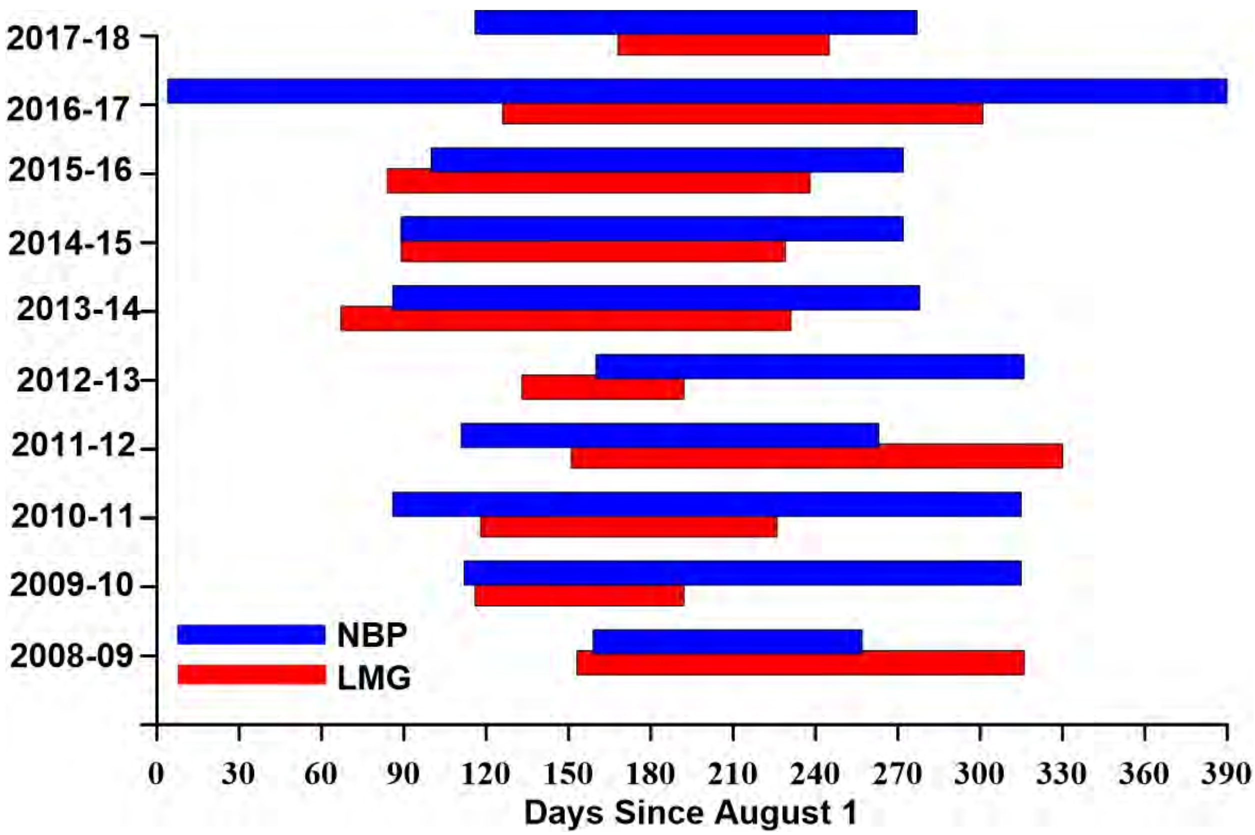


Figure caption: Illustrating the calendar timing of the longest continuous stretch of science operating days - uninterrupted by logistics-only days - for the USAP ships Laurence M. Gould (LMG) and Nathaniel B. Palmer (NBP) each austral summer from 2008-2009 to 2017-2018. (**Important note:** The LMG in particular has many more science operating days every year than shown in this figure, but those are interspersed with logistics-only cruises and so not shown on this figure, which shows only the longest continuous period of science operating days each year.)

It is plain from the figure that during every austral summer examined both the LMG and NBP were engaged simultaneously in science support at sea. Hence, if one of the two ships was unavailable for science service, there would be, in effect, a 50% reduction in available peak-season ship science support days. Thus, there would be maximum impact on science during that critical time of year if the USAP reverted to a single ship and did not replace lost science support days with support from a non-USAP ship.

The USAP ship support fiscal situation is similar in nature to that faced recently by the British Antarctic Survey (BAS) [See section E.4 of this report.] In the end, the BAS replaced two ships - RRS Ernest Shackleton and RRS James Clark Ross - with one ship - RRS Sir David Attenborough. The impacts on BAS science may have been slightly ameliorated by the fact that the James Clark Ross mostly worked in the sector of the Southern Ocean near the Antarctic Peninsula, but the fact is that all parties realize that one BAS ship does not fully replace two BAS ships.

There are strong arguments for retaining two USAP ships:

- Two vessels are needed to accommodate the geographic breadth of US Antarctic and Southern Ocean study regions. Although the NBP has traditionally carried out much of its sea time in the Pacific sector of the Antarctic, it has supported science missions in all Antarctic waters.
- Scheduling US Antarctic and Southern Ocean research must take into account legitimate needs for research at specific times of year in multiple locations, which would be heavily challenged with only one USAP ship to support that work. Examples include ecosystem and biogeochemical studies at specific times in the seasonal cycle, and requirements to reach areas open to navigation (or open enough for mooring work) by the USAP's ships only briefly during the time of the annual sea ice minimum.
- USAP research support is projected to meet increasing scientific demands to study fragile and changing systems. This is borne out by responses to user surveys and via "future science" reports from the National Research Council and other groups.
- Specific seasonal demands for the Palmer-area LTER program require continuity – essentially tethering a ship to a specific Peninsula location every summer season, placing limitations on other science and the ability to respond to rapidly emerging conditions and catastrophic change. Repetition of data collection at specific time intervals and very specific places (such as that achieved by the Palmer LTER) is of great value to science, and may not be possible through vessels for hire, which may not be adequately outfitted or be subject to competing demands from another customer.
- The USAP's repeated Drake Passage crossings have provided a unique and valuable oceanographic time series [XBT probes at ca. 10 km spacing (six times per year), ocean currents via Acoustic Doppler Current Profiling (150 and 38 kHz), ocean-atmosphere partial pressure of CO_2, surface seawater characteristics (temperature, salinity, fluorescence, and transmissivity), and meteorological data (air temperature, wind speed and wind direction)]. With a one-USAP-ship operation this would be in jeopardy, because its continuation would require that a commercial resupply ship would have or be outfitted with appropriate sensors, equipment, and data systems to maintain the quality and continuity of the long-term science.
- There is already intense competition for ship time, and the situation would be considerably exacerbated by reverting to only a single science ship. In addition, the competing demands of ship-based marine and terrestrial work while on-board ship is already problematic, and single ship operations would result in an even tighter ship's schedule, which might preclude terrestrial work. Loss of total days of ship support and high competition for the remaining ship time would likely lower overall proposal success rates for all polar researchers requiring marine support, and have enduring negative impacts on attracting, training, and retaining early-career polar scientists.
- A single ship operational model would result in loss of a significant amount of ship-time dedicated to science and a greater likelihood of compromising both the ability to conduct science and to meet re-supply requirements in an efficient fashion.

Some reduction of only the Palmer-local impact of discontinuation of USAP use of the LMG might be achieved if a regional research vessel, smaller than the LMG, were based seasonally at Palmer Station. This might be a vessel similar to RV Point Sur, which was used there by the USAP one season, or, better, a small ice-strengthened science vessel. The vessel would support

Palmer Station area and limited-reach Peninsula region research. Future study must first make clear, however, what regions and research operations a small research vessel might best serve, and consider the full gamut of impacts and costs, such as potential impacts on Palmer Station facilities and personnel. Use of RHIB boats to support Palmer Station area research would provide much more limited science support.

Given the history of ship-based science programs in both the Peninsula and Ross Sea regions, access to more remote areas of Antarctica, such as East Antarctica, are already limited, and would be even more severely limited by single ship operations.

Because the UK (and potentially other nations) are faced with scheduling issues, a system of cooperative scheduling and barter or chartering could serve to provide cost savings, increased flexibility and access to different capabilities in much the same way that the U.S. Academic Research Fleet or the cooperative arrangements in Europe and the Arctic do. We note, for example, the Arctic Research Icebreaker Consortium (ARICE; https://www.arice.eu). ARICE is "An international collaboration strategy for meeting the needs of marine based research in the Arctic." Their mission is based on the recognition of ".... the lack of available research icebreakers from Europe and beyond that can operate yearlong in the ice covered Arctic Ocean, and a weakly coordinated polar research fleet impedes Europe's capacity to investigate the changing Arctic. There is thus an urgent need for providing polar scientists with better research icebreaker capacities for the Arctic, to address the knowledge gaps and to develop policy recommendations for a sustainable usage of the Arctic Ocean and its resources."

E.7 Recommendations

The major recommendations of this effort include:

1. The RV Subcommittee strongly and unanimously supports a two-ship model to support USAP operations and research in the Southern Ocean.

2. Recognizing that the present USAP ships - ARSV Laurence M. Gould (LMG; constructed 1997) and RVIB Nathaniel B. Palmer (NBP; constructed 1992) - represent a significant existing national resource well in use, the RV Subcommittee recommends retaining them until their replacements are ready for service, meanwhile optimizing their facilities and operational framework while still in use by the USAP.

3. The Laurence M. Gould is already well used, but if it were necessary to broaden the fiscal support base for the ship, the Subcommittee recommends devising and putting into place a new charter agreement for the LMG with an eye to opening opportunities for science and logistics chartering by other nations. (The present charter agreement is soon to expire, and so the timing is appropriate.) The Subcommittee specifically recommends investigating entering into a long-term agreement with UK/BAS (British Antarctic Survey), for example using the LMG to carry out a small number of annual BAS station support visits and/or provide ship support for BAS Peninsula region science missions. If LMG refit activities are scheduled, the RV Subcommittee recommends that upgrades should be carried out only if they are required to meet USAP and BAS marine science

and station logistics support needs during the LMG's remaining expected time with the USAP. The RV Subcommittee does not recommend heavy investment in LMG upgrades or in extending its USAP service life.

4. If it is not feasible to design and construct a replacement for the NBP within the next 13 years, the RV Subcommittee recommends that the ship's science support facilities be improved and that the expected service life be lengthened (to 2032). The RV Subcommittee further recommend that a Service Life Extension Program (SLEP) of the NBP be carried out to (a) extend and assure the lifetime of crucial ship's systems, and (b) provide upgrades on a priority basis to the NBP's science support facilities and capabilities. In priority order: The latter should include refurbishment and modernization of the ship's laboratories and climate controlled science spaces, attention to the ship's over-the side handling equipment and winches, relocation of the main CTD winch (or other modifications to improve CTD operations in open seas), improved capabilities for deployment and recovery of AUVs, ROVs, and gliders, and improved workboat operations (not simply a Zodiac). Reducing discharges while on station and in the ice, and increasing the time discharges can be managed, should be investigated. Attention should be given to improving habitability. Consideration could be given to a modest increase in science berthing and increasing real-life mission endurance to 75 days. The SLEP will not change the ship's size or ice capabilities and should be sized and managed to be feasible with minimum loss of ship availability to USAP science, perhaps by incremental work over several years during annual maintenance periods.

5. Future USAP ship operations should employ a two-ship model: (1) one science station support and science ship to support the USAP's (and potentially other entities') Peninsula bases and marine science, and (2) one larger, more capable ship to support wide-ranging science and logistics in the Southern Ocean and that could conceivably also support research in the Arctic and global oceans when not in use in the Antarctic. Technical and fiscal planning for replacement ships should begin approximately 10 years (7 at a minimum) before each new ship enters polar service and involve continual input and oversight from the US polar marine science community throughout planning, design, construction, testing, and science systems performance verification. However, the RV Subcommittee recommends that a study first be made to assess the overall total cost differential (including design, construction, plus multiple years of operation) of alternatively supporting USAP and other US polar science with two identical polar research and support ships, instead of one larger and one smaller ship as at present.

6. Although not part of the Subcommittee's charge, it is clear that if a two-ship model for USAP continues in the future, an effort to define Science Mission Requirements for the LMG replacement is needed. This is especially true if the second ship is expected to support both science and logistics in the region of the Antarctic Peninsula as well as potentially supporting science and logistics for others such as the British Antarctic Survey.

7. If and only if it is determined by the support agencies that long-term federal budget restrictions combined with ship operating expenses prohibit extending the present two-

ship mode of USAP marine support without serious impacts on polar science support, the Subcommittee recommends the following:

a) Retire the LMG as a USAP ship at the end of its present contract.
b) Upon retirement of the LMG, revert to non-USAP ships for support of Palmer Station and a significant share of USAP Peninsula region marine science support. Such ships should be supported via long-term arrangements to aid planning and provide assurance of support. The ships could come from the commercial marketplace, or the US or other nations' marine or polar programs. (The LMG could conceivably be a contender.)
c) It remains preferred that principal logistics support for Palmer Station be carried out long term via a single ship. This makes it feasible to outfit the support ship with sensors (meteorological, ADCP, sea chest measurements), XBT launchers and a basic data system so that the oceanographically-critical Drake Passage crossing time series measurements continue.
d) If there were to be only one USAP ship, the issue of marine science support for Palmer Station and nearby Antarctic Peninsula areas must be addressed. In particular, the Subcommittee notes there is a regional peak in science support needs during the Austral summer. This coincides with the peak operating season in all other Antarctic waters for the much-wider-ranging NBP (and all other Antarctic ships). Thus, the NBP replacement vessel cannot be considered regularly available at that time in the Peninsula region. The Subcommittee notes, however, that it may be feasible to provide local RV support. Examples include the "Abel J" (mentioned in studies reviewed by the Subcommittee), or a ship similar to the former Academic Research Fleet RV Point Sur, which did once make a trip down to Palmer Station. It would be beneficial if a local RV were ice capable to the point where it could be used in the fall and early winter from Palmer Station. A small ship, even if moderately ice-capable, may need to be evacuated or hauled out during winter. Some enhancements to Palmer Station vessel support facilities may be required, such as increased vessel fuel storage, safety and navigation systems support, local support for qualified mariners, and so forth.
e) The RV Subcommittee recommends that a new committee be formed now to closely examine the needs for marine science support at and near Palmer Station and in the nearby Antarctic Peninsula region, detail the options (with priorities and costs) for the USAP to provide that support, and provide recommendations.
f) The RV Subcommittee unequivocally supports continued operation of a principal USAP polar science ship (presently the NBP) to support Ross Sea and southern-ocean-ranging US marine research, specifically without unduly restricting operations of that ship to the Antarctic Peninsula region at any time of year.

8. The Subcommittee reviewed previous documents relating to the science mission requirements for a future Antarctic polar research ship, and also those for ships designed to carry out similar underlying science missions in non-polar waters. The Subcommittee also carried out a community survey regarding related matters. The Subcommittee then prepared an updated list of Science Mission Requirements, including discussion of priorities.

The Subcommittee focused on two different paths regarding the characteristics of a future polar research ship:

1. There is enduring science community enthusiasm for design, construction, and operation of a polar research ship with increased ice operation capability, endurance, berthing, storage, and science support facilities over those represented by the Nathaniel B. Palmer. The Subcommittee notes that there would be a significant increase over the NBP in terms of construction and operation costs, especially resulting from providing the desired “PC3” ice operations capability, i.e. “Year-round operation in second-year ice, which may include multi-year ice inclusions”.

2. If it is not feasible for the USA to provide and support a polar research ship with significantly enhanced operational and science capabilities over those represented by the Nathaniel B. Palmer, the Subcommittee supports continued, long-term USAP utilization of a global-ranging NBP-like ship via construction of a new polar research ship meeting as many as feasible of the Science Mission Requirements identified by the Subcommittee, but not with substantially increased ice capability (which is an expensive enhancement with regards to both construction and operation), prioritizing new science capabilities of this ship to meet construction and operation budget realities. Priorities should focus on capabilities that are the most general in terms of applicability and that will have the greatest impact on planned and predicted USAP science and logistics support. These might include, compared to the NBP, improved capabilities for deployment and recovery of AUVs, ROVs, and gliders, improved workboat operations, a functional moon pool, greater scope of biological and geophysical support capabilities, temperature-controlled environmental rooms, improved capability to work in typical Southern Ocean open sea swell for operations over the side and stern, and improved helicopter capabilities. The ice class of the new ship in independent operations should be similar to (or slightly greater than) that of the NBP, except that hull strength, ice maneuverability, and cold weather safety of the new ship should be sufficient to enable operations with an escort icebreaker in all seasonal Antarctic ice year-round and in multi-year Antarctic ice which is accessible within the operational envelope of a US Coast Guard heavy icebreaker, which might be used as an escort on special deep-ice missions. Any size increases over and above the NBP should be restricted to those required to meet regulatory requirements.

Whichever path is chosen, scientific and technical design of a Nathaniel B. Palmer replacement must be timed so that the new polar research ship is constructed, tested, and ready to enter science service upon the NBP’s retirement. With either path, many other considerations must be attended to, such as providing laboratories of various types, an easy to clean uncontaminated seawater line equipped for ready addition of guest instrumentation, and high-speed data processing. The subcommittee notes strong input from the marine geophysical research community urging that compressors for seismic operations be included, as well as the capability for geotechnical drilling. The new ship should be capable of docking at the new Palmer Station pier. The propulsion system should provide increased maneuverability. Hybrid diesel propulsion should be considered for quiet, low pollution operations. Open-ocean performance specifications should be as "sea kindly" as feasible during steaming and on-station work in Southern Ocean waters..

The research and training that the USAP supports require a polar research ship with considerable range and long endurance, able to operate in the Antarctic region year-round, carry a large scientific party and crew, support a very wide range of state-of-the-art science operations, support the helicopters and cargo needed for continental operations, and to do so expeditiously and sustainably, providing a comfortable, safe environment meeting all regulatory mandates. Some aspects of the science mission requirements are especially significant in terms of their potential impact on ship construction and operating costs. These include, for example, icebreaking capacity, range and endurance, capacity for winter operations, the size of the human complement, and cargo capacity. To provide a ship that meets future science needs and national interests in the Southern Ocean and Antarctica, significant cost hurdles can be expected with regard to nearly every one of these factors. With either of the recommended paths, the result will be a ship that costs more per day to operate than do US Academic Research Fleet global-class open-ocean research ships. One cost savings, of a sort, can potentially come from the icebreaking capacity of a new USAP polar research ship. Increasing icebreaking capability above present NBP performance would add significantly to ship construction and operating costs, but the Subcommittee notes that if a new ship were built to only modestly better icebreaking capability than that of the NBP, it could work as needed with a US Coast Guard or other escort icebreaker to accomplish future science missions requiring more robust icebreaking. Such work with escort icebreakers would benefit from long-term expeditionary planning to make most effective and efficient use of what is viewed as an occasional, though vitally important, opportunity.

Several issues need to be addressed by a more thorough study that weighs the pros and cons of conducting research with an NBP-like vessel (ice class PC4) using an icebreaking escort vessel as opposed to a single "super NBP" vessel (ice class PC3). Such a study would:

i. Determine the operational costs for PC3 versus PC4 vessels.
ii. Determine if a PC4 vessel meeting all the SMRs outlined herein could conduct the same research when operating in conjunction with an ice escort vessel.
iii. Project the demand for research in heavy ice conditions capable of being conducted by a PC3 vessel (number of missions/year, duration and type of missions).

Once these issues have been resolved, assess the cost-benefits of building and operating a PC3 vessel as a stand-alone vessel versus a PC4 operating with an escort icebreaker.

Technical and fiscal planning for replacement ships should begin approximately 10 years (7 at a minimum) before a new ship enters polar service, and involve continual input and oversight from the US polar marine science community throughout planning, design, construction, testing, and science systems performance verification.

The subcommittee recommends that the Leidos Vessel Studies report be paid close attention in future development of operational and design specifications for new USAP polar research and supply ships.

9. The USAP should evaluate alternative operational models for its ships, for example NSF-funded design, construction, and testing, under supervision and then operation by a principal ship-operating academic institution, or a long-term charter agreement aimed at a ship built to specification, with the design construction, and operation contracts overseen by a principal ship-operating academic institution. With either or other models, operating agreements should permit occasional use of the ships for science and support missions by other nations' Antarctic programs when a ship is not in use by US researchers.

10. Design and construct a replacement for the Laurence M. Gould: The future Laurence M. Gould replacement should be designed to optimally support both USAP Antarctic Peninsula science and Palmer Station logistics, plus use as chartered support ship for BAS (or other nations as feasible) science and logistics. While, due to financial constraints, this ship would be owned by the US, careful co-scheduling would allow shared access to this resource. An LMG replacement ship more expensive to charter and operate than the LMG is not envisioned unless the USAP's share of the total costs is less than (or at least no more than) the USAP's present annual cost for the LMG (now paid solely by the USAP). The LMG replacement ship should be ice-strengthened but does not need to be an icebreaker, and it should be outfitted for oceanographic research in a manner similar to the LMG.

    As an alternative to replacing the Laurence M. Gould with another Palmer Station-bound LMG-like ship, the USAP should investigate the advantages of constructing and operating two identical NBP-sized ships. There would be major savings in total design and construction costs, and real-world operational costs might be nearly similar, meanwhile adding a huge degree of flexibility and capability to the USAP fleet. Costs to the USAP might be ameliorated by occasional use of one ship for other US research, such as for occupying GO-SHIP transects, or use in marine geophysical research. Another way to reduce costs to the USAP would be to operate the ships via charter agreements that permitted chartering to other Antarctic programs when a USAP ship was not needed for USAP or other US research and support.

11. To help offset costs, the USAP should consider operational models for its ships that would permit occasional use of the ships for science and support missions by other nations' Antarctic programs (UK/BAS is specifically noted), when not in use for US researcher and support missions. The RV Subcommittee supports an approach that develops and maintains greater cooperation and shared resources among Antarctic research programs. A system of cooperative scheduling and barter or charter could serve to provide cost savings, increased flexibility and access to different capabilities in much the same way that the U.S. Academic Research Fleet or the cooperative arrangements in Europe and the Arctic do.

12. The RV Subcommittee recommends that the USAP make expeditionary planning an explicit, routine aspect of an appropriate portion of the available ship time for the NBP (and its replacement) and possibly the LMG (and its replacement). For example, with community guidance, NSF and other polar research support agencies might create long-advance-notice opportunities for unique, specialized science, expeditions to regions of special interest, and/or winter and heavy ice operations (such as operations with an escort

icebreaker), so that the science community could mobilize (workshops, proposals, etc.) sufficiently in advance. As part of this process, the support agencies should build working relationships with operators of icebreakers which might occasionally be utilized as escort vessels for the USAP principal polar research ship, thus effectively and temporarily increasing its ice classification without the construction and operation expenses attending to a higher ice class polar research ship.\

F. Community Survey

F.1 Survey Process

The subcommittee drafted a survey consisting of 28 questions using Survey Monkey. The survey questions were approved by NSF OPP and then announced to the science community on July 16 and 17, 2018. Direct requests were sent to a list of scientists and operational personnel with experience in the Polar regions using the Survey Monkey mail feature. Using various sources and subcommittee members personal knowledge, a list of 156 people was developed, approved and used to solicit responses to the survey. In addition, a link to the survey was distributed through the UNOLS News email list reaching a much broader segment of the science community. The survey was also made public through the NSF OPP and UNOLS Facebook pages. The survey was active for approximately one month with the last response received on August 13, 2018.

The survey was divided into 4 sections: Questions 1 - 11 asked for information about the respondents experience and research interests including where, when and how ships were used; Questions 12 - 24 focused on the capabilities and requirements for USAP ships; Question 25 focused on the need for one or two USAP ships; and Questions 26 - 27 focused on the direction of future science in the Antarctic and Question 28 asked for any additional comments not covered by the survey questions.

A complete compilation of the questions and responses is attached as appendix 3 to this report.

F.2 Survey Responses - Participants Analysis

A total of 93 people responded to our survey. Of this number, the majority (46%) were senior scientists. Mid-career scientists made up 22% of the respondents, while early-career scientists and post-docs made up 6% each. Graduate students accounted for 2% of the respondents. Respondents who identified as Other (e.g. technical support, operations, etc.) contributed 11% to the total.

Current and past use of the USAP vessels has been primarily at the Antarctic Peninsula (26%), according to the respondents of our survey. The Ross Sea is a close second, with 18% of the respondents having conducted research there in the past or at present. Other key regions included the Amundsen Sea (11%), the Weddell Sea (11%), and the Bellingshausen Sea (10%). The

Scotia Sea, East Antarctic, and Sub-Antarctic regions were identified as current/past study regions by <10% of the respondents. Other regions were identified by 5% of the respondents.

As with current and past use, highest future use of the USAP vessels will be at the Antarctic Peninsula (23%) and the Ross Sea (17%). The Amundsen, Weddell and Bellingshausen Seas were highlighted as regions where 12%, 12%, and 11%, respectively, of the respondents plan to conduct their future research. The Scotia Sea, East Antarctic and Sub-Antarctic were identified as future study regions by <10% of the respondents each. 4% of the respondents identified Other Regions for their future research, including the entire Southern Ocean, the Circum-Antarctic Boundary, and the South Pole (which of course does not require research ship support).

The majority of respondents have conducted or are currently conducting research in the summer (41%) and spring (25%). Only 20% of respondents have worked in the autumn, and only 14% in the winter. Future use of the USAP vessels will increase slightly during the autumn (22% of respondents) and winter (15% of respondents), while plans for summer research were highlighted by marginally fewer individuals (38%). Future use of the USAP vessels in the spring remained at 25%.

We asked the respondents to tell us more about their current/past and future field work and provided an open text box in which they could respond. We then categorized their responses according to equipment and/or instruments needs by either noting what equipment/instruments they specified or inferring likely equipment/instruments based on the type of research they mentioned. 53% of the respondents conduct research that requires the use of winches. This number remains steady (55%) for anticipated future use. There is an anticipated increase in the use of acoustic instruments (including multi-beam, chirp, sub-bottom, EK80, and ADCP) from 28% at current/past levels to 32% in the future. Future use of surface underway data was anticipated by 24% of respondents (up from a current/past use of 20%). Approximately 20% of respondents use the USAP vessels for sample processing activities, while closer to 30% use the vessels for transport to field stations or remote field sites. While only 10% of respondents currently use autonomous vehicles (including AUVs, gliders, drifters, floats), 20% anticipated using them in their future research. 8% of respondents require ice sampling capabilities at present, and this is likely to rise to 12% in the future. Similarly, 9% of respondents make use of small-boat operations, with this value increasing to 14% in the future. Current/past research supported by helicopter operations was mentioned by only 5% of the respondents, but 9% list this capability as something they will need in their future research. Approximately 8% of respondents use and plan to use moorings and meteorological data for their current and future research. ROV and UAV applications were listed by 2% of the respondents as being part of their current/past work, but 5% and 4%, respectively, listed these instruments as being part of their planned future research. Drilling operations were listed by 2% of respondents for their current/past work, and 3% for their future planned work. No respondents listed LIDAR as something they currently use, or have used in the past, and only 1% of respondents listed LIDAR for their future research. Less than 2% of respondents require communications systems for their research on USAP vessels. (The Subcommittee interprets "requiring communications systems" to mean that such systems are an integral component of the actual research, as opposed to enabling standard off-ship communications.) It is important to point out that 9% of respondents have not used USAP vessels before.

In terms of suitability of the current USAP vessels, the largest issues were found with instrumentation (30% said instrumentation was not currently suitable, while 39% said it was), dynamic positioning/sea keeping (25% said this was currently not suitable, while 40% said it was), and ice operations (32% said the current USAP vessels were not suitable for this, while 24% said it was). Overall, 53% of respondents said that berthing numbers on the LMG were suitable (14% said "no"); 20% of respondents suggested alternate berthing numbers for the LMG, the most common of which was 45 berths. 58% of respondents felt that the berthing numbers on the NBP were also suitable (11% said they were not); 19% of respondents suggested alternate berthing numbers for the NBP, the most common of which was, like the LMG, 45 berths. Science space was an issue for 20% of the respondents, while 47% felt that science space is suitable for their research needs. The USAP vessels' handling systems were rated as suitable by 46% of the respondents, but 14% found this aspect was currently unsuitable. 43% of the respondents felt that the networks on the USAP vessels were suitable. However, 23% of respondents think that the networks need improvement. When asked whether a support ice breaker would be useful for their research, 26% of the respondents said "yes" and 17% said "no". Current helicopter operations were seen to be suitable by only 10% of the respondents, while only 14% found them unsuitable. The remaining respondents either did not answer the question or were not certain how to answer, suggesting a small potential user pool.

The SMR identified 6 key needs for the new USAP vessel/s. "Acoustically quiet" and "habitability" were identified as the most critical SMR needs, according to 31% and 38% of respondents, respectively. The SMR needs that were deemed as unnecessary by the majority of respondents were "geotechnical drilling" (46% of the respondents) and "seismic" (40% of the respondents). SMR needs that were identified primarily as "nice, but not critical" included "acoustically quiet" (32%), "habitability" (41%), "moon pool" (33%), and "helicopter" (37%). 20% of respondents did not answer this question.

Regarding the fleet size, the majority of respondents (49%) said that two vessels are necessary. 11% of respondents felt that one vessel might work, but only under certain conditions. 9% of respondents said only one vessel was necessary. 31% of respondents chose not to answer this question.

The majority of respondents agreed that the two key science challenges identified in the SMR report were still appropriate (68% for Challenge I, and 65% for Challenge II). Only 3% of respondents said that Challenge I was no longer appropriate, and 5% said the same for Challenge II. 27% and 28% of respondents did not answer the question for Challenges I and II, respectively.

Most of the research questions identified by the SMR report were seen as still being relevant by the respondents. Q.1. received the highest percentage of "no" votes (15%), while Q.2. and Q.9. were the next highest "no" vote recipients (8% and 9%, respectively). Q.6. received the highest percentage of "yes" votes from the respondents (75%), and other questions that were considered important were Q.3. (63%), Q.5. (61%), Q.7. (68%), Q.10. (68%), Q.11. (67%), Q.12. (65%), and Q.14. (60%). The remaining questions were identified as still important by < 60% of the respondents. A number of respondents were not sure of the answers, ranging from 0-22%. Between 24% and 25% of the respondents chose not to answer the questions.

F.3 Survey Responses - Infrastructure Requirements Analysis

F.3.1. Survey:

The current maximum non-crew berthing capacity of the USAP ships is 37 on LMG and 39 on NBP (both include contractor science support staff and helo crews if carried).

a) Is the current maximum science berthing on the LMG sufficient for your work now and in the future? [Drop-down menu, only choose one option]:

b) Is the current maximum science berthing on the NBP sufficient for your work now and in the future? [Drop-down menu, only choose one option]:

c) If you said No to either 1.a or 1.b, please indicate what berthing capacity is appropriate.

A little over half of the respondents were satisfied with the number of berths for scientists and staff on the LMG, currently at 37. Fourteen of the 94 respondents indicated a preference for an increased number of berths, ranging from 40-66, however, the higher numbers of 60 and 66 berths reflect single opinions each. Five respondents suggested 45 berths and 3 suggested 50 berths.

Fifty-seven % of the respondents were satisfied with the number of berths for scientists and staff on the NBP, currently at 39. Numbers for increased berths ranged as high as 80 (1 respondent), however increasing to either 45 (5 respondents) or 50 (4 respondents) were more common suggestions.

One respondent noted that "The issue tends not to be "number of berths" but rather how those berths are managed, with unfortunately the momentum building in recent years to favor the contractor as opposed to the science. However, overall, the demand on vessel support is increasing and will no doubt continue in the future, so any plan for new vessels should default to increasing the number of available berths. Regarding question 14 specifically, the LMG is currently inadequate and the NBP borderline adequate."

One respondent noted that space "should increase proportionally with an increase in berths."

F.3.2. Survey:

Is the available laboratory space, deck area and science storage space on the USAP ships generally sufficient for your work in the future? [Drop-down menu, only choose one option]

*Please describe how this could be improved. (*Open text option - limit word count to 250 words)*

About 1/3 of the respondents had specific comments and suggestions regarding the adequacy of lab, deck and storage spaces on the two ships. These are divided into general comments, comments specific to the LMG and comments specific to the NBP, but the overall messages are applicable more generally to the USAP vessels.

GENERAL COMMENTS:

Many respondents noted problems with space, with regard to a variety of work spaces on the ships. They noted that this is particularly significant when multiple projects are using the ship at once, even though these larger bio-geo-chemical-mooring cruises may be rare.

Respondents noted that spaces can be cramped, and suggested more wet lab space, more easily configurable spaces, more general work space for setting up laptop computers for scientists and students, and space for spreading out and testing field gear. Problems noted included a need for larger aquarium space (inside and outside and deck) to conduct experiments with live organisms under appropriate environmental conditions and to hold fish during fishing operations, more storage space in the -80 Freezers, more storage space for ice samples, and more than one instrument platform high up, capable to carry 200+lbs, ideally 360° field of view. Respondents requested more chemical fume hoods and clean labs that are contamination free with respect to trace metals, and also other contaminants. Increasing interest in doing molecular analysis in real time in the field, in order to inform further sampling, for example, requires lab space which can be kept sufficiently clean and isolated for this kind of work to be conducted. Scientists suggested that more environmentally controlled rooms or vans would be very useful. Several noted that “both ships need more space for core processing” and that “modern laboratory and computational researcher space is needed, including connection to flat screen for the visualization of complex data sets.”

Many respondents directed their comments toward deck space. Comments focused on the need for improved deck space appropriate for launch and recovery of small boats, unmanned aircraft and AUVs. Others noted a need for “space that is specifically designed for deck incubations, with easy/adjacent lab space.” One respondent noted that “the deck area should include enough room for seabed drilling vans or any vans associated with drilling activities” and as well, the space should accommodate sediment sampling. In terms of accommodating drilling, “Sea bed drill rigs require a lot of deck space - e.g. for the British Geological Survey Rock-Drill2 (RD2), 7 x 20ft containers, ~ 100,000 kg, as well as space for the launch system and winch. The German MeBo drill rig requires use of a substantial A-frame and has a similar deck space requirement. A moonpool type deployment would be preferable, being close to the center of motion and protected from sea ice. But such sea bed drilling systems are designed for a back deck or over-the-side deployment, and I’m not sure they would fit through a 4x4m moon pool. Ability to deploy a geotechnical rig through the moonpool would partly address the same need.”

LMG specific

In general, respondents noted that the LMG is “too small for modern lab work” and “especially the deck which can be extremely crowded when the LMG is carrying a lot of cargo for Palmer Station. This in return makes our work on the back deck not optimal for efficient and accurate catch sorting (poor lighting, not enough space, ...). Also, as mentioned before, one goal is to develop more collaborative work with scientists sharing common interest in sampling location but not completely overlapping interest in the biological material. This would make the lab space, deck space, aquarium room size, and storage on the LMG, limiting factors, especially when a lot of the room is already used by cargo/supplies for the station.” In particular, space limitations were noted as problematic for “larger more complex projects.”

Respondents also noted that some of the labs and their arrangement are not as functional as necessary. For example, “the wet lab can only be accessed weather permitting. I have lost experiments because we were not allowed outside during bad weather. All science lab spaces should have safe inside access.” “The aquarium facility on the LMG is substandard …. It needs to be accessible without going out on deck and configurable for more than huge fish holding tanks.” “Chemical storage could be better integrated with other spaces on the LMG.”

NBP Specific

Many respondents had positive comments regarding the NBP, noting that the “labs are largely sufficient and can be adapted to many different projects.” One respondent noted that “the NBP is close but try visiting one of the many vessels recently built for ocean research by other nations and you'll get the picture. The US is WAY behind in terms of providing modern, well-functioning labs and over-the-side research capabilities in the polar regions.”

Scientists noted a shortage of deck space, storage space and space in wet labs when multiple science parties, or complex projects, multi-disciplinary share the ship. They noted that, “even though labs are generous, a big multi-disciplinary program work likely overfill the present NBP labs.”

In terms of deck space, “Accommodating multiple containers on deck and still having clear space for crane operations was a problem.” And “The forward deck space on NBP is currently unusable so long cable runs or sampling tubes are required for clean air sampling off the front deck. Undisturbed ice sampling (remotely by lidar or em) is currently not doable on the NBP as there is no bow crane and instrument cables need to be shorter than the current long run back to warm lab space. Provision of wireless connections, ethernet ports and/or instrument vans or shelters on the foredeck are needed. On the rear deck, current access to the ice is limited to the starboard side which precludes oceanographic (CTD) sampling using the Baltic room or starboard A-frame.”

One respondent noted that “NBP labs are good (and are well maintained) and spacious, but could be better. More care is needed to have more nearly complete assortment of power types, compressed air, seawater, etc, etc. in more of the labs. Not sure if there is a full-out climate-controlled lab (well below to well above freezing, with unistrut, lights, full range of hook-ups, etc - actually there should be two of them). Don't think the NBP has a lab on one of the higher decks for the teams doing air/sky work.” Other respondents noted limited fume hood space and the need for better climate control, particularly in the main labs. The importance of well-functioning environmentally controlled rooms for seawater processing and experimental work also was noted.

F.3.3. Survey:

Is the suite of scientific support instrumentation on the USAP ships sufficient for your current work (e.g. acoustical profiling & mapping systems, meteorological instruments, underway *seawater measurements, CTD or other lowered instrument packages, sample collection and storage facilities, etc.)? [Drop-down menu, only choose one option]*

*Please describe how this could be improved. (*Open text option - limit word count to 250 words)*

About 50% of the respondents were satisfied with USAP instrumentation on the ships while, the other half of the respondents made specific suggestions for improvement. Of those who commented, 30% noted insufficient acoustic instrumentation on the ships, including the need for higher quality seabeam capability (the lack of a hull-mounted echo-sounder on the LMG was noted by several respondents) and improved, higher-resolution hull-mounted sub-bottom 3.5 kHz systems. One scientist noted, "As far as I know, both the hull-mounted acoustic profiling system and the seismic system have not been upgraded in many years and we now lag behind the equipment on other nations' vessels as far as sub-bottom profiling." On the LMG, the lack of hull-mounted systems is seen as "a critical gap in our ability to study the Antarctic marine ecosystem in a meaningful and quantitative way. Towing instruments is not possible in most conditions and requires many people and the data are often corrupt. Towing a fish also strains equipment unnecessarily and breaks it quickly, as was done this past season on the LMG with new echo-sounders that were purchased. These are designed to be hull-mounted and are not being used appropriately." In addition, the lack of multi-beam capability on the LMG was seen as detrimental for both science and "also for charting and getting into remote field camp locations (for safety reasons)." Four respondents also expressed a need for bioacoustics capabilities; in addition, "the ships need to be acoustically quiet."

Two respondents suggested adding an underway Tow-Yo CTD "that will bring the USAP ships into the 21st century" and two suggested "use of a lowered ADCP (LDCP) with the CTD" and USAP support for the LADCP. One respondent said that "USBL capability would be a great improvement, in particular for LADCP and microstructure surveys, as well as mooring operations." Two respondents indicated a need for trace metal clean rosettes, with one saying that "In general, given the important role trace metals play in the Southern Ocean and the expansion of trace metal research in recent years, future ships could broaden their user base and build in new research collaborations if they enhance their capabilities for trace metal sampling (TMC rosette systems, clean labs/lab vans)." Also, "support for CTD operations in the open ocean is more limited than that on present Academic Research Fleet Global-class ships due to limitations of the NBP Baltic room."

Four respondents suggested improvement in the underway seawater systems, which they say are outdated and not clean, and which should make many additional measurements. Improvements in the future should focus on ease of "periodic cleaning and for subsampling, in addition to adding in-line instrumentation." Finally, it was noted that "if someone figures out a way to improve performance of the underway seawater system in ice, (and the sonar-related systems during icebreaking), that would be nice."

Five respondents focused on coring capabilities, noting that the need for longer piston coring capability (40 m), and improved setup for both piston coring and mega-coring. In line with these comments was the suggestion for a core locker (+4°C) with racks for safe storage of sediment cores. One response was specific, "For my work, ideal capabilities would be: Seismic profile capability. For IODP and similar marine geological drilling, it is essential to understand the seafloor and subsurface, both for interpreting past ice sheet extent and for best placement of drill sites. A compressor for airgun sound sources are integral to this capability. Ability to deploy a sea-bed drill rig, from the back deck, or through a moon pool. Ability to fit a geotechnical drilling rig over the moon pool would also address the same need, although sediment core recovery is hampered by ship heave for ship-based drilling. Station-keeping ability to remain at a drill site for up to 2 days. The maximum radius of movement depends on the system, but may be as little as 10 m. Fume hoods in the laboratory and fume exhaust handling in order to use hydrogen fluoride (HF) to isolate pollen and dinoflagellates from marine sediment. I understand that it would require some retrofitting for the N.B. Palmer to be able to do this at the moment."

Many respondents focused on having dedicated gliders, AUVs, UAVs and drones (with extended payload and range) on the ships, all of which then leads to the need for appropriate launch and recovery capability for larger vehicles, as well as deck configuration options. Bottom imagery capability, both still photo and video, was seen as important; "A reasonably sized ROV that could work with an elevator would be a HUGE step forward for the USAP marine program. Ideally the ROV could run transects or do site-focused sampling. A standard sensory package (like on WHOIs Sentry) would be nice as would as a manipulator to sample or run experiments at depth." Another respondent suggested, "We could enhance the underway optical properties sampling. Inclusion of a ifcb would help characterize sources of high frequency scattering. Higher frequency nortek profilers to get surface structure would help." While another suggested, "Better capabilities to collect krill under the ice would be ideal. It is important to understand the role of sea ice in the life cycles of krill, particularly in light of the changing climate. At the moment, it is challenging to collect under-ice krill from the ships. Perhaps implementation of a SUIT sampler, such as AWI is using, or availability of ROVs/AUVs with under-ice video and sampling capabilities?"

As elaborated on more specifically within other questions, and summarized elsewhere in this report, is a need for smaller, capable crafts that can work in shallower areas.

Specific comments from single respondents:

- Improvement needed in the trawls and including better configuration on the back deck for benthic trawl sorting operations.
- Automatic cameras for ice observations.
- Aquarium room doesn't have enough capacity.
- Both ships need improved internet/data transfer capabilities for receiving ice imagery and weather imagery.
- Internet, comms and radio are always limited.
- Stabilized high-resolution thermal imaging with 360° FOV. For bird and marine mammal detection underway.
- I believe these ships are not measuring air-sea fluxes.
- Add wide-bandwidth echosounders, multi-beam sonars, long-range scanning sonar, sub-bottom profiler, hydrophone arrays, moving-vessel profiler, ROV, continuous-underway fish-egg sampler, and hull-mounted sound-speed and dissolved oxygen sensors. Add high-bandwidth Ethernet for video and instrumentation control and access via "remote presence."

F.3.4. Survey:

Are the network and other technical systems on the USAP ships sufficient for your work now and in the future (e.g. intra-net connectivity on the ship, internet connectivity and bandwidth to external sites, satellite communications, mapping and GIS capabilities, desk space and support for personal workstations, navigation systems, time servers, clean power, etc.)?

[Drop-down menu, only choose one option]:

Please describe how this could be improved. [Open text option - limit word count to 250 words]

A number of respondents emphasized the need for more bandwidth and greater internet connectivity on the USAP vessels. They stated that the "restrictive internet access made science difficult at times". Specifically, downloading relevant papers and software, and transmitting data from the ship to shore-based PIs and researchers. Some respondents need the ability to "receive high-resolution remote sensing data", noting that the current "bandwidth is not generally sufficient to handle downloads of real-time large volume datasets".

One respondent noted that the "recent upgrades to internet services and capacity are much better than they have been in the past".

Other data processing-related comments revolved around the addition of "remote access to instrumentation control and data, and video presence". Another respondent stated that "quality of the data, the data coverage and the accessibility of data coming off the ships" is sometimes less than clear. This person was referring to meteorological data, underway seawater measurements, XBT transects during crossings, and ADCP data.

*******ORIGINAL COMMENTS BELOW******

- *On previous cruises on which I participated,* ***restrictive internet access*** *made science difficult at times as it was difficult to download relevant papers and software. On previous cruises for which I provided remote support it was* ***sometimes difficult to transmit the required data*** *to shore for processing and QC.*
- *I think a good molecular-clean lab facility would be useful in the future. As DNA sequencing technology continues to improve at some point we will want to be able to sequence samples at sea, in order to inform our sampling plans, and optimize our limited ship time. If such sequencing capabilities were to become a reality* ***more internet would also probably be necessary*** *in order to transfer data to bioinformatics servers back on land.*
- *There has got to be a way to* ***increase bandwidth on the ships****. Our cruises depend on near real-time remote sensing data.*
- *For a cruise in the sea ice zone, the ability to receive high-resolution remote sensing data is very valuable.*
- ***Bandwidth is not generally sufficient*** *to handle downloads of real-time large volume datasets such as high resolution satellite images which will become more common in the near future. Collaborative space with reasonable sized wall displays for displaying mapping/GIS/Remote Sensing and other electronic information would be a useful addition to future vessels. At least on the LMG, this type of non-traditional lab space is limited.*
- ***Internet connectivity can probably be better*** *even on the existing ships; access to the web for data access would be nice on a regular basis. Desk space is good though and IT support is typically excellent.*

- *Current systems are sufficient (I often bring my own computers), but better internet connection to the external sites would be good. The access to real-time navigation data through intranet could be better (works, but usually takes some setting up)*
- *Some find it suitable though.*
- *Recent upgrades to internet services and capacity are much better than they have been in the past. Greater connection allows for better communication with vendors and technical support and allows for much faster and better communication of information, data, etc.*

Other comments:

- *The effectiveness of the ships could be increased multi-fold by adding "remote access" to instrumentation control and data, and video presence.*
- *However, the quality of the data, the data coverage and the accessibility of data coming off the ships has note been clear issue (e.g. meteorological data; underway seawater measurements, XBT transects during crossings, ADCP)*

F.3.5. Survey:

Are the winch, A-frame, crane and small-boat operations capabilities of the USAP ships sufficient for your work now and in the future? [Drop-down menu, only choose one option]

Please describe how this could be improved. [Open text option - limit word count to 250 words]

Small boats

A number of respondents mentioned the need for small boat operations in their future research in Antarctica and emphasized the need for continued support of small boat operations.

Small boat operations, specifically launch and recovery, could be improved in a number of ways, according to the respondents. One respondent mentioned that the "deck area could be improved significantly to make deploying small boats quicker and more functional". One respondent suggested the addition of smaller side J-frames (though no more specifics were provided). Dynamic position and sea-keeping capabilities, particularly of the LMG, were noted as being problematic for safe and efficient launching and retrieval of small boats. "Forward-looking sonar and/or other navigation aids to allow the vessel to safely operate in shallower waters in order for it to go closer to shore to support small boat operations" were listed by one respondent as additional capabilities that should be considered.

One respondent mentioned that small boat operations limited ship-board science because there were not enough marine technicians to conduct both at the same time. One respondent suggested that further training of marine technicians to operate small boats from the USAP vessels in challenging conditions would be useful, given that "it was clear that small boat work was difficult". Another respondent recommended that the "NSF/USAP consider the design of the Icelandic small boat called Rafnar, which is considered by Navy to operate better (significantly better) in rough seas due to unique hull design. See: https://rafnar.is/pages/about-us". Zodiacs were seen to be better for small boat operations than the "Cajun Cruncher", though when Zodiacs are on board, space becomes an issue.

According to several respondents, Zodiacs and other small boats used by the USAP are limited in a number of ways. They are small and have limited capabilities in sea ice. One respondent mentioned the need for helicopter support for research teams that must be transferred to shore. One respondent felt that the small boat operations were not as nimble as they need to be, particularly when recovering and deploying autonomous vehicles. Another respondent said that there were too few small boats and that access to those available was limited. Zodiacs were listed by one respondent as not being suitable for shallow-water surveys, very close to shore. The types of surveys in question were not mentioned though.

One respondent recommended that the USAP add instrumented small craft for nearshore surveys, though it was not clear if they meant unmanned craft or not. One respondent summed up the general response from all those who mentioned small boat operations: “Need more and larger small boats that can be launched easily”.

Additional Survey Comments about small boats under other questions:

- *We will require small boat support for tagging and biopsy work.*
- *Ships will be used to support CTD rosette/water bottle collections, net tows, acoustic echo sounder surveys, ROV/AUV operations, dive operations (if permitted), marine mammal and bird observations, small boat work, sea ice work.*
- *Continued support of small boat operations.*
- *The deck area could be improved significantly to make deploying small boats quicker and more functional.*
- *We anticipate needing helicopter support, and using a combination of USAP vessels and small vessels (RIBS and zodiacs).*
- *Smaller side J frames might be useful in addition to existing equipment. Small boat ops will always be necessary.*
- *One problem comes in when multiple science parties are on board and then there are not enough scientific staff to do multiple tasks---for example, can't core while small boats are away, not due to equipment limitations, but because the same persons are needed for each task.*
- *It was made clear that small boat work was difficult, so perhaps more use and training on these would be helpful.*
- *The capabilities are fine at the moment and the near future, although the only small-boat operations are usually done by zodiac. Not good enough for real near shore or shallow water surveys.*
- *The current small boat (Cajun Cruncher) is worthless and was only deployed once during my five cruises. We have successfully used zodiacs on two cruises and seem to be the best solution for small-boat operations. There are problems with storage of these interfering with other work during other operations when not in use.*
- *Future projects that rely on small boats are always limited, the inflatables are great but small.*
- *…we have used small boats with great frequency (to, e.g., visit field sites, deploy field camps, etc.), especially during field seasons where we haven't benefited from helicopter support. Although Zodiacs and the aluminum landing craft are perfectly suitable when sea ice isn't super-extensive, the fact that these boats cannot get through most ice is highly problematic. Our team needs to be able to land on our islands of interest to conduct our work. When, as is often the case, even in late summer, these islands are ringed by sea ice, we cannot use small boats to access them. This is why having helicopter support in 2016 was so beneficial; indeed, the reason we were given access to helicopters in the first place was because NSF recognized that we likely wouldn't be able to meet our research objectives with small boat support alone. If our team was permitted to walk, transport gear, etc. over sea ice/fast ice, then we could likely perform our work with small boat support alone. But since, to date, we have not been permitted to do this, helicopter support has become vital to the success of our project. (I suspect this is the case for*

any research team that needs to access sites on land that are frequently surrounded by frozen ocean.)

- *It is not clear to the respondent if the NBP small boat operations are as nimble as they need to be for working with autonomous vehicles, etc. Probably need the capacity to easily deploy/recover two work boats.*
- *Add instrumented small craft to conduct surveys of marine life and their oceanographic and seabed habitats nearshore, where the ships cannot safely navigate, and where land-based predators forage.*
- *Small boat operations are not sufficient. The boats are limited in number and access to them is restrictive.*
- *Need more and larger small boats that can be launched easily.*
- *The addition of aluminum-hulled RHIBs was great. Having a pulpit for our research needs is ideal and greatly appreciated. A faster mechanism to get boats on and off would be ideal.*
- *The LMG has often times had stability issues that make small boat deployment challenging but for the most part we would not work in those kinds of conditions. The ride, of course, could be improved on the LMG to handle better in rough seas.*
- *We don't conduct over-the-side ops, except for getting team members/gear into small boats to land on our islands of interest. The ships are sufficiently stable in most seas; nevertheless, most of our team members are typically incapacitated for much of the journey through Drake Passage. (I doubt much can be done about this though, given how ridiculously rough the Drake can be.) As noted above, sea ice is a significant problem for us, though this isn't so much a problem with the icebreaking capabilities of the vessels. Again, the issue is that there is typically sea ice between the closest point the ship can reach to a given island of interest and the island itself. Due to the depth of its hull and the 'shallowness' of the water, the ship can't just break ice all the way to shore; instead, it gets as close as it safely can and then we try to reach the island by Zodiac or aluminum landing craft. But given that Zodiacs/landing craft can't really break ice, this is often a huge problem for us. For example, in 2009, the LMG got us well within sight of Vega Island, but we never actually reached that island given that it was ringed by fast ice.*
- *Forward-looking sonar and/or other navigation aids to allow the vessel to safely operate in shallower waters in order for it to go closer to shore to support small boat operations.*

F.3.6. Survey:

Are the general handling characteristics of the USAP ships with respect to dynamic positioning for over-the-side operations and stability in heavy seas and/or sea ice sufficient for your work now and in the future? [Drop-down menu, only choose one option]

Please describe how this could be improved. [Open text option - limit word count to 250 words]

There were 31 responses, with respondents often dealing with both dynamic positioning and sea keeping issues together.

The LMG's sea keeping performance, and overall performance in heavier seas (whether underway or on station) was consistently criticized. For example, a respondent noted that "passenger safety in the staterooms/bunks needs to be improved … people were wedging themselves into their bunks with life jackets to prevent ejection from their bunk while they slept." Other LMG notes include it "is not a pleasant ship to work off", ["has very poor performance in heavy seas", and "has issues in regards to maneuverability for over-the-side operations … when the sea is not calm, many over-the-side operations (fish traps retrieval, CTD casts) are not possible on the LMG". An LMG summary was in effect provided by one respondent: "very poor performance in heavy seas … it's sea ice capabilities are virtually non-existent".

The NBP's sea keeping performance, and overall performance in heavier seas and sea ice (whether underway or on station) received mixed opinions. For example, "the NB Palmer dynamic positioning is fine in average conditions, but not strong enough in heavy sea ice or strong winds". The NBP's limits in the ice extend to more than making way: "Ability to hold station in more ice (which I guess means more thruster capability) would certainly increase what we are able to do in our current programs." A specific comment regarding desired performance: "Sea bed drill rigs, despite being connected to the ship by a flexible umbilical cable, require quite limited vessel movement during drilling. The exact radius limit depends on water depth and the drilling system but may be as little as 10 m or less over a period of up to two days." The NBP is the USAP ship for in-ice (and on-ice) work. Yet, "sea ice operations have been challenging with the NBP - yet this will be a critical demand for research programs going forward. Design a ship that is sea ice capable and that is designed to get science access to sea ice floes". Although one respondent noted "need improved capability to maintain station, particularly during coring and drilling", another noted "the NBP was able to move a couple of meters at a time in any requested direction for our benthic camera operations".

A comment serving as a general summary was provided by one respondent: "precise dynamic positioning is needed". But not all the problems cited by respondents related to the ships themselves, with lack of officer experience and crew training for work in the ice on some cruises being a limiting factor. A more general comment: "both the LMG and NBP are marginally incapable vessels that never really lived up to the performance we were promised when they launched. These vessels have "gotten us by", but they are overall far inferior to just about everything else out there." Another note regarding the human side of desired performance that "there is a benefit to having people feeling good and being productive that is worth the cost over the lifetime of a ship".

F.3.7. Survey:

Are the in-ice operation capabilities of the USAP ships sufficient for your science now and in the future? [Drop-down menu, only choose one option]

Replies sorted by career stage/position (Numbers in parentheses are percentages.)

	Yes	No	Don't know	Blank or N/A
Senior	12 (12)	20 (19)	7 (7)	8 (8)
Mid-Career	8 (8)	4 (4)	7 (7)	4 (4)
Early	2 (2)	2 (2)	1 (1)	1 (1)
Post-Doc	-	2 (2)	1 (1)	3 (3)
Grad Student	-	1 (1)	1 (1)	-

Other (Support, retired, Technician)	-	3 (3)	1 (1)	10 (10)
Total	22 (23)	31 (32)	18 (18)	26 (27)

Sorted by type of platform type (categories combined because many respondents fell into both). Some subjective decisions on my part as to platform category for a respondent. (Numbers in parentheses are percentages.)

	Yes	**No**	**Don't know**	**Blank or N/A**
Oceanographic, ship-based or station-based	18 (12)	27 (27)	14 (14)	13 (13)
Geo/Glacial, station-based or camp	5 (5)	4 (4)	4 (4)	2 (2)
Other	-	-	-	11 (11)
Total	22 (23)	31 (32)	18 (18)	26 (28)

The largest number (31) of respondents feel that the ice-capabilities of the present set of Arctic Monitoring and Assessment Programme (AMAP) vessels is inadequate ("no" category) while 22 felt that these are adequate presently ("yes" category). Eighteen respondents were unsure and 26 did not respond (many of these were tech and/or support staff). The responses were clearly dependent upon the type of work being done with the ocean ship- and station-based respondents feeling strongly that a better ice-breaking capability is required now and in the future. A total of 37 comments were offered on this topic. Most (72%) were made by the "no" respondents. In aggregate all of the comments point to the desirability of a more ice-capable RV and were concerned about the lack of ice-breaking capability in both the NBP and LMG. The concerns centered about extensive delays due to heavy ice, the inability to reach desirable sampling locations, the need to work in areas of heavier ice concentrations, and future desires and needs to conduct research in the shoulder seasons and winter when heavier ice concentrations are expected. Two comments specifically stated that the US should have, as a minimum, one PC3 class RV for AMAP and another mentioned that the US needed an ice-breaking RV in order to remain competitive in Antarctic research with respect to both maintenance of terrestrial stations and the ability to conduct at-sea research.

F.3.8. Survey:

If your science requires greater in-ice capability, would it be sufficient to provide an escort icebreaker for a USAP science ship of the present in-ice capability? [Drop-down menu, only choose one option]

Yes: 25 No: 16 Don't know: 23 N/A or no response: 33

These results are somewhat equivocal. The N/A or no response category was the largest with 33 entries. For those that did respond (64), 25 (39%) felt that they could work successfully with an escort. A substantial number (23 or 36%) were uncertain about the utility of the escort while 16 (25%) felt that an escort would not suffice for their research.

F.3.9. Survey:

If your research requires helicopter support, do you feel that your needs in this regard are currently met? [Drop-down menu, only choose one option]

Please describe how this could be improved. [Open text option - limit word count to 250 words]

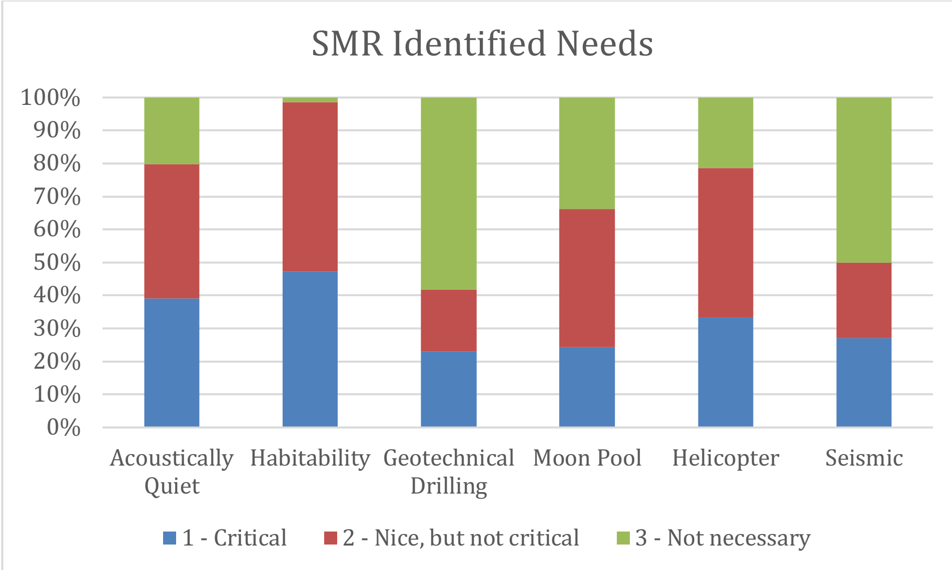
Only 20% of respondents had specific comments regarding helicopter support. Most of these indicated a critical need for the air support and suggested that the costly nature of operations makes it difficult to get funding for projects that require helicopter support. One respondent noted that "if helicopter support was available from both ships it would allow for a greater scope of work and capabilities of collecting information and surveying that is not currently available. This would be greatly appreciated for long-term planning." Respondents noted that helicopters "are a potentially irreplaceable means of access to ice-free areas in remote coastal locations that are not otherwise accessible," "may provide the only possible access for many interesting research sites" including coastal locations where access by ship is limited by sea ice, and are critical for glacier-ocean studies. Finally, it was noted that helicopter support can facilitate navigation as well as science.

Several recommendations for helicopter operations were made. In general, respondents suggested that helicopter support needs to be simplified; this might be easier if helicopters are used more routinely. Current helicopter size was deemed too small, and operations had "limited ability to operate in anything but perfect, cloud-free, weather conditions. Greater ability to work in partial cloud cover would allow more flight days." Several respondents noted the impact that helicopter support had on space – "Without hanger and extra berthing, helos are mostly a non-starter," and "ice work often requires extra vans to be placed on the NBP and this often constrains the use of helos."

F.3.10. Survey:

Please review the UNOLS SMR-identified outfitting objectives for a new polar research vessel, below. Rate the importance of each for your research on a scale of 1-3. 1 = critical; 2 = nice, but not critical; 3 = not necessary.

Acoustically quiet ship with minimal underwater-radiated noise
Habitability
Geotechnical drilling
Moon pool operations
Helicopter operations
Seismic capability



F.3.11. Survey:

What additional capacity or capability do you feel is lacking in the current USAP ships that may be required in the future to meet future scientific objectives in your field? [Open text option - limit word count to 500 words]

Of the survey respondents, 58% included specific information regarding "additional capabilities." These responses, which are summarized below, reflect a wide variety of concerns from the community, ranging from ice-breaking capabilities, to handling abilities for AUVs, ROVs and unmanned aircraft, and to personnel and berthing issues.

Better sea-keeping abilities were suggested by several respondents. It was noted that greater open water stability is needed for operations, and improved ability to work over the side safely in heavier seas/winds than NBP can now do. One respondent noted that greater stability would allow transit time to be more productive scientifically. Habitability issues were noted by several respondents, including the importance of personal comfort and privacy for decompression time (private cabins) in the rough seas and high stress operating environment of the Southern Ocean.

Four respondents requested greater in ice operation capability, including longer endurance in the ice. Improved ice breaking capability was noted by 4 respondents, including the specific need to get into multiyear ice to sample. In addition, more reliable ability to cross sea ice – for example, via helicopters, is important for shore-based work. Additional helicopter support was noted by four additional respondents.

Six people noted that the ship(s) need to be able to handle (launch and recover) the increased use of a suite of newer instrumentation, such as uCTDs, gliders, AUVs, ROVs, automatic ice cameras, submersibles, drones, and unmanned aircraft. "Any new ship should be built with the expectation that robotic platforms will be increasingly important. This means ensuring the deck layout can accommodate varied drone operation .... For underwater vehicles, a moonpool could be very valuable in ice provided it can be kept clear of ice .... Easy access to the instrument well to mount acoustic comms instrumentation for autonomous vehicle operation would be useful." One other respondent noted the need for ultra-short baseline - underwater acoustic positioning.

Four respondents indicated the need for hull mounted and underway echo sounders, with one noting the need for forward-looking sonar and/or other navigation aids to allow the vessel to safely operate in shallower waters in order for it to go closer to shore to support small boat operations.

Three people commented on the need for longer (30-40 m) piston coring capability, and on-board core scanning (ITRAX and Geotek?) facilities.

Four respondents indicated a need for improved facilities for working with trace metals (3) and the addition of a molecular-clean lab facility (1). Comments included improvements in trace metal clean labs and vans, and in a trace metal clean water sampling system.

The need for higher bandwidth internet capability was noted by two respondents.

Several respondents had specific comments regarding both exterior (6) and interior (7) spaces and systems. For example, one person suggested that the ships have dedicated and well-engineered deck incubators with flowing ambient seawater and that the system would be even better if temperature/ light/ ocean acidification control systems could be engineered into it. Another noted attention to a bow tower for air sampling, and another noted the need for different frequency ADCPs. One respondent suggested the need for a landing craft to bring larger supplies ashore or for remediation projects, a helipad, deck and hold storage for building materials, and more fuel tankage.

Other comments were more general, including larger deck space with flexibility in configuration of lab and deck layouts, and the possibility of over-the-side operations from a few different access points on the ships. In terms of interior space and systems, respondents added the need for good wet and dry lab spaces accessible from inside the ship, good flow through water system that does not heat up or change properties (temperature, no bubbles, loss of phytoplankton), gravity meters, and more gimbal-style tables or other methods for working in the lab while the ship is in motion. One respondent noted that all ships should have seismic capabilities.

More general capabilities that were discussed that could impact ship design include: the ability to better support large multi-disciplinary cruises, the ability to conduct air-sea flux measurements, improved sample collection methods, including those for higher trophic levels (better trawl sorting equipment, for example), the ability to retrieve and store large quantities of ice samples, collected through ice coring supported by helicopter operations, and eventually transported to CONUS and university facilities for analysis, and support for diving operations. One respondent noted that extremely long transit and logistics durations (6 weeks) relative to the working time (2 weeks) precludes many research possibilities and is extremely inefficient, and finally – one respondent simply wants more ship time for projects!

Four respondents indicated the importance of skilled, experienced manpower – specifically noting the need for experience with sediment coring and fishing operations, and top notch technical and operational science support. One person noted safety concerns regarding inexperienced young scientists, and the subsequent critical need for well-trained MTs.

Personnel-wise, while the need for trained manpower was noted, one person expressed concern that their footprint be small (2-3 person). Berthing was also brought up by several other respondents, who noted that in the future, we can anticipate longer cruises involving more interdisciplinary work, which will require increases in endurance and berth spaces for the science party, including technicians and helo crews. The use of berthing space for transit passengers was also noted as taking away berths for science. In addition, one person noted that improved berthing for transit passengers was needed.

F.3.12. Survey:

How do you envision projected climate/weather shifts over the next 40-50 years affecting your science support needs from USAP ships? [Open text option - limit word count to 100 words]

Thirty-nine respondents discussed anticipated impacts of climate change on ship-based work, with only 7 indicating an expectation of little to no change. Of those who wrote about changes, four major threads of comments emerged, focused on changes in sea ice distribution and extent, changes in sea state associated with greater storms and windiness, easier access to areas that are currently inaccessible due to ice, and greater overall research demand given rapid changes.

Nine people addressed reduced sea ice and the likelihood of easier ice-breaking operations, the possibility of using less ice-capable ships, and greater ability to perform more operations further south, and into austral spring/fall and winter. Several respondents noted their interest in following the sea ice habitat wherever it occurs. As one respondent wrote, "Changing climate/weather will continue to place importance on the scientific work done by USAP vessels. Because most of what we do is already focused on the extreme edge of the working capability of the NBP, and our interest is in the edge of the ice position, wherever that is, changes over the next 40-50 years will not lessen the conditions in which we work or where we want to work. Rather, the places in which we are interested will shift." Finally, despite most respondents anticipating less sea ice, they noted the unpredictability of future patterns of sea ice extent, and that sea ice extent is increasing in some sectors of the Antarctic.

One respondent stated that while "it's possible that climate changes will relieve the need for enhanced ice-operation capabilities, on the other hand we might expect more frequent and/or larger storms that could increase the need for seaworthiness of the next polar vessel." Greater stability in open water was noted by 10 respondents, who anticipate windier conditions and a more turbulent sea state. They suggested the need for larger ship and/or "greater stabilizing technologies than currently present in USAP vessels" as well as "a significant increase in "weather days" built into cruise planning and grant funding."

In general, most respondents noted a heightened motivation for more USAP research and increased demand for ship-time and year-round ship operations. Greater geographic access to areas currently inaccessible due to heavy sea ice cover is predicted to expand the geographic scope of research, as will the exposure of terrestrial field sites, opening up opportunities for further field work to be supported by both ship and helicopters. Given the kinds of changes in progress, one respondent also noted the need to get closer to ice shelves and icebergs. Other respondents also noted the increased urgency for more field-based research, given the vulnerability of the Antarctic to climate change and unpredictability of response. People discussed greater direct sampling, use of greater robotic instrumentation, more deployment/recovery of unmanned systems to improve monitoring capabilities, and the need, by coupled studies, for a combination of helicopter support and increased use of AUVs.

F.4 Survey Responses - USAP Fleet Configuration Analysis

Survey:

> *The following questions provide the opportunity for you, as a USAP ship user, to comment on the configuration of the USAP fleet. With ship costs increasing and projected NSF 'flat' budgets, it is possible that the USAP may need to reconfigure its fleet to a one-ship operation. This could, however, open some new opportunities. For example, the savings of going to one ship may open options of increased support from helicopters, fixed wing aircraft, and smaller, but more capable vessels like the RHIBs; more advanced aerial and underwater vehicles; and increased bandwidth on the ships. Greater partnerships with other National Antarctic Programs could transpire. Note: In the case of a single-ship operation, it is anticipated that resupply of Palmer Station could be via commercial charter but may on occasion use the single USAP science vessel.*
>
> *1 If USAP OPERATED a single ship and had more flexibility for using other assets, how would this impact your future Antarctic research? If you think that two ships are required, please explain.*

Sixty-three respondents provided comments regarding one versus two ships, with the majority indicating that two ships are necessary to conduct USAP science. Those respondents who felt that single ship operations would be acceptable suggest that conditions – such as accommodations for "proper" scheduling of Palmer Station resupply, use of chartered ships as needed, and a single vessel with increased ice capabilities, helicopters, acoustic instrumentation, and extensive small boat capabilities. One respondent noted that "we have started using platforms of opportunity but they are limited in their sampling capacity and ability to spend dedicated time in one location or survey areas." Respondents also suggested increased remote presence and instrumented small craft. It was noted that "freeing up resources for potential expansion of helicopter operations would be potentially very valuable for a lot of research that we can't now undertake." Commercial charter of passengers and resupply to Palmer was noted, but respondents were concerned about "risk to USAP operations" and although increasing use of RHIBs which are great for shore-based work on the Peninsula, this was not seen as adequate to offset the use of a second research vessel. The added use of Coast Guard icebreakers also might help, but needs good coordination and oversight of science equipment. Increased partnering with other national programs was suggested as a priority, with one respondent citing the joint NSF-NERC (UK) initiative as a good template – one that addresses some of the challenges of separate funding mechanisms.

More respondents expressed the need for two vessels to accommodate the geographic breadth of study regions, legitimate needs for specific times of year for work and increasing scientific demands in a fragile and changing system. Several noted the already intense competition for ship time, which would be exacerbated by having only a single ship. Many respondents were concerned about having a single ship that conducted both science and re-supply, and pointed to other national programs as negative models, suggesting that "the science becomes secondary and extremely poorly supported and more competitive." In addition, specific seasonal demands for the Palmer LTER were noted. While respondents recognized the scientific justification and success of the LTER program, a program that is dependent on its continuity, this tethers a ship to the location every summer season, placing limitations on other science and the ability to respond to rapidly emerging conditions and catastrophic change. In addition, given the history of ship-based science programs in both the Peninsula and Ross Sea regions, access to more remote areas of Antarctica, such as East Antarctica, might be limited severely by single ship operations, where it might be that operations alternate between the Peninsula and the Ross Sea. Others noted the competing demands of ship-based marine and terrestrial work while on-board ship, suggesting that a single ship would result in tight scheduling that might preclude terrestrial work. Specific comments regarding single ship operations include that the NBP is not capable of docking at the Palmer pier and so cannot support specific kinds of science (fish work), and that the ADCP time series crossing Drake Passage is unique; with a one-ship operation this would be in jeopardy, since the commercial ship would not have ADCP capability.

General suggestions from the community survey included the need for increased transparency of ship scheduling and field site prioritization, especially in a one ship model that might alternate geographic scope of field work (Peninsula – Ross Sea). Additional comments suggested increased collaboration and cooperation with other international programs as crucially necessary, and increased use of AUVs, ROVs, the uCTD and automatic ice cameras as both highly useful and leading to better use of ships, e.g. automatic cameras running on geophysical cruises. One respondent suggested greater air support in the Peninsula, flying people/equipment more, and minimizing Drake transits. Finally, several respondents voiced a fear that one ship operations would greatly reduce US leadership in Southern Ocean science, reduce operations in remote locations, and ability to respond rapidly, and potentially result in a loss of scientists conducting marine-based research in Antarctica. Specific comments are noted below:

- *A single capable ship with the option of using chartered ships as needed would be ok. Especially if the single vessel has increased ice capabilities, helicopters, and extensive small boat capabilities.*
- *One ship, but with acoustic instrumentation, remote presence, and instrumented small craft.*
- *If resupply to Palmer station were done by commercial vessel, then the basis for prioritization of the Antarctic region to be studied in year X vs Year Y would need to be transparently spelled out. For example, it would be very bad to break the fantastic LTER time series off the WAP in the month of January [I am not and have never been a LTER PI; my science has benefited greatly from their long time series] because the one ship is to be scheduled in the Ross Sea or Amundsen or elsewhere in the month of January. Hence, the need for 2 ships is highest in Jan-Feb, lesser in the shoulder seasons (Nov-Dec, March-May) when arguably the biggest ecological changes will be felt (ie, growth season starting earlier and lasting longer), and least in winter. Even with all the other options described above, many require a bigger vessel to deploy from (i.e., helo, autonomous vehicles/air/water/surface). The new Palmer RHIB is great and clearly extended and sped our operations; and made them safer, but they are still for short distances from shore, in good weather, short sorties, and very small teams. Again, if USAP were to have a single vessel, the criteria by which field site prioritization are to be made should be transparent to all.*
- *I think it's a mistake to scale back to a single Antarctic vessel, particularly as someone who was told for multiple years in a row that there was no room for us on Antarctic vessels - partly the reason that we (eventually) got in to Palmer Station. Commercial charter of passengers and resupply to Palmer seems to add an element of risk to USAP operations. I don't see how increasing use of RHIBs (which are great for shore-based work on the peninsula) will offset use of an entire research vessel.*

- *For fishing operations and especially reaching special depth where some specific specimens can be caught, smaller vessels like RHIBs are not viable options (RHIBs can't trawl the bottom for fish). This would risk to put an end to USAP fish research on and around the Peninsula. This would also severely harm all the benthic ecology research that is not relying on scuba-divers to collect samples. One ship could work but it would have to be flexible in use, which in return would reduce the capacities for oceanographic studies. It would also impact greatly the sectors of Antarctica that USAP could be studying.*

References

Advisory Committee to the Office of Polar Programs (2019, draft) *An Advisory Overview for the Office of Polar Programs*.

Anonymous (2010) *Re-supply and Science Support Evaluation of Palmer Station and the Antarctic Peninsula Region,* Martin, Ottaway, van Hemmen & Dolan, Inc., Red Bank, New Jersey, 160pp.

Antarctic Research Vessel Oversight Committee (2006) *Advancing U.S. Polar Research Through the Acquisition of a New polar Research Icebreaker*, 51 pp.

Madsen, Robert T. (2014) *Regional Class Research Vessel Design Green Ship Initiatives*, Oregon State University, Corvallis OR, doc 12100-054-01, rev. P3. https://ceoas.oregonstate.edu/ships/rcrv/pdf/12100-054-01_Green_Ship_Initiatives_Rev_P3.pdf_

National Academies of Sciences, Engineering, and Medicine (2015) *A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research*. Washington, DC: National Academies Press. 155 pp.

National Research Council (2011) *Future Science Opportunities in Antarctica and the Southern Ocean*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13169.

National Research Council (2011) C*ritical Infrastructure for Ocean Research and Societal Needs in 2030*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13081.

National Research Council (2015) *A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research*. https://www.nap.edu/read/21741/chapter/1

National Research Council (2015) *Sea Change: 2015-2025 Decadal Survey of Ocean Sciences*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21655.

National Science Board (2020) *Vision for the National Science Foundation*, http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsb05142. (2005)

National Science Foundation Strategic Plan (2018).

Takahashi, Taro, T. Newberger and S. C. Sutherland (2018) *Assessment of the Underway Science Seawater Supply and Underway pCO2 Measurements Aboard the N.P. Palmer*, Lamont-Doherty Earth Observatory, Palisades, NY.

Young, Ian, and Augustinus Ribal (2019) *Multiplatform evaluation of global trends in wind speed and wave height*, Science 364, 548–552 (2019) 10 May 2019

Appendices

1. **Charge to Sub-Committee**
2. **Updated SMR recommendations**
3. **Community Survey Questions and Responses**
4. **Assessment of the Underway Science Seawater Supply and Underway pCO2 Measurements Aboard the N.P. Palmer.**

Appendix 1. Charge to the Subcommittee

National Science Foundation
Directorate for Geosciences / Office of Polar Programs
Review of U.S. Antarctic Program Research Vessel Procurement Specifications
Formation and Charge to the Committee
March 19, 2018

The National Science Foundation (NSF) hereby initiates the formation and operation of an ad hoc Subcommittee of the NSF Office of Polar Programs (OPP) Advisory Committee (the Committee) on the U.S. Antarctic Program's Research Vessel Procurement. The purpose of the Subcommittee is to review and assess the science mission requirements and operational capabilities of replacement Antarctic research vessels. Outcomes of their assessment will be in the form of a report to the Committee. The report should specifically state whether or not the Subcommittee feels the vessel specifications as outlined will adequately support sea-going science in the Southern Ocean and along the Antarctic Peninsula. The report may include recommendations to NSF for further improvement of the specifications.

Context

The United States Antarctic Program (USAP) currently operates two research vessels: the light icebreaker Nathaniel B. Palmer (NBP) and the ice-strengthened research and supply vessel Laurence M. Gould (LMG). The vessels, built in 1992 and 1997, respectively, are approaching the ends of their current contracts (2020 for LMG, 2022 for NBP) and either are at, or are approaching, the end of their nominal 30-year service lives. As such, a new vessel procurement solicitation needs to be developed that ensures the Antarctic scientific community is continued to be supported with state of the art sea-going facilities designed to operate in these harsh environments. Since the current vessels are approaching their end of service lives, refurbished or new-build vessels need to be considered. These vessels may operate for the next 10-30 years, and therefore their capabilities must be sufficient to support science in the coming decades.

The Charge

The Committee is asked to:

1. Review and verify the continued validity of the University-National Oceanographic Laboratory System (UNOLS) 2012 Polar Research Vessel Science Mission Requirements, the 2016 NSF/OPP Antarctic Vessels Request for Information, and the 2018 ASC-provided Vessel Studies Reports;
2. Prioritize each proposed vessel's capabilities and operational requirements;
3. Consider the two-ship operational model of the US Antarctic Program, and evaluate the advantages and disadvantages of moving to a one-ship operating model.
4. Engage the broader scientific community to ensure vessel capabilities and characteristics are able to meet a majority of anticipated needs for the duration of the 10-year charter, and possibly for the lives of the vessels (~ 30 years). Elements of the recommended prioritized vessel capabilities should be provided in sufficient detail to enable NSF to make subsequent appropriate adjustments in response to available funding.

5. A summary of the outreach efforts and input received from the science community should be included in the final, submitted report.
6. The subcommittee will develop activities to address the elements of the charge.

The Subcommittee is asked to provide an initial report/response at the April 2018 OAC meeting and its final report by September 2018 for presentation to the AC/OPP, so NSF can consider them in formulating the FY 2020 Budget Request.

Appendix 2. Science Mission Requirements, Updates

D.1 Overview

The updated Science Mission Requirements (SMRs) recommended by the subcommittee for a USAP Polar Research Vessel are summarized in this Appendix. Here, only the Subcommittee's updated SMR appears. Section D of the full report provides the background and context for these recommendations. The "D.x.x" labeling system used in Section D is retained here for convenience.

D.2 Science Mission Requirements, Updates

D.2.1 Size and general requirements

Updated SMR

The size and power of a new icebreaking research vessel for the Antarctic is dependent on available funds and driven by those requirements considered the highest priority. At a minimum, the vessel should be at least as large and capable as the NBP. However, to achieve many of the research and support requirements described in this document it will need to be larger and more powerful. Maximum draft should be constrained by the need to service particular ports/stations such as Palmer Station with a 30-foot maximum draft nominally required.

Special Features that will impact overall size and power: Icebreaking capability with Polar Code P4 or even P3 along with an endurance of 70 to 90 days will have the biggest impact on size and power. Other driving features include the berthing capacity, a box keel, 4m x 4m interior moon pool, lab van capacity (4 or 5), helicopter support, 24/7 internet, small boat operations, design for flexible use of both starboard and port rails for instrument deployment, capacity to carry >15 standard 20-foot intermodal containers in the hold and on decks; size of wastewater holding tanks; all vessel underway discharge must be consolidated to one side of the vessel providing a "clean working side"; capacity to transport, deliver and pump >60,000 gallons of various grades of diesel such as Antarctic Grade diesel, to Antarctic research stations; ability to fully operate in water temperatures 28°F to 90°F and air temperatures of -40°F to 100°F and wind speeds of 100 knots; ability to conform to IMO Polar Code regulations, as required.

D.2.2 Accommodations and habitability

D.2.2.1 Accommodations/Berths

Updated SMR
Berthing and support facilities for >45 science and technical personnel (threshold) and >55 science and technical personnel (objective).

Priorities: Threshold requirements rated as "must have, as is";

Objective requirements rated as “nice but not necessary”

D.2.2.2 Habitability

Updated SMR

Accommodations and personnel spaces shall be designed to maximize comfort and reduce fatigue and to meet and/or exceed industry standards for acceptable noise and vibrations levels. All areas on the vessel, including lab and living areas, must meet American Bureau of Shipping HAB+ (WB) notation for habitability standards.

Common areas (non-working spaces) include gym, sauna, lounges, conference rooms and galley. The gym is considered quite important and should be adequately sized for a variety of exercise methods, some of which require open spaces for movement. Fitness equipment should be ample and located in one or more dedicated spaces noise-isolated from staterooms. Conference rooms need to be designed to consider noise and ability to conduct remote conference (video and audio). Separate and smaller learning centers to support linked programs with universities are needed to allow conference meetings to occur concurrently. Additional considerations include provisions for maintenance of interior temperature standards during Antarctic winter conditions, provision of spaces to store and change into polar clothing, a large and comfortable lounge (as in the NBP), and isolation of living, dining, and lounge spaces from ship, equipment, and icebreaking noise. The “hotel” area of a polar RV is a 24/7 quiet zone and thus should be as isolated as feasible from other areas of the ship such as main passageways, equipment rooms (such as thrusters, engines, winches and fans), exterior hatches, and main ladderways. Multiple places to work or relax (such as on the NBP) are desirable. The galley should be equipped and staffed to serve four meals per day (i.e., to include hot food at mid-rats).

HVAC - Temperature ranges and environmental conditions:

Maintain temperatures in normally occupied spaces (A/C spaces) of at least 70°F in the heating season and 75°F or lower in the cooling season. Other spaces can have relaxed requirements based on the use of the space. Use SNAME Technical and Research Bulletin No. 4-16 for guidance. Environmental conditions range from a minimum air temperature of -40°F or less and seawater temperature of 28°F in winter and a maximum dry bulb air temperature of 100°F (82°F wet bulb) and seawater temperature of 90°F. (Objective/desired: Same as minimum with wider range of environmental conditions and/or additional capacity for heating and cooling.)

HVAC - Relative Humidity percentages:

Laboratories require a non-condensing environment and shall have a relative humidity of 50% relative or lower. Other A/C spaces shall have a relative humidity of 55% or lower.

HVAC - rate of air changes: Use SNAME T&R Bulletin No. 4-16 for guidance.

Airborne noise in ship compartments and at deck stations shall be specified such that the weighted sound pressure levels meet or exceed the requirements of the ABS Hab + (WB) notation as an objective and ABS Hab (WB) as the threshold. Laboratories and other normally occupied spaces shall meet the standards for offices (60 dB or lower). Working Decks should meet the requirements of Machinery Control Rooms (70 to 75 dB). Staterooms shall be sound insulated to limit noise between cabins as much as possible for privacy. Airborne noise specifications should be developed using an experienced shipboard noise consultant.

The ship and all ship components shall be free from excessive vibration. Vibration is excessive when it results in damage or danger of damage to ship structure, machinery, equipment or systems, or when it interferes with the proper operation of the ship and all ship components. Vibration is also considered excessive when it interferes with the safety, comfort or proficiency of personnel, or with scientific operations. In particular, vibration should be at a minimum in areas where microscope work or other sensitive scientific equipment is in operation. The following criteria should be used: Vibration in normally occupied spaces shall be limited to a maximum allowable velocity of 160 mils/sec (4 mm/sec) in maximum repetitive amplitude terms for a frequency range of 1 to 100 Hz in accordance with revisions to ISO 6954 recommended by SNAME T&R Bulletin 2-29A.

The vibration of the masts and other structures supporting vibration-sensitive equipment shall be limited to that level acceptable to the manufacturers of mast-mounted equipment, or ±0.1g over the frequency range of 1 to 100 Hz, whichever is less.

The vibratory response of the propulsion system over its entire power range and speed range through 115 percent of maximum shaft RPM shall be limited according to manufacturer's recommendations and so as not to harm installed machinery.

Lighting levels shall generally exceed by 30% the values given in IESNA RP-12-97, Marine Lighting, Table 3. Laboratories shall have 100 foot-candles of light, staging bays and working decks shall have 70 foot-candles of light. In the laboratories, individual lights or groups of lights shall have independent switches to allow them to be controlled separately to provide varying light levels. Navigation spaces shall be equipped with red illumination in addition to the normal lighting.

Enhanced Habitability: The productivity of all personnel sailing in these vessels can be enhanced by providing comfortable, aesthetically pleasing spaces, and by including, to the extent possible, areas for off-hour activities other than staterooms and workspaces such as a library, lounge, or conference room with tables, good lighting, video capability, etc. Equipment and appropriate space for exercise should be provided. Human engineering principles should be applied in the design of workspaces. As an example, the distance from the deck to the underside of the finished overhead should be 7.5 to 8 feet. Headroom space and room for the installation of tall equipment should be maximized while balancing the need for cable trays, adequately sized ventilation ducts, lighting, etc.

Priorities: Requirements rated as "must have, as is"

D.2.3 Operational characteristics

D.2.3.1 Icebreaking

Updated SMR

The new vessel should have icebreaking capability that exceeds that of the existing RV *Nathaniel B. Palmer*. For this reason, the Objective SMR goal is the priority and under no circumstances would it be acceptable to end up with icebreaking capabilities less than PC 4 or less than the *Palmer*.

Objective: >4.5 feet with 12 inches of snow at a continuous speed >3 knots. Polar Code: PC 3 - year-round operation in second-year ice which could include multi-year ice inclusions.

Threshold: Capability of independently breaking sea ice with a thickness >3 feet. Polar Code: PC 4 - year-round operation in thick first-year ice, which may include old ice inclusions.

As per the recommendations in the ASC Vessel Studies Report, the ice performance requirements should incorporate the following design criteria:

- Ice flexural strength = 500 kPa
- Average speed in thin (0.5 m or less) ice = 5 to 6 knots
- Level ice astern = 1.4 m (4.5 ft), same as ahead
- Maneuvering characteristics (turning radius, turning out of an existing channel, starturn, etc.)
  - Maximum turning diameter of 3×LWL to 4×LWL in 1.4 m (4.5 ft) level ice ahead
  - Maximum turning diameter of 2×LWL to 3×LWL in 0.7 m (2.3 ft) level ice
  - Ability to break out of its own channel in 1.4 m (4.5 ft) level ice

Design issues to be resolved include the ability to penetrate ice ridges (e.g., the typical ridge size to be transited, backing and ramming ability). We note that Antarctic sea ice tends to be less prone to ridging than Arctic sea ice, so ridge penetration requirements for a vessel primarily operating in the Arctic do not necessarily apply to operations in the Antarctic. Consideration needs to be given to vessel performance in compressive ice and in old ice (noting that the Antarctic tends to have more first-year ice than the Arctic. Antarctic sea ice tends to be covered with thicker snow than Arctic sea ice so the design criteria should consider these differences .

Priorities: Objective and Threshold requirements rated as "must have, as is"

D.2.3.2 Endurance & Range

Updated SMR

Endurance of >70 days (threshold) / >90 days (objective) underway and 17,000nm without replenishment. Average annual operational tempo of 250-300 days.

Priorities: Threshold requirements rated as "must have, as is"; Objective requirements rated as "could manage with something less stringent"

D.2.3.3 Speed

Updated SMR

Minimum transit speed of 11 to 12 knots in ice-free waters.

Priorities: Requirements rated as "must have, as is"

D.2.3.4 Sea keeping

Updated SMR

Sea-keeping capabilities should permit work in rough seas of the Polar Regions and sufficient environmental control to allow year-round work in the polar seas. The vessel must also operate in the heavy seas of the open polar ocean as well as within sea ice.

The vessel should be fully operable in SS4 and for most routine operations in SS5. Vessel motions should be minimized through hull design, weight control and the use of passive or active anti-roll devices such that personnel can safely work in the SS6 or greater.

Safety of equipment operation and deployments should also be taken into account.

Suggested targets for maximum motions in SS5 are as follows subject to further study:

Limit maximum vertical accelerations to less than 0.15 g (rms)
Limit maximum lateral accelerations to less than 0.05 g (rms) at lab deck level.
Limit maximum roll to less than 3 degrees (rms)
Limit maximum pitch to less than 2 degrees (rms)

Priorities: Requirements rated as "must have, as is"

D.2.3.5 Station keeping and dynamic positioning

Updated SMR

Dynamic Positioning System > ABS DPS-0 (threshold) / ABS DPS-1 (objective).

Dynamic positioning relative to a fixed position in 35-knot wind, sea state 5, and 2 knot current. The maximum excursion allowed should be ± 5 meters (equal to navigation accuracy) from a fixed location for operations such as bore hole re-entry through sea state 4 at best heading and up to ± 20 meters at best heading through sea state 5. DP system design and operation should minimize noise, vibration, and adverse effects on the operation of acoustic systems as much as possible, and these issues should be evaluated early in the design process. The DP system should have outputs for interfacing with science systems.

Performance is more important that ABS certification.

Priorities: Threshold requirements rated as "must have, as is"; Objective requirements rated as "nice but not necessary"

D.2.3.6 Track line following

Updated SMR

The vessel should maintain a track line while conducting underway surveys for spatial sampling and geophysical surveys within ± 5 meters of intended track and with a heading deviation (crab angle) of less than 45 degrees with 30 knots of wind, up to sea state 5 (2.5 – 4 m wave heights) and 2 knots "beam" current. This target may be required for ship speeds as low as 2 knots. Straight track segments shall be maintained without large and/or frequent heading changes.

Priorities: Requirements rated as "could manage with something less stringent"

D.2.3.7 Ship and winch control

Updated SMR

Ship control and control of major deck machinery should be designed and specified with an integrated approach that maximizes visibility, communications, safety and efficiency of operations during over-the-side deployments, cargo operations, small boat operations and recovery of instrumentation from the sea and air. Control of major deck machinery includes winches, frames, cranes, Launch and Recovery Systems (LARS), drilling systems, seismic systems, moon pool systems, helicopter operations and other similar systems. Good visibility requires clear sightlines to aft working deck and starboard side working deck deployment areas from the ship control and winch control stations to the greatest extent possible. This can be augmented if needed with video cameras, especially to areas blocked from view such as the moon pool. If a separate aft control station is necessary to accomplish the visibility requirements careful consideration should be given to the amount of ship control to include in addition to winch and handling system control. Communications and video monitoring requirements are critical in the design of an aft control station.

Priorities: Requirements rated as "must have, as is"

D.2.3.8 Underwater radiated noise

Updated SMR

Significant efforts should be directed towards making the ship as acoustically quiet as practical without negatively impacting icebreaking capabilities. Significant and detailed technical compromises are necessary to achieve a reasonable balance between the performance of ships' acoustic systems and the power and strength necessary to be an efficient icebreaker.

Special consideration should be given to machinery noise isolation, including heating and ventilation. Propeller(s) are to be designed for minimal cavitation, and hull form should attempt to minimize bubble sweep down. Airborne noise levels during normal operations at sustained speed or during over-the-side operations using dynamic positioning shall conform to standards in USCG NVIC No. 12--82 and IMO Resolution A.468(XII), "Code On Noise Levels On Board Ships." Sonar self-noise should meet or exceed manufacturer's requirements. The use of a drop keel or retractable centerboard could be considered to improve acoustic system performance.

Underwater radiated noise and airborne noise specifications should be developed using an experienced shipboard noise consultant. Underwater radiated noise criteria that are less stringent than ICES 2009, such as those used for the Ocean Class AGORs or the RV *Sikuliaq*, should be considered as a target.

Priorities: Requirements rated as "could manage with something less stringent"

D.2.3.9 Helicopter support

Updated SMR

Ship operations in remote areas of both polar regions necessitate helicopter capability to support transfer of personnel, vessel logistics, ice reconnaissance, expanded scientific reach with the vessel as a mobile science base, and emergency medical evacuations. The ship shall be capable of landing and supporting two helicopters that each are able to make 150 nm round trip with 3 passengers and 1200 lbs. of cargo (for example, Bell 214, Sikorsky S-70, or landing a (USCG) HH60). The flight deck shall be structurally capable of landing a larger single rotor helicopter.

The hangar shall be sized to house the two smaller helicopters with the rotors folded and the necessary storage/shop capability. On board aviation fuel capacity shall be adequate to support two helicopters for up to the endurance of the ship, based on flying one helicopter for four hours for 1/3 of the underway days. Accommodations for the helicopter crew and technicians would come out of the science berths.

The following describes a range of aviation capabilities that should be considered:

- Helicopter-deck for landing of helicopters for cargo and personnel transfers or Unmanned Aerial Vehicles (UAV) in support of ice navigation or scientific operations including the capability of housing or servicing of the helicopters or UAVs
- Helicopter-deck able to support the landing/takeoff and re-fueling by helicopters of a maximum takeoff weight of 13 tons. This is for Search and Rescue (SAR) or transfer operations by a larger helicopter, not the ship based aircraft
- Helicopter-deck and hanger suitable for the operation of two mid-size aircraft of up to 5 tons maximum weight each and based on board the vessel.
- Jet A1 (aviation) fuel in permanent or portable storage tanks.
- Helicopter re-fueling equipment capable of operation in the Polar environment.
- De-fueling capability of the aircraft whilst aboard.
- Access to Helicopter-deck to allow safe transfer of cargo from slung loads for VERTREP (vertical replenishment) operations with an assumed weight of 1500kg operations
- Suitable deck tie points for up to two aircraft.

- The Helicopter-deck is to comply with all international requirements such as CAP 437 and ICS guide to helicopter/ship operations.

Priorities: Requirements rated as “could manage with something less stringent”

D.2.3.10 Off Vessel Support for Field Work and Logistics

<u>*Updated SMR*</u>

The vessel must be capable of support for field work off vessel on the ice, in boats, on islands and other land based field camps and stations. It must also be capable of supporting transport of personnel, supplies and equipment to stations and field camps. Requirements that support these activities are contained in SMR elements for Cranes (including accommodation ladder for rapid deployment to and from the ice), Vans, Storage, Work Boats, Helicopters and inherent in many others such as endurance, icebreaking, dynamic positioning, sea-keeping, etc.

In developing the operational profile and design specifications the support for these activities off the ship should be carefully considered.

Priorities: Requirements rated as “must have, as is”

D.2.4 Over-the-side and weight handling

D.2.4.1 Over the side handling

<u>*Updated SMR*</u>

An integrated approach to design and specification of weight handling and over-the-side equipment based on required science performance requirements is required. Take into account current advances in technology and tension member (wire/cable) developments including the use of synthetic cables. Plan for the use of temporarily installed systems for some requirements such as large ROV systems, longer length coring, drilling, etc. Design should support flexibility and safe/efficient operation. Create arrangements that will protect winches from the weather, allow for use to multiple locations such as over the stern and the side or to the moon pool. Consider innovative designs for deployment of systems in ice and very cold conditions. For example, some recent research icebreaker designs include a “side pool” system that creates a protected ice-free area alongside the ship’s starboard side CTD launching area. The use of an over-the-side handling system single source vendor or system integrator should be considered.

Priorities: Requirements rated as “must have, as is”

D.2.4.2 Winches & Wire

Updated SMR

These vessels should be designed to operate with a new generation of oceanographic winch systems that are an integral part of the equipment handling and deployment system. The winches should provide fine control (0.1 m/min under full load); maximum winch speeds should be at least 100 meters/min; and constant tensioning and other parameters, such as speed of wire, should be easily programmable while at the same time responsive manual control must be retained and immediately available at any time. Manual intervention of winch control should be available instantly for emergency stop and override of automatic controls. Wire monitoring systems with inputs to laboratory panels and shipboard recording systems should be included. Wire monitoring systems should be integrated with wire maintenance, management, and safe working load programs. Local and remote winch controls should be available. Remote control stations should be co-located with ship control stations and should be located for optimum operator visibility with reliable communications to laboratories and ship control stations. Winch control and power system design should be integrated with other components of over-the-side handling systems to maximize safety and protection of equipment in heavy weather operation and to maximize service life of installed wires. Adequate provisions for connecting slip rings and ship's power and data network to the E-M and F-O cables should be included in the design. Electric drives and motors should be used whenever possible.

Two hydrographic-type winches capable of handling up to 10,000 meters of wire rope, electromechanical or fiber-optic cables having diameters from 1/4" to 1/2" should normally be installed. Winches should be readily adaptable to new wire designs with sizes within a range appropriate to the overall size of the winch. At least one winch should be capable of supporting both over the side and moon pool operations.

A heavy winch complex capable of handling 12,000 meters of 9/16" wire/synthetic wire rope and/or 10,000 meters of 0.68" electromechanical cable (up to 10 KVA power transmission) or 0.681 fiber optics cable should be permanently installed. This complex is envisioned as one or two winches with the possibility of multiple storage drums that could be interchanged in port. Alternately this could be a traction winch with two or more storage drums that can be used interchangeably. Winches should be adaptable to new wire/cable designs including synthetics within a range appropriate to the overall size of the winch. At least one winch should be capable of supporting operations over the stern and starboard side and one should also be capable of supporting operations through the moon-pool.

Winches handling fiber-optic cable should normally be traction winches that allow storage of the cable under lower tension unless new technologies in wire construction allow otherwise. This includes winches for both 0.681" and smaller cables.

Additional special-purpose winches (e.g., clean sampling, pumping, multi-conductor) may be installed temporarily at various locations along working decks. Winch sizes and power requirements should be considered during the design phase in order to establish reasonable limits based on the vessel size.

Permanently installed winches should be out of the weather where feasible to reduce maintenance and increase service life. The trawl/tow winch should be below the main deck, but smaller winches may be located in semi-protected areas of upper decks to allow for better fairlead.

Wire fairleads, sheave size, and wire train details need to be integrated with the general arrangement as early in the design process as possible in order to increase the possibility of limiting wire bends and overly complicated wire train. Sheave sizes, number, and locations should be designed to maximize wire life and safe working load. Requirements in 46 CFR 189.35 - “Weight Handling Gear” and in the UNOLS Research Vessel Safety Standards should be adhered to. It should be possible to fairlead wires from permanent winches over the side or over the stern.

Details of winch location should include provisions for easily changing wire drums, spooling on new cable, and changing from one storage drum to another, and for major overhaul of winches so that these operations can take place with minimum time and effort in port. Some operations, such as re-reeving wires through fairlead blocks or switching the wire being used through a frame or with a traction winch, should be factored into designs so that the operations can be performed at sea safely and efficiently.

Priorities: Requirements rated as “must have, as is”

D.2.4.3 Cranes, Frames and Handling Devices

<u>*Updated SMR*</u>

Onboard cranes capable of reaching all areas of the working deck including the flight deck to move cargo, science equipment, and capable of moving loaded 20-foot intermodal containers on and off the vessel. A suite of modern cranes should be provided to handle the required cargo loads, scientific equipment deployments in the cold weather conditions of the intended operating area and should be integrated with the entire over-the-side handling system. The main heavy lift cranes should be considered at a minimum, that of the NBP the Main, FWD 20,000 lbs @ 40ft and Main, AFT 50,000 lbs. @ 60ft. The highest rated crane needs to have the capacity and reach to service a Geotechnical drilling rig. One or two cranes that provide the capability to reach all working deck areas and that are capable of offloading vans and equipment weighing up to 20,000 lbs. to a pier or vehicle in port is desirable. This will generally mean being able to reach approximately 20 feet beyond one side of the ship (usually starboard) with the design weight. At least one crane should be able to deploy buoys and other heavy equipment weighing up to 10,000 lbs. up to 12 feet over the starboard side at sea in sea state 4 or 5 if possible. At least one crane should be articulating in order to keep the load close to the crane head.

One or two smaller cranes, articulated for work with weights up to 4,000 lbs. at deck level and at the sea surface, with installation locations forward, amidships, and aft should be provided. They would also be usable with relocatable crutches as an over- the-side, cable fairlead for vertical work and light towing. If the design includes the need to store and launch boats or to deploy equipment from the foredeck, then design for cranes or weight handling should accommodate those needs. Cranes may need to have servo controls, motion compensation or damping as part of the integrated over the side handling systems. The ship should be capable of installing and carrying portable cranes for specialized purposes.

At a minimum one crane should have a man riding certified whip. This will allow for placement of personnel via man basket over the side of the vessel, onto the sea ice, small craft or ice shelf. Additionally, a readily deployable gangway or accommodation ladder should be provided for efficient deployment to and from the ice or shore.

A Stern A-Frame and handling devices on the Starboard and possibly Port side should be included to properly handle intended instrument deployments with wires and cables fairlead from installed and temporary winches. Design specifications and safe working loads should be based on the breaking strength of the intended wires and cables in accordance with 46 CFR 189.35 and the UNOLS Research Vessel Safety Standards.

Stern A-Frame dimensions and range of motion should accommodate intended instrument and equipment deployments. The size and safe working load should be greater than or equal to that on *Palmer* or the Global Class AGOR 23 Class vessels. As a minimum the stern frame should be designed for a dynamic safe working load of 30,000 lbs. through its full range of motion, and it must be structurally engineered to handle 1.5 times the breaking strength of cables up to one inch, such as the tether for large ROV systems (up to 120,000 lbs. breaking strength). The stern frame should have a 15-ft minimum horizontal and 25-ft vertical clearance from the attachment point for the block to the deck. At least a 12-ft inboard and outboard reach is required. Consideration should be given to an A-Frame design that incorporates a forward maintenance position to facilitate changing blocks and wire leads as well as an outboard position parallel to the sea surface or near to it for deployments in ice similar to the A-Frame on *Sikuliaq*.

A launch and recover system coupled to one or both of the hydro-winches to function as a CTD Handling System over the starboard side near mid-ship or from a Baltic room or the moon pool should be designed to allow safe and efficient hands free deployment of a large GO-SHIP CTD system in ice or in open waters of sea state five or greater.

Additional Starboard side handling devices and moon pool devices should be designed for safe and efficient deployment of nets, towed devices, coring devices, small ROVs, etc. At least one Starboard side device should be capable of supporting wires or cables fairlead from the heavy winch complex.

Cranes or handling systems for rescue boats and work boats should meet regulatory requirements and be designed and located for efficient, rapid and safe deployment of the boats in sea state four or greater. The ability to load cargo, equipment and personnel safely should be included in the arrangements for boat handling systems.

Priorities: Requirements rated as “must have, as is”

D.2.4.4 Towing/Trawls/ice-clearing stern

Updated SMR

The ship should be capable of towing large scientific packages up to 10,000 lbs. tension at 6 knots, and 25,000 lbs. at 4 knots. Winch control should allow for fine control (± 0.1 meters/min) at full load and all speeds. Winches should be capable of sustaining towing operations continuously for days at a time. Towing operations include mid- to low-load operations with mid-water equipment such as towed undulating profilers, single and multiple net systems, and biological mapping systems. Other systems may involve larger loads and spike loads such as deep towed mapping systems, bottom trawls, benthic grabs, camera sleds, and dredges.

The vessel should be capable of towing multi-channel seismic streamers and air guns. Icebreaking design should consider the capability of creating sufficient ice-free area astern to allow the towing of nets and other equipment astern while icebreaking.

Priorities: Requirements rated as "must have, as is"

D.2.4.5 ROV support

Updated SMR

The ship must be able to host and deploy/recover Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV), both with a wide variety of capabilities. Provision for operations in ice-covered seas needs to be made, such as the possibility of deployment through a moon pool or over the side after ice clearing, with a capable handling system. Adequate deck space for up to four ROV support vans and dedicated launch and recovery systems along with sufficient deck and tie down hardware strength to accommodate the loads created with ROV/AUV systems will be required for the largest currently available systems. A hanger bay with climate control for staging ROV/AUV operations will not only facilitate these operations but many others as well. The capability to support JASON operations can be used as a guiding example; the US National Deep Submergence Facility provides up-to-date documents with support requirements for these systems. Other considerations include how and where cables should go over the side, how and where free-swimming vehicles should be recovered (e.g. moon pool, cable dock, open water maintained by the ship), and how subsea vehicles will be navigated. For AUV/ROV operations the stern frame should be designed for a dynamic safe working load of 30,000 lbs. through its full range of motion, and it must be structurally engineered to handle 1.5 times the breaking strength of cables up to one inch, such as the tether for large ROV systems (up to 120,000 lbs. breaking strength). The stern frame should have a 15-ft minimum horizontal and 25-ft vertical clearance from the attachment point from the block to the deck. At least a 12-ft inboard and outboard reach is required.

Priorities: Requirements rated as "must have, as is"

D.2.4.6 Unmanned Aerial Systems (UAS) support

Updated SMR

The vessel should be capable of launching and recovering small unmanned aircraft for multiple science surveys, ice survey and reconnaissance (remotely or autonomously operated).

The design of the next generation polar research ship should meet the basic needs of UAS shipboard requirements, including:

- communication (air band radios),
- sufficient “real-estate” to install system antennas (omni and directional),
- sufficient physical clearance for take-off and landing (generally not an issue),
- crew training on basic UAS ship-based operations, and
- sufficient internet bandwidth to access remote sensing and aviation forecast products needed for flight planning.

In some instances, rapid response via small boat (e.g. Zodiac) will be necessary to retrieve a UAS (e.g. drone) that malfunctions. Drones are designed to return to launch GPS coordinates when batteries die or if any malfunction occurs. At sea, this may be problematic if the ship has drifted and will result in the drone crash-landing into the ocean.

Priorities: Requirements rated as “must have, as is”

D.2.5 Science working spaces

D.2.5.1 Working deck area

<u>Updated SMR</u>

Working deck(s) area of >4,500 ft2 (threshold) / 5,500 ft2 (objective).

Deck loading should meet the current ABS rules (i.e. designed for a 12-foot head or 767 lbs/sq ft). The total aggregate load on the main working deck should be maximized within the constraints of deck size, variable science load and stability. An aggregate total deck load of 100 Tons is required to maintain the capability of the existing vessel. Point loading for some specific large items (such as vans and winches) should be evaluated in the deck design since these may generate loads of 1,500 lbs/sq ft or higher.

All working areas should provide 1”-8NC (SAE National Coarse Thread) threaded inserts on two-foot centers with a tolerance of ± 1/16” on center. The bolt down pattern should be referenced to an identifiable and relevant location on the deck to facilitate the design of equipment foundations. The inserts should be installed and tied to the deck structure to provide maximum holding strength (rated strength should be tested and certified). Tie down points should be provided for any clear deck space that might be used for the installation of equipment including the foredeck, 0-1 deck, bridge, and flying bridge and should extend as close to the sides and stern as possible.

Stern deck area should be as clear as possible and highly flexible to accommodate large and heavy temporary equipment. Bulwarks should be removable and all deck- mounted gear (winches, cranes, a-frames, etc.) should be removable to a flush deck as much as possible to provide flexible re-configuration.

The design should provide a dry working deck with provisions for allowing safe access for deployment and recovery of free-floating equipment to and from the water. Traditionally low freeboard and stern ramps have been provided as means to accomplish this goal. The use of stern ramps has been limited and should be included in new designs only if required by specific planned operations. Low freeboard facilitates launch and recovery operations but results in wetter decks and less reserve buoyancy. The use of innovative design features to facilitate safe and effective equipment launch and recovery while maintaining dry and safe weather decks should be carefully considered. Removable bulwarks with hinged freeing ports to provide dry deck conditions in beam or quartering seas have proved effective. The use of a moon pool can be considered.

A clear foredeck area should be capable of accommodating small, specialized towers, booms, and other sampling equipment as much as possible. Providing tie down sockets, power, water, and data connections will facilitate flexible use of this space.

Additional deck areas should be provided with the means for flexible and effective installation of incubators, vans, workboats, and temporary equipment. (See relevant SMRs below for details.)

All working decks should be equipped with easily accessible power, fresh and seawater, air, data ports, and voice communication systems. Adequate flow of ambient temperature seawater for incubators should be available on decks supporting the installation of incubators.

All working decks need to be covered by direct visibility and/or television monitors from the bridge. Gear deployment areas should maximize direct clear visibility.

The main exterior working deck should be equipped with means to keep key working areas ice free, for example via boilers to circulate a water/antifreeze mixture under the deck.

Priorities: These requirements are rated as "must have, as is", except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as "must have, as is", with the Objective requirements rated as "could manage with something less stringent".

D.2.5.2 Laboratories

Updated SMR

Scientific laboratory space of >5,700ft2 (threshold) / 6,500ft2 (objective) to accommodate up to 45 scientists. Walk in refrigerators and freezers for scientific work and sample storage (-20° to 10°C) for science samples. Lab spaces (with approximate square footage) should include the following:

- Aft Dry Lab (~1100)
- Forward Dry Lab (~1100)
- Wet Lab (~900)
- Hydro Lab (~750)
- Baltic Room/Staging Area (~700)
- Electronics Lab/Computer Lab (~700)
- Climate Controlled Spaces
    - Environmentally Controlled Lab (~100) [used for Autosal on *Palmer*]
    - Built-in climate-controlled workspaces. Built-in refrigerators/freezers. At least 2 rooms must be included. Cooled independently. Seawater drops in each room.

Humidity controls in each room. High quality fixtures, corrosion resistant. Deck bolts and drains. Temp range 15°F to 50°F with variance of +/- 2°F (-10°C to 10°C with variance of +/- 1°C).

- Bio Lab (~400)
- Aquarium Room, with flowing seawater (~400)
- Marine Technician Shop (~150)
- Electronic Technician Shop/Electronic Equipment Room, with separation of computing facilities with climate control and limited vibration (~100)
- Microscope Room (~20)
- Changing/Mud Room (~100)
- Hazardous material storage lockers

The design should also accommodate these functions as much as possible as separate spaces, within other lab spaces or with space for dedicated lab vans:

- Gravitometer room
- Gimbaled platform
- Electrophoresis equipment
- Trace Metal Clean lab
- Core Processing Facilities

Priorities: These requirements are rated as "must have, as is", except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as "must have, as is", with the Objective requirements rated as "could manage with something less stringent"

D.2.5.2.1 Layout & construction

<u>*Updated SMR*</u>

Flexibility and support for different types of science operations within limited space are the important design criteria for these vessels. Benches and cabinetry should be flexible and reconfigurable (e.g. SIO erector set and/or Unistrut™). Bench and shelving heights should be variable to allow for installation and use of various types of equipment. Bench tops should be constructed of materials that will allow equipment to be tied down or secured easily and that can be cleaned and replaced as necessary. The ability to easily install or remove cabinets and drawers as needed should be included. Provisions for large, flat chart/map tables including a light table should be incorporated in the lab design.

- There must be high quality benches and cupboards installed in all lab areas.
- Countertops should be chemical resistant (chemtrek, etc.).
- Countertops could have brass inserts for eyebolts in a grid pattern, every 2 feet.
- Overhead cupboards should be high quality and have LED adjustable task lighting available.

Refer to the section on habitability for guidance on the importance of lighting and air circulation. Include natural lighting in most labs, with the ability to black out portholes. Light levels in labs should meet UNOLS standards, 100 foot candles.

Labs should be fabricated using materials that are uncontaminated and easily cleaned. Furnishings, HVAC, doors, hatches, cable runs, and fittings must be planned to facilitate maintaining maximum lab cleanliness. Spaces and materials that may trap chemical spills should be avoided.

Static dissipative deck coatings to reduce static damage to electronics should be required in the "ET" shop and computer/electronics spaces and recommended in other lab spaces. Deck coatings should protect the ship's structure, be easily cleanable, easily repairable, and resistant to damage from chemical spills. Deck materials or padding should provide safe footing and minimize fatigue to working personnel that need to stand for long periods.

The distance from the deck to the underside of the finished overhead should be 7.5 to 8 feet. Headroom space and room for the installation of tall equipment should be maximized while balancing the need for cable trays, adequately sized ventilation ducts, lighting, etc.

Through the design process, minimize the incursion of "ship stuff" (e.g., air handlers, gear lockers, electrical panels and transformers not related to the labs, sounding tubes, valve controls, food freezers and etc.) into the lab space.

Labs should have bolt downs (1/2"-13NC on two-foot centers) in the deck in addition to Unistrut™ on the bulkheads and in the overhead. Fiberglass Unistrut™ should be considered as an alternative to galvanized steel. Deck bolt downs on one-foot centers should be considered for some areas.

Locations for two fume hoods with explosion proof motors in the main lab and one in the wet lab should be included in the laboratory layouts. Exhaust ducting, electrical connections, and sink connections should be permanently installed in place to allow for easy installation and removal of fume hoods. Fume hood locations should accommodate hoods at least four feet wide. Snorkel system with removable snorkels must be present in all labs. 1-4 snorkels per lab. Fume hoods and snorkels must not recirculate into ship and shall exhaust safely to atmosphere away from personnel.

Sinks should allow for flexible installation, removal, and additional sinks when needed. At least two locations in the wet lab and four locations in the main lab (some of which are located with the fume hoods discussed above) should be provided with stubbed out plumbing at convenient locations. More locations can be provided if possible. At least one large sink with a sediment trap that is easily accessible for cleaning should be included. Drains should be designed to work at all times, taking into account operating conditions that create various trim and list conditions, rolling, etc. Drains should be capable of being diverted over the port side, into holding tanks, or to the normal waste system, and should allow for continuous discharge of running water. Sinks should be large enough to accommodate five-gallon buckets and the cleaning of other equipment.

Work with radioactive materials should be restricted to radiation lab vans that remain isolated from the interior of the vessel.

Other design criteria to consider and include as much as possible include:

- Clean sites for genomics and trace organic and metals analysis and sample preparation.

- Bulkhead pass throughs to adjacent labs and spaces in all labs with approved watertight and fire boundary ratings. Allow for growth in the number of cables.
- Ships compressed air drop available on ceilings in each lab. Ships compressed air must be sufficiently clean to support a liquid nitrogen plant 30-40 psi.
- Installed gas bottle racks in all labs, removable, 5 bottles each.
- Oldham MX43 gas detector or equivalent installed in all labs.
- Specific laboratory HVAC requirements to be carefully designed and installed. To include independent temperature control for each space, filtered to provide high quality air with the intakes located away from contaminating sources, minimum 8 - 10 air changes per hour.
- Fresh water, hot and cold must be available in all labs. 1-3 sinks per lab. Salt water from the uncontaminated seawater system must be available in each lab. Seawater must be available in copious quantity in an aquarium room and an outside area to support incubations.
- Lights must be controllable in the aquarium room to darken space.
- There must be filtered emergency eyewashes on all sinks, emergency showers in each lab. There should be drains under all showers. Emergency showers at least 20 GPM. Eye washes at least 0.4 GPM.
- Microscope Room [should be] quiet, low vibration, [with] space reservation for anti-vibration table, compressed air connections, water and sink, no window required.
- Clean Lab [will have] high flow HEPA hood and laminar flow hood. Laminar flow at the door. Trace metal clean (no metals inside of this lab).
- Small flammables cabinet. Located near exterior door where TMC CTDs are done.
- Small anteroom for clothes changing preferred.
- Ice makers required in 1 or 2 labs.
- Deionized (DI) water required in 2 or 3 labs.
- Capability of storing instruments and sampling gear, washing nets, and processing benthic samples in a warm environment during winter operations.
- Doors must be wide enough for cargo.
- Laboratory spaces shall be located on Main Deck, adjacent to each other and the working deck area as much as possible.

Priorities: Requirements rated as "must have, as is"

D.2.5.2.2 Electrical

<u>*Updated SMR*</u>

Each lab area is to have a separate electrical circuit on a clean bus and continuous 'household' quality power. The electrical system capacity and design should take into account provisions for the cruise variable connection of systems with large electrical motors or power demands. Provision for multiple simultaneous connections should be possible for 480V 3-phase, 208 – 230V 3-phase and single phase, and 110V single phase with 50 to 200 amps service for vans, laboratories, and on deck. Final design specifications should take into consideration common electrical requirements for currently used and planned equipment, and excess capacity should be designed in to the maximum extent possible. Uninterruptible power should be available throughout all laboratory spaces, bridge/chart room, and science staterooms. The use of modular UPS design can be considered. Separate circuits should be available for tools and other equipment that will not interfere with clean power circuits. Use current IEEE 45 or equivalent standards for shipboard power and wiring and current IEEE standard for UPS and clean power specifications.

Electrical service for the labs should include:

- 110 VAC, single phase 75-100 amps service for each lab
- 208/230 VAC, 3-phase, 50 amps, "readily available" (i.e., in the panel, or 1-2 outlets)
- 480VAC, 3-phase available "on demand" (for example, run into the lab from auxiliary outlets on deck).

Examples of lab and science support electrical requirements include the following:

- 120VAC Ship Power - Ship power system servicing all lab and computer spaces with at least 8 x 20 Amp circuits per lab in addition to the UPS service. Lab Receptacles - Two 120 volt, single-phase receptacle strips, each fed by a 20 amp circuit breaker, shall be provided for every 6 linear feet of bulkhead and shall be installed at a height of approximately 42 inches above the finished deck. Each strip shall have six standard NEMA 5-20R receptacles.
- Foreign Equipment Power Capability - 2x 20 Amp per lab and computer space at 220V 50Hz.
- Weather Deck Power Service - 2x 100 Amp 3-Phase 208V, 4x 60 Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering deck containers and portable equipment. Some systems may need as much as 200A of 440V 3-phase AC power.
- Container Hold Power Service - 2x 100 Amp 3-Phase 208V, 4x 60 Amp 3-Phase 208V, and 2x 100A 440V 3-Phase power for powering container hold containers and portable equipment.
- 120VAC 30 Amp Power Service - Each Lab, Computer Space, Science Workshop,
- Staging Area and Aquarium Space shall have at least one 30 Amp 120V 60Hz circuit provided in addition to normal 20 Amp service.
- For van hook-ups - Electrical connections for 20 amps 440 VAC 3-phase, 40 amps 230 VAC 3-phase, and 40 – 50 amps 208 VAC single phase should be provided. 30 amps 110 VAC single phase may also need to be provided, but usually can be provided by panels in the van from step down transformers. There may occasionally be a possible need to supply electrical power to cargo vans being carried en route to science stations.

Scientific wire ways must be considered throughout the ship connecting relevant scientific work spaces. These wire ways must be accessible for frequent change out of cabling to support various scientific missions. Double-tiered wire trays, with one tray above hidden ceilings for long term cable placement and one tray below the ceiling for rapid cable routing are required. Science wireway routing will be defined between various laboratories and include other working areas including the pilot house, main and forward mast, staging bay and aft working deck. Science wire ways should be separated from power and other signal cables. Transitions through watertight bulkheads and decks will be appropriately protected with approved pass through systems. Where applicable, conduit piping to connect scientific work spaces on different ship levels shall be used.

The quality of the electrical power supplied to science systems is also important. Electrical power quality specifications should be implemented and met (e.g., a specified maximum percent total harmonic distortion at a common reference point, along with voltage, stability, phase, and power quality rating specifications). Experience shows clean power reduces undue temperature rise in electrical equipment and systems, lengthens equipment life, reduces failures, and reduces noise in circuits

The design should include a specific electrical power plan for each laboratory or other designated science space, including locations designed to support science vans, climate-controlled chambers, and so forth. The power plan should follow, and if needed improve on, the guidelines of the Leidos and Ocean-class SMRs for voltages, outlets, wire ways, etc. The electrical power specifications in the science design should also be specific in terms of power quality. Consideration should be given to the feasibility of using software-defined power systems.

Priorities: Requirements rated as “must have, as is”

D.2.5.3 Vans

<u>*Updated SMR*</u>

Space is needed for carrying at least 7 “UNOLS Standard” lab vans or equivalent on the main aft deck plus the aft areas of decks above the main deck. For example, these vans might include specialized lab space (such as for working with radioisotopes, under contamination free and trace metal free conditions and/or other environmentally controlled conditions), or operator-supplied support vans for specialized ROVs, coring, or drilling equipment. Space is also needed in an area forward of the pilot house - sited to provide the best feasible degree of protection from heavy seas - for up to two additional “UNOLS Standard” lab vans.

In addition, capacity to carry at least 4 (Threshold) or 8 (Objective) standard containers (including, for example, laboratory, berthing, or frequently-accessed storage vans) in an accessible and human habitable working area below decks is needed.

All container tie-down locations intended to support laboratory vans should be supplied 20 amps 440 VAC 3-phase, 40 amps 230 VAC 3-phase, and 40 – 50 amps 208 VAC single phase should be provided. 30 amps 110 VAC single phase may also need to be provided, but usually can be provided by panels in the van from step down transformers; non-freezing fresh water and seawater lines; non-freezing grey water line; compressed air, and data and communications hook-ups, including for the ship’s emergency notification system.

Additional spaces should be provided for standard 20-foot intermodal containers being carried in transit to/from Antarctic research sites, containing equipment for other marine expedition legs, or to carry stored wastes, emergency supplies, or other items. Spaces intended for such vans do not require the full range of hook-ups for laboratory vans, but at a minimum must have 120/240 volt power available, plus data and communication hookups.

The total count of supported vans in all spaces should be at least 20 (Threshold), with ≥24 preferred (Objective).

Priorities:

These requirements are rated as “must have, as is”, except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as “must have, as is”, with the Objective requirements rated as “could manage with something less stringent.”

D.2.5.4 Storage

<u>Updated SMR</u>

Storage spaces should be provided in all classes represented by those presently on the Nathaniel B. Palmer, with at least that ship’s present capacities except: (1) Increased capacity, above that of the NBP, is needed for hazardous items storage, including in the laboratories, and also for chemical wastes. (2) Significantly increased storage is needed for scientific cargo for other expedition legs and delivery to scientific sites, partially via increased capacity to carry standard 20-foot cargo containers protected from weather and seas, but also for bulk cargo. Also, climate-controlled storage spaces (at least two, with temperatures individually selected from at least -20°C to +10°C) should be larger than those on the NBP and outfitted for optional use as climate-controlled laboratories.

These storage spaces will include:

- storage for resident technician deck and rigging equipment and spares
- storage for resident technician shop equipment and spares
- storage for resident computer technician equipment, supplies, and spares
- reagent and hazardous materials storage
- storage for spares for ship’s science gear
- storage for specialized outdoor/weather clothing
- storage for spares and boxes for scientist-provided science gear
- climate-controlled storage (at least two, with temperatures individually selected from at least -20°C to +10°C), able to accommodate 10-foot long cores, sited to permit an access path for the cores from the aft working deck
- storage for compressed gas cylinders from the science teams
- storage for chemical and other scientific wastes
- storage for helicopter parts, spares, and flight suits
- storage for bulk cargo items to be delivered to Antarctic sites

In most of the classes noted above this would include support for the storage needs of multiple cruise legs. The basic scientific cargo storage space should be at least twice that (Threshold) or ≥3-4 times that (Objective) of the Academic Research Fleet global-class research vessels.

Priorities:

These requirements are rated as “must have, as is”, except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as “must have, as is”, with the Objective requirements rated as “could manage with something less stringent”.

D.2.5.5 Science load

<u>*Updated SMR*</u>

Sufficient variable science load should be included in weight, draft, stability calculations taking into account the required variable scientific equipment and systems, science storage, vans, helicopters, additional work boats and deck load.

Priorities: Requirements rated as “must have, as is”

D.2.5.6 Workboats

<u>*Updated SMR*</u>

There are two needs for small boats in addition to the requirement for a rescue boat:

3) Transfer of scientists and their gear from ship-to-shore and ship-to-ice to make measurements, install instruments, and collect samples
4) Conduct supplemental research activities that are made away from the mothership.

The research vessel should be equipped with two 20-to-30-ft rigid hull inflatable boats (RHIBs) or the equivalent to address the first need. There are alternatives to the RHIB that are under development, which may be more suitable for operation in the rough and cold seas surrounding Antarctica. These alternatives should be given equivalent consideration. The RHIB (or alternative) location on the research vessel should facilitate safe, easy and efficient launching and recovery.

The research vessel should also include a scientific workboat (~30 ft LOA) specifically fitted out for supplemental operations at sea including data/sample collecting, instrumentation, and wide-angle seismic measurements. The workboat should have 12-hour endurance and include both manned and automated operation and clean construction.

Priorities: Requirements rated as “must have, as is”

D.2.5.7 Masts

<u>*Updated SMR*</u>

The ship shall have a permanently mounted foremast that is equipped with an instrument platform for permanently mounted atmospheric and meteorological sensors. The instrument platform shall also be capable of temporarily mounting additional sensors with preinstalled cableways for routing power and data cables. Access to the instrument platform shall be built into the foremast to allow at sea servicing and installation of sensors. The foremast shall be wired by 2 x 20 Amp circuits in a waterproof junction box and include an accessible wireway linking the foremast with interior scientific wireways. Provisions for the installation of ice lights if required should be included in the design of the foremast. The foremast should have at least 3 inlet ports for air sampling. Each port should be connected to ¼" Teflon tubing that run from the foremast through a conduit to the foredeck and into the compartment below the foredeck. The ability to close off the inlet tubes to prevent water seepage when not in use is important. The ability to blow compressed air into the tubing to expel liquid water during sampling is also required. The foredeck should include space for an air-sampling van with clean science power (110V and 220V) available to the van. Similarly, the below deck compartment should have the same power supplies available. Both locations should have access to the science Ethernet. The foredeck van should also be able to incorporate additional inlet tubes and sampling ports that feed directly into the van. Care should be taken that sewage line vents are not located near the van or foremast.

The main mast shall be provided with yardarms capable of supporting five scientific packages each weighing 100 pounds and measuring 2 feet wide by 2 feet long by 3 feet high. This mast should have a clear view of the sky and able to support multiple GPS antennas, meteorological and optical instrumentation. This mast shall have a top working platform of at least 3'x10' in size for servicing instruments, be wired by 4x20 Amp circuits in a waterproof junction box and include an accessible wireway linking the midships mast with interior scientific wireways.

The foredeck should also include a standard deck bolt pattern that easily allows the installation of a temporary (secondary) mast, davit, or crane. The davit or crane would facilitate the mission-specific bow deployments of a temperature/conductivity (or other sensor) chain to sample the undisturbed upper ocean.

There should be the capability to install temporarily larger and heavier atmospheric instruments (e.g., aerosol filter samplers, lidars, and upward looking radiometers, vertically pointing cloud radars) on the deck atop the bridge or other suitable place where there is an unobstructed view of the sky. There should be the ability to secure these instruments to the deck plates or the rails, with unobstructed views of the sky, adequate power, and the ability to connect to the interior scientific wireways.

Because the vessel will often be operating in sea ice, scientists will need to be able to map sea ice and sea ice drift in the regions in which the vessel is operating. This can be facilitated by having the ship's X-band radar data made available in near real time to the science team. Provision should be made to do so.

Mast and Flying Bridge design and layout must consider the mounting and location of Satellite communications systems that allow for unobstructed view of communications satellites.

Priorities: Requirements rated as "must have, as is"

D.2.5.8 Geotechnical Coring and Drilling

Updated SMR

The vessel must 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. Drilling in Antarctic waters typically requires at least one additional ship to reposition icebergs that threaten the drilling ship when engaged in operations.

The vessel must be equipped to acquire long stratigraphic sections (40 - 50 m via a jumbo piston core or other long core system) and be capable of accommodating temporarily-installed geotechnical drilling to 300-400 m below sea floor, at water depths of up to 1250 m in ice covered areas.

Improvement in sediment coring capabilities is linked to adequate laboratory and storage space for initial core analysis and cold storage.

Priorities: Requirements rated as “must have, as is”

D.2.5.9 Moon pool operations

Updated SMR

The vessel shall be designed with a moon pool that meets the following requirements:

- 4 meters by 4 meters in size, with sufficient internal overhead clearance for Jason, Ropos, Mebo, to allow temporary installation of drilling rigs (see Geotechnical Drilling above).
- The moon pool must be closed to the sea when not in use. Capable of being pumped down free of water and ice when the bottom door(s) for the pool are closed.
- Include a system to clear ice when in use.
- Accessible from an environmentally controlled compartment with sufficient space and support systems to enable the deployment of scientific gear including CTDs, ROVs, VPRs, nets, drilling systems, portable ADCPs, etc.
- Shall be supported by the same oceanographic winches that support over the side operations.
- Located as close to the center of motion of the ship as is practicable so as to minimize the impact of the ship's motion.

Priorities: Requirements rated as “must have, as is”

D.2.5.10 On deck incubations

Updated SMR

Deck incubator positions (unshaded by structure) with a means for securing to the vessel shall be provided. Seawater delivery to each incubator with a flow capacity of 50 gallons/min is required. The total number of incubators to be serviced at one time should be determined taking into account available deck space and input from science users and will determine total pump capacity required. It should be possible that at least two deck incubators can be used simultaneously side-by-side. Plumbing should include valves that can be fine-tuned to adjust flow rates. Incubator seawater should be within 1°C of ambient seawater temperature. Outflow drainage will be required, the bigger the drainage hole the better. Design criteria must take into account operations in freezing weather, particularly when air temperatures are well below seawater temperatures causing drain lines and water discharged on decks to freeze. Heat tape right at the outflow can be useful in preventing freezing. Deck space designated for incubators should preferably be located on the same deck as the CTD station such that researchers conducting experiments that make use of large amounts of seawater collected from the CTD do not have to hand-carry heavy buckets of seawater up stairwells, which increases the risk of falling and injury.

Priorities: Requirements rated as "must have, as is"

D.2.5.11 Marine mammal & bird observations

<u>Updated SMR</u>

Design of the pilothouse area and/or flying bridge should include provisions for making weather-protected, heated, and obstruction free (at least a combined 180 degrees forward of the beam) observations by two to three scientific personnel. Bird and mammal observers will be on watch continuously during daylight hours and observation locations should include secured, but removable chairs, access to the navigation/data network, and a protected location for portable computers and/or logbooks. Mounting locations for big eyes or similar devices may be required for some observers. Observer locations should be free from radiation hazards generated by radars and other communication equipment.

Provision of an icebridge proving these capabilities could also be considered.

Priorities: Requirements rated as "must have, as is"

D.2.6 Science and shipboard systems

D.2.6.1 Navigation

<u>Updated SMR</u>

Best available navigation (real-time kinematics, differential, P-code, and 3-axis GPS) capability shall be provided with appropriate interfaces to data systems and ship control processors for geo-referencing of all data, dynamic positioning, and automatic computer steering and speed control. Backups and redundant systems should be provided to ensure continuous coverage. Best available electronic charting (e.g., ECDIS) and bridge management system shall be provided. GPS aided attitude heading reference system (AHRS) and/or other available systems for determining ship heading, speed, pitch, roll, yaw, etc. as accurately as possible should be installed and integrated into ship and science systems.

Bridge navigation, management, and safety systems will meet all regulatory requirements and facilitate effective science operations with minimal manning. Systems should be designed so that any changes to bridge navigational display and control systems will not have any effect on science data collection processes. Communication of waypoint information between science and bridge system should be an integral part of the system. Specification, purchase, and installation of systems should take place as close to delivery as possible to ensure the most up-to-date systems. Provisions for temporary installation of short or ultra-short baseline acoustic systems and other navigations systems when necessary should be included so that they can be integrated with existing systems.

ABS Requirements for Notation NIBS (Navigational Integrated Bridge System) should be considered as a design and construction requirement.

Priorities: Requirements rated as "must have, as is"

D.2.6.2 Data network, onboard computing, and data processing

Updated SMR

High-speed data processing facilities capable of handling large data sets for rapid processing, display, evaluation, and archiving are needed. Typical data sets might include: LiDAR elevation surveys from glaciologists, seismic imaging and multibeam swath map output. It should also include receiving real-time updates of the ship's navigation data and disposition of the X-band radar data for analysis by the science party.

A split IT network with dedicated USAP servers and other equipment separate from any crew IT network is necessary. Four network drops per stateroom are required (2 - person owned computers, 1 - smart tv, 1 - IP phone). 1 network drop per common area, lab and others to be defined for WIFI (WAP). 2 drops per station in all computer / dry lab areas. 4 network drops in IT / ET workshop. CCTV must be available in every lab. A central command station for all operations must be available, this includes a radio and CCTV at hand, and room for a number of monitors. GPS strings must be available in every lab. All labs should have WIFI access and LAN drops, at least every 4 bench feet.

Data processing-related comments from the user survey included the need for the addition of "remote access to instrumentation control and data, and video presence". One respondent stated that "quality of the data, the data coverage and the accessibility of data coming off the ships" is sometimes less than clear. This person was referring to meteorological data, underway seawater measurements, XBT transects during crossings, and ADCP data.

A data presence system shall be capable of local (ship-based) data processing and further visualization of real-time data with the potential for a shore-side component. The shore-side component may not be as important in the new Antarctic vessel/s, but if it is something of interest then the limiting factor is always going to be bandwidth, so this should be kept in mind.

When dealing with large datasets there are important considerations that need to be made. For example, for the multibeam, data processing tools are required, as is an added level of expertise to run the software. Having these systems already installed on the ship will enable PIs to efficiently plug-and-play the instrument they need and visualize data in real-time. Therefore, it is recommended that user input be sought by the NSF to identify key data-intensive instruments needed by a wide user group and to have these and the support systems they require set-up on the vessels.

Finally, in terms of facilities necessary, it is essential that there be a lab dedicated to servers, etc. that has adequate space for racks and other DAS equipment.

Priorities: Requirements rated as "must have, as is"

D.2.6.3 Real time data acquisition system

Updated SMR

A well designed "system" is required for real-time collection of data from permanently installed sensors and equipment as well as from temporarily installed sensors and equipment that allows for archiving, display, distribution, and application of the data for a variety of scientific and ship-board purposes. This system should be designed and specified by a group of knowledgeable science users and operators. Further, this system should be integrated with the data network and other onboard systems with access to data and displays available in staterooms and all working spaces. It should include real-time updates of the ship's navigation data and disposition of the X-band radar data for analysis by the science party. While planning for this system should begin at early stages to ensure that it is integrated into the ship's infrastructure, the actual specification of hardware and operating system should be made as close to the delivery of the vessel as possible to ensure an up-to-date system.

Priorities: Requirements rated as "must have, as is"

D.2.6.4 Communications – internal

Updated SMR

Internal communications includes phones, PA, entertainment systems, ship alarms, some bridge comms, via LAN, voice and CCTV connections throughout laboratories and living spaces, preferably via fiber-optics running throughout vessel.

Internal communication system providing high quality voice communications throughout all science spaces, working, berthing areas should be provided, and be available to all inhabited vans. Point to point and all-call capabilities are required such as 21mc and 1mc systems. A sound powered phone emergency system should be included.

All staterooms should have phones for internal communications. A primary and backup (spare) telephone switch capable of providing one voice line to every space on the ship and access to off-ship services such as INMARSAT or equivalent equipment should be provided. Voice telephone wiring to all spaces on the vessel should be installed.

Consideration should be given to including installed equipment to support pagers, mobile phone/radio (UHF) communications, or other versatile methods for contacting personnel.

Alarm and information panels should be installed in key workspaces, common areas, and all staterooms. The alarm system and information panels should connect to vans seamlessly.

The ability to install closed circuit television monitoring and recording of working areas should be provided to improve operations and safety. There should be CCTV outlets in all science spaces and staterooms, with channels available in those locations to monitor science operations and environmental conditions. The ability to install monitors (flat screen) for all ship control, environmental parameters, science and over the side equipment performance should be available in all, or most, science spaces, common areas, and staterooms.

Infrastructure for internal communications and data networks should adhere to IEEE 45 standards (or current guidelines) for keeping signal and power wiring separate and other safe reliable design considerations.

While planning for this system should begin at early stages to ensure that it is integrated into the ship's infrastructure, the actual specification of hardware and operating system should be made as close to the delivery of the vessel as possible to ensure an up-to-date system.

Priorities: These requirements are rated as "must have, as is".

D.2.6.5 Communications – external

<u>Updated SMR</u>

Primary high-speed Internet access will be provided by a Very Small Aperture Satellite (VSAT) system. A location for installing a 2 to 3 meter VSAT or similar actively stabilized antenna will be provided in the design with a full-sky view. Above 70 degrees Latitude Internet connectivity will be provided by ganged (load equalized) systems via Low Earth Orbit (LEO) satellite systems such as Iridium Pilot, or one of several emerging LEO offerings that may provide more bandwidth than Iridium over the poles. A flat panel phased array antenna should be considered. The operating area and schedule of the ship will probably require it to be outside of VSAT footprints often and therefore a location for an Inmarsat™ antenna such as a Fleet Broad Band™ will also be required. Goal should be a radio uptime requirement of 99% uptime for satellite radios, either by dual radome or some other means

Ship-based weather satellite receivers (e.g. Terascan™ and Dartcom) provide real- time visual and infrared imagery from NOAA HRPT and DMSP satellites with no delay. The PRV design will have a suitable mounting location for a 1.5m dynamic antenna to support direct satellite reception.

A split IT network with dedicated USAP servers and other equipment separate from any crew IT network is recommended. Due to limited top deck space, it is likely that satellite antennas will need to be shared between the ship and USAP IT networks.

The technical specifications for external communications should be re-evaluated at final design time to take into account recent technical developments. The actual specification of hardware and operating system should be made as close to the delivery of the vessel as possible to ensure an up-to-date system.

Priorities: These requirements are rated as "must have, as is".

D.2.6.6 Scientific Seawater System

<u>*Updated SMR*</u>

Flow-through scientific seawater system capable of delivering >40 liters/minute (threshold) / 100 liters/minute (objective) to all laboratory spaces. Include an alarming system for seawater if it over pressurizes or shuts off. Anti-icing: develop requirements to deal with de-icing that does not affect seawater requirements. Piping material should be corrosion resistant and as chemically neutral as possible within the limits of regulatory requirements.

The underway seawater sampling system should consist of an intake near the bow and the surface to provide uncontaminated seawater, resistant to ice-clogging, while the ship is underway and/or stationary. Careful attention to system design for operations in ice is necessary to minimize and mitigate ice-clogging drawing on lessons learned from other ice capable research vessels. A secondary intake location for use if the primary intake is compromised by heavy seas or ice clogging.

This system will support a suite of standard sensors (temperature, conductivity, depth, and fluorescence), but also be flexible enough to include multiple ports for additional sensors. The system should be designed to optimize flexibility and maintenance. A minimal lag time between intake and arrival at the sensor packages and the lab sinks with an objective of less than 2 minutes is desired.

Final location of intakes for underway seawater sampling should be determined following final hull design to minimize thermal contamination, bubbles, intake blockage, and to maximize water flow.

The underway system should be designed with the following criteria:

1. Minimize the time lag between intake and sampling location (sensor suite and/or lab sinks). If more than one intake is installed ensure that the intake being used is flagged in the data stream.
2. Provide underway seawater taps at least 4 sinks in lab-accessible spaces (although the more access points the better should be the rule). This will allow users to configure to either continuous or discrete sampling of underway seawater according to their needs. Additional access points should be provided in sinks in other labs (chem. labs, trace metal

labs, wet lab, and ability to access underway seawater from labs in vans on deck). While these sinks will not be used exclusively for underway seawater sampling this arrangement provides the option for cruises that will utilize underway flows extensively for a variety of sampling. User-supplied sensors that would be installed near sinks include flow cytometers, LISST (laser-based particle imaging), and cavity ring down systems for measuring gases (CH_4 and N_2O) and pCO_2. However, all of these could be installed next to a sink with seawater access. It is important to minimize the time between water intake and delivery of the intake to the sink.

3. The underway system should be designed so that any additional sensors (user-supplied or ship-supplied and not requiring a sink) can be mounted in close proximity to the ship's 'standard' CTD-fluorometer package. The likely suite of additional sensors would include optical sensors (backscatter, transmissometer, additional fluorescence sensors), nitrate (suna or ISUS), pH (Seabird), O_2 (SBE 43 or optode-based). Although these additional sensors could be standalone with their own datalogging, the underway system should be designed to allow the voltage output to be recorded and merged with the ship's underway data feed. It is important to minimize the time between water intake and delivery to the sensors.
4. The foredeck should have a standard deck bolt pattern that easily allows the installation of a davit or crane that would facilitate the mission-specific bow deployments of a temperature/conductivity (or other sensor) chain to sample the undisturbed upper ocean.
5. The underway sampling system should include an infrared sensor installed at the bow for measuring sea surface skin temperature.
6. Maintenance of the underway sampling system is critical for obtaining high-quality data. The system should be designed to conduct periodic (approximately daily) back-flushes with freshwater or a dilute bleach rinse, to prevent accumulation of growth/biofilms in the underway plumbing. The system should have the ability to access coarse strainers for conducting daily rinses. This can be done by bifurcating the inflow so that one side can be taken out of line for cleaning.
7. The foremast should include ducting so that underway air-sampling can be undertaken with the air ducted through the ship to and accessible via ports in the main, wet and chemistry labs.

Priorities: Requirements rated as "must have, as is"

D.2.6.7 Acoustic systems (including deep and shallow multibeam, echosounder, sub-bottom profiling; ADCP)

<u>Updated SMR</u>

The hull design and structure for transducer installation should support the installation and operation of the following systems:

- Deep Ocean multibeam bathymetric mapping system
- Shallow Water multibeam bathymetric mapping system

- 38 kHz and 75 kHz Acoustic Doppler Current Profilers, and if space permits, a 150 kHz or 300 kHz system for use in shallow water.
- 3.5 kHz Sub-Bottom Profiler, CHIRP or Parametric Narrow Beam
- 12 kHz Echosounder
- Bioacoustic Sonars – 38, 120 and 200 kHz transducers as a minimum, 18 and 70 kHz desired in addition.
- Ultra-short baseline (USBL) underwater systems positioning transponder
- 12 kHz Acoustic Release transponder
- Hydrophones and Hull-mounted Underwater Cameras
- Other Requirements:
    - At sea transducer maintenance capability wherever possible.
    - A drop down keel in order to minimize effects from bubble sweepdown and provide additional science capability for the installation of mission specific equipment without need of a dry dock should also be considered carefully.
    - Hull design or features designed to minimize bubble sweepdown
    - Noise and vibration treatments to minimize SONAR self-noise

Priorities: Requirements rated as "must have, as is"

D.2.6.8 Seismics

Updated SMR

The science objectives require periodic use of a broad range of marine seismic sources for reflection and/or refraction studies. The vessel should have the power and infrastructure to deploy seismic gear, including towed multichannel streamers at speeds of 3.5-4.5 kts in moderate (3/10-4/10) sea ice cover.

Recommend the continued inclusion of onboard compressors for seismic operations. The compressors currently on the NBP, Seismic Air Compressors (Borsig-LMF) 1,200 scfm at 2,000 psi, are adequate.

Priorities: Requirements rated as "must have, as is"

D.2.6.9 Project science system installation and power

Updated SMR

The Science Mission Requirements in general are designed to support the provisions required for installing equipment that is brought on board occasionally such as SeaSoar, MOCNESS, MR1, Deep Tow, towed sonars, portable seismic reflection systems, gravimeters, and specialized ADCPs. Taut and slack tether ROVs, AUVs, remotely piloted aircraft, and other systems should also be readily accommodated. A very wide variety of scientist-supplied sampling and laboratory equipment must be accommodated, in a variety of locations on the ship, including, but not limited to, all laboratories, all science decks, and access points on the scientific seawater system, including near the intake. The types of equipment will need to be defined during concept and preliminary design cycles, and as much flexibility as possible should be designed. Generally providing power sources, deck space, mounting locations, and data connections will accommodate most needs, however, in some cases it may be necessary to provide fuel, hydraulic power or other services.

The electrical system capacity and design should take into account provisions for the cruise variable connection of systems with large electrical motors or power demands. Provision for multiple simultaneous connections should be possible for 480V 3-phase, 208 – 230V 3-phase and single phase, and 110V single phase with up to 50 amps service for vans, laboratories, and on deck. Final design specifications should take into consideration common electrical requirements for currently used and planned equipment, and excess capacity should be designed in to the maximum extent possible.

Priorities:

These requirements are rated as “must have, as is”, except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as “must have, as is”, with the Objective requirements rated as “could manage with something less stringent”.

D.2.6.10 Discharges

Updated SMR

Compliance with new environmental regulations, such as emissions and discharges, is required. All vessel underway discharge must be consolidated to one side of the vessel (normally port side) providing a “clean working side”. The PRV will need to adhere to MARPOL and IMO Polar Code regulation with respect to discharges of wastewater and solid waste. MARPOL regulations dictate that the waste must be held in holding tanks until the vessel is in ice-free waters. Generally treated wastewater discharges can be made in areas having ice concentrations >0.1. Untreated water discharges must be 12 nmi. from land or ice and/or shore. In addition, there can be no discharge of food wastes onto ice.

The desired holding times of all sewage could possibly be increased beyond minimum regulatory requirements to meet scientific needs for time alongside ice. Some recent research icebreaker designs have demonstrated a hold time of 20 days for black water and 60 days for gray water, far exceeding current NBP or LMG capacity. A careful evaluation of daily waste water generation and holding time requirements should be made as part of the design once crew complement and as waste treatment and holding tank specifications are developed. As a minimum, a holding period of at least 4 days is required for other vessels, but should be greater for a vessel working in ice-covered areas.

Priorities: Requirements rated as “must have, as is”

D.2.7 Construction, operation & maintenance

D.2.7.1 Green ship

Updated SMR

Environmental, sustainable ship design features should be incorporated in vessel design, but in use must not interfere substantively with critical mission performance criteria such as icebreaking capacity, endurance, and range. These features might include incorporation of recycled materials, non-polluting equipment and instrumentation and fuel efficient or alternative fuel technologies to make these vessels as environmentally friendly and cost effective as possible. Based on best research ship practices at the time of design and construction, specific equipment and materials should be specified. Green ship technologies might include use of reflective exterior paints and electrochromic glass to reduce HVAC loads, use of devices which provide improved oil-water separation, improved marine sanitation devices, design for use of environmentally safe oils, use of software-defined shipboard electrical power systems, and use of selective catalytic reduction (SCR) for emissions control.

A hybrid battery system should be considered as a potential addition to a diesel-electric configuration, with a goal of being able to provide zero emission periods for air sampling and quiet ship operations. Unless there is substantial improvement in battery technology, it is not envisioned that extended underway propulsion would be supported under battery power, but instead that on or near station battery operation periods of approximately 4 (Threshold) to 12 (Objective) hours be feasible.

Priorities:

These requirements are rated as “must have, as is”, except that where both Threshold and Objective requirements are listed, the Threshold requirements are rated as “must have, as is”, with the Objective requirements rated as “could manage with something less stringent”.

D.2.7.2 ADA compliance

Updated SMR

Implement ADA Guidelines as *feasible to accommodate disabilities that meet USAP qualifications for participation,* within the budget and size constraints for the vessel. Reference: ADA Guidelines for UNOLS Vessels_Final_Feb08.pdf.

Priorities: Requirements rated as “could manage with something less stringent”

D.2.7.3 Maintainability

Starting with the earliest elements of the design cycle, the ability to maintain, repair, and overhaul these vessels, and the installed machinery and systems efficiently and effectively with a small crew should be a high priority. This ability is a science mission requirement in the sense that increased reliability and fewer resources and man-hours devoted to maintenance and repair means more time and personnel support for science. Ship layout should include adequate space for ship repair and maintenance functions such as workshops with proper tools, spare parts storage, and accommodations for an adequate number of crew. Design specifications should include provisions for reliable equipment (including adequate backups and spares) that are protected from the elements to the maximum extent possible. Equipment monitoring systems and planned maintenance systems combined with configurations that provide for reasonable access by repair and maintenance personnel will help ensure that equipment remains in the best possible condition. Specifications for equipment should require all equipment vendors to provide parts lists, manuals, and maintenance procedures in electronic form for integration with a Computerized Maintenance Management System (CMMS). This will all reduce the overall cost and effort for maintaining a reliable research vessel.

D.2.7.4 Operability

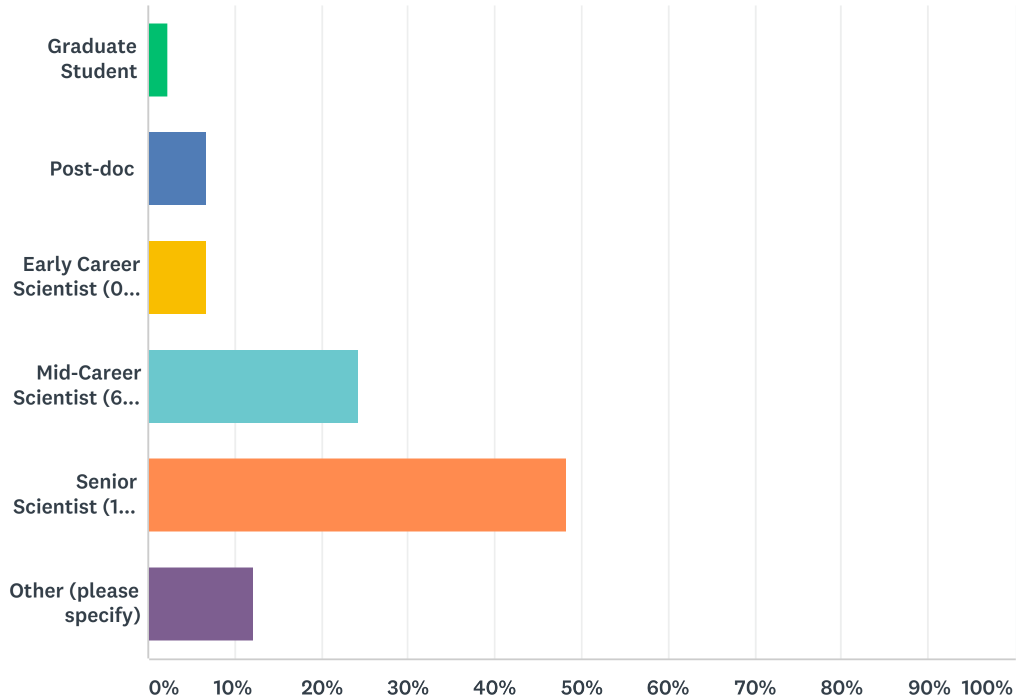
Design should ensure that the vessel could be effectively and safely operated in support of science by a well-trained, but relatively small crew complement. The remote Southern Ocean and Antarctic conditions, available ports, and shore side services should be considered during the design process. The impact of draft, sail area, layout, and other features of the design on the ability to operate the vessel during normal science operations should be evaluated by experienced operators, technicians, scientists, and crewmembers.

D.2.7.5 Life cycle costs

A thorough evaluation of construction costs, outfitting costs, annual operating costs, and long-term maintenance costs should be conducted during the design cycle in order to determine the impact of design features on the total life cycle costs.

Q1 Please indicate your current career status

Answered: 91 Skipped: 0



ANSWER CHOICES	RESPONSES	
Graduate Student	2.20%	2
Post-doc	6.59%	6
Early Career Scientist (0-5 years since Ph.D.)	6.59%	6
Mid-Career Scientist (6-15 years since Ph.D.)	24.18%	22
Senior Scientist (16+ years since Ph.D.)	48.35%	44
Other (please specify)	12.09%	11
TOTAL		91

#	OTHER (PLEASE SPECIFY)	DATE
1	Non PhD scientist mid-career	8/13/2018 8:52 AM
2	Technical support for research vessels	8/8/2018 10:50 AM
3	domain expert; technical support; over 20 years since PhD	7/27/2018 6:22 PM
4	retired	7/25/2018 9:17 AM
5	Support Staff	7/25/2018 7:15 AM
6	Engineer, but I was a marine computer and instrumentation specialist for several years on board both vessels.	7/25/2018 4:00 AM
7	Science Support	7/23/2018 9:46 PM
8	MS, 30+ years, semi-retired	7/23/2018 11:23 AM
9	Senior, semi-retired, instrumentation engineer	7/23/2018 11:18 AM

10	retired	7/17/2018 12:08 PM
11	Technician	7/17/2018 7:12 AM

Q2 Please provide a 2 to 3 sentence description of your field of study.

Answered: 91 Skipped: 0

#	RESPONSES	DATE
1	Ecosystem studies around the Antarctic Peninsula. We maintain two field camps and a ship survey, mostly involving the ecology around Antarctic krill.	8/13/2018 8:52 AM
2	Marine microbial ecology, most recently nitrogen geochemistry	8/9/2018 6:43 AM
3	Using ROVs, HOVs, and AUVs to study deep water column ecology.	8/8/2018 1:17 PM
4	Evolution and phytogeography of antarctic marine fauna	8/8/2018 1:08 PM
5	Marine Science and Conservation	8/8/2018 11:37 AM
6	Use Antarctic diatoms to infer ice sheet (most notably WAIS) history and subglacial processes. PI on ANDRILL, WISSARD and other projects plus IODP drilling. Some work with ice cores.	8/8/2018 11:30 AM
7	N/A	8/8/2018 10:50 AM
8	Melt rates of Antarctic Ice Modern and past climate change impacts Ocean Ecology Sea Ice processes Paleoclimatology	8/8/2018 9:12 AM
9	Marine geology, principally the marine sediment record of ice sheet change on Antarctica over glaciological and geological timescales.	8/7/2018 2:52 PM
10	I am a biological oceanographer interested in the way physical-biological interactions at glacial margins impact phytoplankton. In my work, which is at its root interdisciplinary, I use an array of sampling methods and tools, including field-going research (hydrography, incubation experiments), remote sensing, and analysis of model output (atmosphere, circulation).	8/7/2018 12:41 PM
11	My lab focuses on the phylogeography and genetics/genomics of marine benthic invertebrates in the Southern Ocean. To date, we have investigated the genetic structure of multiple species of pycnogonids (sea spiders), nemerteans, and a suite of echinoderms from multiple Antarctic ocean basins.	8/6/2018 5:39 AM
12	Ultraviolet radiation effects on microbial communities has been the dominant focus. Current project focuses on the importance of mixotrophy in the southern ocean.	8/5/2018 12:45 PM
13	Biological oceanography, microbial ecology	8/5/2018 8:50 AM
14	I am biological oceanographer. As a zooplankton ecologist, my work focuses on the processes by which energy and elements are transferred from primary producers to vertebrate predators and to the deep ocean.	8/3/2018 11:43 AM
15	Mesoscale ship and land based high resolution remote sensing of antarctic marine fauna (emperor penguins and large whales)	8/2/2018 1:30 PM
16	I study the ecology and physiology of marine organisms, specifically how zooplankton and fish respond to environmental stressors. I employ multiple approaches including laboratory experiments and field studies using diverse platforms (ships, underwater gliders, moorings).	8/2/2018 9:41 AM
17	Antarctic Marine Geology/Paleoceanography	8/2/2018 7:33 AM
18	I am a physical oceanographer interested in how ocean turbulence, mesoscale to small-scale, influences the larger-scale overturning circulation. I am also interested in ocean-ice interactions.	8/1/2018 8:48 PM
19	I study Quaternary sediments and stratigraphy on the shelf and on raised marine shorelines.	8/1/2018 12:40 AM
20	My research focuses on responses of marine phytoplankton to environmental change. Studies include field sampling, taxonomic quantification and molecular analyses.	7/30/2018 7:31 PM
21	Marine biogeochemistry as it pertains to the ocean carbon cycle and environmental controls of biological productivity, and paleoceanography as it pertains to changes in the circulation and biological productivity of the Southern Ocean that regulated glacial-interglacial variability of atmospheric CO2.	7/30/2018 1:06 PM

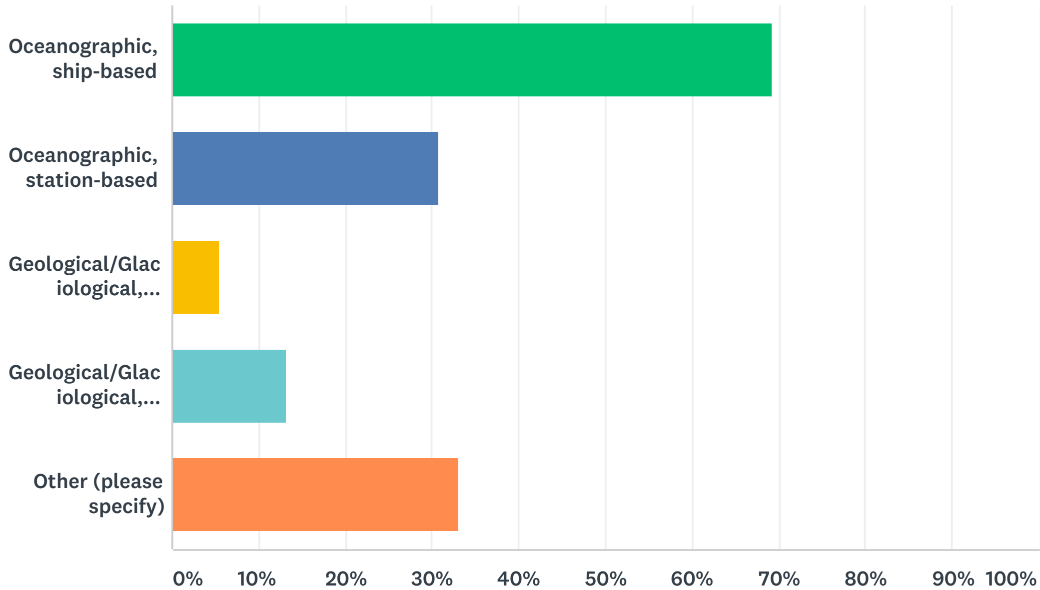
22	Sea ice physics, mass balance and ice-ocean interactions, ice growth and decay processes, remote sensing of sea ice thickness and snow depth, autonomous platforms.	7/30/2018 7:49 AM
23	The future of West Antarctic climate, as contextualized by ice core paleoclimate records (200-2000 years).	7/29/2018 9:09 PM
24	I have to primary fields of study. The first is remote sensing of snow, glaciers and other aspects of the cryosphere. The second is the study of anthropogenic impacts in Antarctica.	7/29/2018 11:43 AM
25	We work with ocean currents using acoustic Doppler current profilers (ADCPs). Our group develops and maintains the shipboard ADCP acquisition and processing software, "UHDAS", which is installed on LMGould and NBPalmer. We monitor data quality via automated email messages and work with scientists to get the most out of their datasets while at sea and after the cruise.	7/27/2018 6:22 PM
26	I study fish (mostly Notothenioids) evolution and adaptations, at the morphological, ecological, physiological, and genetic levels.	7/27/2018 4:15 PM
27	Polar Ecosystems Research-	7/27/2018 6:05 AM
28	My group studies microbial processes in the water column. In the waters off Antarctica, we focus on understanding how changing light and oxidative stress are affect phytoplankton physiology, and how these effects may impact carbon export, trophic energy transfer, etc.	7/26/2018 1:31 PM
29	Glaciology, specifically ice dynamics Ice-ocean interaction, such as ocean induced glacier ice melting and effects on glaciers	7/26/2018 12:12 PM
30	Ecosystem studies involving estimations of fish and zooplankton biomass using underwater acoustic sensors deployed from ships and autonomous platforms.	7/25/2018 12:25 PM
31	Ocean Engineering	7/25/2018 12:09 PM
32	I am an igneous petrologist and the main focus of my study is terrestrial and submarine volcanic rocks. Sampling is critical to my study. From the samples collected, I try to investigate their mantle source - its history and evolution.	7/25/2018 10:14 AM
33	Remote sensing (primarily), also use models and field data. Study aerosol-cloud interactions	7/25/2018 9:53 AM
34	Physical oceanography, coupling to atmosphere and biological systems	7/25/2018 9:51 AM
35	physical oceanography carbon cycle data assimilation	7/25/2018 9:43 AM
36	Physical oceanography of polar continental shelf seas involving hydrography, moorings, AUVs.	7/25/2018 9:17 AM
37	Remote sensing, cartography, GIS	7/25/2018 7:15 AM
38	N/A - again, I was a marine computer and instrumentation specialist that sailed on both the LMG and NBP. Between 2006 - 2009, I spent around 8 months on board either ship per year.	7/25/2018 4:00 AM
39	Marine Geology, specifically using sediment magnetic methods to understand earth's past	7/24/2018 4:21 PM
40	I am a physical oceanographer. I have been studying polar contributions to the large scale circulation, decadal-scale changes in seawater properties, and water mass formation and modification (especially in polar regions).	7/24/2018 1:12 PM
41	I am a physical glaciologist that is interested in sub-ice processes on ice shelves and on grounded ice.	7/24/2018 12:14 PM
42	My research focuses on the morphology, evolution, and paleobiogeography of Cretaceous non-avian dinosaurs and birds, particularly those from the Gondwanan (Southern Hemisphere) continents. I am especially interested in deciphering the role that Gondwanan fragmentation played in driving the evolution of terrestrial vertebrate faunas on its component landmasses. To that end, I have conducted fieldwork at Cretaceous localities in South America (Argentina), Africa (Egypt), Australia, and Antarctica.	7/24/2018 11:07 AM
43	Ocean-ice sheet interactions	7/24/2018 9:56 AM
44	I'm a biological oceanographer/microbial ecologist and investigate microbial community function in the water column, sea ice, and other environments.	7/24/2018 9:31 AM
45	Benthic marine ecology of shallow-water communities. This includes studies of chemical ecology, climate change impacts, and community structure.	7/24/2018 9:28 AM

46	Trace metal biogeochemistry- distributions and chemical speciation of trace metals in the water column, and cycling of trace metals during phytoplankton growth and decay.	7/24/2018 6:42 AM
47	Molecular ecology in the polar oceans. Investigating trophic interations (predation and parasitism) in the plankton, and demographic processes and selection/adaptation in megafauna using DNA sequencing.	7/24/2018 6:09 AM
48	Logistics and plans of science projects. Worked in McMurdo and on the LMG.	7/23/2018 9:46 PM
49	Foraging ecology and physiology	7/23/2018 3:30 PM
50	I am an ecologist whose research focuses on identifying and understanding the factors that regulate the demography of Southern Ocean seabirds. This research began in 1974 and is now embedded as part of the Palmer Long-Term Ecological Research program.	7/23/2018 1:49 PM
51	Marine mammal behavioral ecology and bioacoustics	7/23/2018 1:48 PM
52	Physical oceanography and ocean-sea ice-atmosphere interaction. Most field studies have been in the weddell gyre and for the last 20 years along the western Antarctic peninsula.	7/23/2018 12:26 PM
53	Management of Antarctic marine living resources, primarily fisheries but also conservation of biodiversity	7/23/2018 11:46 AM
54	Bottom and deep water formation processes and interaction of these processes with the global climate system, including MOC, glacial-ocean and sea-ice ocean interactions. Regions of interest include the Weddell, Ross, Amundsen-Bellingshausen seas and Sabrina Coast.	7/23/2018 11:23 AM
55	Design, develop, install, and support real-tie instrumentation for marine and polar scientists.	7/23/2018 11:18 AM
56	Astrophysics and Cosmology from millimeter wave observations with telescopes located at the South Pole.	7/23/2018 11:04 AM
57	Marine geology and polar science	7/23/2018 10:55 AM
58	Oceanography, ecosystem dynamics	7/23/2018 10:53 AM
59	Marine geology and geophysics - focused on developing paleoclimate records from marine sediment cores	7/19/2018 2:20 AM
60	Antarctic zooplankton ecology, with a focus on Antarctic krill.	7/18/2018 2:38 PM
61	Antarctic fish physiology and biochemistry	7/17/2018 3:29 PM
62	Ship operations and engineering with extensive experience on icebreaker research ships.	7/17/2018 12:08 PM
63	Earthquake seismology	7/17/2018 11:50 AM
64	physical oceanography	7/17/2018 11:48 AM
65	Air-ice-ocean interactions and sea ice properties and processes primarily in the Antarctic sea ice zone but also in the Arctic.	7/17/2018 11:48 AM
66	Ocean waves, air-sea interaction, wave-ice interaction, nearshore processes	7/17/2018 10:08 AM
67	Benthic ecosystem ecology/ biological oceanography	7/17/2018 10:04 AM
68	I am a marine geologist interested in paleomagnetism, environmental magnetism, and understanding past glacial changes.	7/17/2018 9:23 AM
69	Mantle convection, ocean ridge tectonics, crustal accretion, and magma genesis.	7/17/2018 8:51 AM
70	Oceanography focused on use of unmanned systems: AUVs, ASVs and UAS.	7/17/2018 8:40 AM
71	I am a paleoceanographer interested in how marine organisms record and respond to past climate events. Specifically, my work combines foraminiferal paleoecology and geochemistry to investigate how marine ecosystems respond to climate perturbations, particularly ocean deoxygenation, ancient greenhouse climates, and the KPg mass extinction.	7/17/2018 8:28 AM
72	I am using Marine Geophysics, seafloor mapping, sediment samples and oceanographic measurements to study and reconstruct past ice sheet extent and dynamic on the Antarctic continental shelf and pathways of warm CDW across the shelf to the current ice sheet.	7/17/2018 7:59 AM
73	The drivers of phytoplankton community structure with emphasis on diatom ecology and microzooplankton grazing.	7/17/2018 7:43 AM

74	I am a microbial ecologist/oceanographer with particular focus on factors controlling the diversity of microbial assemblages and linking diversity to biogeochemistry and ecosystem functions. I have sailed to the Ross Sea and spent time at Palmer Station.	7/17/2018 7:34 AM
75	Geophysics, science support	7/17/2018 7:12 AM
76	Redox reactions in diverse systems, particularly on coupled nutrient cycles.	7/17/2018 6:55 AM
77	Southern Ocean biogeochemistry in the modern ocean and from Pliocene to present	7/17/2018 6:41 AM
78	Physical oceanography	7/17/2018 6:34 AM
79	I study the transfer of kinetic energy in the ocean over the scale gap between lateral stirring and true dissipative mixing. I study the impact of the atmosphere - ocean interactions on these physical processes. I study the physics-biological implications of these processes.	7/17/2018 6:31 AM
80	Air-sea biological-chemical processes and fluxes; biogeochemical signaling; phytoplankton-bacteria intractions	7/17/2018 6:28 AM
81	My speciality is Marine Geology of the Arctic Ocean. I use gravity, bathymetry and multi-channel seismic reflection data to examine the structure and stratigraphy of this ocean basin. I want to reconstruct the history of Amerasia Basin.	7/17/2018 1:18 AM
82	Impacts of climate on soil biogeochemistry and microscoping biological communities	7/16/2018 9:09 PM
83	Physical oceanography and climate science using global scale in situ observations, including hydrography and profiling floats.	7/16/2018 8:51 PM
84	Terrestrial geological records of ice sheet change, mostly focused on surface exposure dating	7/16/2018 6:40 PM
85	Biological oceanography - specifically, primary production in polar regions and how this is controlled by environmental variability.	7/16/2018 1:51 PM
86	Marine geology, stratigraphy, and sedimentology---focus on glacial history.	7/16/2018 1:47 PM
87	Ecology of zooplankton and krill	7/16/2018 11:59 AM
88	Marine Biogeochemistry, ocean carbon and oxygen cycles	7/16/2018 11:58 AM
89	Fisheries Oceanography, acoustic and pelagic studies, Krill biology and ecology	7/16/2018 11:03 AM
90	I am a sea-going process-oriented observational physical oceanographer with particular interest in internal waves, turbulence and mixing, as well as dispersal in the ocean. While I do not have a strong regional focus, I have done work in Antarctica before.	7/16/2018 10:51 AM
91	I study the foraging behavior, ecology, and population demographics of marine mammals and the impacts of long-term environmental change on marine mammals.	7/16/2018 10:49 AM

Q3 Please indicate what your current research is. Select all that apply.

Answered: 91 Skipped: 0



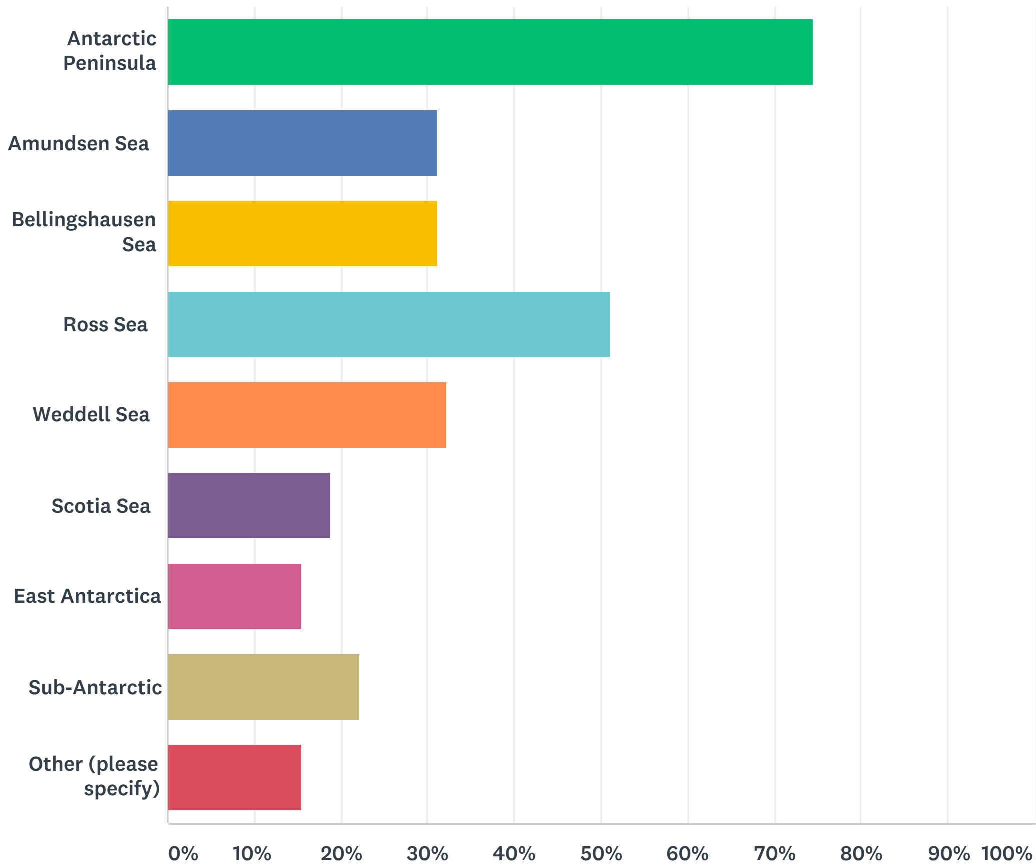
ANSWER CHOICES	RESPONSES	
Oceanographic, ship-based	69.23%	63
Oceanographic, station-based	30.77%	28
Geological/Glaciological, station-based	5.49%	5
Geological/Glaciological, remote field camp-based	13.19%	12
Other (please specify)	32.97%	30
Total Respondents: 91		

#	OTHER (PLEASE SPECIFY)	DATE
1	Biology, ecology, ship and station-based	8/8/2018 11:37 AM
2	support ship-based research	8/8/2018 10:50 AM
3	marine geological drilling (IODP, Andrill)	8/7/2018 2:52 PM
4	Biophysics	8/2/2018 1:30 PM
5	Marine Geological/Ship based	8/2/2018 7:33 AM
6	Geography, station and ship based	7/29/2018 11:43 AM
7	Organism Biology, Ship and Station-based	7/27/2018 4:15 PM
8	Glaciology, ship-based	7/26/2018 12:12 PM
9	remote sensing	7/25/2018 9:53 AM
10	Remote Sensing	7/25/2018 7:15 AM
11	N/A	7/25/2018 4:00 AM
12	Paleontological/Geological, remote field camp-based	7/24/2018 11:07 AM
13	Science Support	7/23/2018 9:46 PM

14	predator-prey studies	7/23/2018 11:46 AM
15	Oceanographic, ship based and moored instruments	7/23/2018 11:23 AM
16	I only do "research" in support of engineering designs.	7/23/2018 11:18 AM
17	Astrophysics from South Pole station	7/23/2018 11:04 AM
18	Marine geology and geophysics - ship-based	7/19/2018 2:20 AM
19	physiology & biochemistry, ship- and station-based	7/17/2018 3:29 PM
20	Consultant on USCG HPIB	7/17/2018 12:08 PM
21	oceanographic	7/17/2018 11:48 AM
22	Sea ice research requiring use of autonomous vehicles and buoys and specialized sampling conducted in over-the-side operations.	7/17/2018 11:48 AM
23	Geological, ship-based	7/17/2018 8:28 AM
24	geological, ship-based	7/17/2018 7:59 AM
25	Geological, ship-based	7/17/2018 1:18 AM
26	Terrestrial/soil	7/16/2018 9:09 PM
27	Oceanographic, autonomous-based	7/16/2018 8:51 PM
28	Geological/Glaciological, ship-based	7/16/2018 1:47 PM
29	NOAA operates its own camps and uses NSF vessels to supply	7/16/2018 11:03 AM
30	Not oceanographic necessarily, but marine mammal/organismal	7/16/2018 10:49 AM

Q4 Please select the broad geographical region/s of Antarctica where your research has been focused. Select all that apply.

Answered: 90 Skipped: 1



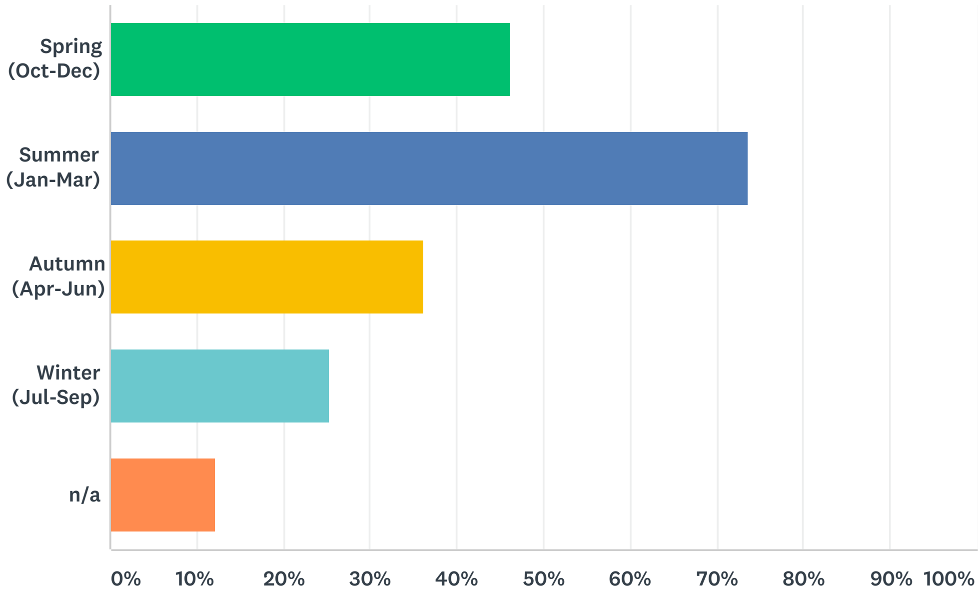
ANSWER CHOICES	RESPONSES	
Antarctic Peninsula	74.44%	67
Amundsen Sea	31.11%	28
Bellingshausen Sea	31.11%	28
Ross Sea	51.11%	46
Weddell Sea	32.22%	29
Scotia Sea	18.89%	17
East Antarctica	15.56%	14
Sub-Antarctic	22.22%	20
Other (please specify)	15.56%	14
Total Respondents: 90		

#	OTHER (PLEASE SPECIFY)	DATE
1	trying to get funding for E. Antarctica	8/8/2018 1:08 PM

2	N/A	8/8/2018 10:50 AM
3	We support the ships wherever they go.	7/27/2018 6:22 PM
4	And I would like to expand to other areas in the future.	7/27/2018 4:15 PM
5	South Georgia Island	7/25/2018 12:25 PM
6	Not focused on the Antarctic yet. Hope to be in the future	7/25/2018 9:53 AM
7	Arctic only	7/25/2018 9:17 AM
8	entire Southern Ocean all the way south to the continental shelf	7/24/2018 1:12 PM
9	Sub Antarctic Islands	7/23/2018 9:46 PM
10	Arctic and mid-latitude oceans	7/23/2018 11:18 AM
11	South Pole	7/23/2018 11:04 AM
12	N/A	7/17/2018 11:48 AM
13	American-Antarctic and SW Indian Ridges	7/17/2018 8:51 AM
14	I have not worked in the Antarctic since 1990.	7/17/2018 1:18 AM

Q5 In what season/s has your research primarily been focused? Choose all that apply.

Answered: 91 Skipped: 0



ANSWER CHOICES	RESPONSES	
Spring (Oct-Dec)	46.15%	42
Summer (Jan-Mar)	73.63%	67
Autumn (Apr-Jun)	36.26%	33
Winter (Jul-Sep)	25.27%	23
n/a	12.09%	11
Total Respondents: 91		

Q6 Briefly describe (100 words or less) how you have used USAP ships to support your research.

Answered: 91 Skipped: 0

#	RESPONSES	DATE
1	The NBP was used for a research platform during our winter surveys. The Gould has been used for opening and closing field camps.	8/13/2018 8:52 AM
2	conducted standard hydrographic sampling (Niskin rosette), with sample prep including ship-board incubations	8/9/2018 6:43 AM
3	As surface support platforms for ROV and trawling operations, in ice, adjacent to the ice edge, and around icebergs.	8/8/2018 1:17 PM
4	Need to conduct broad geographic sampling of marine invertebrates. Have used trawls, coring, and bottom imaging in addition to standard oceanographic instruments on the ships (e.g., ADCP).	8/8/2018 1:08 PM
5	Research on marine megafauna species and their environmental context. Conduct species occurrence and abundance data, deploy instruments, deploy tags, collect biological samples	8/8/2018 11:37 AM
6	To date have not sailed on a USAP ship, but have used core material recovered many times through my career to date.	8/8/2018 11:30 AM
7	I have not used USAP ships	8/8/2018 10:50 AM
8	Many cruises over the past 36 years....CTD casting, coring, net towing, underway measurements, UAV deployments. I couldn't even write the proposals if we didn't have ships available...but I'd be working in/for a different country if that were the case.	8/8/2018 9:12 AM
9	Up to now I have not used USAP ships, but I am interested in scientific drilling to about 100m sub-seafloor, from a polar research vessel. IODP has approval and funding for an Antarctic mission-specific platform expedition to the Mertz glacier area, but due to ship availability, drill rig readiness, and cost, this expedition has been postponed twice so far.	8/7/2018 2:52 PM
10	I've sailed on the Palmer on three occasions (2006, 2010, 2012), first as an undergraduate and then as a graduate student. In all cases I've used the ship as a platform to collect hydrographic observations, primarily from CTD but also from a custom optics rosette, with water samples (e.g. nutrients, pigments, flow cytometry), analyzed in the Palmer's lab space. The cruises have been interdisciplinary, with ship time usually split between several disciplines, including some necessitating helicopter support and zodiac deployments.	8/7/2018 12:41 PM
11	We have utilized ships for collections based research (nets, epibenthic sleds, etc.) along with collecting covariate data (multi-beam sensors, other environmental information).	8/6/2018 5:39 AM
12	Six cruises, three along the peninsula, three in the Ross sea. Sampling limited to CTD water samples and deployment and retrieval of in situ arrays	8/5/2018 12:45 PM
13	I've used the USAP ships for conducting oceanographic surveys, CTD hydrocasts, moon-pool sampling, net tows, conducting onboard mesocosm incubations on the deck and in the environmental room, used ROVs from the aft deck, used onboard lab facilities extensively	8/5/2018 8:50 AM
14	I have sailed on two 6-week LMG cruises in the Antarctic Peninsula/Bellingshausen sea region during summer. I have spent a multi-month field season working from small boats at Palmer Station.	8/3/2018 11:43 AM
15	Have not used USAP ships yet, moved from europe to US academic system 3 years ago	8/2/2018 1:30 PM
16	I have been involved in multiple projects in different regions of Antarctica. I have participated in annual Palmer LTER cruises, conducted independent laboratory-based research at Palmer Station (collaborating with ships to collect krill), and participated in a Ross Sea cruise to support a glider-based study with ship-based groundtruthing sampling (net tows/trawls).	8/2/2018 9:41 AM
17	Support for coring and sesimic operations	8/2/2018 7:33 AM

18	We have used USAP ships to both deploy and recover ocean gliders. We have carried out these operations both from Zodiacs and using the ship's winch. We have also carried out traditional hydrographic work.	8/1/2018 8:48 PM
19	They have been used to collect cores, multibeam, and seismic offshore as well as deploy me to look at raised marine sequences on land.	8/1/2018 12:40 AM
20	To conduct time series sampling and geographic comparisons of phytoplankton species succession and distribution, along with measurements of physiological parameters. Field work includes measurements of hydrographic parameters (e.g., salinity, temperature, etc.).	7/30/2018 7:31 PM
21	Ships have been used to collect water samples for analysis of trace element and isotope concentrations and biological variables; ships have been used to collect sediment cores for paleoceanographic work.	7/30/2018 1:06 PM
22	I have sailed on the Nathaniel B Palmer five times on cruises in the sea ice zone (50-60 day cruises). These cruises typically involved sea ice sampling at ice stations and deployment of buoys and autonomous vehicles.	7/30/2018 7:49 AM
23	I have not currently used ships, but considering that significant focus is needed at the ice-ocean-atmosphere triple-point, ship-use by glaciologists and ice core paleoclimatologists should increase in the future.	7/29/2018 9:09 PM
24	We used USAP vessels to sample marine sediments in the Palmer Station area to evaluate anthropogenic pollution.	7/29/2018 11:43 AM
25	Our primary goal for USAP ships is support of other peoples science, but two specific examples of scientific interest are (1) GOSHIP cruises (2) any time Palmer or Gould go across the equator we are interested.	7/27/2018 6:22 PM
26	USAP ships (exclusively the LMG) have supported my research by being a supply vessel (bringing us in and out of Palmer Station, bringing our experimental apparatus, ...) and by being equipped for fishing operations (Trawls and traps), having, while limited, capacities to transport live fish back to station, and having various labs to perform some dissections on board and appropriate temperature controlled storage for samples (freezers). In addition, at few occasions it supported my research with oceanographic data collection (XBT, sonar, etc).	7/27/2018 4:15 PM
27	I have used the ships to gain access to coastal sites as well as ice-covered areas of the Southern Ocean for physical chemical and biological oceanographic sampling	7/27/2018 6:05 AM
28	In addition to transport to Palmer Station, we used the LMG for a research cruise off the WAP. Operations involve CTD water column sampling, on deck experiments, sediment trap deployments.	7/26/2018 1:31 PM
29	I have used USAP ships twice, for the LARISSA and the FJORD-ECO projects. In the Larissa project we used the NBP with helicopters to gain access to glaciers in the eastern Antarctic Peninsula. In Fjord-Eco we used ships and zodiacs for access to near-glacier bedrock in Andvord Bay to establish weather stations and timelapse cameras	7/26/2018 12:12 PM
30	Acoustic surveys of krill and fish and their oceanographic habitats; and resupply of land-based predator monitoring sites.	7/25/2018 12:25 PM
31	Get to where I am going.	7/25/2018 12:09 PM
32	I dredged samples from the seafloor and seamounts in the Adare Basin using the NB Palmer (NBP0701 cruise in Dec. 2006 – Jan. 2007).	7/25/2018 10:14 AM
33	I am writing a proposal that uses some USAP ship-based data, from a collaborator	7/25/2018 9:53 AM
34	We have utilized the Gould and Palmer for extensive oceanographic research, including ship-based studies, to deploy and recover moorings and AUV gliders, and as platforms to support land-based science and installations of high-frequency radars, time lapse cameras, and automated weather stations, and to support small boat sampling using zodiacs.	7/25/2018 9:51 AM
35	My research analyzes observations enabled by USAP	7/25/2018 9:43 AM
36	Have not used	7/25/2018 9:17 AM
37	Providing remote sensing data and vessel tracking. Have never done research on the vessels themselves.	7/25/2018 7:15 AM
38	I am not a researcher, but I worked on both vessels.	7/25/2018 4:00 AM

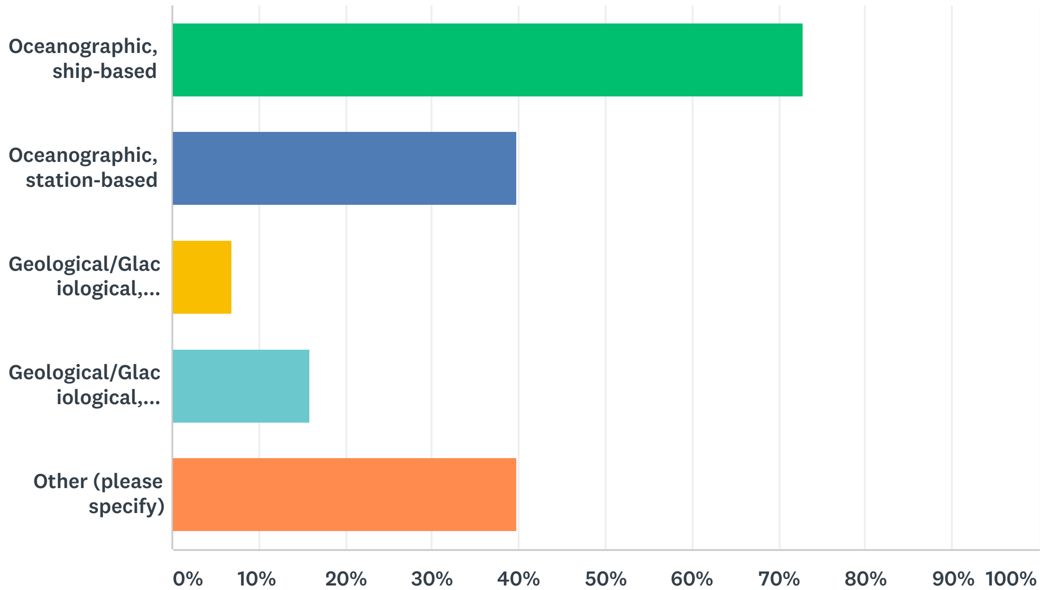
39	Worked on sediment cores collected from USAP ships and curate those now for the community	7/24/2018 4:21 PM
40	I have used the NBP as chief or co-chief scientist for 3 CTD/rosette-oriented cruises (30+ days, and 2 60+ day cruises), and co-led planning for 3 other similar long cruises on that ship. I have sailed on the LMG as an observer in the Peninsula area.	7/24/2018 1:12 PM
41	I have never used USAP ships to support my science, beyond logistics (i.e., shipping to McMurdo)	7/24/2018 12:14 PM
42	I have participated in two paleontological expeditions to the James Ross Island Group on the northeastern tip of the Antarctic Peninsula (in 2009 and 2011) and led a third (in 2016). The first two were supported by the LMG and the last was supported by the NBP. The ships were used for the following: (1) round-trip transit to the study area, from Chile; (2) as a 'home base' for planning and some operations (especially in 2016, when our team had greater flexibility due to the availability of helicopters); (3) transport of field supplies and equipment, plus collected specimens on the return trip; (4) assistance with deployment of field camps; and (5) real-time outreach activities (again, especially in 2016, when, taking advantage of the NBP's satellite connectivity, we conducted live videoconferences and a Reddit Q&A session, posted blogs and tweets from the field, etc.).	7/24/2018 11:07 AM
43	Participated to one cruise on NB Palmer (and many on other RVIB), used numerous past observations supported by Palmer and Gould.	7/24/2018 9:56 AM
44	I've used the LMG for work in the WAP region, and to access Palmer Station. I envision using the NBP and LMG for future work in the WAP and Ross Sea regions.	7/24/2018 9:31 AM
45	Mostly transport to/from Palmer Station but also to support diving studies. Will be doing completely ship-based diving next year.	7/24/2018 9:28 AM
46	I have had two cruises on the R/V/I/B Palmer. Shipboard activities included use of the Palmer TMC rosette and OPP trace metal van for water column sampling, and shipboard incubations using water from the TMC rosette in an onboard incubator freezer van and in deckboard seawater flow-through incubators. Built a TMC 'bubble' in the main lab for incubation sampling and setup.	7/24/2018 6:42 AM
47	We investigated krill feeding from two cruises on the NBP. These ships provided transportation, platforms for deploying nets, and also served as laboratory and aquarium space for running experiments.	7/24/2018 6:09 AM
48	Worked as the Medic and Deck Hand on the LMG.	7/23/2018 9:46 PM
49	Large and small boat support for whale research, including tagging, prey mapping and drone surveys.	7/23/2018 3:30 PM
50	Almost entirely for at-sea surveys, support of remote field camps and support of small boat operations in and around sea ice and remote island locations.	7/23/2018 1:49 PM
51	Underway sampling, including krill sampling; platform for launching small boats to study cetaceans;	7/23/2018 1:48 PM
52	We use the Gould every austral summer to survey a large grid on the western Antarctic peninsula. I have used the Palmer to perform winter process studies in the seasonal sea icd fields of the Atlantic sector and western Antarctic Peninsula.	7/23/2018 12:26 PM
53	oceanographic (hydrography and biology) and hydroacoustic surveys, deployment of autonomous instruments (gliders and moorings), logistics support for remote field camps	7/23/2018 11:46 AM
54	USAP vessels have provide primary support for oceanographic station occupation, mooring deployment and turnaroud. Use has been both as primary project and as add on. I have also participated in non-polar cruises on NBP	7/23/2018 11:23 AM
55	I sailed on numerous legs on the Palmer in support of it's first generation multibeam swath mapping sonar and supported remedial efforts in drydock.	7/23/2018 11:18 AM
56	Only for shipping cargo to Antarctica	7/23/2018 11:04 AM
57	I have used the vessels for seafloor mapping, sub-bottom imaging for core site selection, sediment coring, water column sampling, and as a helicopter platform for ship to shore transport.	7/23/2018 10:55 AM
58	All data collected aboard ships.	7/23/2018 10:53 AM
59	I have used both the NBP (longer piston cores than LMG) and LMG to collect marine sediment cores, with sampling strategy based on swath mapping (NBP only) and sub-bottom data (NBP for multi-channel seismics, both ships have 3.5 kHz).	7/19/2018 2:20 AM

60	I have been a part of oceanographic expeditions aboard both the LMG and NBP in summer and in winter. The LMG has also supported my research at Palmer Station by getting me there and back.	7/18/2018 2:38 PM
61	Fishing operations using benthic otter trawls, blake trawls, and baited fish pots deployed from the LMG off the southwestern shore of Low Island and in Dallmann Bay.	7/17/2018 3:29 PM
62	na	7/17/2018 12:08 PM
63	Have not yet used USAP ships	7/17/2018 11:50 AM
64	N/A	7/17/2018 11:48 AM
65	Starting with Ice Station Weddell in the first cruise of the NB Palmer in 1992, I have conducted sea ice sampling in five cruises using the NB Palmer on AnzFlux (1994), APIS (2000), SIMBA(chief scientist)(2007), and PIPERS (chief scientist)(2017). All cruises conducted sea ice sampling for physical and biogeochemical properties and geophysical probing using electromagnetic instruments.	7/17/2018 11:48 AM
66	haven't	7/17/2018 10:08 AM
67	I have used ships to investigate sea floor communities in the peninsula region and across the sub antarctic islands. This has been through using trawl, grab, and the hydroball (a small and inadequate ROV that leaked).	7/17/2018 10:04 AM
68	My first research cruise was on the Palmer as part of an interdisciplinary expedition. I have used sediment cores collected as part pf my graduate school research.	7/17/2018 9:23 AM
69	I used the Eltanin as part of the US-Argentine collaborative project	7/17/2018 8:51 AM
70	I have coordinated research on CG Polar icebreakers for NSF from 1996-@2002.	7/17/2018 8:40 AM
71	I have used cores collected by USAP ships to study climate change in the southern ocean and the response of organisms there to rapid climate events.	7/17/2018 8:28 AM
72	used the NB Palmer to map the seafloor, take sediment samples and perform oceanographic measurements	7/17/2018 7:59 AM
73	I was involved in a transect from Antartica to New Zealand looking at stable isotopes of nitrogen and silicon in the water column and sediments. We used the USAP ships for a variety of sediment cores, and water column characterization.	7/17/2018 7:43 AM
74	I traveled to the Ross Sea as a postdoc in 2005 where we studied microbial diversity in sea-ice and through the water column from the NB Palmer. More recently I have traveled on the LM Gould back and forth to Palmer Station.	7/17/2018 7:34 AM
75	data source employment source	7/17/2018 7:12 AM
76	Research aboard the R/V Palmer has allowed for sampling and on board incubations for phytoplankton co-limitation by Co, Fe and Mn in the Ross Sea.	7/17/2018 6:55 AM
77	I participated on NBP1702 to collect seawater and sediment core samples along 170W	7/17/2018 6:41 AM
78	I have used them for traditional hydrographic studies, including water sampling and chemistry.	7/17/2018 6:34 AM
79	Mainly as ships of opportunity to sample the water. As adjoint to tracer release experiments. To study Near drakes pasage.	7/17/2018 6:31 AM
80	Mostly transit to and from Palmer Station	7/17/2018 6:28 AM
81	I have not previously used USAP ships.	7/17/2018 1:18 AM
82	Transport to research sites on islands/mainland along latitudinal gradient of the Antarctic Peninsula, and laboratory space to process samples.	7/16/2018 9:09 PM
83	For GO-SHIP hydrographic sections, and deployment of autonomous floats with shipboard hydrographic support	7/16/2018 8:51 PM
84	1. Helicopter platform for access to inaccessible coastal ice-free areas (e.g., LARISSA cruise). 2. Collection of ice-proximal glacial marine sediment	7/16/2018 6:40 PM
85	As a platform to collect water samples and sample the sea ice over a wider area. Also, as a platform to conduct experiments.	7/16/2018 1:51 PM
86	Almost my entire career has been based on work I or others have done from the NBP, on which I have completed 9 of my 10 field seasons and on which 2 of 3 scheduled cruises will take place.	7/16/2018 1:47 PM

87	For sampling krill and zooplankton and phytoplankton, deploying cameras to observe krill behavior, using acoustics to estimate krill abundance, behavior and distribution. Samples were sorted and preserved in ethanol for later molecular analysis. Others were preserved using standard procedures.	7/16/2018 11:59 AM
88	Deployment of instruments on the Gould.	7/16/2018 11:58 AM
89	We have used NSF vessels to conduct annual winter studies in the peninsula. We use the vessels to open and close our camps and we will begin using the vessels to deploy and recover gliders and moorings	7/16/2018 11:03 AM
90	As a sea-going oceanographer, access to ship time is crucial for my work. In the context of several different projectsI have participated on multiple cruises on the Palmer, including as a Chief Scientist. I have carried out survey work with CTDs, LADCPs, and microstructure profilers, and I have deployed and recovered moorings.	7/16/2018 10:51 AM
91	We utilize USAP ships for conduct visual surveys, collect environmental data (e.g. oceanographic measurements), survey prey via echosounders, and as a platform to launch small boats for tagging/biopsy operations	7/16/2018 10:49 AM

Q7 Please indicate what your future research will be. Select all that apply.

Answered: 88 Skipped: 3



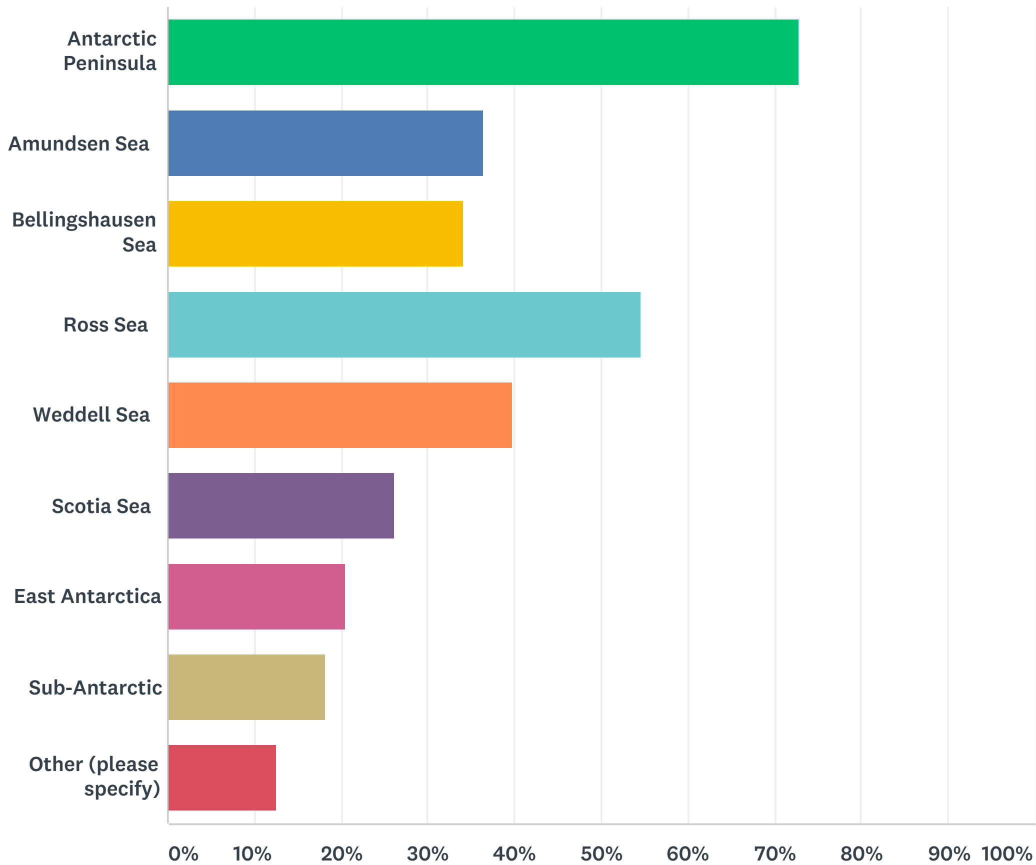
ANSWER CHOICES	RESPONSES	
Oceanographic, ship-based	72.73%	64
Oceanographic, station-based	39.77%	35
Geological/Glaciological, station-based	6.82%	6
Geological/Glaciological, remote field camp-based	15.91%	14
Other (please specify)	39.77%	35
Total Respondents: 88		

#	OTHER (PLEASE SPECIFY)	DATE
1	remote sensing, gliders and moorings	8/13/2018 9:05 AM
2	I am likely retiring soon and do not anticipate future cruises	8/9/2018 6:45 AM
3	also trying for station based work with organismal focus	8/8/2018 1:10 PM
4	Biological and ecological, station and ship-based	8/8/2018 11:38 AM
5	Geological/Glaciological, ship-based	8/7/2018 2:54 PM
6	Ice-shelf based - which may include coupled oceanographic ship based work	8/5/2018 8:51 AM
7	Marine Geological, ship based	8/2/2018 7:33 AM
8	Oceanographic/sea ice from robotic platforms (i.e. from ships in the near future, but potentially from bases).	7/30/2018 7:51 AM
9	Geography, ship and station based	7/29/2018 11:43 AM
10	Organism Biology, Ship and Station-based	7/27/2018 4:17 PM
11	glaciology, ship-based	7/26/2018 12:13 PM
12	remote sensing	7/25/2018 9:54 AM

13	no longer active	7/25/2018 9:17 AM
14	N/A	7/25/2018 4:01 AM
15	Paleontological/Geological, remote field camp-based	7/24/2018 11:07 AM
16	Marine mammal biology	7/23/2018 3:30 PM
17	same as indicated was done in the past	7/23/2018 11:47 AM
18	After 2021 I do not plan future research. Until then, my research will primarily involve mooring recovery and deployment.	7/23/2018 11:24 AM
19	Aircraft, and autonomous vehicle based instrumentation, mostly in the Arctic	7/23/2018 11:20 AM
20	Cosmology and Astrophysics from South Pole	7/23/2018 11:05 AM
21	marine geology and geophysics, ship-based	7/19/2018 2:21 AM
22	physiology, ship- and station-based	7/17/2018 3:30 PM
23	na	7/17/2018 12:09 PM
24	Air-ice-ocean interaction measurements with emphasis on the use of underway automatic instrumentation and autonomous vehicles (UAS, AUV, ROV, and Glider).	7/17/2018 11:53 AM
25	oceanographic	7/17/2018 11:49 AM
26	Ridge research along the Antarctic Plate Boundary	7/17/2018 8:52 AM
27	Geological, ship-based	7/17/2018 8:29 AM
28	marine geology, geophyiscis ship-based	7/17/2018 7:59 AM
29	sea-ice	7/17/2018 6:36 AM
30	Geological, ship-based	7/17/2018 1:19 AM
31	Terrestrial/soil - station and field camp-based	7/16/2018 9:11 PM
32	Oceanographic, autonomous instrument-based	7/16/2018 8:51 PM
33	Geological/Glaciological, ship-based.	7/16/2018 1:48 PM
34	Glider deployments and recovery and mooring deployments and recovery	7/16/2018 11:04 AM
35	analysis of available observational data	7/16/2018 10:52 AM

Q8 Please select the broad geographical region/s of Antarctica where your future research will be focused. Select all that apply.

Answered: 88 Skipped: 3



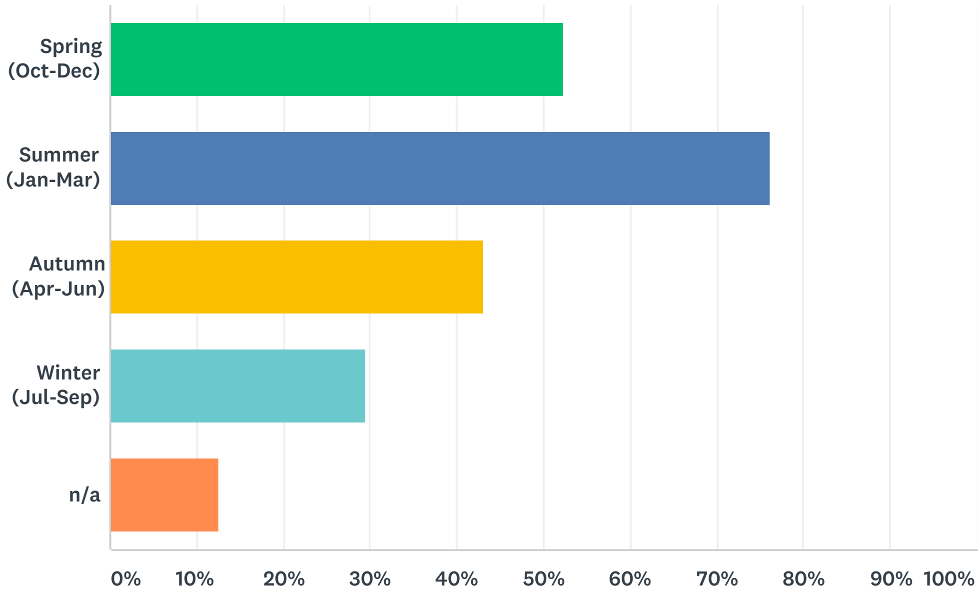
ANSWER CHOICES	RESPONSES	
Antarctic Peninsula	72.73%	64
Amundsen Sea	36.36%	32
Bellingshausen Sea	34.09%	30
Ross Sea	54.55%	48
Weddell Sea	39.77%	35
Scotia Sea	26.14%	23
East Antarctica	20.45%	18
Sub-Antarctic	18.18%	16
Other (please specify)	12.50%	11
Total Respondents: 88		

#	OTHER (PLEASE SPECIFY)	DATE
1	wherever the ship goes	7/27/2018 6:23 PM

2	All oceanic regions of the Southern Ocean	7/25/2018 9:54 AM
3	not applicable	7/25/2018 9:17 AM
4	N/A	7/25/2018 4:01 AM
5	same as earlier reply: all Southern Ocean waters south to the AA continental shelf.	7/24/2018 1:14 PM
6	Unlikely to work in the Antarctic	7/23/2018 11:20 AM
7	South Pole	7/23/2018 11:05 AM
8	A future ship should be capable of working in all geographical regions.	7/17/2018 12:09 PM
9	N/A	7/17/2018 11:49 AM
10	Circum-Antarctic Plate Boundary	7/17/2018 8:52 AM
11	I expect to keep working in the Arctic.	7/17/2018 1:19 AM

Q9 In what season/s will your future research primarily be focused? Choose all that apply.

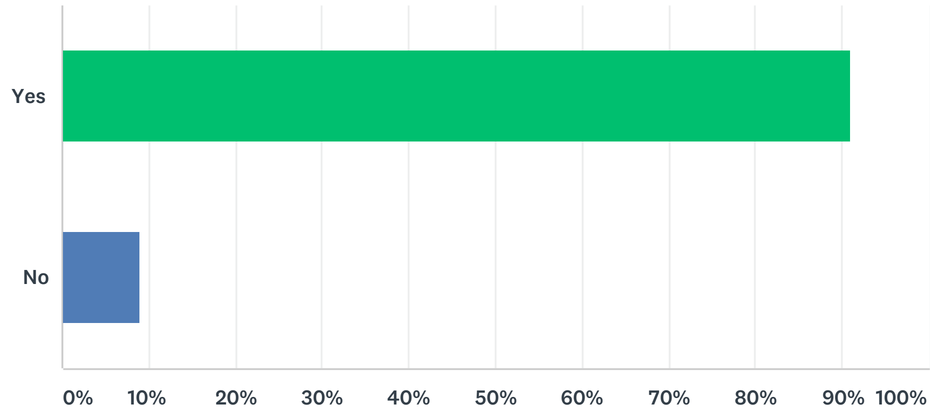
Answered: 88 Skipped: 3



ANSWER CHOICES	RESPONSES	
Spring (Oct-Dec)	52.27%	46
Summer (Jan-Mar)	76.14%	67
Autumn (Apr-Jun)	43.18%	38
Winter (Jul-Sep)	29.55%	26
n/a	12.50%	11
Total Respondents: 88		

Q10 Will your future Antarctic research require USAP ships?

Answered: 88   Skipped: 3



ANSWER CHOICES	RESPONSES	
Yes	90.91%	80
No	9.09%	8
TOTAL		88

Q11 Briefly describe your intended use of USAP ships in the future?

Answered: 78 Skipped: 13

#	RESPONSES	DATE
1	To deploy and recover gliders and moorings. To assist in putting in and removing field camps.	8/13/2018 9:06 AM
2	As surface support platforms for extended ROV and AUV operations beneath and adjacent to pack ice and free-floating icebergs.	8/8/2018 1:22 PM
3	The same - broad geographic sampling of marine invertebrates - trawls, cores, bottom imaging. And used of standard oceanographic equipment (eg. ADCP, CTD).	8/8/2018 1:11 PM
4	Collect biological samples. deploy instruments, tag animals, access research locations	8/8/2018 11:39 AM
5	Follow-up on linking WAIS history from subglacial sampling (hot water drilling and hopefully RAID) to continental shelf & rise coring off shore.	8/8/2018 11:33 AM
6	To determine melt rates of the Ice Sheet. To understand Southern Ocean CO2 uptake/release.	8/8/2018 9:13 AM
7	I am interested in scientific drilling to about 100m sub-seafloor, from a polar research vessel. IODP has approval and funding for an Antarctic mission-specific platform drilling expedition to the Mertz glacier area, but due to ship availability, drill rig readiness, and cost, this expedition has been postponed twice so far. I proposed and would be a co-chief for this expedition. It would investigate Antarctic paleoclimate through a range of future-relavant atmospheric CO2 conditions, from the middle Eocene, through the onset of large-scale Antarctic glaciation, and into the Oligocene.	8/7/2018 3:07 PM
8	I am planning on continuing research at glacial margins, regions where other sources of data (remote sensing, moorings, etc) are impractical to use, unreliable, or otherwise difficult to obtain. Ships would be used to access coastal (<150 km from shore) regions for hydrographic surveys and deploy short-term moorings. Station work would include incubation experiments based on water samples collected in the field, via ship or zodiac as support.	8/7/2018 12:44 PM
9	We wish to perform collections from throughout the Antarctic, with a large focus on field excursions to East Antarctic basins to expand our sample collections.	8/6/2018 5:40 AM
10	Continued expansion of previous microbial ecology work	8/5/2018 12:47 PM
11	oceanographic hydro-surveys, ROV and AUV work, onboard biological and biogeochemical assays and incubations (extended duration process studies), zodiac work to access sea ice off the ship.	8/5/2018 8:53 AM
12	I intend to participate on multi-disciplinary oceanographic projects to understand how variable environmental conditions in coastal Antarctic waters influence ecosystem structure, biogeochemical cycling, and fisheries production. This research will focus on wintertime processes, sea ice processes, and glacial melt processes to fill in the most pressing knowledge gaps.	8/3/2018 11:43 AM
13	Installation of on-the-way detection technologies for marine mammals for Long-term ecological research in the open ocean	8/2/2018 1:31 PM
14	I am interested in surveying different regions for food web comparisons (phytoplankton, copepods, krill, fish) and conducting physiological experiments on multiple trophic levels. The existing ships are not well suited for sampling of higher trophics (fish), which has limited this research currently.	8/2/2018 9:43 AM
15	seismic surveying, MB surveying, coring	8/2/2018 7:34 AM
16	I anticipate continuing to use USAP ships to deploy and recover ocean gliders broadly around the margins of Antarctica. Within the next five years, we hope to have a glider program that can also sample under sea ice. Deployment and recovery operations in the marginal ice zone will be important.	8/1/2018 8:51 PM
17	Collecting shallow marine cores and geophysics. Also deploying remote field camps.	8/1/2018 12:42 AM
18	Similar to description above.	7/30/2018 7:32 PM

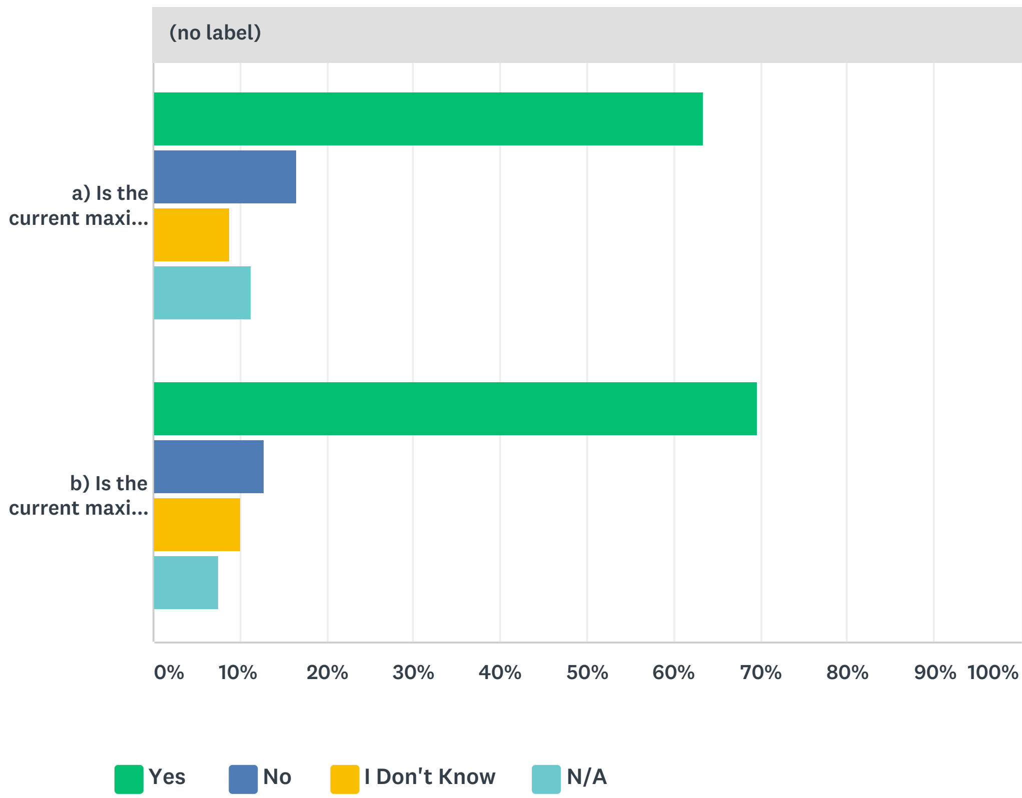
19	Specifically, we hope that the Palmer will be available for a GEOTRACES cruise into the Amundsen Sea. Further into the future, we envision a rapid growth in research on chemical-biological coupling and its impact on the ocean carbon cycle. This will require large ships capable to supporting large numbers of scientists doing interdisciplinary biogeochemistry research.	7/30/2018 1:09 PM
20	My research will likely continue to evolve ice station work from USAP ships, but I expect over time will continue to use more robotic platforms and buoys, so that cruises can be shorter and potentially spend less time in the ice.	7/30/2018 7:53 AM
21	USAP ships would be used to compliment and amplify ice-based records and measurements near the ice-ocean-atmosphere interface. Ships could also be used to support ice-based field camps and return ice core samples via helicopter to the RV and then CONUS through the use of refrigerated containers.	7/29/2018 9:11 PM
22	Diving off of the Antarctic Pennisula	7/29/2018 11:44 AM
23	Support shipboard ADCP and GOSHIP cruises	7/27/2018 6:23 PM
24	I plan on continuing studying the morphology, physiology, and genetic of Notothenioids fish (and expanding to the two other main classes of fish found in Antarctica - Snailfishes and Eelpouts) into a broad evolutionary and adaptation perspective. Because of this, one crucial aspect will to be access contrasted species inhabiting contrasted habitats (e.g. benthic vs pelagic; high antarctic vs sub-antarctic, etc). Therefore, I would intend to use the USAP ship in the future to not only transit to Antarctic stations but also to go explore, fish, and collect specimens from various locations and at various depth using different apparatus. With a goal of being able to keep them alive until station. In addition, I would like to incorporate more oceanographic and ecological approaches such as using multi-beam sonar to accurately map the floor (the single beam sonar on the LMG is not appropriate for that us), cast CTDs, and use bottom floor visualization techniques (yo-yo cam, ROVs, etc). Finally, one of my goal is to try to develop more collaborative work with other researchers interested in using similar field techniques for other purposes (sharing a trawl catch with invertebrate biologist for example).	7/27/2018 4:33 PM
25	Intending use of ships to access coastal fjords and other areas where glacial ice (shelves and otherwise) enter the ocean- Ships instrumentation and capabilities should allow deployment and recovery of physical oceanography systems (tethered and remotely operated); Additionally the ships should have capabilities to deploy personnel for recovery of ice samples and for processing of ice samples on board	7/27/2018 6:09 AM
26	Similar to our current operations: CTD water sampling, on deck experiments, sediment trap deployments. These operations involve equipment that is rapidly increasing in both capability (e.g. autonomous sensing/sampling) and cost. We are also relying more and more on near real-time remote sensing data products.	7/26/2018 1:37 PM
27	I am most interested in using USAP vessels as access platforms for glaciology in places where access is not otherwise possible. This is particularly the case on the Antarctic Peninsula (both sides). This is one of the most rapidly changing areas of the planet, yet field based science is near impossible. Field work in these areas would require helicopters on the NBP. The ship is equipped for that, but the asset is rarely used. One impediment seems to be that helicopter budgets come out of the science program, while ship support comes out of logistic support. The addition of helicopters has other logistical advantages, such as scouting sea ice conditions and scientific advantages, such as enabling multi-disciplinary projects	7/26/2018 12:17 PM
28	Acoustic surveys of krill and fish and their oceanographic habitats; and visual observations of krill and fish predators.	7/25/2018 12:26 PM
29	Transportation	7/25/2018 12:09 PM
30	I hope to use data available from collaborators on upcoming cruises	7/25/2018 9:54 AM
31	We will utilize USAP ships for oceanographic, biological and glacier coupled studies. We would also need helicopter support for some of these studies, especially for ocean-glacier interaction studies. We would also utilize the new RIBS out of Palmer Station for towed vehicles.	7/25/2018 9:53 AM
32	Analysis of observations enabled by USAP ships	7/25/2018 9:44 AM
33	Collect cores to assess the history of the various parts of the Antarctic Ice sheet and to further understand the dynamics of the geomagnetic field.	7/24/2018 4:25 PM
34	Intended use the same as past uses: long CTD/rosette-oriented transects, examining decadal-scale variations in the waters and circulation of the global ocean, including the Southern Ocean.	7/24/2018 1:15 PM

35	I hope to perform sub-ice-shelf research from shipborne platforms in the future to understand sub-ice-shelf processes and in particular grounding zone processes.	7/24/2018 12:16 PM
36	More or less the same uses as in 2009, 2011, and 2016. I should note, however, that ships may not be entirely necessary for the type of research that my collaborators and I are interested in conducting. For instance, we could potentially just *fly* to our field area (landing, e.g., at Base Marambio on Seymour Island) rather than taking one of the vessels. (This would presumably be much more feasible if we were to work in collaboration with another nation's Antarctic program [in this particular example's, Argentina's].) If we *do* benefit from vessel support in the future, then it would be preferable to use the ship(s) in the manner we used the NBP in 2016; that is, as a means to deploy helicopters, which gave us much greater capacity and flexibility than we had in our 'ship-only' expeditions during 2009 and 2011.	7/24/2018 11:14 AM
37	Primary platform to launch various assets in the ocean and deploy instruments on ice using Helicopter support.	7/24/2018 9:58 AM
38	Access to marginal ice zone along WAP, access to coastal polynyas, sea ice sampling.	7/24/2018 9:32 AM
39	To support diving studies in some projects and for access to Palmer Station in others. It is critical to have ships capable of reaching Palmer throughout the year.	7/24/2018 9:30 AM
40	Field/water column sampling, incubation experiments across polar front and other natural biogeochemical gradients.	7/24/2018 6:44 AM
41	Of course dependent upon acquiring funding, I would like to further investigate the role of parasites in krill demographic processes and secondary production. This would require the use of ships to collect samples from a range of environments, and either the use of ship-board aquarium facilities, or the use of ships as transport to Palmer station for use of their aquarium facilities.	7/24/2018 6:12 AM
42	Transportation, logistics and supply, helicopter base, survey, and remediation.	7/23/2018 9:48 PM
43	Grant-supported research on whale biology and ecology	7/23/2018 3:31 PM
44	The same as previously described given that the "driving context" for our work is the continued development of long ecological time series as part of the PAL LTER.	7/23/2018 1:51 PM
45	similar to current, but better underway sampling for krill and other water column animals (i.e., whale food); better tracking capabilities; continued support of small boat operations;	7/23/2018 1:50 PM
46	To perform an intense multi-disciplinary study of a large polynya situated on the northern half of the western Antarctic peninsula	7/23/2018 12:44 PM
47	same as in the past	7/23/2018 11:48 AM
48	I don't have personal aspirations to do ship-based research in the USAP program but have some potentially useful thoughts	7/23/2018 11:20 AM
49	seafloor mapping, sub-bottom profiling, coring, drilling, drone deployment, water column sampling	7/23/2018 11:00 AM
50	Ships will be used to support CTD rosette/water bottle collections, net tows, acoustic echo sounder surveys, ROV/AUV operations, dive operations (if permitted), marine mammal and bird observations, small boat work, sea ice work.	7/23/2018 10:56 AM
51	Marine geology and geophysics - sediment coring, swath mapping, multi-channel seismics - for paleoclimate research	7/19/2018 2:22 AM
52	I have just received funding for 5 years (CAREER grant) to conduct research at Palmer Station in the winter. I will make use of the USAP ships to get to and from Palmer Station and also to collect Antarctic krill on the southbound voyage. I am on a pending proposal to conduct research from the LMG and Palmer Station within the Palmer Deep Canyon in the summer. I hope to continue using USAP ships to address important issues in Antarctic pelagic ecology, with a focus on Antarctic krill.	7/18/2018 2:41 PM
53	Fishing operations as described earlier.	7/17/2018 3:30 PM
54	I don't intend to use them, but I believe future USAP ships should be capable of operation year round. They should have a good suite of acoustic systems and protected over the side deployment areas.	7/17/2018 12:11 PM

55	Activities while similar to other experiments on air-ice-ocean and biogeochemistry, will rely heavily on using the ship as a "low-flying" vehicle for suspended instrumentation for measuring ice thickness and snow depth by electromagnetic instruments and also mounted infrared and visible cameras. Station work will involve using drones and underwater vehicles to characterize the local environment and using the ship as a base station for AUV and glider operations.	7/17/2018 11:57 AM
56	Marine seismology	7/17/2018 11:51 AM
57	Sampling of seafloor communities along the continent including the peninsula. Ideally with deep submergence capability as the community has move beyond trawling to sample the seafloor. Ideally this would include a ship that can support USBL both for ROV and gear deployment.	7/17/2018 10:13 AM
58	I would like to see USAP ships continue to collect sediment cores and geophysical data that will be archived in national repositories for use by the greater scientific community (whether I am directly involved in their collection or not).	7/17/2018 9:25 AM
59	Geological sampling and survey of the Circum-Antarctic plate boundary	7/17/2018 8:53 AM
60	Use of ships to deploy/retrieve unmanned systems, e.g. Wavegliders, WAM-Vs, and UAS.	7/17/2018 8:42 AM
61	platform for coring and plankton tow collection	7/17/2018 8:29 AM
62	acquire seismic and subbottom data, mapping the seafloor, take sediment samples and conduct oceanographic measurement including lunching AUVs	7/17/2018 8:01 AM
63	I would like to use USAP ships for research along the Palmer Peninsula and potentially get back to the Ross Sea. I would conduct sampling via CTDs, on seasonal sea-ice (cores) and performing deck incubations. I think a well-engineered system for flowing seawater research on the deck of the next ship should be a priority.	7/17/2018 7:39 AM
64	multibeam and TSG data at the base weather and sea state also	7/17/2018 7:13 AM
65	I would like to survey large areas of the coastal southern ocean to examine particulate and soluble composition of trace elements	7/17/2018 6:56 AM
66	Using the Palmer and/or Gould to collect seawater and/or sediment core samples	7/17/2018 6:41 AM
67	Essentially hydrographic	7/17/2018 6:36 AM
68	Deploy and recover uuvs, sample the water as opportunistic, deploy velocity fine structure sensors or tow them. Co locate with satellite and auv surveys. Radar and lidar surface characterizations	7/17/2018 6:34 AM
69	EIther transit to/fro Palmer Station or process-based experimental work with seawater and some air sampling, station-based, examining different microbial commun ities, either as a function of space (location) or time (seasonality)	7/17/2018 6:30 AM
70	Transport to islands/mainland/stations for accessing field sites and laboratory space for processing samples.	7/16/2018 9:11 PM
71	GO-SHIP repeat hydrographic section (summer only), deployment of autonomous instruments (summer only, but for year-round observations from instruments)	7/16/2018 8:52 PM
72	Potential access to ice-free areas in remote coastal locations that are not otherwise accessible.	7/16/2018 6:42 PM
73	Same as it is now - as a platform for sampling and experimentation.	7/16/2018 1:52 PM
74	I would like to continue with geophysical and coring work throughout West Antarctica. In addition, I would like to have a sea-floor drilling project (like MeBo) in the Ross Sea.	7/16/2018 1:49 PM
75	We would like to expand our underway high-resolution observations in the Southern Ocean, documenting the current state and changes in the carbon and oxygen budgets	7/16/2018 11:59 AM
76	Deployment and recovery of moorings and gliders, ship based ecosystem research, opening and closing NOAA camps	7/16/2018 11:05 AM
77	I intend to continue my career as a seagoing oceanographer and I expect that I will keep requesting ship time more or less as before. (On average I have been at sea about 1 month per year.) I expect that the work will be similarly involving both survey and moored instrumentation. I furthermore anticipate use of autonomous assets (gliders, floats, ...) in my future projects.	7/16/2018 10:55 AM
78	We will require hull-mounted and underway sampling of prey using echosounders for our work. This is a critical requirement and not currently available on the LMG. We will require small boat support for tagging and biopsy work.	7/16/2018 10:50 AM

Q12 The current maximum non-crew berthing capacity of the USAP ships is 37 on LMG and 39 on NBP (both include contractor science support staff and helo crews if carried).

Answered: 79 Skipped: 12

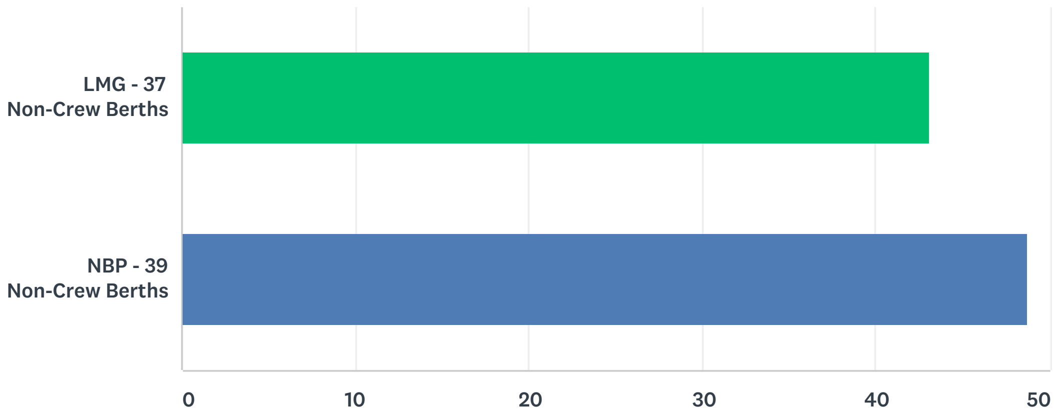


(no label)

	YES	NO	I DON'T KNOW	N/A	TOTAL
a) Is the current maximum science berthing on the LMG sufficient for your work now and in the future?	63.29% 50	16.46% 13	8.86% 7	11.39% 9	79
b) Is the current maximum science berthing on the NBP sufficient for your work now and in the future?	69.62% 55	12.66% 10	10.13% 8	7.59% 6	79

Q13 If you said No or I Don't Know to either 12.a or 12.b above, please indicate what berthing capacity is appropriate by entering a new number for each ship below (answer must be a whole number):

Answered: 21 Skipped: 70



ANSWER CHOICES	AVERAGE NUMBER	TOTAL NUMBER	RESPONSES
LMG - 37 Non-Crew Berths	43	818	19
NBP - 39 Non-Crew Berths	49	878	18
Total Respondents: 21			

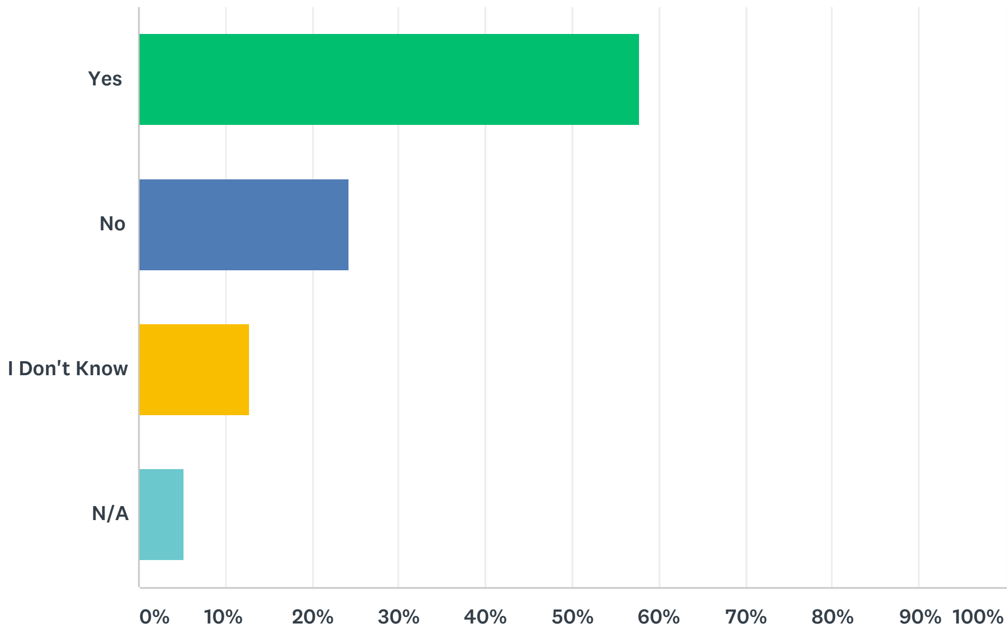
#	LMG - 37 NON-CREW BERTHS	DATE
1	40	8/8/2018 9:39 AM
2	37	8/6/2018 5:44 AM
3	45	8/5/2018 12:54 PM
4	45	8/3/2018 11:44 AM
5	45	8/2/2018 9:50 AM
6	40	7/30/2018 1:20 PM
7	45	7/27/2018 4:55 PM
8	5	7/26/2018 2:02 PM
9	66	7/25/2018 12:12 PM
10	37	7/25/2018 10:19 AM
11	44	7/25/2018 10:00 AM
12	37	7/25/2018 9:26 AM
13	50	7/24/2018 9:41 AM
14	50	7/24/2018 6:25 AM
15	40	7/23/2018 10:05 PM
16	60	7/23/2018 3:39 PM
17	45	7/23/2018 2:46 PM
18	50	7/23/2018 11:14 AM

19	37	7/16/2018 11:15 AM

#	NBP - 39 NON-CREW BERTHS	DATE
1	55	8/8/2018 9:39 AM
2	39	8/6/2018 5:44 AM
3	45	8/5/2018 12:54 PM
4	50	8/3/2018 11:44 AM
5	45	8/2/2018 9:50 AM
6	50	7/30/2018 1:20 PM
7	67	7/25/2018 12:12 PM
8	39	7/25/2018 10:19 AM
9	50	7/25/2018 9:26 AM
10	45	7/24/2018 2:17 PM
11	39	7/24/2018 9:41 AM
12	40	7/24/2018 6:25 AM
13	45	7/23/2018 10:05 PM
14	80	7/23/2018 3:39 PM
15	55	7/23/2018 2:46 PM
16	50	7/23/2018 11:14 AM
17	45	7/17/2018 12:40 PM
18	39	7/16/2018 11:15 AM

Q14 Is the available laboratory space, deck area and science storage space on the USAP ships generally sufficient for your work in the future?

Answered: 78 Skipped: 13



ANSWER CHOICES	RESPONSES	
Yes	57.69%	45
No	24.36%	19
I Don't Know	12.82%	10
N/A	5.13%	4
TOTAL		78

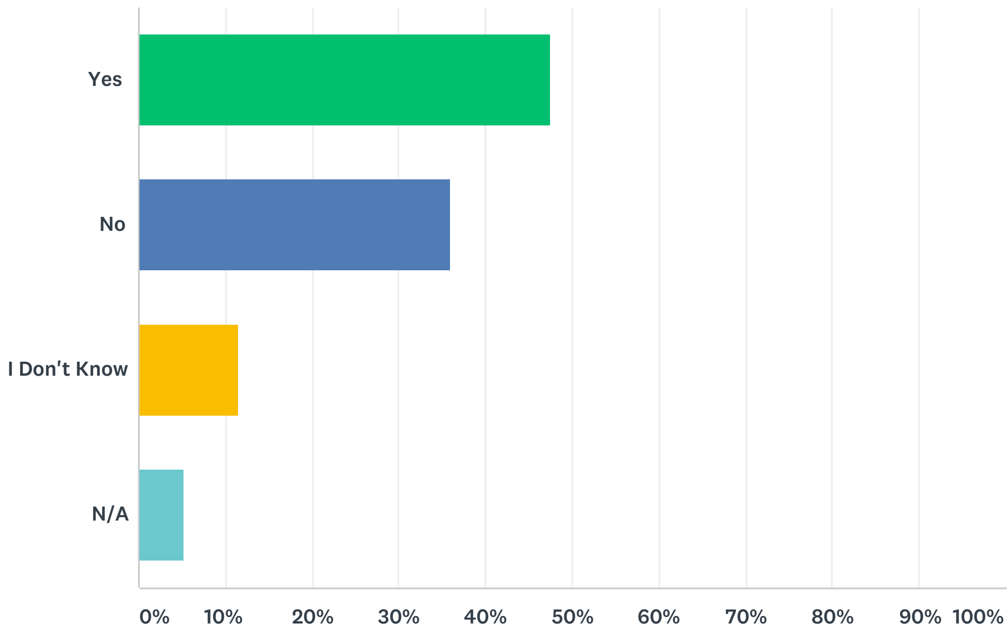
#	IF YOU THINK THIS COULD BE IMPROVED, PLEASE DESCRIBE HOW:	DATE
1	Generally yes - the main issue I run into is storage space in the -80 Freezers. Additional freezer space would be helpful.	8/8/2018 1:34 PM
2	Sea bed drill rigs require a lot of deck space - e.g. for the British Geological Survey Rock-Drill2 (RD2), 7 x 20ft containers, ~ 100,000 kg, as well as space for the launch system and winch. The German MeBo drill rig requires use of a substantial A-frame and has a similar deck space requirement. A moonpool type deployment would be preferable, being close to the center of motion and protected from sea ice. But such sea bed drilling systems are designed for a back deck or over-the-side deployment, and I'm not sure they would fit though a 4x4m moon pool. Ability to deploy a geotechnical rig through the moonpool would partly address the same need.	8/8/2018 9:50 AM
3	The LMG is WAY too small for modern lab work. The NBP is close but try visiting one of the many vessels recently built for ocean research by other nations and you'll get the picture. The US is WAY behind in terms of providing modern, well-functioning labs and over-the-side research capabilities in the polar regions.	8/8/2018 9:39 AM
4	Wet laboratory space could be better on the NBP. I want to emphasize the importance of environmentally controlled rooms - these are heavily used on the cruises that I've been on, but they are not always available or in operating condition. Any future ship may want to include additional wet lab space (for bench chemistry and molecular biology), in addition to environmentally controlled rooms for seawater processing and experimental work.	8/5/2018 9:10 AM

5	Larger aquarium space (inside and outside and deck) will be important for conducting experiments with live organisms under appropriate environmental conditions.	8/3/2018 11:44 AM
6	More than one instrument platform high up, capable to carry 200+lbs, ideally 360° field of view	8/2/2018 1:35 PM
7	Deck area should include enough room for seabed drilling vans or any vans associated with drilling activities. Laboratory space is too cramped, and should include space for core cutting, scanning, etc	8/2/2018 7:46 AM
8	Glider operations require open deck space. The current USAP ships are adequate for this, as long as deck space is not occupied by lab vans or storage vans.	8/1/2018 9:00 PM
9	It would be helpful to have more chemical fume hoods. Clean labs (contamination free with respect to, for example, trace metals, but also other contaminants) should be built into future ships.	7/30/2018 1:20 PM
10	For some complex cruises (e.g. my most recent one), deck space and science storage was pretty tight on the Palmer. This may be a rare occurrence, but it would have been helpful to be able to put three container labs on the back deck and still keep some space clear for crane ops.	7/30/2018 8:27 AM
11	Our project used minimal sampling equipment and was adequate for our work, but may not be representative of larger more complex projects. Chemical storage could be better integrated with other spaces on the LMG.	7/29/2018 11:56 AM
12	The lab spaces, deck area, and science storage are just enough for the current science. Especially the deck which can be extremely crowded when the LMG is carrying a lot of cargo for Palmer Station. This in return makes our work on the back deck not optimal for a efficient and accurate catch sorting (poor lighting, not enough space, ...). Also, as mentioned before, on goal is to develop more collaborative work with scientist sharing common interest in sampling location but not completely overlapping interest in the biological material. This would make the lab space, deck space, aquarium room size, and storage (on the LMG) limiting factors, especially when a lot of the room is already used by cargo/supllies for the station.	7/27/2018 4:55 PM
13	When undertaken in isolation Yes the space has been ok and the storage space is sufficient; but many of the projects don't generally happen in isolation; rather they are often undertaken with other science projects on board and the storage capacities for ice samples has been limited and required many containers to be deployed on ships (for storage and for work on ice); when this has happened the ships utility has become limited due to deck space limitations.	7/27/2018 6:39 AM
14	Storage can become a problem. For example, on LARISSA it was very difficult to store all batteries for land-based work and it was often awkward getting this equipment to the helo deck	7/26/2018 12:24 PM
15	NBP labs are good (and are well maintained) and spacious, but could be better. More care is needed to have more nearly complete assortment of power types, compressed air, seawater, etc, etc. in more of the labs. Not sure if there is a full-out climate controlled lab (well below to well above freezing, with unistrut, lights, full range of hook-ups, etc - actually there should be two of them). Don't think the NBP has a lab on one of the higher decks for the teams doing air/sky work. Even though labs are generous, a big multi-disciplinary program work likely overfill the present NBP labs.	7/24/2018 2:17 PM
16	I have not used the NBP. The aquarium facility on the LMG is substandard (no surprise that it was an afterthought) and much less functional than what had been on the Polar Duke. It needs to be accessible without going out on deck and configurable for more than huge fish holding tanks.	7/24/2018 9:42 AM
17	Should increase proportionally with an increase in berths.	7/24/2018 9:41 AM
18	There is increasing interest in doing molecular analysis in real time in the field, in order to inform further sampling. The ships do not have a lab space which can be kept sufficiently clean and isolated for this to be practical at the moment.	7/24/2018 6:25 AM
19	Modern laboratory and computational researcher space is needed, including connection to flat screen for the visualization of complex data sets.	7/23/2018 3:39 PM
20	The issue tends not to be "number of berths" but rather how those berths are managed, with unfortunately the momentum building in recent years to favor the contractor as opposed to the science. However, overall, the demand on vessel support is increasing and will no doubt continue in the future, so any plan for new vessels should default to increasing the number of available berths. Regarding question 14 specifically, the LMG is currently inadequate and the NBP borderline adequate.	7/23/2018 2:46 PM

21	Space is adequate for the common (frequent) small ship science cruises. The hard issue to solve is how do you accommodate the rare - say once per year - "large" (e.g. bio-geo-chemical, or mooring) cruise. If there is no clear and "obvious" way to support those cruises then well informed potential PIs will not propose them, thus excluding those "classes" of science.	7/23/2018 11:44 AM
22	Both ships need more space for core processing, general work space for setting up laptop computers for scientists and students, and space for spreading out and testing field gear. Related to #13- need space for 30 scientists (PIs, students), exclusive of marine technicians and helo crews.	7/23/2018 11:14 AM
23	Yes on the Palmer, no on the Gould. The Gould's spaces are too small and the wet lab can only be accessed weather permitting. I have lost experiments because we were not allowed outside during bad weather. All science lab spaces should have safe inside access.	7/23/2018 11:10 AM
24	It's not too bad, but I think there is room for improvement. More environmental controlled rooms or vans would be really useful (in the case of the LMG, any environmental controlled rooms or vans would be great).	7/18/2018 2:49 PM
25	We could use more aquarium space to hold fish during fishing operations.	7/17/2018 3:35 PM
26	The forward deck space on NBP is currently unusable so long cable runs or sampling tubes are required for clean air sampling off the front deck. Undisturbed ice sampling (remotely by lidar or em) is currently not doable on the NBP as there is no bow crane and instrument cables need to be shorter than the current long run back to warm lab space. Provision of wireless connections, ether net ports and/or instrument vans or shelters on the foredock are needed. On the rear deck, current access to the ice is limited to the starboard side which precludes oceanographic (ctd) sampling using the baltic room or starboard A-frame. In the past, we had a port side ice access which allowed ice sampling to proceed at the same time as oceanographic operations from the starboard side but both the current inexperience of the crew, and an overbearing command structure have led to curtailment and inefficiency of the ice work. The single-best cure for better ship operations of USAP would be to place the administration under UNOLS rather than the type of contractor-operator presently which has seriously degraded the performance of the NBP in the past decade.	7/17/2018 12:40 PM
27	Due to a programatic level decision, research along the plate boundary was rather unwisely terminated to the detriment of Antarctic science in general due to parochial interests that wished to sequester the funds for their own projects. Accordingly I am unfamiliar with the current ship facilities, but such a facility including the ability to handle rough seas (i.e. a large ship), and an ability to work into the ice is required (as along the western American-Antarctic Ridge) is needed, and currently unavailable through UNOLS.	7/17/2018 9:06 AM
28	Main point here is that consideration in ship design should be given to launch and recovery of unmanned aircraft.	7/17/2018 8:56 AM
29	More deck space to better accommodate sediment sampling and AUV work would be good. The fact that on the NB Palmer the main dry lab is shared for sediment work and other projects is not ideal. A larger wet/mud/sediment lab would be good.	7/17/2018 8:18 AM
30	As I noted above, it would be useful to include space that is specifically designed for deck incubations, with easy/adjacent lab space. Storage space seems sufficient.	7/17/2018 8:03 AM
31	The Palmer could definitely use more fume hood space as well as better climate control, particularly in the main lab.	7/17/2018 7:02 AM
32	It has worked because of on deck storage availability in vans	7/17/2018 6:49 AM
33	The LMG did not have an available 220V socket for running certain pieces of equipment (like a muffle furnace)	7/16/2018 9:18 PM
34	The NBP labs are largely sufficient and can be adapted to many different projects. Sometimes there is a shortage of space in wet labs when multiple science parties overlap.	7/16/2018 2:05 PM
35	The deck area could be improved significantly to make deploying small boats quicker and more functional.	7/16/2018 11:24 AM
36	More wet laboratory space, as well as more configurable spaces	7/16/2018 11:15 AM

Q15 Is the suite of scientific support instrumentation on the USAP ships sufficient for your current work (e.g. acoustical profiling & mapping systems, meteorological instruments, underway seawater measurements, CTD or other lowered instrument packages, sample collection and storage facilities, etc.)?

Answered: 78 Skipped: 13



ANSWER CHOICES	RESPONSES	
Yes	47.44%	37
No	35.90%	28
I Don't Know	11.54%	9
N/A	5.13%	4
TOTAL		78

#	IF YOU THINK THIS COULD BE IMPROVED, PLEASE DESCRIBE HOW:	DATE
1	The trawls and cores are generally OK but could be improved. The large shortfall in capabilities (for my research at least) is sea floor imaging. By this I do not mean side-scan sonar - but video and photo capabilities. A reasonably sized ROV that could work with an elevator would be a HUGE step forward for the USAP marine program. Ideally the ROV could run transects or do site-focused sampling. A standard sensory package (like on WHOIs Sentry) would be nice as will as a manipulator to sample or run experiments at depth.	8/8/2018 1:34 PM
2	Need better launch and recovery capability for larger vehicles, as well as deck configuration options .	8/8/2018 1:29 PM
3	Fisheries acoustics, like ANY modern oceanographic vessel.	8/8/2018 11:49 AM

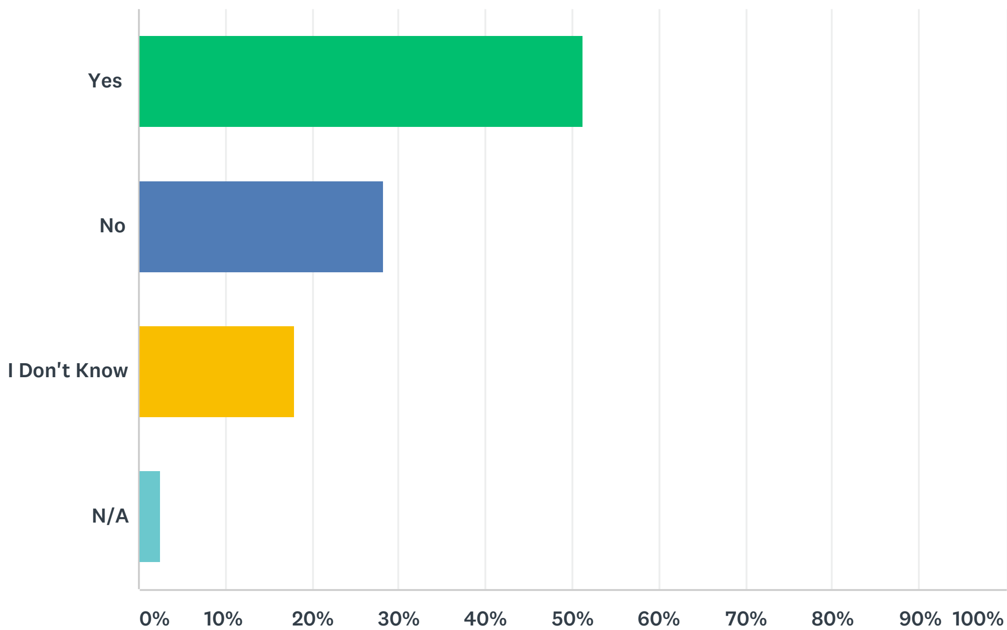
4	For my work, ideal capabilities would be: - Seismic profile capability. For IODP and similar marine geological drilling, it is essential to understand the seafloor and subsurface, both for interpreting past ice sheet extent and for best placement of drill sites. A compressor for airgun sound sources are integral to this capability. - Ability to deploy a sea-bed drill rig, from the back deck, or through a moon pool. Ability to fit a geotechnical drilling rig over the moon pool would also address the same need, although sediment core recovery is hampered by ship heave for ship-based drilling. - Station-keeping ability to remain at a drill site for up to 2 days. The maximum radius of movement depends on the system, but may be as little as 10 m. - Fume hoods the laboratory and fume exhaust handling in order to use hydrogen fluoride (HF) to isolate pollen and dinoflagellates from marine sediment. I understand that it would require some retrofitting for the N.B. Palmer to be able to do this at the moment.	8/8/2018 9:50 AM
5	Need better support for AUV's and UAV's as well as daughtercrafts that can work in shallower areas. We do not have sufficient ice breaking capabilities to access important ice-covered areas in winter and spring. The underway seawater system should make MANY additional measurements. The ship needs a budget to keep up with the times and to buy decent equipment every 5 years or so. I know this is all about $ in a limited funding environment but it's pretty clear that stations have been getting the lion's share of the resources. Time to tend to the vessels.	8/8/2018 9:39 AM
6	Generally my answer is yes to this; underway seawater systems should be better planned for periodic cleaning and for subsampling, in addition to adding in-line instrumentation to.	8/5/2018 9:10 AM
7	A scientific echosounder system (such as SIMRAD EK80) would be very valuable for my work.	8/3/2018 11:44 AM
8	Stabilized high-resolution thermal imaging with 360° FOV. For polar baer and marine mammal detection underway	8/2/2018 1:35 PM
9	The existing ships are not well suited for sampling for higher trophics (fish) which I would like to focus on in future work.	8/2/2018 9:50 AM
10	the multibeam system on the palmer should be upgraded, as should the CHIRP. The Gould should have a MB system, and doesnt. The transducers on both ships should be replaced. The underway seawater systems are outdated and not clean. The CTDs are aging and should include TE rosettes. Core storage coolers should be larger and contain racks. Not enough -80 space	8/2/2018 7:46 AM
11	The Gould really needs multibeam - not only for science but also for charting and getting into remote field camp locations (for safety reasons). I also think a core locker is essentials. Seems like a refrigerated room might also be useful for other sciences too (e.g. Biology).	8/1/2018 12:54 AM
12	In principle, yes, but in practice often the equipment doesn't work as desired, either because of technical problems with the instruments or because the contractor-supplied technicians are not adequately prepared to operate the equipment.	7/30/2018 1:20 PM
13	Our project used minimal sampling equipment and was adequate for our work, but may not be representative of larger more complex projects	7/29/2018 11:56 AM
14	It would be great to have a multi-beam sonar on the LMG. Also, the back deck is not organized in an optimal way for benthic trawl sorting operations. Also, the aquarium room doesn't have enough capacity.	7/27/2018 4:55 PM
15	Potential for work on ice samples has been limiting at times; Science instrumentation deployed on USAP ships has generally been ok- However, the quality of the data, the data coverage and the accessibility of data coming off the ships has note been clear issue (e.g. meteorplogidal data; underway seawater measurements, XBT transects during crossings, ADCP)	7/27/2018 6:39 AM
16	Add wide-bandwidth echosounders, multi-beam sonars, long-range scanning sonar, sub-bottom profiler, hydrophone arrays, moving-vessel profiler, ROV, continuous-underway fish-egg sampler, and hull-mounted sound-speed and dissolved oxygen sensors. Add high-bandwidth Ethernet for video and instrumentation control and access via "remote presence".	7/25/2018 12:37 PM
17	We anticipate needing helicopter support, and using a combination of USAP vessels and small vessels (RIBS and zodiacs)	7/25/2018 10:00 AM
18	I believe these ships are not measuring air-sea fluxes. It would be great to have that information!	7/25/2018 9:50 AM

19	This is a very soft "no" - really the answer should be "yes" because the NBP underway systems are good. Even the underway seawater systems works reasonably well. But if someone figures out a way to improve performance of the underway seawater system in ice, and the sonar-related systems during icebreaking, that would be nice. Support for CTD operations in the open ocean is more limited than that on present UNOLS Global-class ships due to limitations of the NBP Baltic room. This is not an "instrument" problem, and will be elaborated upon if the appropriate question arises later in this survey.	7/24/2018 2:17 PM
20	SADCP need to be maintain. Other than that it is generally good.	7/24/2018 11:19 AM
21	The LMG needs to support helicopter operations.	7/24/2018 9:41 AM
22	In general, given the important role trace metals play in the Southern Ocean and the expansion of trace metal research in recent years, future ships could broaden their user base and build in new research collaborations if they enhance their capabilities for trace metal sampling (TMC rosette systems, clean labs/lab vans).	7/24/2018 7:36 AM
23	Better capabilities to collect krill under the ice would be ideal. It is important to understand the role of sea ice in the life cycles of krill, particularly in light of the changing climate. At the moment it is challenging to collect under-ice krill from the ships. Perhaps implementation of a SUIT sampler, such as AWI is using, or availability of ROVs/AUVs with under-ice video and sampling capabilities?	7/24/2018 6:25 AM
24	Space is always at a premium particularly when multiple projects are going on simultaneously. Internet, comma and radio are always limited.	7/23/2018 10:05 PM
25	Current ships (at least the LMG) lack even the basic instrumentation for first order oceanographic research, such as hull-mounted echosounders.	7/23/2018 3:39 PM
26	Yes, with the caveat that our work is not dependent on much on-board instrumentation.	7/23/2018 2:46 PM
27	Could use a lowered ADCP (LDCP) with the CTD	7/23/2018 12:52 PM
28	LMG does not have hydroacoustics -- it or it's replacement would benefit from having such instrumentation	7/23/2018 11:51 AM
29	I am no loner "current" on the equipment or the level of support. I can say with some confidence that there was a time when neither the equipment nor the level of technical expertise was on par with the UNOLS fleet and yet there were far more USAP personnel on board.	7/23/2018 11:44 AM
30	LMG lacks swath mapping capabilities. The sub-bottom 3.5 kHz system on both ships needs greater resolution. Both ships need improved internet/data transfer capabilities for receiving ice imagery and weather imagery.	7/23/2018 11:14 AM
31	The ships need to be acoustically quiet.	7/23/2018 11:10 AM
32	Longer piston coring capability (40 m) - current limit is 25 m on NBP	7/19/2018 2:32 AM
33	The LMG does not have a hull-mounted echosounder, this is really important for my work. The NBP does have one, however.	7/18/2018 2:49 PM
34	There is pressing need for: a. an Underway CTD system (uCTD) that will bring the USAP ships into the 21st century b. Automatic cameras for ice observations with support for image processing and archiving c. Dedicated glider, auv, rov and drone systems.	7/17/2018 12:40 PM
35	Need high quality seabeam capability.	7/17/2018 9:06 AM
36	FALKOR just tested an underway Tow-Yo CTD that worked down to 500' supposedly. That seems an interesting option.	7/17/2018 8:56 AM
37	The current instrumentation seems adequate but I haven't been on dedicated Antarctic research cruise in more than a decade. My recent experience has been transport to Palmer Station on the LMG.	7/17/2018 8:03 AM
38	The piston coring setup, as well as mega-coring for collecting surface sediments was insufficient for the high opal sediments in the Southern ocean	7/17/2018 6:45 AM
39	Less instrumentation should be supplied and more focus on using them in a wider variety of circumstances	7/17/2018 6:41 AM
40	We could enhance the underway optical properties sampling. Inclusion of a ifcb would help characterize sources of high frequency scattering. Higher frequency nortek profilers to get surface structure would help. Add onboard drones with extended payload and range.	7/17/2018 6:40 AM

41	Most of the equipment is at least adequate and some of it is excellent. As far as I know, both the hull-mounted acoustic profiling system and the seismic system have not been upgraded in many years and we now lag behind the equipment on other nations' vessels as far as subbottom profiling.	7/16/2018 2:05 PM
42	The LMG needs to have an underway echosounder system. This is currently a critical gap in our ability to study the Antarctic marine ecosystem in a meaningful and quantitative way. Towing instruments is not possible in most conditions and requires many people and the data are often corrupt. Towing a fish also strains equipment unnecessarily and breaks it quickly, as was done this past season on the LMG with new echosounders that were purchased. These are designed to be hull-mounted and are not being used appropriately.	7/16/2018 11:24 AM
43	In general these are sufficient. LMG could use an appropriate fisheries acoustics package	7/16/2018 11:15 AM
44	1. USBL capability would be a great improvement, in particular for LADCP and microstucture surveys, as well as mooring operations. 2. USAP support for LADCP work would be useful.	7/16/2018 11:04 AM

Q16 Are the network and other technical systems on the USAP ships sufficient for your work now and in the future (e.g. intra-net connectivity on the ship, internet connectivity and bandwidth to external sites, satellite communications, mapping and GIS capabilities, desk space and support for personal workstations, navigation systems, time servers, clean power, etc.)?

Answered: 78 Skipped: 13



ANSWER CHOICES	RESPONSES	
Yes	51.28%	40
No	28.21%	22
I Don't Know	17.95%	14
N/A	2.56%	2
TOTAL		78

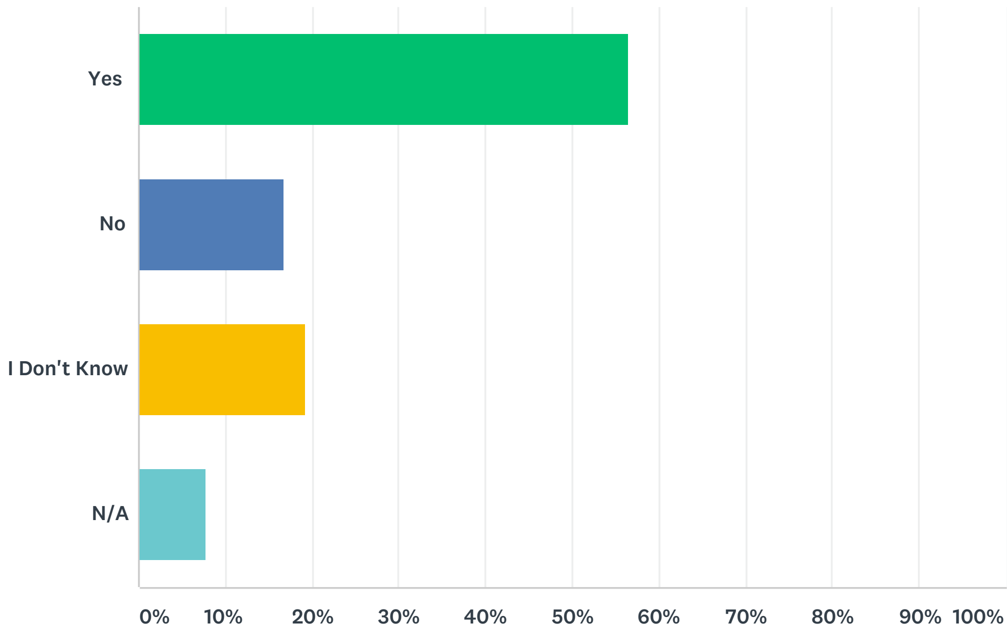
#	IF YOU THINK THIS COULD BE IMPROVED, PLEASE DESCRIBE HOW:	DATE
1	In general yes. Bandwidth could be improved to aid collaborative efforts with those not on the ships.... outreach would also benefit with increased band with. mapping capabilities on the Gould are limited and should be improved.	8/8/2018 1:34 PM
2	But there is always room for improvement.	8/8/2018 1:29 PM
3	Computers are outdated, networking systems are outdated, external communications are limited. Computer policies are restrictive and in many cases do not make sense	8/8/2018 11:49 AM
4	I have not sailed on the N.B. Palmer, but I am familiar with the internet connectivity from the JOIDES Resolution, which is very good (and expensive). Key usage would be for weather and ice forecasts, outreach activities like live interviews, and so on.	8/8/2018 9:50 AM
5	Lighten up on the security-related productivity killers.	8/8/2018 9:39 AM

6	I have been working in Antarctica for over 35 years - the advances in technology and communication have been great, but can always improve to take advantage of current tech - and there is the expectation that outreach increase, which often requires good communication with the home institutions and communities	8/5/2018 12:54 PM
7	Internet connectivity can probably be better even on the existing ships; access to the web for data access would be nice on a regular basis. Desk space is good though and IT support is typically excellent	8/5/2018 9:10 AM
8	The ability to remotely communicate with autonomous sensors and vehicles in the future will be greatly improved as bandwidth is improved.	8/3/2018 11:44 AM
9	internet connectivity is terrible. it should be upgraded and users should have inter and intranet texting ability, as provided on other UNOLS ships.There is too much space for workstations and aging technology, and not enough workable table space.	8/2/2018 7:46 AM
10	Currently we work with a small number of gliders. We anticipate that our group (and others) will increasingly be working with larger fleets of gliders or networks of different types of autonomous vehicles. Decision making for these various platforms will require frequent situational awareness or context updates in the form of weather maps, sea ice concentration maps, sea surface temperature and height information. This will require improved internet connectivity and bandwidth if possible. It may also require more support for personal workstations that may be carrying out autonomous piloting and planning of networks of autonomous vehicles.	8/1/2018 9:00 PM
11	Every time I go aboard they are getting better. But it seems like more bandwidth is always needed... GIS facilities could be a little better too... I think the Argentinian vessel is better equipped in some ways than ours...	8/1/2018 12:54 AM
12	Internet connectivity and bandwidth on both the NBP and LMG are inadequate. Additional space for desks/workstations would deb much appreciated.	7/30/2018 7:39 PM
13	For a cruise in the sea ice zone, the ability to receive high-resolution remote sensing data is very valuable. We	7/30/2018 8:27 AM
14	Bandwidth is not generally sufficient to handle downloads of real-time large volume datasets such as high resolution satellite images which will become more common in the near future. Collaborative space with reasonable sized wall displays for displaying mapping/GIS/Remote Sensing and other electronic information would be a useful addition to future vessels. At least on the LMG, this type of non-traditional lab space is limited.	7/29/2018 11:56 AM
15	Generally "good enough".	7/27/2018 6:27 PM
16	Internet bandwidth could be improved.	7/27/2018 4:55 PM
17	It does not seem the evolving capabilities of the satellite communications has been communicated clearly or lately	7/27/2018 6:39 AM
18	There has got to be a way to increase bandwidth on the ships. Our cruises depend on near real-time remote sensing data.	7/26/2018 2:02 PM
19	The effectiveness of the ships could be increased multi-fold by adding "remote access" to instrumentation control and data, and video presence.	7/25/2018 12:37 PM
20	Current internet speed, access and bandwidth limits our science and outreach efforts	7/25/2018 10:00 AM
21	Within the ship, the NBP provides excellent support for user computers, network, and technical systems. (This is partly due to the amount of space, installed facilities, etc., and partly due to the ship carrying up to 4x the computer support personnel carried on UNOLS Global-class ships.) There could perhaps be improved support on/off the ship for true scientifically-needed network and computing services. This would likely be at the cost of throttling back "personal" internet use (via satellite). Whatever rules HighSeasNet comes up with should probably be applied to the USAP ships.	7/24/2018 2:17 PM
22	Although already surprisingly good, the Internet connectivity of the ships could be much better. In my team's particular case, better connectivity could give us much greater capacity for public outreach. For instance, the live Skype conferences we conducted were well-received, but were also difficult due to connectivity issues (e.g., 'pixellation,' lags, etc.). As a related aside, it'd also be awesome if connectivity from field camps could be improved, rather than being essentially limited to satellite phone comms as it is now.	7/24/2018 12:30 PM

23	In 2009 internet connectivity was not great but well maintained and managed. Next generation Iridium may help in that regard.	7/24/2018 11:19 AM
24	It is absurd in this day and age that the USAP ships don't have internet connectivity, particularly when working relatively far north. This is critical to maximize scientific productivity.	7/24/2018 9:41 AM
25	Ships inherently make work spaces small, and internet, gis and computer support are always limited and in demand.	7/23/2018 10:05 PM
26	Current ships (LMG) lack basic gear related to ARGOS, personal workstations, etc.	7/23/2018 3:39 PM
27	Network and technical systems on both the LMG and NBP are primitive compared to technologies being installed/updated on other vessels doing similar work in Antarctica by other countries.	7/23/2018 2:46 PM
28	I'm comfortable saying that the need for ship/shore bandwidth for direct support of science operations, for technical support and planning, for moral and welfare and for ship/logistics will only continue to grow and operating at the margins of the footprints of geostationary satellites, supplying "enough" bandwidth will always be a challenge.	7/23/2018 11:44 AM
29	Accidentally put this in previous questions. The ships need greater capability to receive imagery for planning operations and more desk space for laptops. Having ArcGIS or (QGIS) capability on the ship would be very helpful.	7/23/2018 11:14 AM
30	I am not sure what they are currently.	7/23/2018 11:10 AM
31	Internet connectivity could be improved.	7/17/2018 3:35 PM
32	I have not sailed on the ships in a while and cannot comment on their internet connectivity.	7/17/2018 10:33 AM
33	The new Sentinel satellite system has the capability of ship to satellite optical comms; this would greatly increase bandwidth capabilities, and such a system should be tested. Likewise the Canadian QEYSSat is scheduled for launch in a couple years and will provide quantum communication capabilities, also at high bandwidths. These fundamental changes in ship to shore communications should be considered during ship design.	7/17/2018 8:56 AM
34	Current systems are sufficient (I often bring my own computers), but better internet connection to the external sites would be good. The access to real-time navigation data through intranet could be better (works, but usually takes some setting up)	7/17/2018 8:18 AM
35	I think they're adequate but again, I haven't conducted ship-based Antarctic research since 2005.	7/17/2018 8:03 AM
36	Internet bandwidth could be improved	7/17/2018 7:02 AM
37	space for computer/laptop-based work is in short supply when the LMG is full; the lounge is full; and cabin desks can only be used if both occupants are on the same schedule. Working in the LMG galley is the option I've used.	7/17/2018 6:49 AM
38	Recent upgrades to internet services and capacity are much better than they have been in the past. Greater connection allows for better communication with vendors and technical support and allows for much faster and better communication of information, data, etc.	7/16/2018 11:24 AM
39	These were sufficient. Future ships should simply increase capacity as possible.	7/16/2018 11:15 AM
40	On previous cruises on which I participated, restrictive internet access made science difficult at times as it was difficult to download relevant papers and software. On previous cruises for which I provided remote support it was sometimes difficult to transmit the required data to shore for processing and QC.	7/16/2018 11:04 AM

Q17 Are the winch, A-frame, crane and small-boat operations capabilities of the USAP ships sufficient for your work now and in the future?

Answered: 78 Skipped: 13



ANSWER CHOICES	RESPONSES	
Yes	56.41%	44
No	16.67%	13
I Don't Know	19.23%	15
N/A	7.69%	6
TOTAL		78

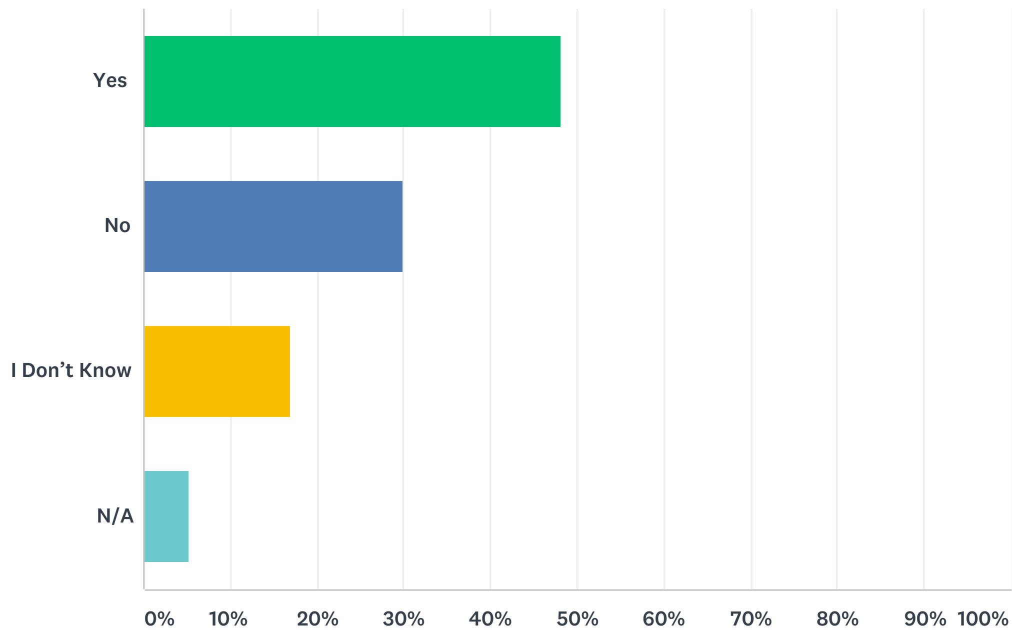
#	OTHER (PLEASE SPECIFY)	DATE
1	Provided they are in good working order - it seems like winches are regularly "acting up"	8/8/2018 1:34 PM
2	Small boat operations are not sufficient. The boats are limited in number and access to them is restrictive	8/8/2018 11:49 AM
3	The MeBo sea bed drill rig requires an A-Frame with at least 20 tonnes safe working load. The RD2 and PROD sea bed drill rigs have their own launch systems, and require deck space.	8/8/2018 9:50 AM
4	Need more and larger small boats that can be launched easily.	8/8/2018 9:39 AM
5	Generally yes. Diving support is essential, as is sea ice access - so preparations and planning for both activities is critical for future years planning.	8/5/2018 9:10 AM
6	If we want to do longer coring operations, the winch and a frame systems are not adequate on either vessel. The jumbo piston coring setup on the NBP is unsafe (e.g. overhead wires). More winch power should be included on both ships	8/2/2018 7:46 AM
7	Yes, small boat operations are adequate when the zodiac can be deployed. Other options that would allow deployment of gliders and other instruments without having to use a winch over the side would be helpful.	8/1/2018 9:00 PM

8	I haven't looked into them much yet, but a boat with a little more capability than a ziodiac might be needed for some of the coastal work I would like to do in the future. Something that is 20-30 feet long with an a-frame or heavy-duty davit capable of towing equipment (shallow seismic, fish nets, etc.) that could be deployed in a far away fjord from a research vessel might be a real addition to the USAP capabilities...	8/1/2018 12:54 AM
9	Needs will change as technology evolves. One needs to keep an eye on this.	7/30/2018 1:20 PM
10	These have been adequate, but I have said no because these were not ideal on my last cruise because of multiple failures and inexperienced winch operators which cost us time.	7/30/2018 8:27 AM
11	Our project used minimal sampling equipment and was adequate for our work, but may not be representative of larger more complex projects or projects supporting diving.	7/29/2018 11:56 AM
12	Yes, but could be improved by being able to fish deeper (longer wire) and have a real trawl system on the back deck (instead of having to use a tugger winch as a relay...). Also, the back deck could be made adaptable for the different sampling operations with belts bringing the catch to sorting table, etc.	7/27/2018 4:55 PM
13	Add instrumented small craft to conduct surveys of marine life and their oceanographic and seabed habitats nearshore, where the ships cannot safely navigate, and where land-based predators forage.	7/25/2018 12:37 PM
14	Would like to move to the use of synthetic line to support coring operations.	7/24/2018 4:34 PM
15	Another soft "no". Mostly these matters are good. But they need to be better> The CTD winch and operator installation on the NBP are unsatisfactory for work in moderate seas (which readily enter the Baltic Room). The Revelle and Thompson can definitely do over the side work in heavier seas than can the NBP. This is expensive in terms of ship time lost, which can only be made up by requesting more weather days when a cruise is scheduled on the NBP or cutting science. It is not clear to the respondent if the NBP small boat operations are as nimble as they need to be for working with autonomous vehicles, etc. Probably need the capacity to easily deploy/recover two work boats.	7/24/2018 2:17 PM
16	Our team doesn't make much use of the winch or A-frame. However, we have used small boats with great frequency (to, e.g., visit field sites, deploy field camps, etc.), especially during field seasons where we haven't benefited from helicopter support. Although Zodiacs and the aluminum landing craft are perfectly suitable when sea ice isn't super-extensive, the fact that these boats cannot get through most ice is highly problematic. Our team needs to be able to land on our islands of interest to conduct our work. When, as is often the case, even in late summer, these islands are ringed by sea ice, we cannot use small boats to access them. This is why having helicopter support in 2016 was so beneficial; indeed, the reason we were given access to helicopters in the first place was because NSF recognized that we likely wouldn't be able to meet our research objectives with small boat support alone. If our team was permitted to walk, transport gear, etc. over sea ice/fast ice, then we could likely perform our work with small boat support alone. But since, to date, we have not been permitted to do this, helicopter support has become vital to the success of our project. (I suspect this is the case for any research team that needs to access sites on land that are frequently surrounded by frozen ocean.)	7/24/2018 12:30 PM
17	Future projects that rely on small boats are always limited, the inflatables are great but small.	7/23/2018 10:05 PM
18	Adequate for most operations, but not up to par for large, work-class ROVs. Again the problem of satisfying the needs of "most' programs but making the big programs non-starters so the proposals don't get written.	7/23/2018 11:44 AM
19	I do not know if the current A-frame and winches are sufficient for drilling systems such as MEBO and similar systems.	7/23/2018 11:14 AM
20	The configurations were fine for the work I did.	7/23/2018 11:10 AM
21	On NBP, there is a need for a bow crane and port side rear crane so they are currently insufficient. The current small boat (Cajun Cruncher) is worthless and was only deployed once during my five cruises. We have successfully used zodiacs on two cruises and seem to be the best solution for small-boat operations. There are problems with storage of these interfering with other work during other operations when not in use.	7/17/2018 12:40 PM
22	They would need to be capable of launching an ROV similar to Jason, likely as a two body system. I believe they currently have this capability although it has not been done.	7/17/2018 10:33 AM

23	Need a high speed winch with high working load for coring and rock dredging with an appropriate torque balance wire cable. The capability to launch and recover over-the-side autonomous vehicles and a cable for ROV operations is also needed.	7/17/2018 9:06 AM
24	Recommend NSF/OPP consider the design of Icelandic small boat called Rafnar, which is considered by Navy to operate better (significantly better) in rough seas due to unique hull design. See: https://rafnar.is/pages/about-us	7/17/2018 8:56 AM
25	The capabilities are fine at the moments and the near future, although the only small-boat operations are usually done by zodiac. not good enough for real near shore or shallow water surveys. Not sure if A-frame will be good enough for all future AUV needs (probably is). Mainly talking about the NB Palmer here. I don't know about the LM Gould.	7/17/2018 8:18 AM
26	They seem adequate but I haven't conducted ship-based Antarctic research since 2005.	7/17/2018 8:03 AM
27	It was made clear that small boat work was difficult, so perhaps more use and training on these would be helpful.	7/17/2018 7:02 AM
28	Capability is not the same thing as actually being able to use them, which depends on personnel	7/17/2018 6:41 AM
29	GO-SHIP work has been compromised because of the configuration of the CTD winch and Baltic room, requiring work stoppage in calmer conditions than from other US research vessels of the same capacity.	7/16/2018 9:02 PM
30	All of this is sufficient. One problem comes in when multiple science parties are on board and then there are not enough scientific staff to do multiple tasks---for example, can't core while small boats are away, not due to equipment limitations, but because the same persons are needed for each task.	7/16/2018 2:05 PM
31	The addition of aluminum-hulled RHIBs was great. Having a pulpit for our research needs is ideal and greatly appreciated. A faster mechanism to get boats on and off would be ideal.	7/16/2018 11:24 AM
32	Smaller side J frames might be useful in addition to existing equipment. Small boat ops will alwasy be necessary.	7/16/2018 11:15 AM

Q18 Are the general handling characteristics of the USAP ships with respect to dynamic positioning for over-the-side operations and stability in heavy seas and/or sea ice sufficient for your work now and in the future?

Answered: 77 Skipped: 14



ANSWER CHOICES	RESPONSES	
Yes	48.05%	37
No	29.87%	23
I Don't Know	16.88%	13
N/A	5.19%	4
TOTAL		77

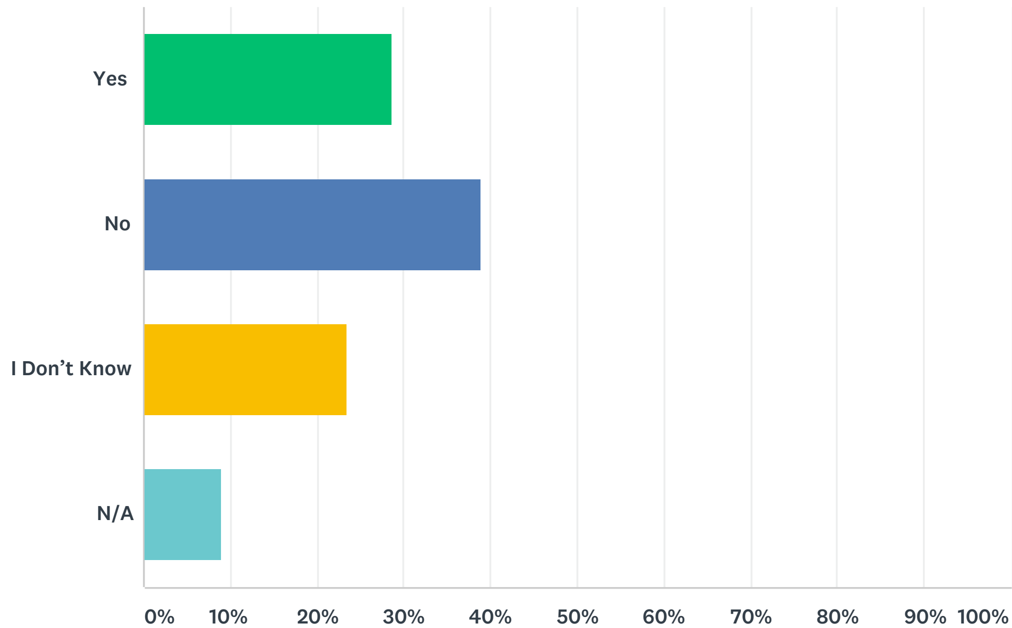
#	IF YOU THINK THIS COULD BE IMPROVED, PLEASE DESCRIBE HOW:	DATE
1	The Palmer is set up well. Stability on the Gould in heavy seas leaves a bit to be desired.	8/13/2018 9:11 AM
2	Unless there have been upgrades (to the Gould) in the last few years, No. In the age, precise dynamic positioning is needed on all ships.	8/8/2018 1:34 PM
3	Sea bed drill rigs, despite being connected to the ship by a flexible umbilical cable, require quite limited vessel movement during drilling. The exact radius limit depends on water depth and the drilling system, but may be as little as 10 m or less over a period of up to two days.	8/8/2018 9:50 AM
4	Modern ship designs with azipod propulsion and common bus electric are the way to go. Hull designs have changed since the NBP was on thew drawing board.	8/8/2018 9:39 AM
5	they could be improved - again technology is much better now that when the LMG and NBP were built in the 90s	8/5/2018 12:54 PM
6	Sea ice operations have been challenging with the NBP - yet this will be a critical demand for research programs going forward. Design a ship that is sea ice capable and that is designed to get science access to sea ice floes.	8/5/2018 9:10 AM
7	Having sailed only on the LMG, heavy seas have limited where we could sample at times.	8/3/2018 11:44 AM

8	The DP should be sufficient, but ability to stay on station often depends on mates, and its hit or miss.	8/2/2018 7:46 AM
9	The Palmer - yes, the Gould - no.	8/1/2018 12:54 AM
10	I do not know how much of this was due to the ship systems, but the NBP appears to have difficult holding ship position relative to the ice and keep a hole clear for over-the side operations in ic (granted conditions were challenging)	7/30/2018 8:27 AM
11	Palmer is OK, with the Ice Knife, but bubbles are a big problem with the Palmer.	7/27/2018 6:27 PM
12	Right now, when the sea is not calm, many over-the-side operations (fish traps retrieval, CTD casts, ...) are not possible on the LMG. A real dynamic positioning system is necessary to improve this.	7/27/2018 4:55 PM
13	not the LMG-- it has issues in regards to maneuverability for over-the-side operations	7/27/2018 6:39 AM
14	Certainly stability (i.e. keeping the boat upright) is the foremost concern, but sea keeping (e.g. motion) should not be a distant second. There is a benefit to having people feeling good and being productive that is worth the cost over the lifetime of a ship.	7/26/2018 2:02 PM
15	The NBP is a slow ship. Despite the specs, the ship usually does only about 9 knots in open seas. This adds ship time (and extra salary costs, etc.) to fixed-plan cruises. On station in open seas, the NBP is prone to allowing seas to be guided down the starboard side where they can quite dramatically enter the Baltic Room. This phenomenon also takes place on the UNOLS Global-class ships, but they do not have Baltic rooms with exposed winches and operators on that deck. All large ships suffer a bit on station in winds due to their sail areas, but Southern Ocean ships have special needs due to heavier swell (often not aligned with local wind, complicating things) and heavier winds. One of the top needs for the NBP replacement is clear thinking and engineering regarding improved coping with winds and seas typical of the Southern Ocean. In the ice, the NBP seems to work well. The ship sometimes carries a professional ice pilot and the difference, compared to USCG icebreakers and their novice crews, can be remarkable.	7/24/2018 2:17 PM
16	We don't conduct over-the-side ops, except for getting team members/gear into small boats to land on our islands of interest. The ships are sufficiently stable in most seas; nevertheless, most of our team members are typically incapacitated for much of the journey through Drake Passage. (I doubt much can be done about this though, given how ridiculously rough the Drake can be.) As noted above, sea ice is a significant problem for us, though this isn't so much a problem with the icebreaking capabilities of the vessels. Again, the issue is that there is typically sea ice between the closest point the ship can reach to a given island of interest and the island itself. Due to the depth of its hull and the 'shallowness' of the water, the ship can't just break ice all the way to shore; instead, it gets as close as it safely can and then we try to reach the island by Zodiac or aluminum landing craft. But given that Zodiacs/landing craft can't really break ice, this is often a huge problem for us. For example, in 2009, the LMG got us well within sight of Vega Island, but we never actually reached that island given that it was ringed by fast ice.	7/24/2018 12:30 PM
17	Some vessels have better dynamic positioning systems that work like a charm, but the NB Palmer and crew are decent enough in my experience.	7/24/2018 11:19 AM
18	The LMG is notorious for flaws in its initial design and has very poor performance in heavy seas. It's sea ice capabilities are virtually non-existent, both from perspective of crew experience (no icebreaker experience) and ship capabilities.	7/24/2018 9:41 AM
19	The NBP was able to move a couple of meters at a time in any requested direction for our benthic camera operations - this was great!	7/24/2018 6:25 AM
20	The LMG had.to have stabilizers added, and has limited ice breaking capability. It is difficult to support logistics ops and station support or remediation from either vessel.	7/23/2018 10:05 PM
21	No, both the LMG and NBP are marginally incapable vessels that never really lived up to the performance we were promised when they launched. These vessels have "gotten us by", but they are overall far inferior to just about everything else out there.	7/23/2018 2:46 PM
22	I expect that the weather and ice conditions in the southern ocean will continue to get more unpredictable. There are certainly "edge" season programs that would require more power, more ice breaking, etc. Again, without a clear option about how this work could be supported these types of programs are non-starters from a potential proposer's perspective.	7/23/2018 11:44 AM
23	The ships need improved capability to maintain station, particularly during coring and drilling.	7/23/2018 11:14 AM
24	The Gould is not capable of much ice work. The Palmer did pretty well.	7/23/2018 11:10 AM

25	The crew's inexperience with setting up for CTD operations in sea ice led to much difficulty in our last cruise. As well the criteria for windage and wire angle were arbitrary and varied depending on which mate was setting up the ship, leading to many stations being cut off after hours of setup time. They also had no idea of how to deal with broken ice floating into the wire or cut off operations unnecessarily at the site of a first crack in the ice cover. Man basket operations were also burdensome, with foolish restrictions on number of people over the side at one time and restrictions (including tether lines!) on how staying within a few feet of the basket for sampling, despite drilling showing the ice was safe for travel. Many of these problems were operational rather than ship characteristics since they were not encountered in previous NBP cruises but were charcteristic of the second-rate operations currently by the current contractor, ECO.	7/17/2018 12:40 PM
26	Haven't used the USAP ships	7/17/2018 9:06 AM
27	The NB Palmer dynamic positioning is fine in average conditions, but not strong enough in heavy sea ice or strong winds. (It's workable however)	7/17/2018 8:18 AM
28	They seem adequate but I haven't conducted ship-based Antarctic research since 2005. I want to note that I was on the LMG in March of 2018 when we had to detour to Ushuaia for a medical evacuation caused by rough seas in the Drake passage. At the very least passenger safety in the staterooms/bunks needs to be improved. People were wedging themselves into their bunks with life jackets to prevent ejection from their bunk while they slept.	7/17/2018 8:03 AM
29	The LMG stability in heavy seas, or lack thereof, can limit work and crossings in rough weather; however, I'd rather be safe and lose a day of ship-time than have injured people, as we've had, even though we were all prepared.	7/17/2018 6:49 AM
30	Baltic room too low to the water	7/17/2018 6:41 AM
31	Ability to hold station in more ice (which I guess means more thruster capability) would certainly increase what we are able to do in our current programs.	7/16/2018 2:05 PM
32	The LMG has often times had stability issues that make small boat deployment challenging but for the most part we would not work in those kinds of conditions. The ride, of course, could be improved on the LMG to handle better in rough seas.	7/16/2018 11:24 AM
33	The LMG needs to go away. It is not a pleasant ship to work off, and it is rather slow. The NBP is a good ship ut it also had difficulty in ise and snow condistion so more ice breaking capability would be good	7/16/2018 11:15 AM

Q19 Are the in-ice operation capabilities of the USAP ships sufficient for your science now and in the future?

Answered: 77   Skipped: 14



ANSWER CHOICES	RESPONSES	
Yes	28.57%	22
No	38.96%	30
I Don't Know	23.38%	18
N/A	9.09%	7
TOTAL		77

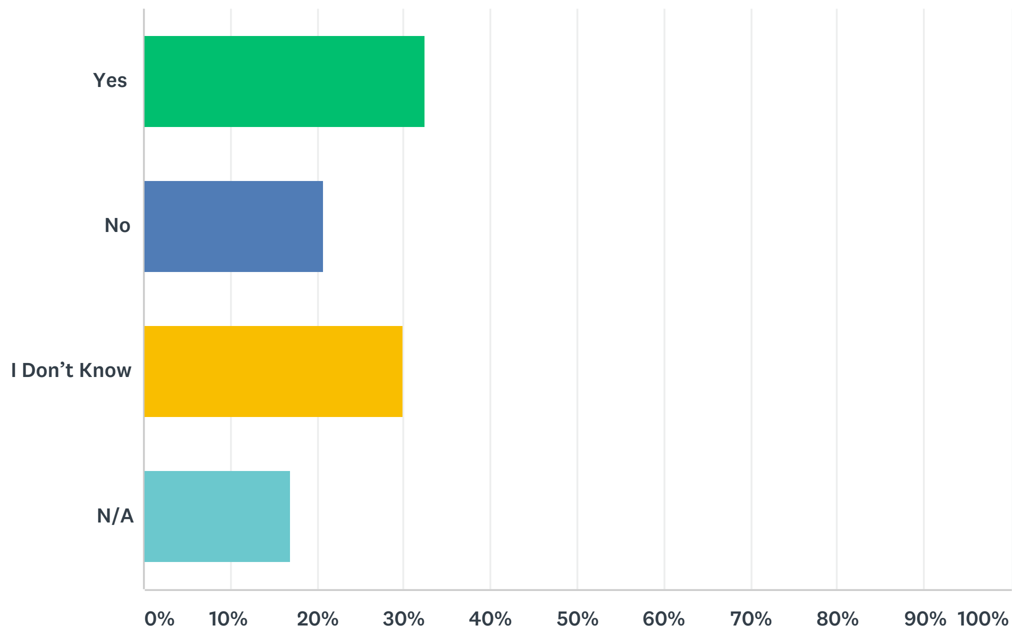
#	IF YOU THINK THIS COULD BE IMPROVED, PLEASE DESCRIBE HOW:	DATE
1	The Palmer did well during our winter studies, though the crew relied heavily on DP instead of understanding how the ship responds to conditions. They got better with more winter voyages.	8/13/2018 9:11 AM
2	It was good to see the report address the ice capability issue. To get at several questions and issues a ship is needed with better ice capabilities. This does not only include getting through the ice - but also being able to use equipment over the side in the ice. I am not saying go back to the moon pool idea... but being able to drop lines off the stern in a ice filled ocean would be worth it given how much money it takes to get the ships to the correct place. Being able to press further into the ice impacts questions that can be asked in a number of scientific fields. This will also impact sampling in year round	8/8/2018 1:34 PM
3	For sea bed drill rig operation, I imagine that the ship would require open water conditions, both for station-keeping and for a back-deck deployment and protection of the umbilical.	8/8/2018 9:50 AM
4	50% increase in ice travel maximums are needed.	8/8/2018 9:39 AM
5	although I have gotten stuck....	8/5/2018 12:54 PM
6	See above. Make a world class ice breaker and one that is designed with studying sea ice in mind.	8/5/2018 9:10 AM
7	Have sailed only on the LMG, ice conditions often limited where we could sample. And reduced our total number of sampling days due to slow-going and even getting stuck in the ice.	8/3/2018 11:44 AM

8	No. We need an icebreaker that can actually break ice. After getting stuck in the ice on the Gould/at palmer station twice in two years, there needs to be an actual ice breaker to support Palmer and peninsula operations.	8/2/2018 7:46 AM
9	Have not previously carried out in-ice operations, but anticipate doing so in the upcoming field season.	8/1/2018 9:00 PM
10	So far yes, but some of the real big remaining science questions require us getting into places currently inaccessible (e.g. southern Weddell Sea, parts of Pine Island Bay, etc.).	8/1/2018 12:54 AM
11	Increased ice capabilities would be a good improvement over the current abilities of the ships. This would benefit not only research in ice areas but also transportation to Palmer and McMurdo Stations.	7/30/2018 7:39 PM
12	The NBP is somewhat limited by the ice conditions it appears to be able to handle for winter cruises in sea ice. This of course has to balanced by the increased operating costs of a heavier vessel vs the number of cruises that will be conducted in heavier ice if the NBP is replaced, but at the same time, this has constrained what science is done from the NBP. My feeling is a modest increase in ice-breaking capability makes sense if the NBP is replaced.	7/30/2018 8:27 AM
13	If a future ship could be designed to deal with heavy sea ice conditions it would be more impervious to the whims of the seasons in the Antarctic.	7/29/2018 9:17 PM
14	Generally yes for past and present aims (that are limited to the capabilities as they now exist); however the ice capabilities as outlined in the past iterations of the PRV designs would allow the work in the coastal regions (e.g. the SW Weddell Sea where major water mass formations occur but have been rarely studied and are likely to be changed/influenced by the major ice shelf calving events). This capability is also desirable to be conducted in other areas- such as the Thwaites Glacier region. Operations in that region now seem to be limited only to the summer sea ice minimum time period because the ships are not capable of going there at other times- times when water mass interactions with the glaciers are likely to be entirely different than during the summer season when melt water stratifications are likely to change the way in which the water masses interact at the interfaces of the continental boundary. Thus, it does seem that the current capabiliy of the ships is now allowing access to study key areas and processes occurring in the Antarctic that are likely shaping how the continental-oceanographic systems are interacting/ changing.	7/27/2018 6:39 AM
15	We need more ships with bona fide ice-breaking capabilities if the US is to remain competitive.	7/26/2018 2:02 PM
16	Some areas can be inaccessible due to heavy ice.	7/25/2018 10:00 AM
17	We need to be able to get to and onto the AA continental shelf regions more easily and in a wider seasonal range than at present. We have definitely had NBP science curtailed by inability of the ship to penetrate farther south. There are at least three ways to improve this: (1) build a bigger, heavier, more ice capable polar research ship, (2) use "a bigger, heavier, more ice capable polar research ship" operated by another nation, or (3) use a more powerful-than-the-NBP escort icebreaker to clear the way in, groom work areas, etc., and lead the way out. My votes would be #3 (using the USCG icebreaker before and/or after the McMurdo break-in, for example), and also use #2 whenever feasible.	7/24/2018 2:17 PM
18	Please see above. Again, the fact that, apart from helicopters, there's no way for our team to cross fast ice to access our islands of interest is hugely problematic for us.	7/24/2018 12:30 PM
19	Winter operations are obviously limited. But that's no small thing.	7/24/2018 11:19 AM
20	Most of the time it is. Ice capabilities greater than that of the LMG would be valuable for accessing Palmer Station in the late winter and early spring.	7/24/2018 9:42 AM
21	Both vessels underperform in this regard, but LMG in particular. I proper icebreaker is absolutely critical to access the areas of greatest scientific interest and to minimize disruptions due to heavy ice conditions. More experienced crew also critical.	7/24/2018 9:41 AM
22	Ice is always the limiting factor in projects, and neither ship has the tankage for fuel to undergo extended ice ops.	7/23/2018 10:05 PM
23	The LMG got stuck in the ice for 4 days on the last trip, this is lost time for productivity and research.	7/23/2018 3:39 PM
24	It might help to have Norwegians or Finns on the design teams.	7/23/2018 2:46 PM
25	Need to be able to handle thicker ice without using all of our fuel	7/23/2018 12:52 PM
26	Not adequate for late or earl season work.	7/23/2018 11:44 AM

27	Greater ice-breaking capabilities would open up more science targets in heavy ice areas such as the inner Weddell Sea.	7/23/2018 11:14 AM
28	Only the Palmer is really ice capable. We used to use Coast Guard ice breakers, which worked well. They provided excellent helicopter support.	7/23/2018 11:10 AM
29	Need ability to get through ice to restock South Pole via Mcmurdo before South Pole Station closes.	7/23/2018 11:08 AM
30	Access to areas currently inaccessible due to heavy sea ice since these areas remain unexplored	7/19/2018 2:32 AM
31	Although it would be nice to be able to get further into the ice.	7/18/2018 2:49 PM
32	Need general improved ice breaking for the NBP replacement.	7/17/2018 12:40 PM
33	I believe that at least one of the USAP ships should have a PC3 ice classification.	7/17/2018 12:16 PM
34	Nb Palmer has decent in-ice capabilities as long as the ice is not too thick. Stronger in-ice capabilities could increase the usable season and allow reaching/working in areas that are not safely accessible with the NB Palmer right now. (I don't think the LM Gould ice capabilities are sufficient for work in areas with heavy ice cover)	7/17/2018 8:18 AM
35	The capabilities seemed OK in 2005 when we were operating in the Ross Sea, but I'm aware of several instances of the LMG getting stuck in flows of seasonal sea ice, so that situation could be improved.	7/17/2018 8:03 AM
36	Possibly ability to braek thicker ice would be helpful	7/17/2018 7:18 AM
37	The LMG can't deal with ice very well. Its schedule, speed and access to Palmer Stn are currently a function of its in-ice capability, among other things and when pertinent. It frequently becomes stuck when caught within loose ice, as you undoubtedly already know.	7/17/2018 6:49 AM
38	This applies to the NBP.	7/16/2018 6:46 PM
39	See above. Ice-breaking capabilities largely sufficient. Keeping station in more ice cover than currently possible would be beneficial.	7/16/2018 2:05 PM
40	The Gould is only ice reinforced. We have very little ability to work in thicker ice, where observations are limited.	7/16/2018 12:52 PM
41	We have been beset in sea ice in the LMG and lost multiple days of operation because of the limited ability to break ice. This is a significant loss and could have been resolved with a fully ice capable platform.	7/16/2018 11:24 AM
42	In general yes, If the future NBP had a z drive rather than propellers, would it make better progress in snow covered ice periods. This is important given the warming occuring at the peninsula. If there is more precipitation (snow) than those conditions need to be what the vessel is best for	7/16/2018 11:15 AM
43	Any improvement in ice breaking capability would allow the vessel(s) to get to more sites more frequently.	7/16/2018 11:04 AM

Q20 If your science requires greater in-ice capability, would it be sufficient to provide an escort icebreaker for a USAP science ship of the present in-ice capability?

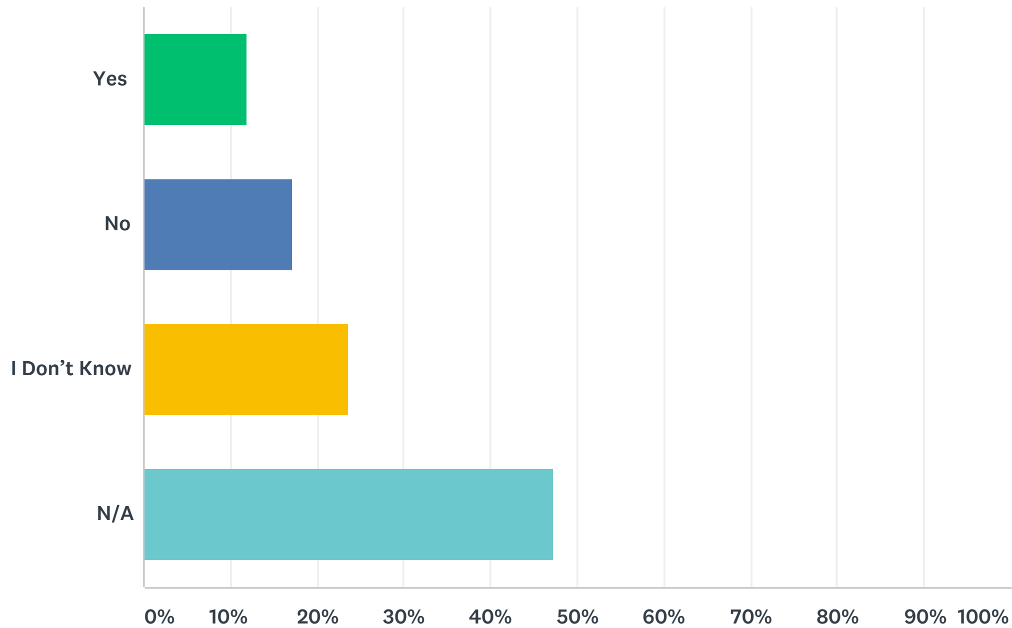
Answered: 77 Skipped: 14



ANSWER CHOICES	RESPONSES	
Yes	32.47%	25
No	20.78%	16
I Don't Know	29.87%	23
N/A	16.88%	13
TOTAL		77

Q21 If your research requires helicopter support, do you feel that your needs in this regard are currently met?

Answered: 76 Skipped: 15



ANSWER CHOICES	RESPONSES	
Yes	11.84%	9
No	17.11%	13
I Don't Know	23.68%	18
N/A	47.37%	36
TOTAL		76

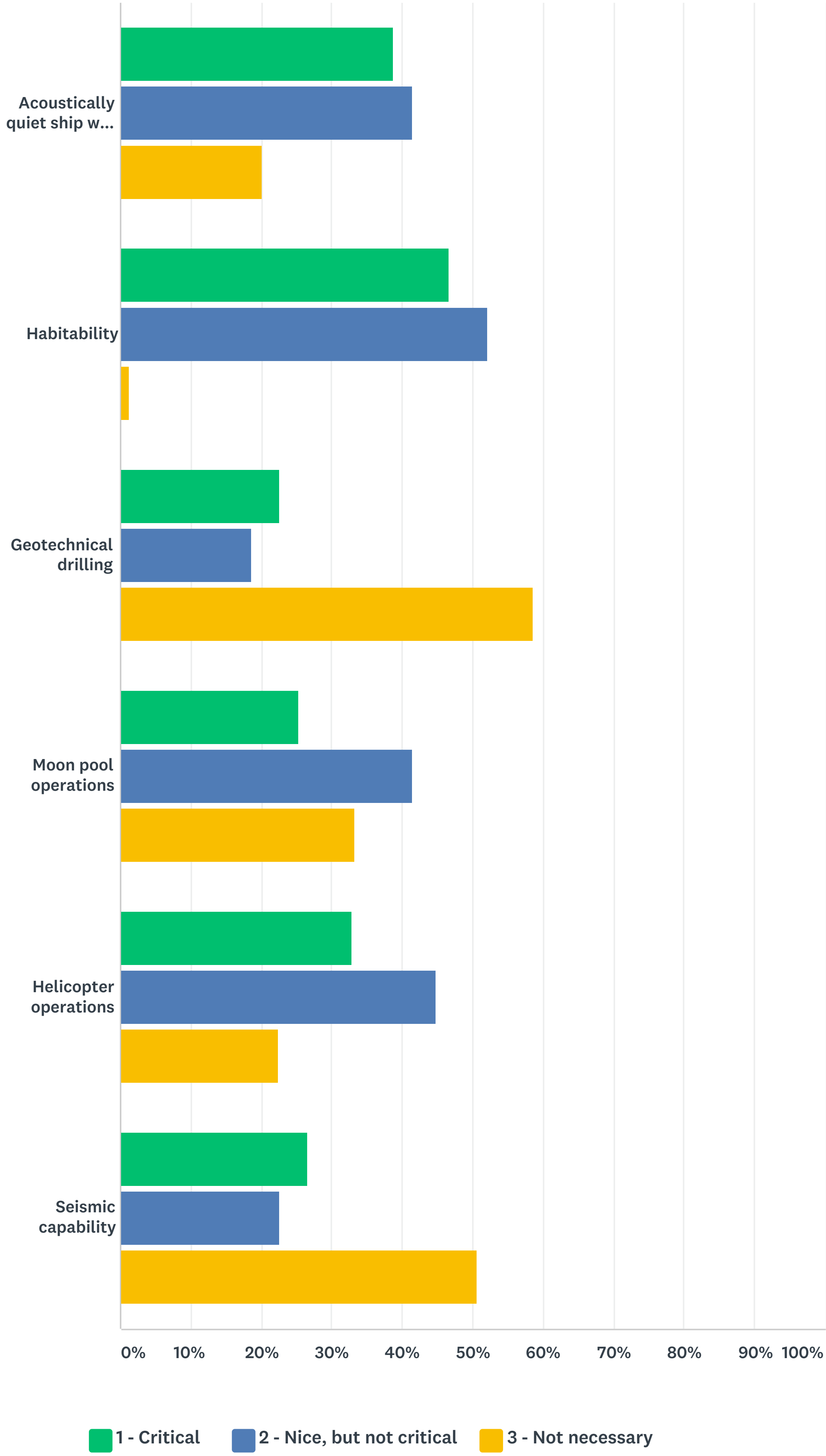
#	IF YOU THINK THIS COULD BE IMPROVED, PLEASE DESCRIBE HOW:	DATE
1	Why no space fro comment to number 20 about escort icebreaker? If is challenging enough to justify ship time for one ship -- do you really want to make PIs justify two ships? I am NA on helicopter support.	8/8/2018 1:34 PM
2	My work would benefit from helicopter support - but this has always been a highly constrained capability to request - I would expect that to continue; but planning for a ship that can at least have 2 helicopters for safety's sake would be a start.	8/5/2018 9:10 AM
3	Ships should not be used as floating hotels for land based research. Marine operations are essential to USAP research and are not sufficiently supported by NSF PM/PDs.	8/2/2018 7:46 AM
4	I had to be rescued by the Argentinians this year because the USAP on the Peninsula does not have access to a helicopter... It severally limits site location access.	8/1/2018 12:54 AM
5	ice work often requires extra vans to be placed on the NBP and this often constrains the use of helos	7/27/2018 6:39 AM
6	Helicopters provide the only possible access for many interesting research sites. Currently it is very difficult to receive helicopter support on ships. This seems to be at least partially due to the fact that ship-based helicopters are not considered part of the USAP base mission and are therefore budgeted out of science budgets, which makes it very difficult to fund.	7/26/2018 12:24 PM

7	Helicopter support is critical for glacier-ocean studies. Currently, it is near impossible to get this funded as it does not typically fall under the logistics budget, but rather on the science budget. This is critical and needs addressing.	7/25/2018 10:00 AM
8	Helicopter support is crucial for an NBP-like ship so that the USAP can support continental and ice science around the AA margin. My research never uses helo support, but it seems clear that the USAP needs a mobile helo base, i.e. helo support built into the NBP or equivalent.	7/24/2018 2:17 PM
9	This is a complicated question to answer in that, in 2016, I think our needs were mostly met (though competition for helicopter time with the other science team aboard the NBP and the fact that the helicopters were grounded when there was even a tiny bit of precipitation or fog caused problems for us). In 2009 and 2011 we didn't have helicopter support at all; this had disastrous consequences for the 2009 season (i.e., only *18 hours* of field time in our study area during a *five-week* cruise), but it didn't really impact the 2011 season since there was little sea ice that year. To the previous question (#20), re: an escort icebreaker -- if this hypothetical ship could bust ice all the way to the shore of Vega, James Ross, or Seymour islands, then it would meet our needs (since Zodiacs could then make their way through the channels cut by this hypothetical escort icebreaker).	7/24/2018 12:30 PM
10	Palmer has some helo support, but I have not seen them being operated as they are costly operations...	7/24/2018 11:19 AM
11	Any replacement for the LMG should be helicopter equipped to expand capabilities along the WAP.	7/24/2018 9:41 AM
12	Only the NBP has hello capability, and it is limited.	7/23/2018 10:05 PM
13	Yes, except that to get the helicopter support is extremely difficult	7/23/2018 12:52 PM
14	Without hanger and extra berthing, helos are mostly a non-starter. There is a good case to be made for using a pair (self-rescue) of big (dual engine, IFR) helos as a force multiplier. For instance, along the ice edge, one could end up with three simultaneous 100 mile apart CTD lines rather than a single ship-based line for much less than the cost of two ships.	7/23/2018 11:44 AM
15	My helicopter experience thus far has been limited, but during those operations it seemed that the aircraft use were small and had limited ability to operate in anything but perfect, cloud-free, weather conditions. Greater ability to work in partial cloud cover would allow more flight days.	7/23/2018 11:14 AM
16	I have used helicopters from the NBP successfully, however it is not considered routine.	7/19/2018 2:32 AM
17	I don't anticipate a need for helo support for my work.	7/17/2018 8:03 AM
18	needs to be simple not overly cumbersome	7/17/2018 7:18 AM
19	I have only sailed on the LMG, never on the NBP. I frequently sail on the I/B Oden as well as Canadian CG vessels in the Arctic. Having a helo on board is invaluable for science, navigation.	7/17/2018 6:49 AM
20	I would be able to access more key field sites if helicopter support along the Peninsula were more readily available.	7/16/2018 9:18 PM
21	For the work that we do, ship-based helicopters are a potentially irreplaceable means of access to ice-free areas in remote coastal locations that are not otherwise accessible. A lot of our work on ice sheet and relative-sea-level change is limited by access to ice-free areas where geological records of these processes may exist, in particular in the Peninsula, Amundsen Sea area, and northern Victoria Land.	7/16/2018 6:46 PM
22	If helicopter support was available from both ships it would allow for a greater scope of work and capabilities of collecting information and surveying that is not currently available. This would be greatly appreciated for long-term planning.	7/16/2018 11:24 AM
23	I don't have any experience with USAP heli ops.	7/16/2018 11:04 AM

Q22 Please review the UNOLS SMR-identified outfitting objectives for a new polar research vessel, below. Rate the importance of each for your research on a scale of 1-3. 1 = critical; 2 = nice, but not critical; 3 = not necessary.

Answered: 76 Skipped: 15

Community Survey: Requirements for U.S. Antarctic Program Research Vessels



	1 - CRITICAL	2 - NICE, BUT NOT CRITICAL	3 - NOT NECESSARY	TOTAL
Acoustically quiet ship with minimal underwater-radiated noise	38.67% 29	41.33% 31	20.00% 15	75
Habitability	46.67% 35	52.00% 39	1.33% 1	75
Geotechnical drilling	22.67% 17	18.67% 14	58.67% 44	75
Moon pool operations	25.33% 19	41.33% 31	33.33% 25	75
Helicopter operations	32.89% 25	44.74% 34	22.37% 17	76
Seismic capability	26.67% 20	22.67% 17	50.67% 38	75

Q23 What additional capacity or capability do you feel is lacking in the current USAP ships that may be required in the future to meet future scientific objectives in your field?

Answered: 61 Skipped: 30

#	RESPONSES	DATE
1	Bottom imaging - ideally better ROV capabilities - can do this now but logistically the cost blows proposals out of the water. The other issue is taking the ships near shore or in uncharted areas. The Captains are understandably cautious. Perhaps being creative with forward looking sonar would put Captains more at easy with moving into unknown waters.	8/8/2018 1:34 PM
2	ROV control room.	8/8/2018 1:29 PM
3	Fisheries acoustics, like on ANY modern oceanographic vessel	8/8/2018 11:49 AM
4	Seismic profiling and scientific drilling capability. These are possible now, but would be better if the new ship is designed with these capabilities in mind.	8/8/2018 9:50 AM
5	Better support for AUV/UAV work. Also see the 2012 SMR. As the primary author of that repoqrt I know what it says and still support it.	8/8/2018 9:39 AM
6	we have routinely torn nets and had equipment damaged via rocks on dredging efforts. Additional backups are essential. Additionally, while we haven't had issues getting one, the YoYo camera setup is essential.	8/6/2018 5:44 AM
7	on board environmentally controlled rooms are critical.	8/5/2018 9:10 AM
8	I support the requirements put forth in the UNOLS "A New U.S. Polar Research Vessel (PRV): Science Drivers and Vessel Requirements"	8/3/2018 11:44 AM
9	Sampling gear and capability for observing higher trophics (fish). Diving capacity: not done much anymore in Antarctic work from what I've seen and heard, but my future research direction will entail this opportunity to study crystal krill abundance and dynamics under ice.	8/2/2018 9:50 AM
10	Long coring... 40 m, core curation onboard, core scanning facilities.	8/2/2018 7:46 AM
11	Continued support for underway data and hull-mounted ADCP.	8/1/2018 9:00 PM
12	Multibeam on the Peninsula ship (Gould) and helicopter capabilities. The Gould currently doesn't ride well enough to make the dead time while transiting useful (can't be productive while spending the other 4 weeks aboard getting to my field sites).	8/1/2018 12:54 AM
13	Trace metal clean labs on board the ships. The existing trace metal clean water sampling system could be improved.	7/30/2018 1:20 PM
14	Any new ship should be built with the expectation that robotic platforms will be increasingly important. This means ensuring the deck layout can accommodate varied drone operation (this is mostly possible now on the NBP). For underwater vehicles, a moonpool could be very valuable in ice provided it can be kept clear of ice (my understanding is the NBP moon pool isn't really useable in ice, though I haven't tried because the access wasn't available on my last cruise due to container placement). Easy access to the instrument well to mount acoustic comms instrumentation for autonomous vehicle operation would be useful (This may be possible to some degree now, but I haven't pursued it very far as we've managed with over the side deployment of transducers)	7/30/2018 8:27 AM
15	Ability to retrieve and store large quantities of ice samples, collected through ice coring supported by helicopter operations, and eventually transported to CONUS and university facilities for analysis.	7/29/2018 9:17 PM
16	I don't know.	7/27/2018 6:27 PM
17	Better sample collection methods (better trawl sorting equipment, etc). More capacities for ROVs and other instruments like these. Even maybe small submarine?	7/27/2018 4:55 PM
18	over-the-side operations from a few different access points on the ships	7/27/2018 6:39 AM

19	Regarding questions 12 and 13: The issue is not the number of berths on the ship, it is the number of berths that are available for research that are in short supply (i.e. the number of berths not filled by people transiting).	7/26/2018 2:02 PM
20	n/a	7/26/2018 12:24 PM
21	gravity meters	7/25/2018 12:12 PM
22	N/A	7/25/2018 10:19 AM
23	1. Different frequency ADCPs, 2. Consistent helicopter support/operation, 3. improved ice capability/escort	7/25/2018 10:00 AM
24	air-sea flux measurements	7/25/2018 9:50 AM
25	I suspect that there will be longer cruises involving more interdisciplinary work, which will require increases in endurance and berth spaces for the science party (including technicians and helo crews).	7/25/2018 9:26 AM
26	Drilling is great, but longer cores, 30 m or more wold be a game changer.	7/24/2018 4:34 PM
27	See previous answers focused on ability to work over the side safely in heavier seas/winds than NBP can now do, and ability to better support large multi-disciplinary cruises.	7/24/2018 2:17 PM
28	Some safe, reliable means to cross sea ice -- either helicopters or something else. This is a problem not only for paleontologists like myself but really anyone who needs to get onshore to conduct their work (e.g., geologists, some glacialogists and ecologists).	7/24/2018 12:30 PM
29	Forward-looking sonar and/or other navigation aids to allow the vessel to safely operate in shallower waters in order for it to go closer to shore to support small boat operations.	7/24/2018 9:42 AM
30	Improved berthing for transit to Palmer Station on LMG is critical.	7/24/2018 9:41 AM
31	Sampling equipment and clean vans/lab space for trace metals.	7/24/2018 7:36 AM
32	I think a good molecular-clean lab facility would be useful in the future. As DNA sequencing technology continues to improve at some point we will want to be able to sequence samples at sea, in order to inform our sampling plans, and optimize our limited ship time. If such sequencing capabilities were to become a reality more internet would also probably be necessary in order to transfer data to bioinformatics servers back on land.	7/24/2018 6:25 AM
33	Submersible or drone use, a landing craft to bring larger supplies ashore or for remediation projects, helipad, deck and hold storage for building materials (palmer needs upgrades and a new pier), more fuel tankage,	7/23/2018 10:05 PM
34	Extremely long transit and logistics durations (6 weeks) relative to the working time (2 weeks) precludes many research possibilities and is extremely inefficient.	7/23/2018 3:39 PM
35	Habitability, in-ice operations/capabilities, open water stability	7/23/2018 2:46 PM
36	most importantly is longer in-ice endurance	7/23/2018 12:52 PM
37	Top notch technical and operational science support with a small (2-3 person) foot print.	7/23/2018 11:44 AM
38	Swath mapping and seismic capabilities on all vessels, flexibility in configuration of lab and deck layouts.	7/23/2018 11:14 AM
39	Good wet and dry lab spaces accessible from inside the ship, good flow through water system that does not heat up or change properties (temperature, no bubbles, loss phytoplankton), acoustically quiet.	7/23/2018 11:10 AM
40	longer piston coring capability geotechnical drilling	7/19/2018 2:32 AM
41	The ability to get into multiyear ice to sample.	7/18/2018 2:49 PM
42	More marine technicians are needed on the LMG to assist with fishing operations. Too often we have inexperienced young scientists (graduate students) working under challenging conditions on the back deck. I feel this is unsafe and unnecessary. While I strongly believe it is important for the scientists to participate in the fishing operations, they need to be supported by trained marine technicians who can work in the more hazardous positions on the back deck (e.g. the yellow zone).	7/17/2018 3:35 PM
43	Increase in autonomous instrumentation for ocean and ice measurements such as a uCTD, glider, AUV, automatic ice cameras among others.	7/17/2018 12:40 PM

44	Better seakeeping than the GOULD.	7/17/2018 12:16 PM
45	N/A	7/17/2018 11:52 AM
46	Due to heavy seas surrounding Antarctic, the need for a larger ship suitable for the conditions there is critical. I would also emphasize that comfort is important in such high stress operating environments, including private cabins that allow for decompression. Operating in rough seas and sea ice is not like cruising through the Caribbean.	7/17/2018 9:06 AM
47	Ability to launch/recovery unmanned aircraft easily	7/17/2018 8:56 AM
48	larger deck space; better AUV and ROV lunch and recovery options (although most systems come with their own system)	7/17/2018 8:18 AM
49	Dedicated and well-engineered deck incubators with flowing ambient seawater. The system would be even better if temperature/light/ocean acidification control systems could be engineered into it.	7/17/2018 8:03 AM
50	Drilling, further ice breaking capability	7/17/2018 7:02 AM
51	capacity for bow tower for air sampling and remote sensing instrumentation	7/17/2018 6:49 AM
52	Good sediment coring teams	7/17/2018 6:45 AM
53	Skilled experienced manpower	7/17/2018 6:41 AM
54	more gimbal-style tables or other methods for working in the lab while the ship is in motion	7/16/2018 9:18 PM
55	NA	7/16/2018 9:02 PM
56	Unknown.	7/16/2018 6:46 PM
57	More ship time for more projects!	7/16/2018 2:05 PM
58	Trace metal clean facilities are lacking	7/16/2018 1:57 PM
59	Ice breaking capacity.	7/16/2018 12:52 PM
60	Hull mounted and underway echosounders are critical. helicopter and ice breaking support around the Peninsula are also necessary.	7/16/2018 11:24 AM
61	USBL capability higher-bandwidth Internet	7/16/2018 11:04 AM

Q24 How do you envision projected climate/weather shifts over the next 40-50 years affecting your science support needs from USAP ships?

Answered: 60 Skipped: 31

#	RESPONSES	DATE
1	If anything great need for ship support if we hope to understand climate based changes. - also might argue a need for more ice capability as it will be necessary to see how near shore regions are impacted.	8/8/2018 1:34 PM
2	Only changing locations.	8/8/2018 1:29 PM
3	Unclear. Suspect that new areas will come accessible.	8/8/2018 11:49 AM
4	Sea ice and polynya patterns are changing, and I imagine that we can anticipate polynyas being open longer in the future.	8/8/2018 9:50 AM
5	We need better open water seakeeping abilities and better ice breaking to understand winter processes - even if there is less summer ice in some areas.	8/8/2018 9:39 AM
6	Needs to stay at current levels or increase.	8/6/2018 5:44 AM
7	God, I hope I am not still working in 40 or 50 years - but in general I think the committee's recommendations are correct, increase general capacity and capability	8/5/2018 12:54 PM
8	more sea ice research, access to ice-shelf edges, and icebergs	8/5/2018 9:10 AM
9	I see projected climate to play a small role in the support requirements for these ships. Even with reduced sea ice area, the greatest knowledge gaps exist in/under sea ice and we must conduct sea in the ice.	8/3/2018 11:44 AM
10	More opportunity to go farther south in the WAP, but if ice increases in Ross Sea during this time, access to study sites (e.g., Terra Nova Bay) could be an issue.	8/2/2018 9:50 AM
11	ice support will be required on the Peninsula and we need heavy icebreaking capabilities in the Weddell Sea and East Antarctica, to address important climate questions in those regions. Palmer Station needs to be supported by an icebreaker.	8/2/2018 7:46 AM
12	Increasing need to work in the marginal ice zones, which may occupy a larger area of the Southern Ocean/Antarctic margins	8/1/2018 9:00 PM
13	More access?	8/1/2018 12:54 AM
14	Greater ship stability will allow sustained operations if projected increases in wind speed actually occur.	7/30/2018 1:20 PM
15	Based on IPCC projections, I do not expect ice conditions to change enough to change basic operations in the sea ice zone.	7/30/2018 8:27 AM
16	I'm not sure what this means, but as projected warming propagates southward the Pacific Southern Ocean-facing part of Antarctica, will continue to rapidly change. This is essentially all of West Antarctica, the portion of the continent in which US assets most frequently operate. It will largely be up to us to determine how well we instrument this "front line" of change in Antarctica, which will have large implications globally for sea-level rise and thus coastal community impacts.	7/29/2018 9:17 PM
17	I don't know.	7/27/2018 6:27 PM
18	This is hard to project... but when I usually deploy (April to August, and especially the period of April to June) is often hit by strong storms, which may become either more intense and/or more frequent in the coming decades. Good sea capabilities will be crucial. Also, sea ice has been forming with great variations over the past several years, and it could be possible that thin sea ice start to grow on wider areas and occupy places so far relatively free of ice (Gerlache Strait, various Bays, etc) so good ice capacities will be determinant.	7/27/2018 4:55 PM

19	Random bits of information 1. A common misunderstand is that is likely to be less ice in the Antarctic- this is not necessarily true- E.G, mid-winter sea ice extent seems to be growing (esp in the Ross Sea region) 2- Ice shelf dynamics and interactions with the ocean seem to be more and more critical to advancing the knowledge of the Antarctic and how this has effected the earth systems in the past, how this may effect ecosystems, sea level and mankind in the future	7/27/2018 6:39 AM
20	Not significantly. The Peninsula and Amundson Sea are going to remain hotspots of change	7/26/2018 12:24 PM
21	unknown	7/25/2018 12:12 PM
22	Unfortunately, less ice, so better for my research.	7/25/2018 10:19 AM
23	More ship-based use will needed, more coupled studies will require helicopter support and increased use of AUVs	7/25/2018 10:00 AM
24	These will raise new issues and uncertainties that will likely increase the research demand. There will be increased demand for year-round operations in the Southern Ocean.	7/25/2018 9:26 AM
25	Might open up new areas for research, these could be in areas hard to predict sea ice conditions	7/24/2018 4:34 PM
26	Winds and seas seem to be increasing in our Southern Ocean ops areas. This will require ships which can work in heavier seas, and/or a significant increase in "weather days" built into cruise planning and grant funding.	7/24/2018 2:17 PM
27	I'm actually not sure what, specifically, the most current climate models indicate will happen on the Antarctic Peninsula during the next few decades (apart from the likelihood that the area will get considerably warmer). If, however, this means more sea ice, at least in the near future, then this will likely pose significant problems for my team and any others who need to get on land to perform their research. On the other hand, melting continental glaciers will likely expose 'new' rock, and with it, 'new' fossils, thereby increasing the potential for significant new discoveries. Being able to reach these areas, either by ship or by helicopter, will therefore be critical.	7/24/2018 12:30 PM
28	Little.	7/24/2018 9:42 AM
29	Greater ice handling capabilities to handle highly variable conditions and to investigate regions most vulnerable to future climate change.	7/24/2018 9:41 AM
30	I'm not sure. But I think these projected shifts will heighten the motivation for more USAP research.	7/24/2018 7:36 AM
31	I don't have enough understanding of climate trends in this region to acess this.	7/24/2018 6:25 AM
32	More opportunity for projects as areas become ice.free. remediation projects of legacy camps and bases. Less invasive field camps, more education and enforcement of laws to protect Antarctica including haz mat and monitoring.	7/23/2018 10:05 PM
33	I am envisioning a windier, more turbulent ocean, meaning operations in overall more intense sea states that will require far greater stabilizing technologies than currently present in USAP vessels.	7/23/2018 2:46 PM
34	will need to get closer to the ice shelves.	7/23/2018 12:52 PM
35	Conditions will become less predictable and potentially more limiting for a given size vessel.	7/23/2018 11:44 AM
36	Greater ice breaking capabilities would partially alleviate my concerns about lack of access to heavy ice areas. Improved dynamic positioning would alleviate some concerns over maintaining station in currents and windy conditions.	7/23/2018 11:14 AM
37	easier access to areas currently inaccessible due to heavy sea ice cover - so expansion of geographic scope of research	7/19/2018 2:32 AM
38	Not sure.	7/18/2018 2:49 PM
39	unknown	7/17/2018 3:35 PM
40	Currently unknown for the Antarctic sea ice region so a candidate for increased research.	7/17/2018 12:40 PM
41	More winter work.	7/17/2018 12:16 PM
42	N/A	7/17/2018 11:52 AM
43	Required ability to continue science in varied sea states from high wind and waves to ice conditions.	7/17/2018 10:33 AM
44	Realistically, this is less predictable that most would like to think. The oceans I suspect will get rougher if the sea ice disappears, which makes a larger ship more critical.	7/17/2018 9:06 AM

45	More deployment/recovery of unmanned systems to improve monitoring capabilities.	7/17/2018 8:56 AM
46	Not really. I hope for less sea ice.	7/17/2018 8:18 AM
47	It's possible that climate changes will relieve the need for enhanced ice-operation capabilities, on the other hand we might expect more frequent and/or larger storms that could increase the need for seaworthiness of the next polar vessel.	7/17/2018 8:03 AM
48	maybe it'll let less ice capable ships be used.	7/17/2018 7:18 AM
49	I foresee more frequency of sampling needed, and urgently. The greatest barrier to using USAP ships is the incredible inefficiency on the front end - getting scientists on ships. It took months when it need not and there was no support from USAP in clarifying or expediting the process. It seems like the monopoly USAP has on this kind of research has transgressed into a disregard and disinterest in making an efficient and practical system. Every single scientist I have encountered has experienced tremendous frustration on this front.	7/17/2018 7:02 AM
50	floating or frozen sea ice and glacier ice or only open water are the biggest unknowns. Hence, a vessel that is best at stable sailing in open water [as we may have more of] and strong enough to move through single-tear pack or drift/broken ice [as we may have more of in the fall and winter] will be the balance to strike.	7/17/2018 6:49 AM
51	If there's less sea ice presumably it would be easier to perform more operations further South, and into austral spring/fall	7/17/2018 6:45 AM
52	Not at all	7/17/2018 6:41 AM
53	More uavs less ships, more data, so ships can be adapted to support the ribotic fleet.	7/17/2018 6:40 AM
54	More terrestrial field sites will become exposed, opening up opportunities for further field work	7/16/2018 9:18 PM
55	I expect the support needs will remain the same.	7/16/2018 9:02 PM
56	Unknown.	7/16/2018 6:46 PM
57	Changing climate/weather will continue to place importance on the scientific work done by USAP vessels. Because most of what we do is already focused on the extreme edge of the working capability of the NBP, and our interest is in the edge of the ice position, wherever that is, changes over the next 40-50 years will not lessen the conditions in which we work or where we want to work. Rather, the places in which we are interested will shift.	7/16/2018 2:05 PM
58	I expect that reduction of sea ice will make icebreaking easier.	7/16/2018 1:57 PM
59	We would likely encounter more open water but at the same time are interested in following the sea ice habitat where it occurs	7/16/2018 11:24 AM
60	As a senior scientist I doubt that the changing climate will significantly affect my use of USAP ships during the remainder of my career.	7/16/2018 11:04 AM

Q25 If USAP operated a single ship and had more flexibility for using other assets, how would this impact your future Antarctic research? If you think that two ships are required, please explain.

Answered: 70 Skipped: 21

#	RESPONSES	DATE
1	Two ships are required. Given that the Gould runs supplies to Palmer station on a regular basis, it is tied to that region (as would any ship that took over this job). There would need to be an alternative to supplying Palmer Station. Also ships time is tight in the summer months. So the number of projects that could be supported will be limited at a time when more study is needed. One issue that should be addressed is funding proposal than then only giving the research teams a very limited number of berths. Twice I was kindly awarded ship time (one Gould and one Palmer) but was initially told I could only take 6 investigators. Moreover there was only one other scientist on the ship -- I know this has happened to others as well - -this is just not efficient use of ship resources. Much of my work involves equipment over the side of the ship (lines int he water) for extended times. When some projects tie up the ships for dedicated periods for years in a row (e.g LTER), it cripple the research of others to only have one ship.	8/8/2018 1:43 PM
2	It is difficult to believe that reducing costs by dropping back to a single vessel would yield any significant improvement in operational capabilities; the savings, if USAP were even allowed to keep them, would likely be consumed by more bureaurocracy.	8/8/2018 1:34 PM
3	I think having an understanding of how USAP schedules the current ships is required for this. Right now it does not make any sense to me how this is done, and how thy decide on what assets are available at any given time. It seems to me that any forward-thinking program would embrace flexibility in terms of assets available. Would probably save money.	8/8/2018 11:51 AM
4	More time allotted sediment sampling, especially drilling, makes the need for additional survey operations, so 2 ships are needed to efficiently advance the science.	8/8/2018 11:41 AM
5	There would be more demands on the time of the single vessel, but if the single-ship scenario freed up resources for other assets, it may be worthwhile. For example I know that Antarctic field operations are constrained by availability of fixed-wing aircraft.	8/8/2018 9:55 AM
6	Are you kidding me? The US can't afford 2 ships when much smaller nations have 2 or even 3? It's why we've lost our leadership in Southern Ocean science. I get it that the nutbags currently setting the NSF budget don't care for science - BUT this is very likely to end. As a community we shouldn't even be talking about contracting to a single ship. If we do, it will happen and we will cede polar ocean science to other nations (and lose many great scientists). To me this is simply unacceptable.	8/8/2018 9:42 AM
7	This will simply not suffice. While costs are obviously an issue, there are so many limits to ship time, particularly when groups wish to go to the Weddell or East Antarctica, there is no way that a single ship will suffice for all work.	8/6/2018 5:45 AM
8	Increases the number of smaller projects capable of support	8/5/2018 12:55 PM
9	given regular support required for Palmer station, needs for multiple ocean systems to be studied at least during summer, two ships are a significant asset. Unless Palmer is suppled/ supported by a different vessel, then I think 2 ships as they have been working are essential. The geographic coverage is the constraint of working only on one side of the continent with a 1 ship concept.	8/5/2018 9:12 AM
10	I feel that science is already currently constrained even with two vessels. Less projects are getting funded due to logistical constraints, and maybe not necessarily the funding. I would strongly argue that 1 additional vessel is required to fulfill science goals in the multiple Antarctic regions.	8/2/2018 9:52 AM
11	Two ships are required. One ship would put the community at more risk of falling behind scientifically. There are too many locations that are being ignored because we current ships are dominated by LTER and NOAA research on fish. Marine Geology and Oceanography programs need equal access to ships.	8/2/2018 7:48 AM

12	This would be ok if there was increased support for deployment of autonomous vehicles from US stations. However, this would require vessels that could navigate to (or close to) the continental shelf break.	8/1/2018 9:02 PM
13	Might be difficult for the Peninsula folks and Palmer Station without a dedicated ship (having to balance the Ross Sea side of things...).	8/1/2018 12:54 AM
14	One of the advantages of two ships is that researchers would have a great choice of working locations. Having a single ship will likely limit science in any given season by restricting the geographic range of projects, thus delaying programs until there was sufficient critical mass to send the ship to a specific location. Wouldn't this situation severely limit work to one region or another (e.g., Peninsula vs. Ross Sea)?	7/30/2018 7:43 PM
15	Less ship time available to support oceanographic research would negatively impact my work. There is already competition for ship time during the Austral field season. Reducing to one ship would exacerbate an existing problem.	7/30/2018 1:22 PM
16	I support the cost savings of a single ship if that cost savings can translate to a more ice-capable vessel, and more partnership with other national programs becomes a priority. Most of my USAP cruises have been in winter when there is less demand for the NBP. I have (and expect to continue) to work with other National Antarctic Programs, but planning participation in such cruises can be challenging because of separate funding mechanisms. The joint NSF-NERC (UK) initiative is a good template for this. Getting USAP buy-in to cruises run by other operators might also be away of maximizing use of available assets without placing all the burden on foreign collaborators.	7/30/2018 8:47 AM
17	Given the level of support one of the two USAP vessels currently provides for station science support at Palmer, it is difficult to see how a single ship could continue the same level of science focused at Palmer and elsewhere around the continent.	7/29/2018 11:58 AM
18	The ADCP time series crossing Drake Passage is unique; with a one-ship operation this would be in jeopardy, since the commercial ship would not have ADCP capability.	7/27/2018 6:28 PM
19	For fishing operations and especially reaching special depth where some specific specimens can be caught, smaller vessels like RHIBs are not viable options (RHIBs can't trawl the bottom for fish). This would risk to put an end to USAP fish research on and around the Peninsula. This would also severely harm all the benthic ecology research that is not relying on scuba-divers to collect samples. One ship could work but it would have to be flexible in use, which would in return reduce the capacities for oceanographic studies. It would also impact greatly the sectors of Antarctica that USAP could be studying.	7/27/2018 5:05 PM
20	A fully ice capable ship is needed to access areas around the Antarctic at all times of the year. If Palmer Station is to serviced with a USAP ship- this need is not likely to be met- If Palmer Station operations could be decoupled from the Science Ship then other configurations of the "USAP fleet" could possibly be imagined.	7/27/2018 6:43 AM
21	Having two ships is absolutely essential. What is the alternative? Shutting down oceanographic research in October/November and March/April when the crews at Palmer turn over? The fact that this is even a question on this survey is absolutely nauseating. Other countries are building ice breakers right and left! Having only one ship would effectively surrender the US's status as the global leader in Antarctic oceanographic research.	7/26/2018 2:08 PM
22	Not significantly. In effect it already is, since the LMG almost exclusively serves Palmer Station.	7/26/2018 12:25 PM
23	One ship, but with acoustic instrumentation, remote presence, and instrumented small craft.	7/25/2018 12:37 PM
24	gfhfghg	7/25/2018 12:12 PM
25	N/A	7/25/2018 10:19 AM
26	A single capable ship with the option of using chartered ships as needed would be ok. Especially if the single vessel has increased ice capabilities, helicopters, and extensive small boat capabilities.	7/25/2018 10:02 AM
27	Not sure.	7/25/2018 9:27 AM
28	One ship for all operations seems like a waist and many things can be done with smaller ships. Then the bigger ships get degraded and you are unable to continue to do large operations like coring or siesmics.	7/24/2018 4:36 PM

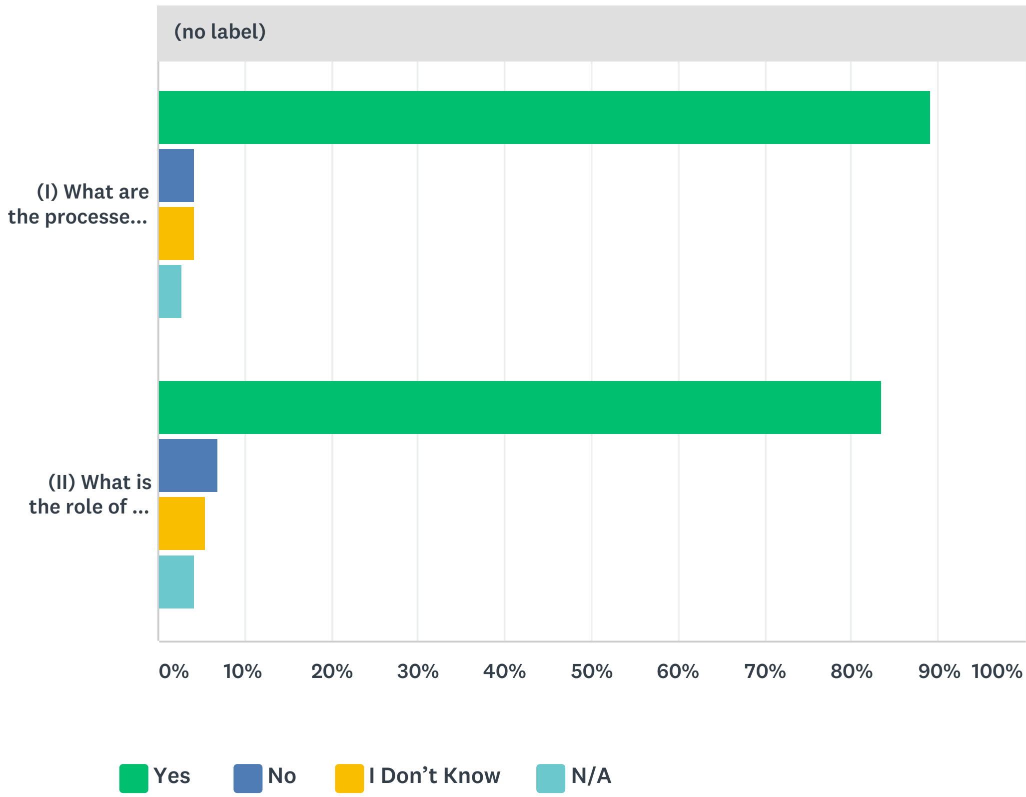
29	With only 2 (OK, 2.5) general-purpose UNOLS Global-class ships, the NBP is being pressed into service outside of the immediate Antarctic region. If the USAP ship was more closely tied to the Palmer area (for science support, assuming "other assets" took care of much of the Palmer Station logistics), this would decrease its availability for use in other areas of the southern ocean and in the other oceans in general. This might make ship scheduling even trickier than it is at present.	7/24/2018 2:30 PM
30	This could well benefit my Antarctic research, since my team really only requires the use of one vessel at most. (With apologies to the dear old LMG, the NBP's capacity for helicopter support makes her a vastly preferable option for us going forward.) Also, as explained in some of my other responses, many of the "new opportunities" mentioned in the statement immediately above could be of great benefit to my team (i.e., "increased support from helicopters," "more capable vessels," increased bandwidth on the ships," "greater partnerships with other National Antarctic Programs").	7/24/2018 12:35 PM
31	Frankly, that is a weird question. Having one ship will obviously divide by two (or more, because logistical supports are generally fixed) the amount of Science time. If there is a way to have a one ship solution and not loose any Science time, that is fine by me. But loosing Science time will necessarily have a negative impact on Antarctic research as a whole.	7/24/2018 11:23 AM
32	One ship would be a huge mistake. There needs to be a ice-capable ship dedicated to WAP operations and **year-round** support of science activities at Palmer Station.	7/24/2018 9:44 AM
33	Given that huge areal extent of the Southern Ocean it is difficult to imagine a single ship being adequate. The WAP requires a full-time vessel and we are already in danger of focusing too much on the WAP and Ross regions.	7/24/2018 9:42 AM
34	My work requires the use of ships, so my primary concern with going to a single ship operation is one of ship time availability. It would also make a difference as to which ship- the Palmer for example is a more suitable platform for my research than the Gould.	7/24/2018 7:38 AM
35	My impression is that it is already difficult to get the ship time I need to do my research - our field work got postponed by a year because of this - and having half as many ship days will make that even harder. One potential work-around would be flying people/equipment more, and minimizing Drake transits. It seems like the ships spend a lot of time going between the peninsula and PA - if people flew in & out of e.g. King George Island or Rothera Base that could save 6-8 days for each cruise - a significant fraction of what are often 30-40 day cruises. Similarly international collaborations could help minimize the time the various ice breakers all spend transiting around the world.	7/24/2018 6:31 AM
36	Two or more ships are required, with greater involvement from a science perspective from the US Coast Guard and their vessels. Every other Antarctic Research program is building purpose built ships, except for the US.	7/23/2018 10:08 PM
37	A single ship would not be sufficient to perform research on par with other developed nations.	7/23/2018 3:40 PM
38	The Palmer Station resupply is but one of many annual activities that are already embedded in the program and depend on ship support. The annual LTER summer cruise is another that is not likely to change given the theoretical perpetuity of these programs, so I just cannot see how a single vessel operation and the charter/use of "other assets" might meet programmatic demands given the already nearly synoptic demands for ship support, for example, in summer in the Ross Sea and the WAP. The LMG already operates nearly 24/7 even apart from whatever is going on in the Ross Sea or elsewhere, and I just do not see this changing given what to me just seems like accelerating interest in WAP research -- and indeed seems to be anticipated in the recently developed, so-called Palmer Master Plan. Palmer has used a variety of "other assets" in the past, including air support through King George Island, and the model did not last that long. At least given the trends and associated conflicts that I already see developing in the program, I just cannot fathom how one vessel instead of two is a solution to anything.	7/23/2018 3:34 PM
39	I think we need 2 ships. One devoted to dealing with winter operations and the other for shuttle runs, resupplying coastal station and performing summer research	7/23/2018 12:53 PM
40	I believe two ships are required to simultaneously support research on different sides of the continent (e.g., near the Peninsula and in the Ross Sea)	7/23/2018 11:52 AM
41	This seems like a non-starter. USAP _will_ drop to one ship and is unlikely to commit the resources that will actually necessary to support the other tantalizing opportunities. The long leads, technical risks, and cost combined with science-focused decision making will spend the money on science	7/23/2018 11:47 AM
42	I believe two ships are required. A single ship with a mission to transfer people and supply Palmer station is too strongly tied to the Penninsula region, and results in many years passing between opportunities to venture to more remote areas such as East Antarctica.	7/23/2018 11:16 AM

43	It is already difficult to get proposals funded due to a lack of ship time. The LTER program already taken up much/all of the Gould's summer ship time in the Antarctic Peninsula region. If Coast Guard ice breakers were available, this might help, but there would need to good coordination and oversight of science equipment.	7/23/2018 11:13 AM
44	With only a single ship, I am concerned that long histories of ship-based research in the Peninsula and Ross Sea would result in an even greater alternation of research in these two regions, limiting ship-based research in less well-studied and more remote regions, as the East Antarctic margin.	7/19/2018 2:35 AM
45	I think that going down to one ship from two would severely limit/restrict the kind and amount of research conducted by US researchers in and around Antarctica. It would increase competition for limited resources too. That said, in the current funding climate, having two ships that aren't always in use due to lack of supported research projects is not that useful either. It's a tough one. I would worry about the continuity of the Palmer LTER if we only had one ship too. Either the Palmer LTER would not be regularly supported, or no other research anywhere else around Antarctica would be possible during January each year. This is assuming the Palmer LTER would require the one ship.	7/18/2018 2:56 PM
46	A ship is needed to operate out of Palmer Station that can dock at the pier for offloading fish. The NBP is not capable of this and so could not function as a single ship supporting Antarctic research.	7/17/2018 3:37 PM
47	Collaboration and cooperation with other international programs is crucially necessary. The addition of an airborne program using IcePod has already been undertaken for our project so this is a welcome development. As mentioned. increased use of AUVs, ROVs and the uCTD and automatic ice cameras will be highly useful and also lead to better use of ships, e.g. automatic cameras running on geophysical cruises.	7/17/2018 12:45 PM
48	Would have to consider what other options and their capabilities are. For example the proposed HPIB for USCG is expected to be very ice capable, but not outfitted very well for science.	7/17/2018 12:17 PM
49	N/A	7/17/2018 11:54 AM
50	A single ship seems limiting	7/17/2018 11:53 AM
51	Less ability to respond to rapidly emerging conditions. (i.e. rapid or response cruises would be even less likely). Increased time between proposal and funding and limited of proposal based vs LTER based research. I could see this has increasing the demands of the ships and limiting the geographic region in which the USAP is able to support science. Other assets do not always have the same capabilities (lab, dynamic positioning, A-frame clearance, ability to launch gear a midship, etc). If the budget does not allow a second ship, the science will likely suffer but may be unavoidable.	7/17/2018 10:36 AM
52	Other than availability, it would likely improve the opportunities for Antarctic research around the Antarctic Plate Boundary if it produced a larger ship.	7/17/2018 9:08 AM
53	Don't know.	7/17/2018 8:57 AM
54	Going to one ship would negatively impact my future Antarctic research. I don't need other assets, I need a ship from which I can deploy piston cores and collect plankton tows. Ship time is limited enough with two ships.	7/17/2018 8:33 AM
55	I am not sure two ships are required, but only if there are other ways (ships) to support Palmer Station. If there is only one ship it will need to be able to operate some season away from the Antarctic Peninsula	7/17/2018 8:20 AM
56	I think it's a mistake to scale back to a single Antarctic vessel, particularly as someone who was told for multiple years in a row that there was no room for us on Antarctic vessels - partly the reason that we (eventually) got in to Palmer Station. Commercial charter of passengers and resupply to Palmer seems to add an element of risk to USAP operations. I don't see how increasing use of RHIBs (which are great for shore-based work on the peninsula) will offset use of an entire research vessel.	7/17/2018 8:13 AM
57	It would water down opportunities esp if this is THE McMurdo ice beaker	7/17/2018 7:20 AM
58	Two ships are required in order to fulfill the research needs to of this fragile and changing system. If there were to be some catastrophic change on one side of the Antarctic, and the ship was doing critical experiments on the other, how could we ever research and document that change? I think two ships is integral to the success of the program.	7/17/2018 7:04 AM

59	If resupply to Palmer station were done by commercial vessel, then the basis for prioritization of the antarctic region to be studied in year X vs Year Y would need to be transparently spelled out. For ex, if t would be very bad to break the fantastic LTER time series off the WAP in the month of January [I am not and have never been a LTER PI; my science has benefitted greatly from their long time series] because the one ship is to be scheduled in the Ross Sea or Amundsen or elsewhere in the month of January. Hence, the need for 2 ships is highest in Jan-Feb, lesser in the shoulder seasons (Nov-Dec, March-May) when arguably the biggest ecological changes will be felt (ie, growth season starting earlier and lasting longer), and least in winter. Even with all the other options described above, many require a bigger vessel to deploy from (ie, helo, autonomous vehicles/air/water/surface). The new Palmer RHIB is great and clearly extended and sped our operations; and made them safer, but they are still for short distances from shore, in good weather, short sorties, and very small teams. AGain, if USAP were to have a single vessel, the criteria by which field site prioritization are to be made should be transparent to all.	7/17/2018 7:03 AM
60	Given that the Palmer LTER frequently uses the Gould, it seems as if two ships are necessary to prevent a monopoly on science in the Antarctic during the seasons the LTER needs the ship	7/17/2018 6:46 AM
61	If resupply is properly scheduled OK	7/17/2018 6:42 AM
62	Two ships can give more coverage spatially and temporally. Goid to have a backup.	7/17/2018 6:40 AM
63	Terrestrial work does not overlap neatly with marine work, requiring separate cruise schedules. It would be difficult for our work to take place, since the ship's scheduling would be tight and there'd be little room for our work to squeeze into the schedule.	7/16/2018 9:20 PM
64	I am not sure what the thinking is about how to service both Antarctic stations with only one ship, along with providing research science support. It has been very difficult in past years to get shiptime such that we had to skip a decade in our decadal repeat hydrography survey of the Southern Ocean. I'm not sure what changed about that, that it's now so much easier that the Palmer has been switched over to working outside the polar oceans, for which it was not designed.	7/16/2018 9:05 PM
65	In general, I would think purely as a function of increased competition for scarce ship time. However, as noted above, freeing up resources for potential expansion of helicopter operations would be potentially very valuable for a lot of research that we can't now undertake.	7/16/2018 6:48 PM
66	I am . not overly familiar with the LMG but I feel that there has been some circular reasoning for its continued support. It was there to support Palmer and therefore lots of projects could take advantage of it. But then, there are lots of projects around Palmer that are being used as a demand for keeping 2 vessels. Seems to be circular reasoning. As I said above, more flexible ship time (everyone needs prime season!) for more projects around all of Antarctica is likely the greatest need and that goes against cutting one of the vessels. But, I do think it is reasonable to reduce the number of back-and-forth runs to the Peninsula in favor of being able to support more, longer, farther cruises in different places.	7/16/2018 2:09 PM
67	If the Palmer LTER is to continue, then two ships are required so that sampling elsewhere can take place	7/16/2018 2:01 PM
68	If the Palmer LTER is to continue, then two ships are required so that work elsewhere can be done. One ship would mean that it is dedicated to sampling the Peninsula every January and other sampling strategies would be precluded, especially the Ross Sea.	7/16/2018 2:00 PM
69	This is hard to determine. We have started using platforms of opportunity but they are limited in their sampling capacity and ability to spend dedicated time in one location or survey areas. Having seen the Australian model of a single ship that does re-supply and science, my general feeling is that the science becomes secondary and extremely poorly supported and more competitive. I would strongly urge for two platforms given the broad geographic areas and scientific needs	7/16/2018 11:26 AM
70	Two ships are required. As long as palmer is resupplied by ships and as long as lter always has december, than there is a need for a second ship to do the work. If you get rid of palmer, than (a) you will have money for ships; (b) you would free up shiptime	7/16/2018 11:17 AM
71	This would only affect my future Antarctic research if my proposals were turned down due to lack of an available vessel.	7/16/2018 11:05 AM

Q26 Two broad challenges were identified by the 2012 SMR report. Please indicate if these challenges and questions are still relevant and if there are others that need to be addressed in the coming years and support by USAP ships:

Answered: 73 Skipped: 18



(no label)

	YES	NO	I DON'T KNOW	N/A	TOTAL
(I) What are the processes and thresholds that control the loss of the Antarctic ice sheet to the Southern Ocean?	89.04% 65	4.11% 3	4.11% 3	2.74% 2	73
(II) What is the role of the Southern Ocean in the global carbon cycle?	83.56% 61	6.85% 5	5.48% 4	4.11% 3	73

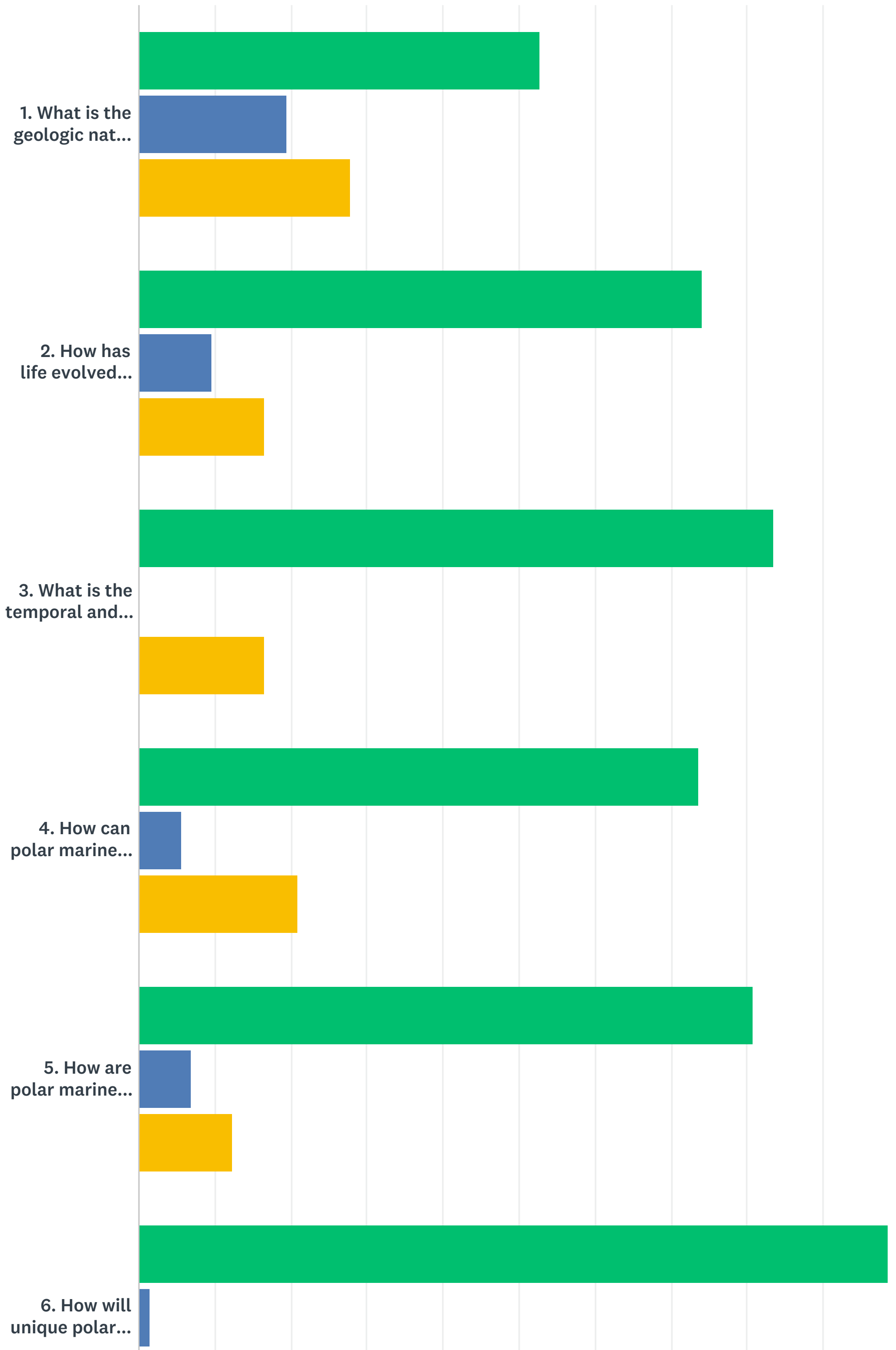
#	PLEASE LIST ANY ADDITIONAL CHALLENGES YOU FORESEE NEEDING TO BE ADDRESSED IN THE COMING YEARS.	DATE
1	How the environment and animals are impacted by these climate changes represented a set of critical processes not covered by these questions? The Antarctic is an "advanced preview" for how biota and ecosystems handle rapid climate change - this has a huge impact on humans and human committees. -- it would be a big mistake not to consider this as a major challenge in Antarctic research. See answer below	8/8/2018 1:54 PM
2	What are the ecological consequences of these changes?	8/8/2018 1:43 PM
3	Well, how about any biological or ecological components of polar ecosystems - some of which are commercially exploited and important to humans in a number of ways.	8/8/2018 12:02 PM

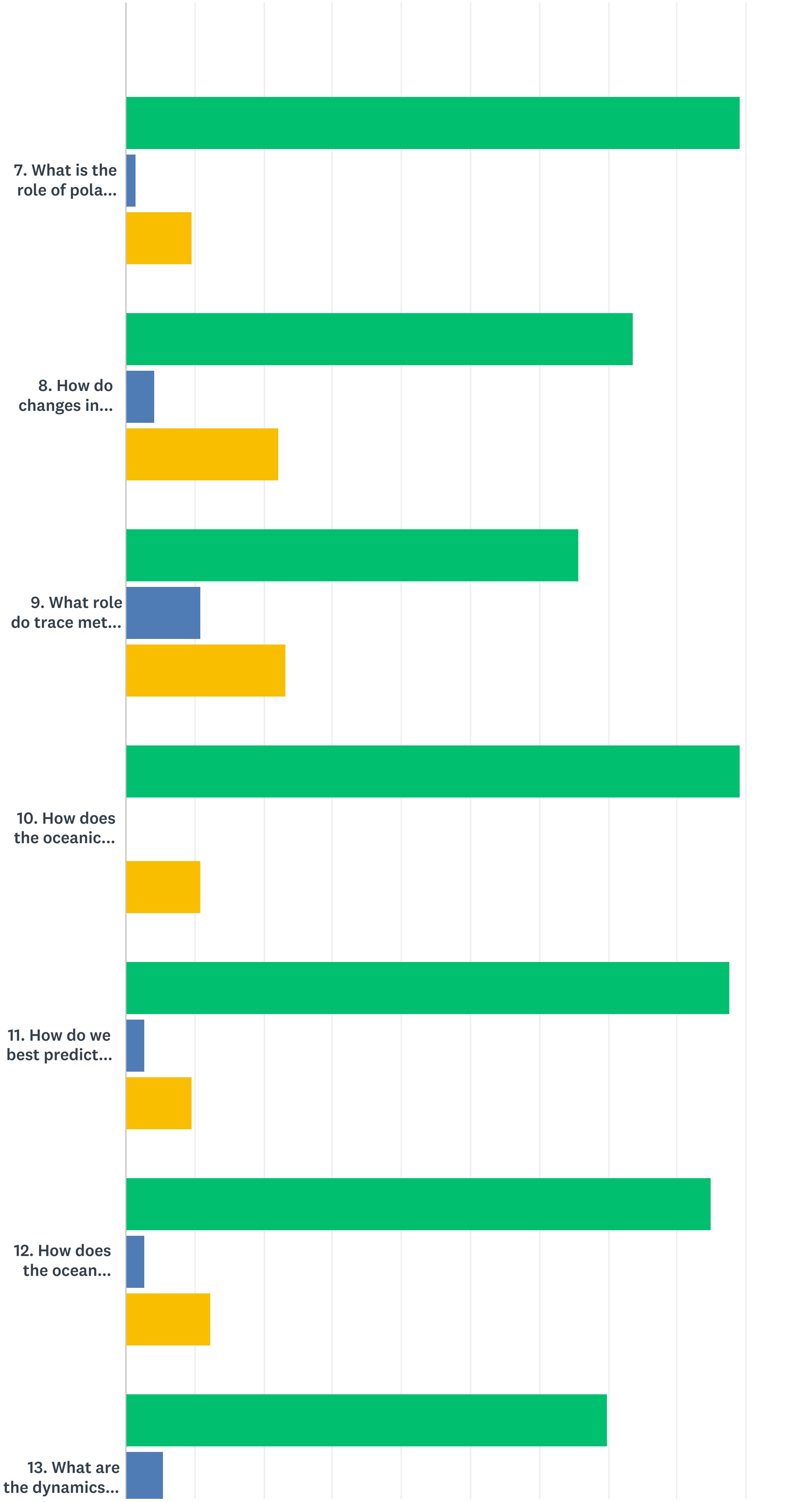
4	Both remain central questions, from which many important sub-questions need to be addressed, spanning biological, physical, and geological challenges. The best breakthroughs often come when all branches of the science communicate and operate in an interdisciplinary way.	8/8/2018 11:49 AM
5	I'd add that the Antarctic marine geological record contributes to both of these challenges, especially for understanding the response of the ice sheets to periods of past climate warmth, as analogies for the planet's warm future.	8/8/2018 10:06 AM
6	Have a look at the Horizon Scan documents as well as the NAS Strategic Visions report. I participated in writing both of those and they represent an updated view of what's important - generally in support of the 2012 SMR document.	8/8/2018 9:53 AM
7	Ocean acidification dynamics Effects of ocean acidification on Antarctic ecosystems	8/2/2018 9:55 AM
8	past Antarctic ice sheet history, particularly vulnerability of the East Antarctic Ice Sheet, which Fretwell data (2013) indicates is as sensitive as WAIS, but is currently almost completely ignored by the USAP. Most catchments contain as much ice as in all of WAIS, yet the USAP throws resources at a system we already understand (PIG, Thwaites).	8/2/2018 7:57 AM
9	Additional question: What are the processes that control the transport of heat to floating Antarctic ice shelves and how will this change in the future?	8/1/2018 9:04 PM
10	What happens as marine-based ice sheets retreat...	8/1/2018 2:38 PM
11	How does the chemical environment regulate (a) the role of the Southern Ocean in the global carbon cycle and (b) the health and fertility of the marine ecosystem.	7/30/2018 1:26 PM
12	These two broad challenges are critical. However, in addition, I think that the study of the biological diversity present in Antarctica is as critical. The Antarctic biological diversity is astonishing and barely understood yet while it may be subject to extreme changes and threats over the next decades. Monitoring this evolution and understanding past, present, and future adaptations put in play by living organisms is as crucial as the ice sheets and SO carbon cycle.	7/27/2018 5:13 PM
13	Still relevant!	7/26/2018 2:11 PM
14	What is the role of the Southern Ocean in the global climate system. Is the geomagnetic field of the earth symmetric on short and long timescales.	7/24/2018 4:41 PM
15	What ecosystem shifts are accompanying and/or caused by and/or related to the changes in the physical-chemical environment of the Southern Ocean, and how are these similar/different and/or related to changes in the ecosystems and physical environment of the other oceans?	7/24/2018 2:35 PM
16	Both of these challenges seem relevant to me, but I'm not an expert in these areas so my responses should be taken with a grain of salt.	7/24/2018 12:41 PM
17	What are the impact of Antarctic ice sheet melt on abyssal water properties and the global thermohaline circulation?	7/24/2018 11:27 AM
18	The challenges are relevant but inadequate to describe ship needs and major scientific objectives.	7/24/2018 9:45 AM
19	Oil exploration, increased tourism, over fishing, haz mat spills, remediation, upgrades and continued support of permanent and seasonal camps.	7/23/2018 10:14 PM
20	What I see as an additional challenge that needs to be addressed is the state of Antarctic marine biodiversity, including how it is changing and what are the causal elements. Biodiversity is changing globally, and we should be using the relative isolation of the Southern Ocean as a baseline to explore and understand the processes with an eye on informing research and models relevant to other marine ecosystems.	7/23/2018 4:50 PM
21	Research and monitoring to determine whether newly established marine protected areas are being effective, achieving their objectives, etc.	7/23/2018 11:56 AM
22	What is the statistically plausible time line of the demise of the big Antarctic ice sheets?	7/23/2018 11:49 AM
23	What is the Southern Ocean's role in the ocean's heat budget and deep water formation. How are marine ecosystems changing with global warming?	7/23/2018 11:18 AM
24	Understanding the capacity of marine organisms to withstand climate change.	7/17/2018 3:39 PM

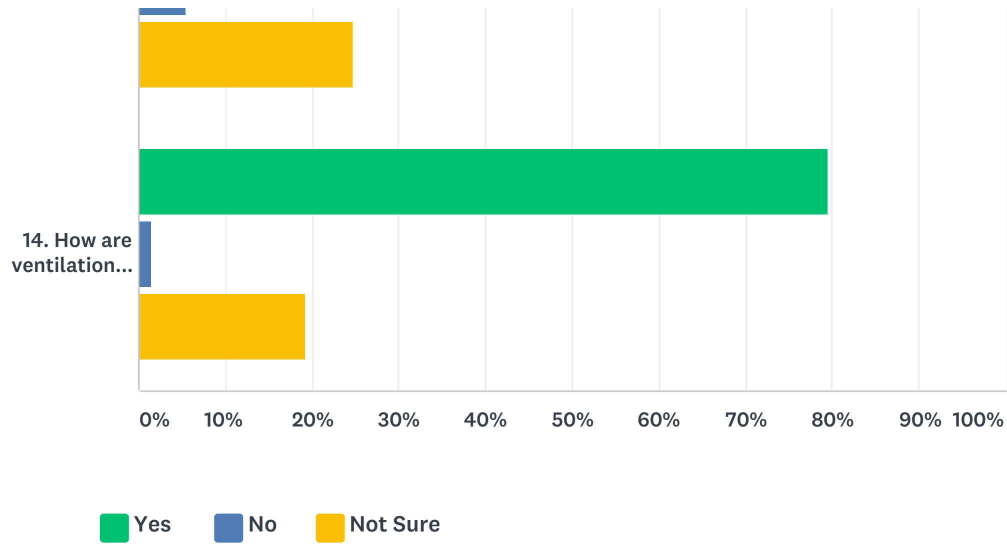
25	The role of sea ice in regional weather, climate, the carbon cycle and in ecosystems are major questions that are massively understudied in the Antarctic, particularly in comparison to the Arctic Ocean. In the Arctic, multiple research cruises are undertaken to study the pack ice zone every year by the US, Germany, Norway, Korea, China, etc. In the Antarctic sea ice zone there have been about a half-dozen winter cruises over the past 25 years by the NBP and a few by other nations. Fundamental questions on the thickness of sea ice, depth of snow cover, ice formation processes are unanswered, with little knowledge also of interannual variability.	7/17/2018 12:56 PM
26	What are the tectonics of the Antarctic region?	7/17/2018 12:31 PM
27	How will the polar ecosystem change in response to shifting climate.	7/17/2018 10:39 AM
28	Little is known of how the southern ocean interacts with the underlying crust and mantle around the plate boundary which requires assessment of the nature and composition of basement. The latter has been shown to be clearly different than at faster spreading ridges like the EPR and the MAR, and thus needs to be fully evaluated. It is now known that the exposure of highly reactive mantle rocks is far greater along the circum-antarctic plate boundary than anywhere else on earth, short of the Gakkel Ridge. Recent geochemical and petrologic work also has shown that the tectonics and geochemistry of the modern plate boundary directly reflects that of the Gondwanan lithosphere, and thus can be key to understanding the nature of what lies below the ice sheet. One curious fact is that glacial erratics are abundant along the plate boundary, but virtually no use has been made of using these for understanding what is beneath all that ice in the hidden continent.	7/17/2018 9:26 AM
29	Changes in ACC and deep circulation.	7/17/2018 8:59 AM
30	How is climate change impacting the microbial diversity and function of Antarctic ecosystems.	7/17/2018 8:17 AM
31	The microbial community needs to be better described, as do small scale processes like weather events and even seasonality	7/17/2018 7:06 AM
32	Number II on carbon makes no sense without a fundamental effort to understand the heat and freshwater fluxes	7/17/2018 6:49 AM
33	Enhanced transport and mixing through Drakes passage and does sea ice dampen surface mixing and. What is the impact on water formation.	7/17/2018 6:44 AM
34	What are the long-term effects of ocean acidification and sea ice changes on the Antarctic ecosytem? What are the processes and thresholds that control Antarctic sea ice extent and volume?	7/16/2018 9:08 PM
35	Impact of an eventual decrease in Antarctic sea ice. Understanding large ecosystems shifts as Antarctic waters warm	7/16/2018 2:06 PM
36	These are very much focused on systems and sampling outside of the biological/ecological area. I believe that the most critical challenges and questions to be supported include understanding how ecosystem structure and function are changing with environmental change. There are now far better abilities to study krill and krill predators and effort needs to be maintained to support these studies.	7/16/2018 11:33 AM
37	These two basic questions are still outstanding.. It would have been better to understand how much research on these two topics was conducted by the vessels, and also would have been good to know how much wasnt funded because of existing shiptime limits. That would help determine empircially whether over last 6 years substantial porgress has been made	7/16/2018 11:20 AM
38	1. Climate monitoring. For a variety of reasons any climate monitoring must include a strong Southern Ocean component, likely including significant moored assets. Mooring operations in the Southern Ocean can be very difficult because of ice blocking access to the mooring sites.	7/16/2018 11:15 AM

Q27 Fourteen key research questions falling under the umbrella of the broad challenges were identified by the 2012 SMR report. For each, please check the appropriate box to show whether you think the question is still pertinent or not.

Answered: 73 Skipped: 18




7. What is the role of pola...
8. How do changes in...
9. What role do trace met...
10. How does the oceanic...
11. How do we best predict...
12. How does the ocean...
13. What are the dynamics...



	YES	NO	NOT SURE	TOTAL
1. What is the geologic nature and extent of the polar continental shelves and what natural resources do they contain?	52.78% 38	19.44% 14	27.78% 20	72
2. How has life evolved in the Polar Regions in response to dramatic events in Earth history?	73.97% 54	9.59% 7	16.44% 12	73
3. What is the temporal and spatial variability of glacial ice and water transfer to and from the oceans?	83.56% 61	0.00% 0	16.44% 12	73
4. How can polar marine research provide accurate assessments of the Antarctic ice sheet?	73.61% 53	5.56% 4	20.83% 15	72
5. How are polar marine ecosystems and organisms adapted to extreme environmental conditions and how is this reflected in biodiversity and evolutionary novelty?	80.82% 59	6.85% 5	12.33% 9	73
6. How will unique polar marine ecosystems respond to climate change?	98.63% 72	1.37% 1	0.00% 0	73
7. What is the role of polar marine ecosystems in the biogeochemical cycles of carbon and other elements?	89.04% 65	1.37% 1	9.59% 7	73
8. How do changes in freshwater cycling in Antarctica affect earth system processes and biogeochemical cycles?	73.61% 53	4.17% 3	22.22% 16	72
9. What role do trace metals and similar compounds have on Southern Ocean ecosystems and how can they be used to understand the complex processes taking place here?	65.75% 48	10.96% 8	23.29% 17	73
10. How does the oceanic heat sink work, where does the heat go as climate warms, and what is the impact on the Southern Ocean and Antarctica?	89.04% 65	0.00% 0	10.96% 8	73
11. How do we best predict trajectories of change in the Southern Ocean and the uncertainties in these forecasts?	87.67% 64	2.74% 2	9.59% 7	73
12. How does the ocean interact with ice shelves?	84.93% 62	2.74% 2	12.33% 9	73
13. What are the dynamics and thermodynamics of polynyas and associated convective processes?	69.86% 51	5.48% 4	24.66% 18	73
14. How are ventilation rates of the deep ocean impacted by deep-water formation in the Southern Ocean?	79.45% 58	1.37% 1	19.18% 14	73

#	PLEASE LIST ANY ADDITIONAL RESEARCH QUESTIONS YOU FORESEE NEEDING TO BE ADDRESSED IN THE COMING YEARS.	DATE

1	Some of these questions are important - but they do not fit under the umbrella of the two broad issues. Carbon cycle does not cover all of biology - trying to force some of these questions under the broad umbrella does not work.... the one of the broad umbrella issues should focus more directly on ecosystem change and organismal adaptation.	8/8/2018 1:54 PM
2	Other biological or ecological components of polar ecosystems - some of which are commercially exploited and important to humans in a number of ways.	8/8/2018 12:02 PM
3	How well are ice sheet and ocean/climate models reconstructing past ice sheet changes as compared with the paleo record? At what point will the models be good enough that we can rely on them as forecasters of future behavior under realistic scenarios?	8/8/2018 11:49 AM
4	During warm intervals of the geological past, what was the ice sheet extent, how fast did it change, and which parts of the ice sheet were most vulnerable to retreat.	8/8/2018 10:06 AM
5	The Horizon Scan developed clearer articulations of these same points.	8/8/2018 9:53 AM
6	past ice sheet evolution and instability of East Antarctic Ice Sheet in vunerable catchments. Understanding heterogeniety of Antarctic ice response in past.	8/2/2018 7:57 AM
7	The list is comprehensive.	7/30/2018 1:26 PM
8	Sea ice has seen and extreme record low ice extent in the past year (far outside recent past variability), coming on the heels of several record maxima. What are the drivers of recent and future sea ice variability and how might this variability be connected to changes in the ocean and ice-shelf systems.	7/30/2018 8:54 AM
9	1. What are the sources of oceanic and biogenic aerosols and how do they impact clouds, precipitation and atmospheric energy budget at high latitudes? 2. What is the dependence of air-sea exchanges on oceanic mesoscale phenomena?	7/25/2018 9:30 AM
10	(see answer to #26)	7/24/2018 2:35 PM
11	How are polar marine ecosystems impacted by fisheries?	7/24/2018 6:35 AM
12	Impacts of shipping, tourism and world political issues.	7/23/2018 10:14 PM
13	What in the system can change if global warming is brought under control to prevent the warmed deep ocean waters from upwelling onto the continental shelves where they will continue to melt the underside of the ice shelves (most important in western Antarctica).	7/23/2018 1:04 PM
14	What are the impacts of multiple stressors (temperature, pH, etc.) on marine communities/ What is the impact of fishing on Southern Ocean marine communities?	7/23/2018 11:18 AM
15	How do we best use Antarctica as a platform for Astrophysical research? How do support CMB-S4 project?	7/23/2018 11:11 AM
16	1. How is the composition of the Antarctic Lithosphere reflected in the composition of the ocean crust formed along the Antarctic Plate Boundary. 2. What can glacial erratics dredged from along the Antarctic Plate boundary tell us about the geology of the hidden continent?	7/17/2018 9:26 AM
17	Less sea ice and glacier ice will impact the heat budget of the overlying air masses such that the atmospheric polar fronts may move N-S; if southward, then the particle and heat load of maritime and continental air masses will reach further onto the Antarctic continent perhaps increasing deposition of natural and anthropogenic particles. As it happens in the Arctic during their winter... The existing weather patterns on the Antarctic continent have, up to now, precluded or minimized these inputs; but they are measured in ice cores. Will this input grow?	7/17/2018 7:10 AM
18	What is the nature of marine particulates in the Southern Ocean, and how are these different from other oceanic basins?	7/17/2018 7:06 AM
19	See answer above.	7/16/2018 9:08 PM
20	These questions are heavily skewed towards the physical sciences and lacking in significant attempts to study organismal biology and ecology. Understanding how climate driven changes will affect krill and krill predators is critical. Understanding the behavior and ecological role of krill predators is still largely unknown. Commitment to long term studies of upper trophic level organisms is critical to understand how environmental change affects the ecosystem. If there is interest in understanding human impacts, a better understanding of how commercial whaling altered and affected krill predators is critical, as is understanding the impacts of the krill fishery on krill predators. None of these last issues have been addressed or considered.	7/16/2018 11:33 AM

Q28 Add any additional comments that might be useful to the Advisory Committee

Answered: 21 Skipped: 70

#	RESPONSES	DATE
1	Because of obvious operational constraints polar research is not keeping up with technological advances being made in much of the rest of ocean science. That is not to say that these constraints can't be overcome.	8/8/2018 1:43 PM
2	The survey is really biased towards research needs in the physical sciences. Where is swerves into biological and ecology, it essentially stops are plankton and weak nekton. There is a whole food web, and it might be good for NSF and USAP to be more inclusive of the needs of researchers focused on higher trophic levels.	8/8/2018 12:02 PM
3	Thank you for your hard work to continue USAP's global leadership in Antarctic research well into the future!	8/8/2018 11:49 AM
4	Keep the heat on NSF for multiple ships. OPP has taken a turn away from marine science support that is damaging. They say it is because of funding but they could also place a higher priority on ships at the expense of many of the big budget items for the stations. If they want to talk about retreating a ,single vessel, why not talk about dropping to 2 stations? The ships are research mills at a higher level than the stations on a per person/per dollar basis. Good luck. I carried this stone for 10 years - and am now going directly to members of congress and the senate with arguments for more polar vessels. Let me know how I can help.	8/8/2018 9:53 AM
5	Thanks for getting to this!	8/5/2018 9:14 AM
6	There should be a consensus statement about the importance of supporting marine geologic operations (including drilling) due to the need for data model integration for future ice sheet predictions. There should also be a consensus statement about the need for shipboard compressors and support for marine seismic and site survey activities, given the need for additional drilling and coring activities in the Southern Ocean and Antarctica's shelves.	8/2/2018 7:57 AM
7	None	7/25/2018 10:21 AM
8	no	7/25/2018 9:30 AM
9	We need concerted efforts to explore the ocean around Antarctica if we are to address many of those questions.	7/24/2018 4:41 PM
10	I think I've beaten this dead horse enough in my responses above, but just in case: sea ice poses a big problem for anyone who needs to access land from the current USAP research vessels. Finding a way around this problem will, in my opinion, greatly increase the efficacy of paleontological and geological efforts in Antarctica.	7/24/2018 12:41 PM
11	I appreciate you taking our opinions into consideration!	7/24/2018 6:35 AM
12	As an organization, we need to make it a priority to support science in the southern oceans and not fall behind everyone else.	7/23/2018 10:14 PM
13	The construction of the two vessels that we now have was in my opinion guided more by politics than science, no doubt the reason why they are barely habitable and borderline capable. Lets hope this changes during the next round of construction if we ever get to that point.	7/23/2018 4:50 PM
14	The question about berthing on the ships asked whether the berthing was sufficient for my research -- which it is. However, berthing is not sufficient to support my research and large programs simultaneously (e.g., I have been unable to secure berthing at critical times when the Palmer LTER is using the LMG)	7/23/2018 11:56 AM
15	Thanks!	7/19/2018 2:36 AM
16	Make the USAP vessel a UNOLS ship if you want a top-tier marine research facility.	7/17/2018 12:56 PM
17	N/A	7/17/2018 11:58 AM

18	The Antarctic Plate boundary is uniquely part of polar research despite its generally lower latitude. Much of it, like the American-Antarctic Ridge is practically inaccessible to UNOLS vessels except at unacceptable risk and discomfort. Thus, the exclusion of this zone from programatic support has rendered this key plate boundary, and what it has to tell us about the geochemical cycle in the southern oceans, the evolution of the antarctic plate, and the corresponding controls on the nature of the plate boundary and the crust and mantle there has effectively put out of bounds. A large ship, with ice-breaking capability is needed for this - and it is very unlikely to appear in the UNOLS fleet in the future, and is the proper domain for a wide spectrum of reasons from sea handling and ice capabilities, to the remoteness of the plate boundary from traditional research focus areas for UNOLs and other northern latitude countries. For example, the SW Indian Ridge has not been visited by an NSF Marine G&G cruise for 17 years since the last cruise occurred in 2001. This is a key problem for paleoceanography as well. Being so remote, there is little opportunity for doing research there using the UNOLS fleet.	7/17/2018 9:26 AM
19	please keep both ships	7/17/2018 8:35 AM
20	Thanks for taking this task on.	7/17/2018 7:10 AM
21	The USAP is too focused on hardware solutions and institutionalized priorities giving precedence to some disciplines over others. The people doing the work are key and this merits rethinking the way things are done.	7/17/2018 6:49 AM

Appendix 4. Assessment of the Underway Science Seawater Supply and Underway pCO_2 Measurements Aboard the N.P. Palmer.

Taro Takahashi, Timothy Newberger and Stewart C. Sutherland,
Lamont-Doherty Earth Observatory, Palisades, NY, August 1, 2018

This report is a brief assessment of the underway seawater sampling system based on the performance of the LDEO underway pCO_2 system being operated aboard the N. B. Palmer in sea ice. Some recommendations are made. For this report, the most recent measurements of partial pressure of CO_2 (pCO_2) in surface waters made during Palmer Cruise 18/02 are used.

1) There are two inlets for the underway water sampling system on the Palmer: The so called "Stern thruster tunnel" inlet is the primary one and the alternate inlet is located in the "moon pool". Each inlet is plumbed to a common pipe that leads to the wet and hydro labs and supplies water to all the instruments including the pCO_2 system there. According to the vessel's chief engineer, intake is selected manually: the intake is switched to the moon pool inlet when the stern thruster was used or when heavy ice prevents a good flow of water to the pumps. The trouble with the moon pool is it fills up faster than the stern thruster tunnel. There is a Deicing pump hooked to the moon pool but that has never worked the way they had hoped. Because of the heavy ice conditions encountered during the 18/02 cruise, he manually switched it to the moon pool, but found that suction was lost faster than through the stern tunnel. Accordingly, he rarely deployed the moon pool inlet.

2) The shipboard data contain a flag of 0 or -1 to indicate the inlet for seawater: either the stern thruster tube or the moon pool inlet. This is important information needed for the assessment of water sample quality. Our processing software detects change in this variable and deletes the few pCO_2 observations after an event to make sure that the equilibrator is flushed with new source water. However, the flag has remained at -1 since 2016, this is likely because the moon pool inlet is not commonly used. However, w*henever seawater inlet is switched, we recommend that these events are recorded in the underway data*.

3) The two water inlets are located quite close to each other, and the pipes from the inlets are joined to the common piping system in a very short distance. A remote temperature probe is located at a short distance from the pipe junction for the measurements of SST (= T_{remote}). Salinity of the pumped water is measured by a TSG unit located in the hydro lab after the water is passed through a degasser.

4) The performance of the science seawater system on the Palmer in ice field is evaluated using temperature data selected for seawater temperatures (i.e. T_{remote}) between -1.3 °C and -1.9 °C (freezing point of seawater) during transit through ice fields (Palmer Cruise 18/02). In the hydro lab, the temperature of the sample water is continuously monitored in the pCO_2 equilibrator (T_{eq}). The difference ($T_{eq} - T_{remote}$) indicates the degree of warming occurred during the transit of seawater through the piping system, and it depends on the flow rate through the pipe and temperature difference between sample water and room. We find that

($T_{eq} - T_{remote}$) remains stable (0.2 ± 0.05 °C) throughout the transits. *This indicates that the underway pumping system supplies a steady stream of seawater in a sufficient rate for scientific studies in ice field.*

5) The quality of pumped water samples is evaluated based on the underway pCO_2 values obtained during transits through ice field waters with -1.3 °C and -1.9 °C. Although we had no information as to the presence or condition of ice, we assume that ice was present. In the LDEO system, the pCO_2 in seawater is measured in a parcel of air equilibrated with seawater pumped continuously into a gas-water equilibration chamber. Measurements (recorded every 3 minutes) are continued for 80 minutes and are interrupted for 20 minutes for the calibration of the Infrared CO_2 analyzer. The pCO_2 value (a mean of 9 minutes) immediately before the interruption is compared with that obtained after it. For homogeneous waters suggested by steady SST and salinity (i.e. presumably no eddies and little turbulence caused by motions of icebergs), which lasted sometimes for several days, the pCO_2 values before and after 20-mintute interruptions are found to agree within 2 μatm. *This indicates uniformity of chemical properties of pumped water in time.* In contrast, when SST and salinity fluctuated suggesting small-scale variations of waters, the pre- and post-interruption pCO_2 values differed significantly by as much as several micro-atmospheres suggesting changes in chemical properties.

6) However, small ice particles are transported sometimes through the pumping system into the equilibration chamber of air CO_2 with seawater sample. In extremely heavy pack ice conditions, ice particles accumulate in the pCO_2 equilibrator, and have to be drained periodically by the technicians on board. We do not know how much the pCO_2 values (and other chemical properties) are affected by the presence and melting of ice particles in the equilibrator. *This is an added uncertainty in the pCO_2 measurements (and associated temperature and salinity data) in sea ice fields. Although the uncertainty should be small, a detailed study should be made.*