ARV: Science Mission Requirements

Science Mission Requirements	Threshold Requirement
Key Performance Parameters (KPP)	
Berthing and support facilities	Provisions for berthing, messing, sanitation, and scientific workspaces for ≥55 science and technical personnel.
Icebreaking:	The capability to independently break ice of ≥ 4.5 feet @ ≥ 3 knots
Icebreaking: Polar Code Notation	Obtain an ABS Polar Code: PC 3 notation
Endurance:	Endurance of ≥90 days underway without replenishment. The criteria for meeting this requirement will be based on a Design Reference Mission (DRM) approved by NSF.
Operational characteristics	
Range:	17,000nm without replenishment at the defined cruise speed of ≥11 knots
Operational Tempo:	Average annual operational tempo of 250-300 days/year
Speed:	Cruise speed of > 11 knots in calm ice-free waters at ≤ 80% of installed propulsion motor maximum continuous rating (MCR) **Objective Requirement:** Cruise speed of ≥ 12 knots in calm ice-free waters at ≤ 80% of installed propulsion motor maximum continuous rating (MCR) and maximum continuous speed of ≥ 14 knots in calm ice-free waters.
Sea Keeping:	≥ SS4 - fully operable ≥ SS5 - operable for most routine operations ≥ SS6 - shipboard personnel can safely work 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) Sea-keeping capabilities and environmental controls should allow year-round work in heavy seas of the Antarctic and Southern Ocean as well as within sea ice. 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. The design should promote the safety of equipment operation and instrument deployments.
Station Keeping and Dynamic Positioning:	Meet ABS DPS-1 performance requirements and the following science mission requirements at best heading: • ± 5 meters in 35 knot wind, SS4 & 2 knot current • ± 20 meters in 35 knot wind, SS5 & 2 knot current
Track Line Following:	As close as possible to objective when meeting requirements for station keeping & DP **Objective requirement:** 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 and 2 knots “beam” current.
Ship & Winch Control:	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 • Provides good visibility with clear sightlines to aft working deck and starboard side working deck deployment areas from the ship control and winch control stations. • An aft winch control station (Deck Operations Station) overlooking the working decks shall be provided. • Where needed visibility can be augmented with video cameras, especially for areas blocked from view

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U/W Radiated Noise	"Sonar self-noise" should meet or exceed manufacturer's requirements. Significant efforts should be directed towards making the ship as acoustically quiet as practical without negatively impacting icebreaking capabilities. • Underwater radiated noise and airborne noise specifications should be developed using an experienced shipboard noise consultant. • 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 • Underwater radiated noise criteria that are less stringent than ICES 2009, such as those used for the RV *Sikuliaq*, RV *Armstrong,* and RV *Ride*, should be considered as a target.
Off Vessel Support for Field Work and Logistics:	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, and inherent in many others such as endurance, icebreaking, dynamic positioning, seakeeping, etc. • In developing the operational profile and design specifications the support for these activities off the ship should be carefully considered. • The requirements for Work Boats and the ability to rapidly and efficiently deploy and recover these work boats is key to meeting this SMR. • Capacity to transport, deliver and pump ≥60,000 gallons of various grades of diesel to Antarctic research stations within the total fuel capacity required to meet endurance requirement.
Science and shipboard systems	
Navigation:	Best available navigation (real-time kinematics, differential, 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.

<table>
<tr><th>Science Mission Requirements</th><th>Threshold Requirement</th></tr>
<tr><td>Data Network:</td><td>
High-speed data processing facilities capable of handling large data sets for rapid processing, display, evaluation, and archiving are needed. System hardware should be designed to accommodate the highest data rates available at delivery of the vessel.

data sets might include LiDAR elevation surveys from glaciologists, seismic imaging and multibeam swath map output.
System should 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 (4) network drops per stateroom are required (2 - person owned computers, 1 - smart tv, 1 - IP phone).
At least One (1) network drop per common area, lab and other areas to be designated for WIFI (WAP).
Two (2) drops per station in all computer / dry lab areas.
Four (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 several monitors.
GPS strings must be available in every lab.
All labs should have WIFI access and LAN drops, at least every 4 bench feet.
There must be a lab dedicated to servers, etc. that has adequate space for racks and other DAS equipment.

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.
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.
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<tr><td>Real Time Data:</td><td>
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
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.

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Internal Communications:	Internal communications including phones, PA, entertainment systems, ship alarms, some bridge comms, via LAN, voice and CCTV connections throughout laboratories and living spaces should be designed and provided with an integrated approach and should include: • 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. • 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. Fiber-optic cabling for data and VOIP communications should be installed throughout vessel.
External Communications:	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. 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 ARV design should have a suitable mounting location for a 1.5m dynamic antenna to support direct satellite reception. The technical specifications for external communications should be re-evaluated at final design time to consider 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.

Science Mission Requirements	Threshold Requirement
Science Seawater System:	Flow-through scientific seawater system capable of delivering ≥40 liters/minute to all laboratory spaces. **Objective requirement:** System capable of delivering 100 lters/minute. The underway system should be designed with the following criteria: • 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. • 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. • Minimize the time lag between intake and sampling location (sensor suite and/or lab sinks) with an objective of less than 2 minutes desired. • 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. • If more than one intake is installed ensure that the intake being used is flagged in the data stream. • 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. • Provide underway seawater taps at 4 or more sinks in lab-accessible spaces • Allow users to configure to either continuous or discrete sampling of underway. • Additional access points should be provided in sinks in other labs (chem. labs, trace metal labs, wet lab) • Ability to access underway seawater from labs in vans on deck). • Design for installation of additional sensors (user-supplied or ship supplied) mounted near the ship's 'standard' CTD-fluorometer package. • 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. • The underway sampling system should include an infrared sensor installed at the bow for measuring sea surface skin temperature. • 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.
Acoustic Systems: General	The hull design and structure for transducer installation should support the installation and operation of the following systems: General Requirements: • At sea transducer maintenance capability wherever possible. • Hull design or features designed to minimize bubble sweep down • Noise and vibration treatments to minimize SONAR self-noise
Acoustic Systems: Multi-Beam Mapping	Deep Ocean and Shallow Water multibeam bathymetric mapping systems.
Acoustic Systems: ADCP	38 kHz and 75 kHz Acoustic Doppler Current Profilers (ADCP) **Objective requirement**: a 150 kHz and/or 300 kHz (ADCP) systems for use in shallow water
Acoustic Systems: Sub-Bottom Profiler	3.5 kHz Sub-Bottom Profiler, CHIRP or Parametric Narrow Beam Profiler.

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Acoustic Systems: 12 kHz systems	12 kHz Echosounder and 12 kHz Acoustic Release transponder
Acoustic Systems: Bio-Acoustic systems	Bio-acoustic Sonars – 38, 120 and 200 kHz transducers as a minimum **Objective requirement**: Bio-acoustic Sonars –18 and 70 kHz in addition to the threshold requirement
Acoustic Systems: USBL	Ultra-short baseline (USBL) underwater systems positioning transponder (e.g., HiPAP)
Acoustic Systems: Monitoring	Hydrophones and Hull-mounted Underwater Cameras (forward looking) for acoustic and bubble sweep down monitoring.
Acoustic Systems: Forward looking SONAR	Forward looking SONAR for navigation
Acoustic Systems: Spare Transducer Wells	At least one spare transducer well for the installation of mission specific equipment. Transducer well should be sized to fit a ≥19" diameter transducer or the maximum size allowable by the surrounding structural members. **Objective requirement**: Two or more spare transducer wells for the installation of mission specific equipment. Transducer wells should be sized to fit a ≥19" diameter transducer or the maximum size allowable by the surrounding structural members.
Seismic:	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. Use Containerized Compressors and systems that can be easily configured on board. Need to have a regular maintenance facility to ensure equipment remains functional. (Seismic Air Compressors (Borsig-LMF) 2 each 385 scfm at 2,000 psi)
Project Systems & Power:	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. Design Considerations include: • The types of equipment will need to be defined during preliminary design cycle, 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 include 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. **Objective requirement:** The ability to provide direct power to select systems designed for foreign power requirements should be considered.

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<tr><td>Discharges:</td><td>Compliance with new environmental regulations, such as emissions and discharges, is required.

• The ARV 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 nm. from land or ice and/or shore.
• There can be no discharge of food wastes onto ice.

Science related requirements:

• All vessel underway discharge must be consolidated to one side of the vessel (normally port side) providing a “clean working side”.
• As a minimum, a holding period for treated wastewater to be 20 days. Onboard marine sanitation device (MSD) to be appropriately sized to be able to process grey or black water at the same or greater rate as USCG standard daily generation rates for crew and passengers.
• A careful evaluation of daily wastewater generation and holding time requirements should be made as part of the design once crew complement and waste treatment and holding tank specifications are developed. Objective requirement: Increase holding time of treated wastewater to 60 days.</td></tr>
<tr><td>Science working spaces</td><td></td></tr>
<tr><td>Working deck area:</td><td>Working deck(s) area of ≥ 5,500 ft2

Design criteria includes:

• Deck loading should meet the current ABS rules
• 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 should be evaluated in the deck design.
• 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 and 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.
• Bulwarks should be removable and all deck-mounted equipment should be removable to a flush deck as much as possible to provide flexible re-configuration.
• Hinged freeing ports or other means should be provided to maintain dry deck conditions in beam or quartering seas.

A clear foredeck area and other additional deck areas should be capable of flexible and effective installation of:

• small, specialized towers, booms, incubators, vans, workboats, UAS, and other temporary sampling equipment.

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 on decks supporting the installation of incubators.
• Covered by direct visibility and/or television monitors from the bridge with maximized direct clear visibility for deployment areas.

The main exterior working deck should be equipped to keep key working areas ice free.</td></tr>
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Science Mission Requirements	Threshold Requirement

Laboratories:	Scientific laboratory space of ≥ 5,700 ft^2 to accommodate up to 55 scientists.
	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)
	• Environmentally Controlled Lab (~100) [Autosal]
	• 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 (~100)
	• Changing/Mud Room (~100)
	• Hazardous material storage lockers on main deck
	• Gravitometer – appropriate space and location to meet operational and any security requirements.
	Objective requirement: Scientific laboratory space ≥ 6,500 $ft^{2.}$ Use Containerized Lab Vans for functions that are not needed on every cruise to the maximum extent possible.

Science Mission Requirements	Threshold Requirement
Layout & construction - General	Flexibility and support for different types of science operations within limited space are the important design criteria for these vessels. Construction and Material Requirements: • 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. • The ability to easily install or remove cabinets and drawers as needed between cruises should be included. • Provisions for large, flat chart/map tables including a light table should be incorporated. • High quality benches and cupboards installed in all lab areas. • Countertops should be chemical resistant where needed. • 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. • 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. • 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. • 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 Unistrut™ on the bulkheads and in the overhead. Consider Fiberglass Unistrut™ • 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. • 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. **Objective requirement**: Installed gas bottle racks in all labs, removable, 5 bottles each.
Layout & construction - Lighting	Lighting Requirements: • Include natural lighting in most labs, with the ability to black out portholes. • Light levels in labs should meet UNOLS standards, 100-foot candles. • Lights must be controllable in the aquarium room to darken space.
Layout & construction - Decks	Lab Deck Requirements: • 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. • Labs should have bolt downs (1/2”-13NC on two-foot centers) in the. Deck bolt downs on one-foot centers should be considered for some areas.

Science Mission Requirements	**Threshold Requirement**

Layout & construction – Fume Hoods, Sinks, Water & Air	Fume Hood Requirements:
	
	• Locations for two chemical rated fume hoods with explosion proof motors in the main lab and one in the wet lab should be included.
	• 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.
	
	Sink Requirements
	
	• 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 located with the fume hoods) 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.
	• Fresh water, hot and cold must be available in:
	  ○ All labs except computer or labs with only electronic equipment.
	  ○ 1-3 sinks per lab.
	  ○ Salt water from the uncontaminated seawater system must be available in each lab with a sink.
	  ○ Seawater must be available in copious quantity in an aquarium room.
	• 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. All lab spaces should have at least one eyewash station.
	Objective requirement: Other design criteria to consider and include as much as possible include: Microscope Room [should be] quiet, low vibration, [with] space reservation for antivibration table, compressed air connections, water and sink, no window required. Ice makers required in 1 or 2 labs.

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Lab Electrical - General	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 consider 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 included to the maximum extent possible. • Clean uninterruptible power should be available throughout all laboratory spaces, bridge/chart room, and other spaces as necessary to protect equipment, data, and operations. o 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. • Scientific wire ways must be considered throughout the ship connecting relevant scientific workspaces. • 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 workspaces on different ship levels shall be used. • The quality of the electrical power supplied to science & ship control systems is very 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).
Lab Electrical – Circuit and Receptacle Requirements.	Electrical service for the labs should include: • 110/120 VAC, single phase 75-100 amps service for 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. • 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). • 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 in route to science stations. **Objective requirement:** Foreign Equipment Power Capability - 2x 20 Amp per lab and computer space at 220V 50Hz or the ability to provide conversion for foreign equipment power requirements when needed.

Science Mission Requirements	Threshold Requirement
Vans:	Total supportable vans in all spaces should be ≥ 20 • Space is needed for carrying at least seven (7) “UNOLS Standard” lab vans or equivalent on the main aft deck plus the aft areas of decks above the main deck. • 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. • Capacity to carry at least eight (8) standard containers (including, for example, laboratory, berthing, or frequently accessed storage vans) in an accessible and human habitable working area below decks. • 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. • 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. • Work with radioactive materials should be restricted to radiation lab vans that remain isolated from the interior of the vessel. **Objective requirement**: Total supportable vans in all spaces should be ≥ 24
Storage:	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, separate from crew hazardous materials. • 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 bulk cargo items to be delivered to Antarctic sites 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 for hazardous items storage, including in the laboratories, and for chemical wastes. 2. Significantly increased storage is needed for scientific cargo. This would include support for the storage needs of multiple cruise legs. The basic scientific cargo storage space should be at least twice that of the Academic Research Fleet global-class research vessels. **Objective requirement:** Maximize scientific storage space available.
Science Load:	Sufficient variable science load should be included in weight, draft, and stability calculations taking into account the required variable scientific equipment and systems, science storage, vans, additional work boats and deck load.

Science Mission Requirements	Threshold Requirement
Workboats:	The research vessel should be equipped with two 20-to-30-ft rigid hull inflatable boats (RHIBs) or the equivalent. • To transfer of scientists and their gear from ship-to-shore and ship-to-ice to make measurements, install instruments, and collect samples. • To conduct supplemental research activities that are made away from the vessel. • Boats should be optimized for work in brash ice and rocky shore landings. In addition, 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. • The scientific workboat shall be launched via its own davit system. Include a landing craft style workboat (25-30 ft LOA) or alternative to ensure the ability to land personnel and supplies ashore in support of field work. The RHIBs and Workboat locations on the research vessel should facilitate safe, easy and efficient launching and recovery. The preference is to be able to launch craft with personnel aboard, rather than transferring people to the boat.
Masts: Fore and Main Mast	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 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. 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 and continuous connectivity at any heading.
Masts: Other Sensor requirements	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.

Science Mission Requirements	Threshold Requirement
Geotechnical Coring & Drilling:	The vessel must be able to core sedimentary sections in ice-covered seas. The vessel must be equipped to acquire long stratigraphic sections (40 m piston core). The vessel 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. 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. **Objective requirement**: 50 m piston core capability.
Deck Incubations:	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. Incubator seawater should be within 1°C of ambient seawater temperature. Fittings for water supply and outflow drainage will be required on the deck and as close to incubator locations as possible. Drain lines should be as large as possible to ensure proper flow through the incubators along with measures to prevent freezing. The total number of incubators to be serviced at one time should be determined considering 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.
Mammals & Bird Observations:	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. **Objective requirement**: Dedicated marine mammal and bird observation area.
Accommodation and Habitability	
Habitability: Mess Deck	Include galley and mess area capable of serving 4 meals per day isolated from noise. **Objective requirement**: Mess deck should be equipped with large windows for easy outside viewing and allow for natural lighting.
Habitability: Polar Clothing Storage	Include space to store and change into polar clothing
Habitability: Quiet Berthing Area	Isolate living spaces from noise; Hotel area to be 24/7 quiet zone
Habitability: HVAC Temperature	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.
Habitability: HVAC Humidity and Air changes	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

Science Mission Requirements	Threshold Requirement
Habitability: Airborne noise	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. • Labs & Normally Occupied Spaces ≤ 60 dB • Working Decks ≤ 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. 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." **Objective requirement:** Meet or exceed ABS HAB++ (WB) notation.
Habitability: Vibration	The ship and all ship components shall be free from excessive vibration. • 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.
Habitability: Lighting	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 and normal lighting. **Objective requirement:** Labs have natural lighting to the extent possible, with the ability to black out portholes.
Habitability: Human Engineering	Human engineering principles should be applied in the design of workspaces, including the use of natural lighting where possible. Headroom shall be maximized where possible with the following defined minimums from the deck to the underside of the finished overhead: • Main Deck Spaces = 7.5 ft • Common Area Spaces = 7.0 ft • Accommodation Spaces = 6.75 ft Headroom space and room for the installation of tall equipment shall be maximized while balancing the need for cable trays, adequately sized ventilation ducts, lighting, etc. **Objective requirement:** • Main Deck Spaces = 8.0 ft • Common Area Spaces = 7.5 ft • Accommodation Spaces = 7.0 ft

Science Mission Requirements	Threshold Requirement
Construction, Operation & Maintenance	
Green Ship:	Meet IMO, USCG, Polar Code and Antarctic Treaty requirements. 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. **Objective requirement:** These features might be included in the design and specifications: • 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. Underway battery operation periods of approximately 1 to 4 hours at slow speeds (1 to 3 knots) or while holding station in calm weather is desired. A hybrid battery system also offers additional benefits in terms of peak power load shaving and instantly available power reserve in case of a generator failure. The capacity of the battery system should be maximized within the constraints of space, weight, and overall project cost.
ADA Compliance:	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. Implement specific guidelines detailed in NSF Memo (Ref 3 Jan 2022)
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. • 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).
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.
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.