Antarctic Research Vessel Science Advisory Sub-Committee (ARV SASC)
of the Office of Polar Programs (OPP) Advisory Committee

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INTRODUCTION

The primary goal of the Antarctic Research Vessel Science Advisory Sub-Committee (ARV SASC) is to provide both general and specific guidance on the design of the research vessel that will be tasked with supporting science for the US Antarctic Program over the next several decades. To accomplish this, over the course of the past 10 months, and through an iterative series of Interim Design Reviews, the ARV-SASC reviewed hundreds of documents that described design features of the proposed new Antarctic Research Vessel (ARV). One of several key performance parameters (KPP) guiding vessel design is that the ship be a "heavy-duty" icebreaker, classified as Polar Code PC3, capable of breaking ≥ 4.5 ft ice @ ≥ 3 knots. With an icebreaking capability superior to that of the current vessel, the RVIB *NB Palmer*, the proposed ARV will be able to access regions of the Antarctic margin that were previously inaccessible due to heavy ice cover, and to work more capably across the Southern Ocean year-round. An endurance of 90 days, another KPP, will facilitate voyages to the more remote parts of the East Antarctic margin, accessible only via long transits, and will take into account the time needed for heavy-duty icebreaking, considered likely as research groups conduct winter work and work in areas with difficult access, even in the warmer months. Finally, the ship will be able to hold 55 science personnel. This number includes both scientists and science support staff, to accommodate multi- and interdisciplinary cruises and those with increasingly sophisticated technical operations.

Our review process was guided by several overarching themes for design, including safety, flexibility, green ship operations, and "future proofing." This ship is planned to come into use in the year 2031 and to serve the community for 40 years. Accordingly, we tried to anticipate how to best accommodate technological advancements that may require different uses of space, for example increased data storage and computing needs, or new types of instrumentation and sensors for underway measurements.
We evaluated (1) the location and interconnectedness of lab and deck spaces, and how they are outfitted, (2) over-the-side handling and scientific package deployment, with consideration of safety and ease of

current and projected operations, (3) ship habitability, including both private and public spaces, with consideration of creating a welcoming, safe, and inclusive environment, and (4) green ship technologies.

We recognize here, as described in our first report, that two specific recommended Science Mission Requirements (SMRs) from the 2019 subcommittee report, the moonpool and a two helicopter-based science capability, are not included in the ARV design under review. In this report we discuss how operations that might have been planned for a moonpool, such as drilling and deployment of ROVs, can be accomplished with the proposed design. In terms of the hangar space for two helicopters, we recognize that the current design does not fully address the concerns raised at the February 9-10 National Academy workshop “Future Directions for Southern Ocean and Antarctic Nearshore and Coastal Research.” The scale of helicopter operations possible on the ARV has grown over the past 10 months, but clearly continued conversations between the NSF and the National Academy group addressing this issue lie ahead.

This fourth and final design review summarizes the status of the ARV design, highlighting the positive changes to ship design that have been introduced over the course of the past 10 months. We also list open issues that have been identified, and that will be addressed and resolved during the next phases of ship design, post preliminary design review (PDR) which took place February 21-24, 2023. We provide specific comments on broad scale aspects of lab space design and over-the-side handling that we recommend be incorporated into ship design, to optimize science operations and we include smaller-scale “in the weeds” comments as a record of elements that we hope are not overlooked as the design is finalized. We include tables that summarize specifics of General and Space Arrangements (Table 1), space allocation (Table 2) and Science Containers (Table 3), as well as tables that address a proposed scope management plan (Tables 4 and 5). We conclude by providing recommendations aimed at creating a workspace and living environment on the ARV that is positive and supportive.

SECTION 1: General Review and Highlighting Positive Changes, Addressing Challenges

The ARV design has evolved greatly in response to a combination of needs. First, the overall dimensions of the ship have grown to meet the Key Performance Parameters of icebreaking capacity (≥ 4.5 ft ice @ ≥ 3 knots), range and endurance requirements (90 days), and to meet seakeeping requirements. The ship design is now at 365 ft length overall (LOA) and 80 ft beam (widest part of vessel). As a consequence of the larger overall dimensions, the ship’s superstructure has been reduced in height, and the weather deck area has increased, with more working space available for science. In addition, there are more single berth staterooms, several with dayrooms, and the stack has been relocated to the port side, opening up an easily navigable central passageway and facilitating the capability of 360-degree observation from the Marine Mammal Observation space. We also note the consideration of green technology throughout the design process, for example, identification of the use of batteries to conserve power consumption and as a reserve. This scale of change has been generated primarily through the knowledge and expertise of the design team.

Changes to ship design also reflect advice from our subcommittee, based on our weekly discussions and the incorporation of suggestions from the many technical experts and research colleagues we have contacted. Highlights include:

- reorganization of lab spaces on the main deck level to cluster wetter lab spaces aft, and drier spaces forward,
- improved connectivity of spaces to foster ease and efficiency of sample and instrument movement,

- identification of a Science Operations Center, Bio/Chem/Analytical Lab, and space allocated to photo and video editing in the Electronics Lab,
- relocation and reorientation of the Science Lab Van Bay on the back deck, providing interior main deck access to three containerized science labs,
- increased size of UAV deck and hangar, and relocation to center position,
- addition of science seawater access to the UAV hangar and deck, increasing flexibility in locating incubator space,
- combining Meteorology Lab and Marine Mammal Observation Space,
- Incorporating a greater number of single berth staterooms, and several with dayrooms intended for private conversation,
- designing common spaces on the 01-deck, a conference room, lounge, and the gym to be large and inviting, with natural lighting, with additional smaller common spaces located on the berthing decks.

Other features of ship design that we are excited about include the comprehensive suite of science underwater sensors, the box keel design, and the inclusion of 4 science support workboats, including two 6-7m Rigid-Hull Inflatable Boats (RHIBs), one 10 m Science Survey Boat, and one Landing Craft. We hope the variety of workboats will allow for greater flexibility in working recovery of over-the-side instruments, science operations in areas away from the research vessel, and landing capabilities of personnel and equipment on shore. The Lab Van Garage provides a sheltered space on the back deck for designated science operations, and the Marine Service Bay is a space for working in a sheltered and easily accessible space (from starboard and aft), with large instruments, such as ROVs and AUVs.

As noted in the introduction, the proposed ship is not designed with a moonpool. Lack of a moonpool means that geotechnical drilling through a moonpool will not be possible. However, the large back and starboard decks, space for specialized science vans, and winch and A-frame capabilities on the new ARV will be beneficial as we continue to assess over-the-side and seabed-based drilling platforms that can access continental shelf drilling sites. The specific requirements for the MeBo200 system of seabed drilling (https://www.marum.de/en/Infrastructure/Sea-floor-drill-rig-MARUM-MeBo200.html) are included as an example in this report, so that likely deck space and over-the-side handling requirements are clear and readily available. We also include links to details about the Shaldril program (https://dosecc.com/shaldril/; https://sd.copernicus.org/articles/1/40/2005/) which utilized a small moonpool located mid-ship on the starboard side of the NBP for drilling. Decisions about the optimal drilling platform will be community-driven and beyond the scope of this report; we simply want to be certain that the ARV will be drilling-capable.

Initial design of the ARV had space on the Aviation Deck for vertical resupply by helicopter, that is, sling loads could be accommodated. Over the course of the review process, the Aviation Deck has increased in size and now has the capability to host the landing and takeoff of a single helicopter. This will facilitate the ease of helicopter use for 2-ship operations and other missions, however as noted in the introduction, continued conversations between the NSF and the National Academy group addressing adding further scope to helicopter support lie ahead.

SECTION 2: Science Systems and Spaces

Here we describe and summarize some of the bigger topics of discussion, with extended details of how critical science systems and spaces might be utilized and optimized.

Science Seawater Systems:
Operating Science Seawater systems in extreme cold temperatures and ice-covered waters is difficult. We emphasize the need for redundancy in the sea-water intakes as well as the pumps feeding the science seawater system in case of equipment failure, freezing or clogging with ice, which has been a common problem during times of VERY cold environmental temperatures. Maintaining water flow is critical all the way through the system, as problems arise if the pumps stop or the drains freeze. We note that the science seawater system consists of two separate systems - 1) high pressure for incubators, aquarium, and any other high-flow applications, and 2) low pressure for seawater feeds to sensors and labs. High-capacity pumps are required for the high pressure system and lower capacity pumps for the low pressure system. It is noted that the diaphragm pumps that are better for the “critters” (they are gentler and are less likely to damage organisms) do not always work well when the vessel is in areas with lots of ice. Ideally the pumps will be accessible to allow the science support team to install the correct type of pump required for the science operations of the cruise. The pumps as well as the intakes should be interchangeable so a pump failure or an intake clog will not create a system failure. The pumps for each system must be capable of dealing with the systems in full use or partial use. It also is important that the system is able to deal with instruments being added or replaced in case of failure, and samples being taken, without varying the pressure significantly.

It will be important for the vessel design to model the ice flow around the hull to identify the best locations for the seawater intakes. Once these locations are specified, studies should be completed to analyze the residence time from the intake (where seawater temperature should be sampled) to the various seawater outlets and also efforts must be made to make sure that the water sampled, especially from a sea-chest, is representative of the water the ship is passing through. The critical factor is that the sea-chest should be flushed constantly or else the system will draw from stagnant water that was held in the sea-chest for a while.

Throughout vessel design, the integrator should consult with others who have operated science seawater in extreme cold and ice. This includes the USCG HEALY and the RV SIKULIAQ. It is assumed that any lessons learned from the RV NBP will also be incorporated.

Specifically, comments received on the design drawings by components are:

Intake:
1. As mentioned above, two intakes are key, especially in ice. Modeling should be conducted to find the optimal intake location.
2. It is important that the system has a grating on the skin of the ship to prevent large materials from getting sucked into intake.
3. The intake should be located away from other discharges to minimize any possibility of contamination. On Healy, there have been issues with sewage discharge but also intake of sediment and biofouling into the SSW system when ice scrapes along the hull.
4. An ice separator which separates small chunks is recommended. This strategy has been implemented on the Healy and NBP; this has proven useful to divert the small ice pieces and send them out the discharge line, preventing frequently clogged strainers.

SSW Pumps:
1. Are the pumps positive displacement or centrifugal type? If the spec is for positive displacement, then there needs to be a design consideration for how to handle over pressurization in the system in order to prevent blowout such as a relief valve with a set point that will direct water back to the intake. The

drawing looks like it will have pressure relief valves but will these send water to the overboard discharge or back to the intake?
2. Multiple pumps may be required to keep the optimal seawater flow rates in ice. Healy has 4x 220 GPM monoflo progressive cavity pumps and we have had to run 3 (typically at a 60/20/20 VFD split) in ice conditions to help keep required flow to our water walls, labs, and aft deck van hookups (all on Main Deck) while also being able to remove ice chunks from the system piping. Healy has fewer lab spaces and sink manifolds, no aquarium, and only overcomes pressure head from 2nd platform to the Main Deck, not to 04 deck.

Supply Lines to labs and other spaces:
1. Recommend having pressure gauges in the Main Deck lab supply manifold, 01 deck aquarium, and 04 deck incubator locations not just at the intake pumps. There is a lot of pressure head to overcome, and it is helpful to have those values available in addition to the flow meters.
2. Recommend y-strainers prior to each sink branch. Sediment settling or small shells and other detritus making their way to sinks and clogging supply lines can be an issue.
3. An intake seawater temperature system should be mounted in an area as close to the intake(s) as possible. This area should be accessible in the case that the sensor needs servicing.
4. What kind of deck exposure will the incubator, working deck, and van supply lines have? Healy has an exterior manifold for SSW supply (as well as potable water) to vans on the aft deck. While in the Arctic, all exposed piping and valves frequently froze despite having lagging and had to be de-iced using hot potable water via hoses run from lab spaces out to the deck.
5. An increased number of scientists are conducting measurements on the dissolved gasses in the underway seawater. Efforts should be made to allow for sampling near the intake, before ice removal devices as these can introduce gases.

Vent and overboard discharge:
Overboard discharge lines can freeze, which can cause the entire system to go down or can cause a rupture in vent lines when the system is over pressurized without an adequate pressure relief line.
The piping may need electric heating tape applied and the run needs to be located in void spaces that are accessible to apply new heating tape to. Recommend access to all parts of the piping run for this reason.

For the drains, for the aquarium room, outlets must also be heated to prevent freezing.

Finally, we recommend consideration of how the Science Seawater System can be cleaned.

Deck Incubator Space:
For maximum flexibility, as long as a space has tie-down capability and piping for seawater, it will be possible to locate deck incubators in those spaces. Currently the plans have seawater piping on the main deck, the 01 deck, and to the aviation deck. Note that incubators need open sky and must not be shaded from other structures on the ship. This can be tricky; in the current plans for deck incubators on the 01-deck, they are shaded by the Aft Crane. Incubators located on upper decks will require extra heavy lifting to move large carboys, but this is something that the elevator could be used for. Smaller, spiked samples in bottles would still have to be carried to stay on the exterior of the ship, in accordance with keeping the interior of the ship radiation free.

Temperature-controlled Cold Rooms and Incubation Experiments:
We anticipate that experimental incubation work will be conducted in the temperature-controlled cold room labs, and that some of these experiments may be conducted with trace-metal clean conditions. We are uncertain if either or both the cold rooms will have SSW plumbing. Each cold room will have a

temperature range between -30 C to +10 C (-20 F to +50 F). Colleagues have indicated the need for tight temperature control (+/- 1 degree C may not be adequate, suggest +/- 0.5 degree C) with adequate air circulation in the cold room to maintain a consistent temperature throughout the room, but they recognize the challenges. They note that if experiments are being conducted at around 0 degrees C, that a temperature control of +/- 1 degree C can really impact the results, if you have the thermal control wavering much above it. Given the range of seawater temperature in the Southern Ocean, from -1.8 to ~ 4 degree C, being able to do experiments to maintain those temperatures accurately is essential for careful physiological/biogeochemical rate-related research. Small changes in temperature can translate to large differences in metabolic rates, so accurate control is needed. For larger, seawater (plankton) mesocosm-style incubations conducted in 1-20-liter bottles or carboys in the refrigerated wet-lab rooms, light controls, the potential to work with UV dosages, is needed to simulate different environmental conditions.

Aquarium Room:

The Aquarium Room location should be as far aft as possible, to facilitate transfer of live animals from the back deck to aquarium room tanks, and be adjacent to the wet lab. Tanks should be modular to the extent possible, and include room for both large Xactic tanks (foot print for up to 6), and a standalone two-shelf/cascading seawater unit (6-8 ft long) that can hold multiple, smaller individual aquaria or bottles. The cascading shelf unit would also have the ability to be plumbed to deliver water to individual small aquaria. For Xactic tanks, the ability to also have shorter tanks (half high; 2-feet tall instead of 4-ft tall) that can be stacked on two-shelf units is desirable. These units would have the same footprint as the full-height Xactic tanks, but allow the option to have 12 tanks instead of 6. The shorter tanks could also be used unstacked to hold and keep at temperature individual buckets (e.g.,10 x 5-gallon/ 20-liter paint-type buckets) or other containers too large for double-shelf cascade tanks.

The room should be plumbed with independent controls for seawater flow to individual Xactic tanks, and to the standalone two-shelf/ cascading seawater unit. It is imperative that the pumps run continually and measures are taken to prevent them from clogging/stopping, especially in ice and winter conditions. We note that fish collected at depth may not be fortified with sufficient levels of antifreeze proteins to protect them from the near-freezing seawater temperature at the surface that is circulated through the ship in the winter. We are not sure if this is also a problem for invertebrates. We request discussion about how to maintain water temperatures so that animals do not freeze during winter cruises - perhaps through temperature control for specific tanks, such as immersion or in-line heaters for warming. In summer, chillers may be needed to keep seawater temperatures sufficiently cold. For conducting pH-controlled experiments in the tanks, the gas bottle racks for CO2 cylinders or other gasses and associated tubing are indicated in the current design. Lighting intensity in the room should also be controlled.

The room should have re-configurable bench space (3-6 ft) for placement of experimental monitoring equipment (e.g., computer attached to temperature or oxygen probes in tanks), and for keeping notebooks, aquarium nets, and other equipment being used off the floor. Removable sills may facilitate moving heavy items in and out of the Aquarium Room. On cruises with high demand for Aquarium Room space, a plumbed “Aquarium van” could be added and located farther aft on the back deck. Importantly, because of the long distance between the A-frame, where animals are brought up on deck, and the aquarium, a system needs to be developed to transport animals in seawater from the back deck A-frame to the aquarium.

Science Vans/Containers:

As required, space for 20 Lab Vans is allocated with 3 science containers in the Lab Van Garage, 2 on the AUV deck, 8 vans double-stacked in the hold, and the remaining vans located on the back working deck. It is important to note that, as described in the Design Team's Science Systems Report "Active Lab vans would only be supported on deck, however Vans stored in the hold will have access to end doors and refrigerator Vans will have electrical service. The containers are served with ample space within the hold about their perimeter, and a folding catwalk allows access to both the forward and aft end of each container." We request clarity on whether this means that Vans in the hold would only have access to electrical, but not water or heat. As described, it seems that Vans in the hold are intended primarily for storage, potentially including refrigerated storage.

We are excited about the inclusion of the Lab Van Garage which allows for protected access to van space from the interior of the ship, even under adverse weather conditions. As noted in the Science Systems Report, however, concerns about isotope contamination in the interior of the ship precludes locating the Rad Van in this space. Continued discussion of strict protocols for use of a Rad Van, the inclusion of a vestibule in the Rad Van, to store polar outdoor gear and boots PRIOR to moving into indoors (lab) or other outdoor spaces, and a sink for handwashing, are actions that are highly recommended. Several other science vans likely would not be situated in the Lab Van Garage, including the multi-sensor sediment core logging van, with its cesium source that requires specific orientation, and seismic compressor vans, which can be very loud. Finally, we note that the Aviation Deck has space for two vans. Table 3 lists and describes potential science containers.

Atmospheric Lab:
We suggest continued discussion of how a fold-down mast, that might be required to facilitate safe flight operations, would impact the continuity of atmospheric measurements given that this is the location of the intake to the atmospheric lab. We also suggest continued attention to the space arrangements. This lab space could house ion chromatography instruments which need a source of deionized water and a sink; the instrumentation requires gas cylinders and compressed air. The space will also need a hood and hazardous materials storage for working quantities of solvents and acids, and sample handling will require a glove box. Internet access and desk space for laptops and data processing is also needed.

Workboats:
Key requirements for small boat operations are safe, easy, and nimble deployment and recovery of boats. Boats must be powerful enough to transit through brash ice. As described in the introduction, plans include 4 science support workboats, including two 6-7m Rigid-Hull Inflatable Boats (RHIBs), one 10 m Science Survey Boat and one larger Landing Craft, with the three smaller boats located on the 01-deck, port side aft. One of the smaller RHIBs and the Science Survey Boat will each have its own davit system for deployment and recovery, which should facilitate faster deployment (as long as boats are fueled and ready to go - and scientists are ready with their gear). The ability to get the boat in/out of the water quickly is highly desirable (e.g., for opportunistic sampling of fast-moving whales or recovery of gliders in tight weather windows); a shared crane to deploy and recover boats means that no other operations can go on while a small boat is in the water, and this could be alleviated if there was a dedicated davit or crane for small boats. We recognize the speed of these operations are subject to safety considerations which are evaluated by the captain and the crew.

We anticipate that all 4 boats may not be needed on every cruise, and that use of fewer boats will, at times, open up 01-deck space, providing more room for incubators and / or science containers. We hope the variety of workboats will allow for greater flexibility in working recovery of over-the-side instruments, science operations in areas away from the research vessel, and landing capabilities of personnel and equipment on shore. The science survey work boat provides extended capabilities for a large range of scientific activity, including, for examples, the ability to collect multibeam data in uncharted areas and areas close to shore, to collect seismic data using a Chirp/Sparker and towed streamer, and to conduct bio-acoustic surveys. The landing craft will improve the ability to move science parties and lots of cargo to shore and make possible work in coastal areas that have access at sea level.

The SOLAS 4.8M RHIBs are requested by frequent workboat user colleagues (whalers and birders) to be part of the workboat complement of the new ARV. These are currently used around Palmer Station for whale UAS, tagging, biopsy, and survey work, and for seabird surveys. The bow pulpit is critical and the aluminum hull makes them much better in ice. The pulpit is also nice for landings because it makes the transition from boat to shore safer, giving you something to hold onto. They are fast and nimble and very safe but have a limited capacity (great for small numbers of people, <5). Frequent workboat users asked about fuel capacity and the likely distance from the ARV that these boats could travel, recognizing that the answer to this question also is dependent on sea state and weather conditions, and safety decisions made by the captain.

Finally, a related question is with regard to rescue capabilities and speed of deployment of the rescue boat. There are criteria for certification of a rescue boat, and rescue operations are tested and practiced.

Handling Systems:

As noted by the Design Team, details regarding the two back deck cranes, aft and starboard, need to be addressed. This includes crane reach - can they place vans where they need to be, and reach boats on 01-level? The aft crane may have too long a reach, and also when stowed, it takes up a lot of space and shades incubator space. The Design Team is trying to keep both cranes the same, so that spare parts and maintenance are streamlined.

The starboard A-frame needs to be able to support Jumbo Piston Coring operations, as well as other heavy workload operations, including those that may be planned for the future, for example, over-the-side and/or seabed drilling. Consequently, the A-frame needs to be situated where it has support from the ship’s structure. Exactly how it will be attached to the ship is not clear yet. When in use and deployed, people are able to walk on the starboard deck. The Design Team notes, as an open issue, the details of placement of the starboard A-frame and its “impact of side frame foundation on wet lab and aquarium.”

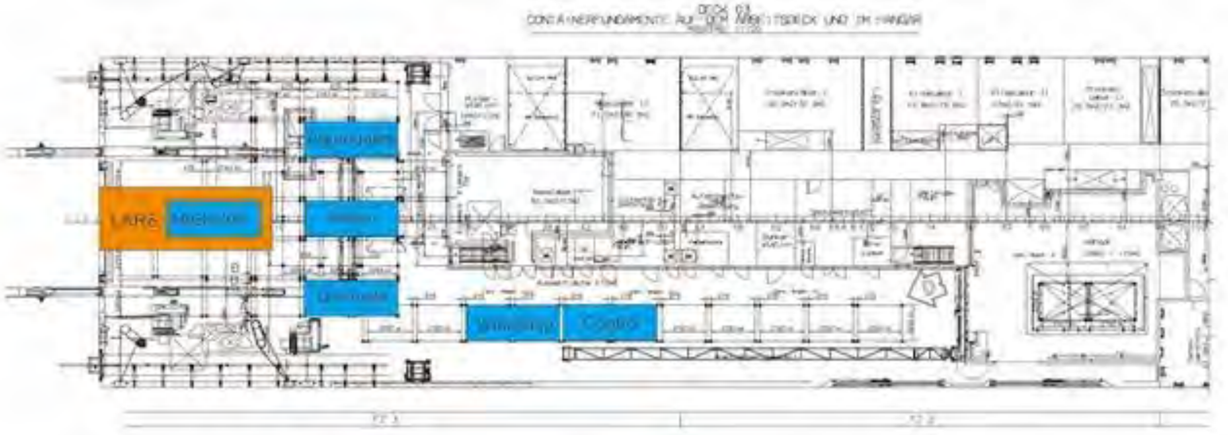
Note that MeBo Seabed Drilling requires a A-Frame lifting capacity (min) of 30 t; this is one drilling system that is being considered for use on the ARV (https://www.bauer.de/export/shared/documents/pdf/bma/datenblatter/MeBo_EN_905.808.2.pdf). We ask for clarification on the conversion of the lifting capacity of 30 t indicated in the MeBo literature, from t to lbs. What does the lifting capacity need to be? Is the 40,000 lbs capacity (Science Systems Report, Table 3) adequate?

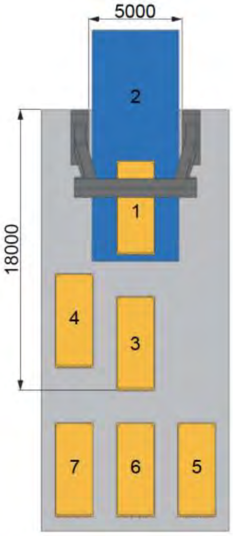
From the director of MeBo Operations and Engineering (Tim Freudenthal):

- Space: 18 x 4.7 m in line of the A-frame for launch and recovery system including winch. In addition, the possibility to install four 20’ containers in the vicinity of the launch and recovery system is required.
- Laboratory for serving logging tools
- Storage room for liner and spare parts
- A-frame and loads: The umbilical (OD 35.5mm, breaking strength 910 kN), winch and overboard sheave belong to the MeBo system. Maximum line safe working load of about 300 kN (= 67,000 pounds). Total wire length of 2700 m currently (could be longer if more space for their portable winch).
- Deck loads in the area of launch and recovery system (weight: 20 metric tonnes plus 13 metric tonnes for the drill rig) and winch (30.5 metric tonnes = 34 US tons). Details of deck loads

depend on the mounting positions and have to be checked separately. Engineering advice needed.

- The total weight of the MeBo system shipped within 7 containers is about 115 metric tonnes. (about 126 US tons)
- Power: 400V and 50Hz, total amperage required is about 500A.
- Staff - 9-10 operator/technicians per cruise.
- Deck Layout:





1 MeBo
2 LARS
3 Umbilical Winch
4 Tool Container
5 Control Container
6 Power Pack for winch and transformer unit
7 Workshop Container

The umbilical winch, the MeBo, LARS and A-Frame have to be in line. The containers 4 – 7 can be stored anywhere on deck of the ship. Required space for installation of LARS and umbilical winch:18 m x 5 m in line with A-Frame Additional space: 4 x 20' containers + working area

Freeboard Height:
As noted in our second report, we are concerned about freeboard height, which is now 13 ft. Instrument deployment and recovery and small boat operations become increasingly difficult as freeboard height increases. This impacts several items that are called out as open issues by the Design Team:

- Personnel transfer to small boats
- Personnel access to water surface for glider/Autonomous Underwater Vehicle (AUV) recovery.

Working with over-the-side and deployed gear in heavy ice cover:
We highlight our concern about the ability to maintain open water access both starboard and port for several kinds of science operations in heavy ice, including deployment and recovery instruments that are tethered to the ship (CTD and coring operations, ROVs, net tows etc.…) and those that are independent (for example, gliders, small boat operations). This concern is shared by the Design Team, who has

prepared an in-depth assessment of the ways in which the ship's thrusters and strategic ship positioning can be used to accomplish this. Since this ship will not have a moonpool, the ability to maintain open space next to the ship is critically important, especially given the plans for winter cruises and expeditions to icier regions than were previously inaccessible.

Meteorologic Lab combined Marine Mammal Observation Space:
The combined space appears to be an efficient and workable use of space.

Trace Metal Clean Work:
Currently, trace metal clean surface water sampling can be conducted using a towfish. Colleagues have indicated that this is not an optimal method, and have proposed an alternative. We include a proposed design here; our goal is to generate further discussion of methods for safe and easy trace metal clean surface water sampling. Given the detailed description below, we suggest direct conversation between the Design Team and polar marine scientists who conduct trace metal work.

"..... a hydrodynamic foil-shaped beam or spar (of Ti?) roughly 5m long, attached to the side of the ship somewhere along the starboard working deck, that is hinged at the attachment point so it could fold up and out of the way during icebreaking (or be detached completely and brought on board). I was imagining it extending down to 2-3m under the surface, but also extending outboard at a 20° angle or so, so that the end of the spar was ~2m from the side of the ship. If the hinge on the outboard side was free to pivot (for fast recovery, or "flying" it over larger bergy bits if needed), the foil could be asymmetric at the lower end to provide downward force and prevent any tendency to rise up underway. A PVC tube would be attached to its trailing edge, possibly bending forward along the bottom of the beam. The clean sampling tube of Teflon or polyethylene would be inserted through this PVC sheath/protector tube. With the intake end of the tube 2m away from the side of the ship, I think it would be outside the contamination "halo" of the ship at any speed about 2 knots. The design would be strong enough to withstand hitting small bergy bits, allowing sampling through hash or young sea ice, but would also be made to break away at its mounting point under sufficient impact, while being held to ship by a Dyneema tether (like F1 car wheels, so they don't go airborne into the crowd in a crash). The beam would thus be recoverable and the structure of the ship would stay intact (Coast Guard approval required). It could be installed/lowered only during surface sampling operations, and otherwise out of the water. The clean pump would be mounted on deck as with current towfish systems, pushing clean water to clean lab spaces. Cleaning or replacing the sample tube would be easy, as it could be pulled on board at any time in minutes. If the hinge allowed >180° rotation, the end of the spar could be secured at working height on board to inspect the intake end without disturbing it. The system could be maintained by MTs, so that clean water could be offered to any PI, including those without towfish experience."

In theory, such a system could be built to run more continuously, and might be able to serve as the sole surface water sampling system for the water wall etc., saving on costs of all the permanent plumbing, sea chest, large built-in pump, etc. that is likely part of the ship design right now, and would all have to be built/installed at the shipyard. It could feed the water wall sensors through a Y in the plumbing downstream of the pump (larger clean pump needed than current towfish pumps, possibly centrifugal; pumps easy to change out since not mounted permanently in bilge). The Palmer's water wall is fed by a system made to flow a LOT more water than it is ever used for, as far as I know. A separate fire-hose non-clean system could still feed on-deck incubation water baths, surface water Radium sampling, and the like that need higher flow rates and/or larger volumes. And the bridge would be able to see the beam while deployed and keep the larger bergy bits away with some attentive steering. I have not discussed this with any engineer, it's just an idea that has been in my head for several years. I would be happy to discuss the idea with those who know more about mechanical engineering and Coast Guard requirements."

SECTION 3: Detailed comments on General Arrangements / Space Arrangements

These comments are quite specific and are based primarily on details from the General Arrangements and Space Arrangements documents. We list these so that they don't get lost along the way, and in some cases, these comments serve as reminders of small changes that have been made already, that we hope are retained.

1. <u>Main Deck</u>:

The **ET shop and IT office** still seem too large. Could space be re-allocated such that the Hydro Lab and/or the Bio/Chem/Analytical Lab is larger? During DR #4, there was discussion of relocating the Transceiver room (depends on straight access to transducers). If this is done, then the Autosal room could be moved into the space now allocated to the Transceiver room, providing additional space for the Hydro Lab and/or Bio/Chem/Analytical Lab.

The **HazMat and Paint Locker** now have interior access. As discussed during DR #4, we suggest switching the location of the two spaces, with the Paint Locker aft of the Hazmat Locker. In addition, all lab space locations with hoods need to have associated hazardous and flammable storage space for working quantities of chemicals. Large quantities of hazardous waste will need storage, likely in containers on the back deck.

The **Microscope Room** is described as having space for three microscopes and their associated supporting computers, reagents and chemicals. Note that this space may also be used for fluorometer work, which, like fluorescence microscopy, requires dark conditions, and bench space, as opposed to desk space.

The **Main Lab** is described as one of the "drier" labs. This is a reminder that working with sediment cores in this space may be common during MG&G cruises; this is very muddy and wet, so we request that this space have easily cleaned floors and sediment traps associated with the sinks.

The **Hydro Lab** can anticipate the addition of more underway measuring systems that make use of space near the water wall. As noted in the DR #3 Report, we reiterate that having adequate space is key.

The details of **Jumbo Piston Core** extrusion are not clear. We believe that extrusion will take place from an aft starboard location – totally out in the weather? How will freezing of the liner inside the barrel be handled? Does positioning of the extrusion device on the aft starboard corner decrease the working length of the JPC?

The relatively large size of the **Server Room** is intended for future expansion, as described in detail in our first report. During DR #4, the possibility of locating server racks that are now in NBP forward dry lab (on the new ARV, the Science Operations Center) be located in the Server Room. This would allow for common access and cooling. We agree that all racks be serviceable from inside one room. Cybersecurity requirements will quite likely mandate that the entirety of each rack be within a restricted/locked area. In general, scientists don't need access to the racks -- individual instruments (which scientists do need to control) can be run by scientists from remote workstations connected over the network to the (secure)

CPUs. CPUs these days are not individual machines, they are virtual machines configured within a centrally-administered cluster, which should be located in a controlled-access location.

We appreciate the identification of forward space in the **Electronics/Computer Lab** allocated for photo/video editing, in support of both science and science outreach.

We requested easy pallet jack access to **Science Stores**. In GA P2, we note that the corner of the ET shop is “cut” to allow easier access to Science Stores from the main passageway, and that the main passageway is wide and can accommodate a standard pallet jack.

We note many other positives that maximize flexibility in use of space, including modular design and adjustable workbenches and shelves, “*Unistrut outfitting of the labs on the bulkheads and in the overhead along with a 2x2 grid of deck sockets”, and “The sink supplies and drains supporting the interior workbenches may be disconnected and made flush to the floor in case they are not needed in the preferred lab arrangement, depending upon the mission.”*

2. <u>01-level</u>:

We suggest that the locations of the **gym** and the **lounge** are switched, and also that the lounge is made bigger and the gym, consequently, smaller.

As discussed during DR #4, we agree that an enclosed, private, **MPC office** is needed on the 01-level.

Is a “**reception desk**” necessary?

3. <u>02-level</u>: science **berthing**, **laundry** and **hospital**, central lounge, associated with luggage space and a large linen locker. Note that natural light access for staterooms meets HAB+ requirements, hence interior space forward is designated as a central lounge.

We note that at this time, only one **laundry** has been identified. We suggest including a second laundry room especially given the number of berths. In addition, a designated laundry room for crew is suggested, perhaps on the 04-level, since the crew work schedules may make it more difficult to thread in time to do laundry, between all the other laundry users.

4. <u>03-level</u>: mixed science and crew berthing, Atmospheric Lab

Several unassigned spaces are located forward, between berthing and the atmospheric lab; we comment just above on the need for a crew laundry, and suggest that unassigned space on the 03-level be considered for this use.

Atmospheric lab – discussed in section 2 above.

5. <u>04-level</u>: crew berthing, UAV hangar and deck

The **UAV hangar** is sized to accommodate large UAVs, and follows from discussion of the Design Team with members of the UNOLS Science Committee on Oceanographic Aircraft Research (SCOAR). The UAV hangar now includes science seawater plumbing, and the **UAV deck** includes tie-downs in case space here is used for incubators, providing greater flexibility. The UAV deck also can accommodate two science containers. The deck is large enough to accommodate helicopter flight operations, for the landing and takeoff of a single helicopter.

6. 07-level:

The **Meteorologic lab** is now incorporated into the **Marine Mammal Observation space**.

SECTION 4: Open Issues

We note that while ship design has evolved, much work remains to be completed. The Design Team describes these open issues, and their plan for the path forward following the Preliminary Design Review, in two documents provided as part of DR #4 documents, the Design Summary Report and Science Systems Report. Below we provide a direct copy of the open issues, *along with limited comments*.

Design Summary Report, Open Issues:

1. The Anti-Roll Tank configuration and arrangement has not been finalized. This will be addressed post-PDR. *No additional comment.*

2. The Bubble Sweep-down performance is pending completion of model test results. Model test results are preliminary at this time and additional hull optimization is required post-PDR.
We understand that considerable effort has been put into modeling bubble sweep-down, and that efforts will continue to minimize this problem. Optimizing multibeam data quality is a high priority.

3. MacGregor has withdrawn from research boat market and alternate deck equipment supplier needs to be identified. The team is reviewing potential vendors and will engage with several post-PDR. *No additional comment.*

4. Further development of Aloft Control Station is required, including assessing whether the Pilot House and the Marine Mammal Observatory (MMO) can be moved forward. *No additional comment.*

5. Further development of winch reeving is required. Winch reeving details will be taken to a higher level of resolution post-PDR, and will continue to be refined through Final Design. This design detail will remain open through production design as specific equipment vendor selection is to be left open for the shipyard to compete with various vendors. *No additional comment.*

6. Main cranes present many interferences. A more detailed structural and deck equipment design specific to vendors will allow for working out the interferences posed by the current design. Furthermore, crane design loads are driving a very large crane design at this time and these requirements should be relaxed in the post-PDR phase. Both factors will enable a more specific detail design of the crane. *No additional comment.*

7. 02 Level catwalk for starboard A-frame service needs refinement. The 02 Level catwalk design will take advantage of detail structural design of the house in support of the A-frame and work in conjunction with the detail design of the Starboard Main Crane interface. This catwalk is planned to provide a walkway between the lifeboat deck and the 02 Level Aft Deck and allow for ease of service for the starboard A-frame top block. *No additional comment.*

8. Munson landing craft needs to be represented in General Arrangement. Specifics of the landing craft will be provided to Munson so that Vendor-Furnished Information (VFI) can be created and applied to the General Arrangement. *No additional comment.*

9. The current incubator location is shaded by deck equipment. The flight deck is a potential location that is unshaded, however, better to find a location near the Aft Working Deck. This will be reviewed in greater detail post-PDR. *We also have pointed out this design problem of shading of the incubators on the port side of the 01-deck, by the aft crane when it is in its stored position. While it will be possible to site incubators on the Aviation Deck, the 01-deck location is favored and will be used by most science teams, given proximity to the other labs.*

10. Using the full recommended KG margin (7.9%), allowable KG to pass stability was exceeded. Margin was adjusted to 4.1% KG margin to allow for compliant stability results. This can be mitigated with ballast and re-examination of assumptions for high wind analysis. Additional review will be conducted post-PDR and the design team will manage KG carefully and identify some KG reduction candidates to buy KG margin. *No additional comment.*

11. Added fuel has pulled the longitudinal center of gravity (LCG) forward, causing a 0.23-degree exceedance of the 0.5-degree P-Spec trim limit. Post-PDR, this can be fixed by reassigning or reducing tanks or shifting the Longitudinal Center of Flotation (LCF) and Longitudinal Center of Buoyancy (LCB) forward for the Hull Variant 8-11 optimization work. *No additional comment.*

12. The current transformers are too large to fit in the Battery Room with the full battery supply. Active front end type transformers will allow a decrease in the size of this equipment. Greater refinement of the required propulsion load and detailing of the load-shedding system will allow for correct sizing of these transformers. *No additional comment.*

13. Develop small boat docking solution/platform for alongside operations and free vehicle grappling. There are yacht and cruise ship systems that are attractive for this purpose. These systems will be investigated in greater detail post-PDR.” *We concur, see comments below regarding personnel transfer to small boats, and deployment and recovery of equipment, with concern for freeboard height.*

Science Systems Report, Open Issues:
Risks and areas of non-compliance are also noted for specific design areas. Critical areas of concern include:

1. Bubble Sweep-down
We understand that considerable effort has been put into modeling bubble sweep-down, and that efforts will continue to minimize this problem. Optimizing multibeam data quality is a priority.

2. Icebreaking while towing
We concur that providing open water aft for towed gear is a high priority.

3. Impact of side frame foundation on wet lab and aquarium
No additional comment.

4. Personnel transfer to ice shelf
Movement of personnel and their equipment to an ice shelf, or to many of the coast-marginal regions of Antarctica, will, in many cases, require air support, as a small boat landing craft option is only possible in

regions at sea level. Given the current design of the ARV, with an Aviation Deck capable of landing a helicopter, this could be accomplished via a 2-ship operation. In this scenario, the scientists (and their gear) aboard the ARV could be transferred via helicopters housed on another polar vessel. The ARV, with its heavy-duty icebreaking capabilities, could facilitate access to areas with heavy ice cover.

5. Personnel transfer to small boats
We have concerns about the freeboard height of 13 feet, which makes small boat operations and instrument deployment and recovery more difficult. In the absence of decreasing freeboard height, it is increasingly important to develop protocols for safe, easy and rapid deployment and recovery of people, equipment and boats, over-the-side. We appreciate that the Design Team has called this out as an area of concern.

6. Personnel access to water surface for glider/Autonomous Underwater Vehicle (AUV) Recovery
As noted in #5, we are concerned about the freeboard height.

7. Locating incubators in non-shaded area
See #9 above from the Design Summary Report list.

8. Centerboard deployment and retrieval method
To be addressed by the Design Team; we provide no extra comments here.

9. Aft Deck Working Crane
See note concerning shading of incubators, above.

SECTION 5: Team Psychological Safety, Trust, and Shipboard Climate:

We recognize the importance of creating a workspace and living environment on the ARV that is positive and supportive. Promoting a respectful and safe environment, and preventing uncivil behavior and harassment will be increasingly important given the longer missions and with a greater number of people on board. In addition, the likelihood of 2-ship operations and international cooperative programs adds the potential for greater cultural and programmatic differences that can impact interpersonal relationships and cruise operations.

This objective can be addressed, in part, through design and arrangement of personal and community space on the ship. For example, incorporating a greater number of equal-sized, single berth staterooms, acknowledges that multi- and interdisciplinary cruises may have co-chief scientists and multiple lead investigators. Dayrooms associated with multiple staterooms provide equitable space for mission planning and discussion of confidential matters. All staterooms have access to natural light. Common spaces promote positive interactions and a welcoming and supportive environment for all on board. Common space décor offers supportive visuals and wellness resources. They are intended to be open to scientists, science support staff and ship's crew. The 01-deck includes a large and inviting conference room, lounge, and the gym, all with natural lighting. Smaller common spaces are located on the berthing decks, allowing for smaller gatherings, including space allocated more directly to crew members who likely need quiet space for paperwork, educational advancement and study.

In terms of physical safety, we suggest that stateroom doors are lockable – perhaps electronic locks with key codes that can electronically record access details. For this option, we are uncertain how to balance safety and privacy, for example, in the case of an emergency on board. We suggest the inclusion of a private, “off-ship” call space - a place accessible to everyone on board, for confidential calls (in contrast to public phone space on the NBP).

Personal behavior is absolutely central to this discussion. We suggest working forward from ongoing UNOLS initiatives regarding a respectful environment at sea; UNOLS has a committee - Maintaining an Environment of Respect Aboard Ships (MERAS) that works on initiatives for the fleet. As part of this effort, the agencies and MERAS created a 3-part series on Shipboard Civility. Participants are required to watch the Module 1 and 2 Videos prior to going to sea. Module 3 is a poster that is specific to the ship which indicates resources available. A clear reporting process that feels safe to the reporter must be in place for when concerning events occur. Bystander training should be included for all members of the team.

From MERAS: “The Maintaining an Environment of Respect Aboard Ships Committee (MERAS) works to facilitate an environment of respect onboard vessels of the U.S. Academic Research Fleet (ARF) and to cultivate and preserve a culture of inclusion, regardless of age, gender identity, sexual orientation, disability, race, religion, nationality, or socio-economic background. The committee provides recommendations to the UNOLS community regarding resources and practices to identify and overcome related workplace barriers in the ARF and assists the UNOLS Council, funding agencies, and the ARF operators in formulation of new policies as needed. Examples of scope, drawn from prior activities, include, but are not limited to making pregnancy and nursing policies of ship operating institutions readily available to users of the ARF, assisting in development of a video to improve civility and eliminate bullying and harassment associated with shipboard research at sea and ashore, and recommending new cruise planning document policies concerning gender expression, support, and safety.” Training around emotional intelligence and normal human responses to trauma may also support potential victims.

Discussions with members of our community identify the critical role of a structured framework for pre-cruise planning and team-building that will facilitate communication and decision-making while at sea. Strengthening positive working relationships will lead to better outcomes, both personally and scientifically. First time chief scientists can benefit from additional training; for example, we point to the UNOLS Chief Scientist Training cruises (https://www.unols.org/nsf-unols-chief-scientist-training-cruise). Leadership teams (Chief scientists, MPC, Captain) working together for the first time also need pre-cruise discussions and coaching around roles and responsibilities. Discussions among all members of the ship’s party, including the ship’s crew, about the importance of morale and the inclusion of morale-boosting activities is recommended. Some activities, such as “soccer on the ice” or “zodiac tours” will need the assistance of the crew, while others will grow organically - giant crossword puzzles in the main passageway, or ship-wide ping-pong and cornhole championships. We realize that these small recommendations may seem minor, but small shared experiences can be the glue that help facilitate collegiality and promote work toward a common mission.

SECTION 6: Other

Scope Management Plan:

As described by the Design Team “The purpose of the Antarctica Research Vessel (ARV) Scope Management Plan (the Plan) is to describe how the project scope is managed (defined, developed, and validated) and to descope the Plan and identify additional scope opportunities for the project. These objectives include defining scope contingency and explaining how scope contingency can be used to account for funding changes and/or project overruns. The Plan also defines decision points or timeframes for exercising options and describes how scope opportunities and descoping options will be achieved.

This document and all scope options will be reviewed periodically to remain current and consistent with the project's ongoing activities."

Accordingly, the Design Team provided two tables, first, a Scope Opportunity Table – a list of options that can be added if funding is favorable and/or if there are cost underruns, and second, a Scope Reduction Table, listing de-scope options if faced with funding issues and/or cost overruns. We present these two tables (Table 4 and 5) along with our prioritizations, as well as brief comments and questions. Note that some items have a more direct science impact and others have more operations impact. For example, two Scope Opportunity "big ticket" items that more directly impact operations - "Facility Modernization" ($4.5 M) and "Palmer Station Pier Dolphin ($14.5 M) – are >50% of the Scope Opportunity costs. While we rank both highly, we wondered if those costs could come from elsewhere in the Polar Budget, since these are not ARV costs directly, though both support the ARV. For several of the options presented, we don't feel we have enough information and/or specific expertise to provide a prioritization, and suggest continued discussion of prioritization of both scope opportunities and reduction.

Single Ship Operations:

Colleagues have asked about whether the USAP will become a single ship operation, with concern for balancing support for Palmer Station, the Palmer LTER, and science operations in other parts of the Southern Ocean. We note that this concern is under consideration, please see: Future plans for USAP vessel support by the ARSV Laurence M. Gould; https://nsf.gov/news/news_summ.jsp?cntn_id=306754&org=OPP&utm_medium=email&utm_source=govdelivery.

FINAL COMMENTS

We thank the design team for their responsiveness to our comments and questions, clearly visible in the changes, large and small, to vessel design from DR #1 to this fourth iteration. The SASC has benefited greatly from discussions with colleagues - researchers, technical support experts, and advisory committees who provided valuable guidance based on their experiences. A large percent of community input was received by the SASC through our direct efforts to reach out, and on a one-to-one basis. Other questions and comments were from attendees at the public Polar Advisory Committee meetings, where the SASC presented our review reports, and through contacts made at the recent National Academy workshop and post meeting follow up. We recommend that the path for design input remains open throughout all stages of ARV development.

We anticipate a growing interest from the community in being involved in vessel design. It is important to recognize both the contributions themselves, and the sense of community that is engendered by being part of the process. Members of the SASC likely will continue to receive comments from our colleagues, and will continue to direct those comments to the NSF. While the SASC members and their email contacts are listed on the USAP website (https://future.usap.gov/arv/) we suggest that a series of small open discussions be held periodically over the course of ARV development, to widen community involvement. We note that some communities, for example the Marine Geology and Geophysics group, already are looking ahead toward the design of equipment, in this case, drilling rigs, that can be deployed off the proposed ARV. Our community has a long lead time, so this kind of early activity will allow scientists to hit the ground running when the ARV is ready to sail.

We also recognize continued community interest in the capability to support on-land and ice-based science for the US Antarctic Program. Identifying the ways in which these can be supported by the proposed ARV, along with other alternatives, will be important for our colleagues whose work requires the ability to place personnel and their gear onto the ice (ice sheet, ice shelf) and coastal outcrops. We anticipate that this will be addressed thoroughly in the National Academy workshop report, where the science drivers for coastal and nearshore science were presented and discussed. While some of the science missions can be accomplished through fixed wing landings and/or landing boat support, this is not universally possible. Brief discussion at the workshop included (1) how to partner with other nations for two-ship operations, and (2) maximizing the use of helicopter support through dedicated heavy helicopter use cruises, preceded by a call for proposals, a model similar to the Deep Field camps on the continent. There was not enough time for these two options to be discussed more completely. We note that strong community interest was voiced at the National Academy workshop to include the capability to support two helicopters on the ARV.

In concluding, we highlight the tremendous volume of information provided by the Design Team and the breadth and depth of design elements that have been covered through the four reports we have submitted. Each report covers new ground; we emphasize continued attention to comments from each report, from workflow patterns and deck plans, to over-the-side handling of equipment, cybersecurity and communications, green ship design and habitability. From the SASC team, we thank you for this opportunity we have had to contribute to the design of the proposed ARV.

List of contacts for comments
Stian Alesandrini, Schmidt Ocean Institute
Chuck Amsler, University of Alabama at Birmingham
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Allan Beaudry, Noise Control Engineering LLC
Kim Bernard, Oregon State University
Stefanie Brachfeld, Montclair State University
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Dwight Coleman, University of Rhode Island
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Helen Fricker, Scripps Institution Oceanography
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Tim Gates, Gates Acoustics
Ali Graham, University of South Florida
Jamin Greenbaum, Scripps Institution Oceanography
Sean Gulick, University of Texas Institute for Geophysics (UTIG)
Jim Happell, UMiami Tritium Lab, Operation SWAB
Jamee Johnson, Science Implementation - Peninsula, USAP
Vicki Ferrini, Lamont-Doherty Earth Observatory
Ari Friedlaender, University of California Santa Cruz
Kevin Jarrum, Paul Johnson, Larry Mayer, (Center for Coastal & Ocean Mapping/Joint Hydrographic Center), Multibeam Advisory Committee (https://mac.unols.org/)
Ted Maksym, Woods Hole Oceanographic Institution
Paty Matrai, Bigelow Laboratory for Ocean Sciences

Alison Murray, Desert Research Institute
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Emily Shimada, Oregon State University
Christine Siddoway, Colorado College
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Maureen Walczak, Paul Walczak, MARSSAM: The OSU Marine Sediment Sampling Group
Julia Wellner, University of Houston
Chris Zappa, Lamont-Doherty Earth Observatory, chair of UNOLS Science Committee on Oceanographic Aircraft Research (SCOAR)

	TABLE 1: General Arrangements and Space Arrangements		
Space + use (new name vs. name in SMR documents**)**	**Location + Connectivity**	**Space Arrangements (P2)**	**Special Considerations**
		normal text (P2 arrangements) *italics text (recommendations for SASC)*	
MAIN DECK			
Science Operations Center (Forward Dry lab)**.** day-to-day cruise planning, work with shipboard data; banks of monitors, dedicated workspaces/work surfaces for charts, laptops, workstations for UAV and drone data downloads and processing, marine geophysics, work with ROV data and satellite imagery.	Dry lab, forward location, easy connectivity to main passage, clear line of communications to bridge, labs and other science support spaces.	General purpose tables (fixed laminate countertops with securing rails) for about 12 people in 3 rows; 12 Science lans; double row monitor wall most forward; 2 large chart tables.	
Main Lab (Aft Dry Lab)**.** Multi-purpose lab, with flexible benches and layout configurations, for science equipment and for processing of water, plankton, and sediment samples; filtration + processing of water samples, sorting plankton, setting up incubation experiments, microscopy (that does not require darkness), description / sub-sampling of sediments.	Wetter lab, more aft location, ease of moving samples and equipment back and forth between main lab, back deck, + Baltic Room. Easy access to refrigeration + freezer space; water work may include carrying 20 liter carboys from Baltic Room and back deck into main lab; sediment cores 1-6 meters long will be carried from deck into main lab + later stored in a cold room, in max 1 m lengths.	SS countertops, as indicated in space arrangements, *are very hard to tie down to; instead we suggest workbench countertops to accommodate the need for tie-downs*; 4 double ss sinks + 3 single ss sinks; fridge, -20 and -80 freezers; 2 large hoods *(will hoods be associated with storage space for working quantities of hazardous materials and flammables?)*; 1 gas bottle rack; 4 compressed air drops; 9 science lans; *Milli-Q water + uncontaminated seawater; working with cores is messy (muddy) - requires sinks w/ sediment traps, and easily cleaned floors and floor drains. Where will the floors drain to? Icemaker? 220V power? Other power?;* note space reserved for incubators; direct assess to lift; use of nesting tables for increased flexibility of use of space and efficiency of use.	
Electronics Lab instrument programming, charging battery packs, sensor calibrations; large format printers; *outreach and telepresence center*	forward location, near Science Operations Center, ET Shop	workbench countertop with space for 14; 4 lockable cabinets + 4 modular cabinets; rack for compressed gas cylinders; 24 Science lans; 4 bookcases; double-doors; forward space allocated to 3-D printing and photo-video edting stations, and printer and plotter area. *Telepresence (comms with colleagues, NSF, + outreach efforts that effectively present excitement of scientists at work) might involve 4-6 people on board*	Prefer movable benches that can be reconfigured using deck bolts, reserving permanently-installed benches in places where there are bulkheads, sinks or fume hoods that preclude them from moving. We like having unistrut on all the bulkheads in the labs, lining up with unistrut on the overhead.
Baltic Room CTD operations	Mid-ship location with other "wet" labs proximal to Baltic Room; *access should be provided through Baltic room to/from adjacent labs*	workbench; rack for compressed gas cylinders; 1 ss double sink; 1 science lan; flammable storage cabinet; *Floor with minimal tripping hazards; Ample floor drains to facilitate rapid water drainage; Door that has sufficient opening for an extra-large 36 place rosette.*	Upper deck catwalk storage?
Wet Lab wet, messy activities - sorting of samples from plankton net tows, fish trawls, dredges, extrusion of multicore sediments, incubation of live animals; site of cleaning moored instruments upon recovery when conditions unsafe on deck.	Wet Lab and Aquarium Room contiguous + near Baltic Room + Back Deck	1 single ss sink + 2 ss double sinks; 2 secure lockable cabinets + 2 modular cabinets; 2 racks for compressed gas cylinders; large ss countertops; ice maker; refrigerator; 1 small hood *(as above, will hood have associated space for storage of working quantities of hazardous and flammable materials?)*; 4 Science lan; 1 compressed air drop; 3 stubbed out plumbing; *Temperature controlled incubator*; *access/ hook ups to flowing seawater and freshwater at multiple sites,* floor drains, *sink space with sediment traps*	Splitting hairs here but is the incubator both Temp and Light controlled? Put icemaker here or in Main Lab?
Aquarium Room wet + messy - aquaria for live organisms	same as above	workbench countertop; rack for compressed gas cylinders; 2 science lan; 1 compressed air drop; 7 salt water valve tank attachment points; *Room for aquarium tanks of various sizes- Aquarium Tanks ideally portable, Xactic tanks; floor drains, sinks with sediment traps; light intenstiy must be controllable to darken space; power, adjustable lighting, temperature control*	Temperature of the room? Is there pallet jack access for moving tanks?; see detailed discussion in report
Hydro Lab site of "water wall" for underway surface seawater characterization; collection of samples for [pCO2] work; nutrient analysis; flow-through instrumentation - thermosalinograph, pCO2 system, fluorometer, transmissometer, nitrate analyzer, FlowCam/CytoBot plankton image analysis, flow cytometry. Outlets to add science supplied instrumentation and/or to collect discrete water samples. Pressure regulated so that as instruments are added/removed the pressure to the online instrumentation doesn't change. Other operations could include Nutrient Analysis, other analyitical instrumentation.	Samples coming from Baltic room and back deck, access to Chemistry lab	workbench countertops; 2 single and 2 double ss sinks; 1 large + 1 small fume hood *(associated storage for working quantities of hazardous and flammable materials)*; ice maker; -80 chest freezer; 1 rack for compressed cylinders; 4 compressed air drops; 4 science lans; secure lockable cabinets and modular cabinets; ice maker; -80C chest freezer; unistrut bolt down; *access to clean water and uncontaminated sea water, Clean power outlets protected from seawater exposure distributed throughout. Analytical work requires relatively good climate control. Anticipate increase in flow-through instrumentation, so larger Hydro Lab may be needed. Image analysis w/plankton directly from seawater line, need for gentle system proximal to intake.* *Historically this has also had the nutrient analysis and other analytical work.*	

Bio / Chem / Analytical Lab (Bio Lab) Sensitive biogeochemical analytical work that requires clean space, excellent venting, climate control. Filtration and processing work with water, plankton, and sediment samples that include work with preservatives and/or poisons.	easy access to Hydro lab and Baltic room? *Note size now 758 sq ft. - this lab could be made even bigger*	workbench countertop; 4 secure lockable cabinets and 4 modular cabinets; 3 racks for compressed gas cylinders; ice maker; -20 freezer; 2 double ss sinks; 2 large fume hoods; 10 Science lan; compressed air drop; *positive pressure and good temperature control*; *access to clean water and uncontaminated sea water; Floor drains required; Note that "hazardous" chemicals will be used in this lab space - need hazardous chemical storage for working quantities; Refrigerator; note specificity of hoods - laminar flow hood and chemical hood mandatory; glove box*	Given expansion of scope of work to be completed in this lab, we suggest increasing the size; seems like space could come from ET lab and/or ET shop?
Cold Rooms 2 rooms for flexibility of temperature control (freezer + refrigeration); storage of samples + analytical work requiring temperature control (porewaters, sea ice cores)	easy access to main lab	each: temp control -30 C to +10 C (-20 F to +50 F) [ARV Pspec]; 1 double ss sink; phenolic countertop; adjustable ss shelving, *red and white lighting*.	Lans?
Autosal Room space for salinometer, climate control	near hydrolab, easy access to Baltic room	2 modular cabinets; 1 rack compressed gas; stainless steel countertop; double ss sink; 1 Lan; *Temp control of 1-2 C, w/ range from 21-23 C (http://www.soest.hawaii.edu/HOT_WOCE/sal-hist-report/2.1.2.html); Ambient temp measured w/ digital thermometer near salinity sample boxes away from Autosal to prevent thermometer from being affected by heat of Autosal and allows thermometer to measure temp of area in which samples have equilibrated.*	
Microscope Room transmitted and epi-fluorescence microscopy, binocular micrososcopy, fluorometer and/or cytometer	mid ship location for stability	Space for 3 microscopes, plus associated computers, and higher workbench countertop space for fluorometer or cytometer (both need low light); One space reserved for anti-vibration table. *Compressed air connections, water and sink. Secure cabinet to stow spare microscope parts and supplies; Drawers under counter in between microscope spaces*	
Gravimeter located in Server Room	Newest gravimeters do not require special security so don't need "special" space	special requirements for mounting instrumentation since this needs to be on a gimbled platform	Space to mount a gimbaled platform in an area that does not see heavy traffic
Bottom Mapping Transceiver Room / Acoustics	Space located within cable run distance to transducers.	Easy access to service hull mounted systems. Suite of sonar and acoustic systems good. Scientists need ability to easily integrate mission specific transducers/transponders, either as part of a drop keel, or using a transducer tube similar to the SIO approach.	
Science Stores includes (1) mostly instrumentation and supplies that the ship supplies and (2) PI provided supplies. Ship supplied Science Supplies in a temperature controlled and permanent place, PI provided extra supplies stored in hold	forward location for easy access to lab equipment and general lab supplies - all dry	Room for pallet jack access so heavier items easily moved; all adjustable stainless steel shelving and shelving with cabinet doors; double doors for easy movement of heavy, awkward, big items; flush hatches/doors so a pallet jack and move over the threshold	
Marine Tech (MT) Shop	Aft location, closest to back deck	workshop bench, locker, vise, lathe, bandsaw, arbour press, drill machine, grinding machine, welding machine and station	
Marine Lab Tech (MLT) Space *(Science Office)*	Forward location, close to Science stores	*Workbench for testing/repair, bookshelf; lockable storage for instrumentation/ equipment/ consumables; desk/computer station w/ lan jack; 2 chairs*	
ET Shop	Forward location	computer top workbench; 3 secure lockable cabinets and 5 modular cabinets; 1 rack for compressed gas cylinders; 2 lockable tool cabinets; wood top countertops; uni-strut; Workbench for electronic repairs, computer station, stores for small electronic spares (fuses, cables, wire, etc.) - something like lockable Lista Cabinets	Space is overly large?; Lans?
Electronic Equipment Room location of servers and server HVAC	Forward location; adjacent to ET Shop and proximal to Operations Center	stainless steel countertops; modular cabinet; 2 science lans; Server racks must be accessible from front and back; not oriented adjacent to bulkheads as currently drawn. Sufficient space in the computer racks for future growth or science supplied instrumentation. Small countertop (composition?) and chair. Important that this space is isolated from the other lab areas and temperature controlled as the servers will generate a lot of heat.	
IT Office	Close to Electronic Equipment Room	2-3? computer stations, easy access to sat comms. terminal(s)	Space is overly large
Hazardous Materials Storage	Aft location; interior access	May also need to utilize a container on cruises where large volumes of hazardous waste is produced, need to consider venting requirements	Addressed in detail in the ARV SASC review documents, with several types of storage needed
Gas Bottle Storage Room SMR call outs 5 gas bottle racks but still need gas bottle storage space for easy bottle exchange on longer cruises	many labs have gas bottle racks	located in Main Lab, Electronics Lab, Baltic Room, ET Shop, Analytical Lab (3), Wet Lab (2), Aquarium Room, Hydro Lab, Autosal Room, Atmospheric Lab, Met Lab	these are now distributed throughout the labs, no specific space allocated for extra bottles - need to address if extra storage racks needed

TABLE 2: Size of spaces (ft^2)

Space + use (name sugg. vs. name in SMR documents**)**	***2022 Habitability Study***	***2019 SMR***	***P1 General Arrangements***	***P3 General Arrangements***
MAIN DECK				
Science Operations Center (Forward Dry lab)**.**	1400	~1100	1131.8	1127
Main Lab (Aft Dry Lab)**.**	1400	~1100	1550.2	1619.3
Computer/Electronics Lab	700	~700	792.7	821.2
Baltic Room	700	~700	703.6	705.5
Wet Lab	580 (more if possible)	~900	900	689.1
Aquarium Room	340	~400	420.2	560.9
Hydro Lab	530 (more if possible)	~750	737.1	738.7
Biochem / Analytical Lab (Bio Lab)	500	~400	758.3	772.6
Cold Rooms	2 @ 100 each, climate control/cold labs		144 each	144.0 each
Autosal Room		~100	100	100
Microscope Room		~100	191.9	127.8
Gravimeter - no longer needs separate space				
Bottom Mapping Transceiver Room / Acoustics	195		180	163.7
Science Stores	4130 (forepeak main deck), Science Hold (16,000)		1098.6	966.8
Marine Tech (MT) Shop	250	~150	280	321.6
Carpenter Shop			360	279.4
Marine Lab Tech (MLT) Space (science space)	260		80	334.7
ET Shop	100	~100 (ET Shop/Electronic equipment room	234.1	590.4
Electronic Equipment Room (Server Room)	230		771.4	751.2
Changing Room/Mud Room		~100	520	400
Hazardous Materials Storage	650		60	84.2
USW Instrument Room (Bow thruster room)	100		?	?
Transciever Room	200		180	163.7
Gas Bottle Storage Room			?	?
IT Office				262.2
OTHER DECKS				
MPC Office				needs to be identified
Atmospheric Lab	300		1661.3	526.5
Meteorologic Lab	340		331.6	see below, included with MMO platform
Marine Mammal Observation Platform	550		1142.4	2043.7 (includes met lab space)
DECK SPACES				
Marine Service Bay	450		480	654.7

Lab Van Bay			369.7	382.1
UAV Hangar and Deck	450 (hangar)		494.1 (hangar) + 5562.8 (weatherdeck)	1394.9 (hangar) + 7183.4 (weatherdeck)
Aft Winch Control Room			146.3	
LEISURE/SOCIAL/MEETING SPACES				
Deck/Level 03:				
Crew Library			600?	400.8
Deck/Level 02:				
Lounge			600	401
Laundry			487.4	783.9
Hospital				829
Deck/Level 01:				
Lounge - intended for noisy social activigties, like movies and cards			809.4	450.3
Conference Room - group work			649.6	705
Gym / Sauna			441.3 + 181.9 + 51.6	684 + 192.9

	TABLE 3: Vans	
SPECIALIZED VANS: UNOLS shared equipment pool (http://marops.cms.udel.edu/uecvp/ and https://ceoas.oregonstate.edu/west-coast-van-pool), or part of the USAP equipment pool (https://www.usap.gov/usapgov/vesselscienceandoperations/). **Operational Requirements (power, water, heating/cooling, venting, network connection) all spaces where vans may be located should have this capability**	**Location + Connectivity; Limitations + Challenges**	**Space Arrangements**
Radioisotope Vans (1-2) depending on which isotopes are being used; please see the following paper for details of how to address radioisotope work: https://par.nsf.gov/servlets/purl/10317467 (Venturelli, R., et al., 2021, A framework for transdisciplinary 14C science: Use of natural-level and 14C-labeling in Antarctic field research. Radiocarbon, 1-14. doi:10.1017/RDC.2021.55)	**Main Deck - exterior location mandatory** to limit possibility of radioisotope contamination of interior of ship; consider pathways of use by scientists and limit possiblity of contamination of ship - **no direct entry without a contamination control zone at the access point.**	https://www.usap.gov/USAPgov/vesselScienceAndOperations/documents/Rad%20Van%2001.pdf; https://www.usap.gov/USAPgov/vesselScienceAndOperations/documents/Rad%20Van%2002.pdf; https://www.usap.gov/USAPgov/vesselScienceAndOperations/documents/Rad%20Van%2003.pdf; https://www.usap.gov/USAPgov/vesselScienceAndOperations/documents/Rad%20Van%2004.pdf
Trace Metals Van	**Main Deck** - place where people can suit up into clean suits connected to passageway to change, this **CAN open directly into ship**	https://www.usap.gov/USAPgov/vesselScienceAndOperations/documents/TMC%20Van%2007.pdf
Seismic Compressors Vans (2 - 3)	**Main deck** with accessible connection to air guns	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). Probably need 2 - 3 compressor vans for a seismic cruise (depending on the array size ranges and rep rates) plus a backup; compressor vans can work in cold weather with a few modifications; they already have powered pre-heaters but in really cold conditions an antifreeze injector is needed for the air outlet.
Seismic Gun Shack workshop for air gun maintenance	**Back deck** - could also use Aquarium Room if cruise conditions permitted	countertops, electric, heated
Seismic Streamer Van	**Back deck**	streamer and winch, does container need to be on deck, or can that be in hold, with winch and streamer mounted on deck?
Jumbo Piston Coring Vans (4) archival supplies, Multi-sensor core logger (MSCL), core splitting & processing, core shipping (refrigerated), a 5th container with CT scanner, but this could also be in MSCL container	**Archival supplies could be in hold, others on back deck**. Refrigerated shipping container instead of storage in cold room, or could have shipping container in port and transfer all cores; Core splitting and processing van and MSCL van on back deck	Archival supplies in hold, no special needs except routine access; Multi-sensor core logger and core splitting/processing need heat, power; Shipping van needs power; MST van must have track pointed outboard toward lightly accessed area, because of cesium source
AUV Vans (2)	**Back deck** with door opening to open back deck for deployment of AUV	specific to each AUV
ROV Vans (4) capability to support Jason, as an example	**Back deck**	https://ndsf.whoi.edu/; Jason, typically shipped with 5 vans and the team brings 4 vans on board - rigging van, tool van, and 2x control vans. The rigging van can go anywhere on board that has access. The tool van is on the main deck close to Jason, and the 2x control vans are on the main deck on some ships, on the 01 or 02 on some ships. Jason can be operated with a single control van if space dictates.
Liquid Nitrogen Plant	**10 ft van. Isolated location (not on the back deck)**	
Atmospheric sampling vans	**UAV Deck**	Need to reinforce the UAV deck to support vans. Need bolt pattern for tying them down.
Light Incubation Van	**not sure**	https://www.usap.gov/vesselScienceAndOperations/documents/Light%20Incubation%20Van%2014.pdf
Decompression Chamber	**not sure**	colleagues asked if ARV would have a decompression chamber; online search indicates available sized as 20 ft ISO container
MeBo 700 drilling rig (one possible drill rig)	**Back deck** and located near the launch and recovery system for the rig	https://www.bauer.de/export/shared/documents/pdf/bma/datenblatter/MeBo_EN_905.808.2.pdf; 18 x 4.7 m in line of the A-frame for launch and recovery system including winch. In addition the possibility to install four 20' containers in vincinity of the launch and recovery system is required.

Table 4: ARV scope opportunity summary table

ID	Title	Technical Impact	Estimated Cost ($M)	Optimal Date: 1 – Before PRR, 2 – Before Launch, 3 – End of Project	SASC Consensus High = first to add; Low = last to add	Comments
1	Weight Handling Equipment Testing Outfit	On-hand waterbags, scales, and associated rigging equipment to allow the crew to conduct the periodically required weight testing of cranes, A-frames, and other weight handling equipment.	$0.24	3	High	use all the time
2	Insurance Spares	Purchase additional spares, beyond baseline minimum defined in RAM plan.	$4.40	2	Medium	could go in operations budget
3	Azimuth Drive Cradles	Would be stored ashore, to provide to the shipyard, for drydocking when drives are planned for removal. Note: 2 cradles	$0.14	2	Medium	how else could azimuths be stored, seems necessary
4	Facility Modernization	Improve Punta Arenas/Port Hueneme facilities for operations and upkeep to support ARV. Note: Budgetary estimate.	$4.50	3	High	but as part of this project?
5	Science Lab Vans	Science lab vans purchased specifically to support ARV science missions. Note: Vans include Electrical, HVAC, and network connections. 4 Vans	$0.92	3	Medium	issues with maintainance, operational expenses to support long-term
6	Portable Science Equipment	Portable winches purchased and staged in Punta Arenas to support ARV science missions. Note: 2 hydro wire winches including cable.	$0.36	3	High	take advantage of UNOLS winch pool; these are well-maintained; but shipping is very costly, so for those used regularly should stay in PA
7	Sensor Calibration Lab	All necessary testing equipment enabling the ship to have its own periodically required calibration of shipboard sensors. Note: Budgetary Estimate	$0.13	3	High	necessary equipment used regularly
8	Telepresence	An advanced installed system that's integrated with the ship's communication systems and science spaces to allow a Ballard-type level of telepresence (URI's Inner Space Center). This technology is above and beyond the current proposed learning center system.	$1.10	3	Low	while desirable, not essential and can conduct successful teleprensence without an advanced installed system
9	Bridge Console Simulator	Provide the simulation module for training into one of the integrated bridge consoles, allowing the module operator to shift into a simulation mode for training. The operator uses the installed control levers and display to practice maneuvering the ship. Should have training modes for DP, icebreaker, station keeping, and maneuvering alongside a pier or other vessels.	$1.30	3	Low	other training insitutes provide these, so investigate this before investing specifically from this project
10	Automated Accommodation Ladder	Minimizes, what is typically, a crew-intensive process in deploying and stowing the accommodation ladder	$0.36	1	Low	non-automated less likely to break; automated may be problematic
11	Accommodation Ladder Boat Platform	Add the capability to the accommodation ladder to attach a small boat platform with fenders to make it safer and easier for the ship to anchor out and ferry people with the small boats	$0.04	1	Medium	worthwhile for ease of loading and unloading into launched small boats
12	SCBA Cascade Refill System	SCBA air bottles are rapidly refilled because the SCBA Cascade Refill System was permanently installed. Note: Single System.	$0.10	2	?	firefighting activities but do these need to be filled rapidly
13	Sensor Platform	Gimballed platform for the ship's science irradiance sensors. Note: Single platform.	$0.64	1	Low	not sure of advantage
14	Gravity Meter	Purchase an ARV dedicated digital gravimeter in lieu of using one from the NSF equipment pool.	$0.45	3	Low	availalble through UNOLS pool but would be on ship permanently
15	Mooring Line Storage Reels	Powered storage reels out of the weather, but located fore and aft to provide storage for the ship's mooring lines Note: 2 systems, electrically powered.	$0.68	3	Low	seems expensive for something that is typically done by hand and not that often
16	Hull Load Monitoring System	Install a hull monitoring system with ice loading and long-term hull fatigue monitoring capabilities-ABS has a number of Hull Condition Monitoring System notations that could be used as reference. Note: Includes Structure, motion, and voyage.	$1.89	1	?	we don't know exactly what this is and unsure why this isn't included if needed for working in heavy ice conditions
17	Condition Monitoring Systems	Expand the use of condition-based maintenance through installing equipment manufactured systems developed specifically for their respective equipment. Note: Budgetary estimate.	$0.89	2	High	safety considerations, helps with planning of maintainance
19	FLIR Camera System	A mast-mounted system with monitoring in the pilothouse. Note: Assume mounting on available mast. Includes remote control single monitoring station.	$0.09	2	Medium	allows visualization of heat, heat loss - useful as a navigation tool
20	Cell Phone Hotspots	Installed system to allow cell phone use from anywhere within the ship	$0.02	2	Low	redundant with WiFi calling, but need better shipboard WiFi
21	Clear Deck Windows in Pilothouse Bridge Wings	Similar to the windows on cruise ships, clear deck windows have a deck window for looking straight down in each of the bridge wings which increases operator's visibility of the waterline. Note: 2 windows installed during construction period with completed engineering prior to PRR.	$0.11	1	High	important for safety, important for along-side recoveries
22	Small boat innovations	Develop advanced and innovative small boat solutions that increases range, capability, and decreases environmental impact. Note: Budgetary LOE estimate.	$0.98	1	Medium	feedback suggested community interest in enhanced small boat capabilities; increased ease and safety for landings

23	Side Pool	Provide ice barrier to protect over-the-side operations in an ice field. Note: Assume installation during construction period. Midship to stern both sides.	$0.73	3	High	how would this be used? Deployed during over-the-side deployments and recoveries n icy waters, also when working in the ice (stationary in very heavy ice cover)
24	Palmer Station Pier Dolphin	Add pier dolphin to increase allowable weather envelop for berthing at Palmer Station.	$14.50	2	Low	originally in design but as design costs increased this was taken out of budget; ARV can dock at Palmer Staion Pier but if winds increase, will need to move off pier without Pier Dolphin -this increases stability of ship at pier; very important but should this be part of ARV budget?
	Total Opportunity Cost		**$34.11**	**-**		

Table 5: ARV scope reduction summary table

Scope ID	**Title**	**Technical Impact**	**Maximum Achievable Reduction ($M)**	**Latest Date**	**High = last to cut; Low = first to cut**	**Comments**
1	Aft Ship Control	Delete ship control capability in the aft science control room	$0.34	PRR	High	safe back deck ship operations
2	Outfitting	Reduce outfitting by the shipyard. Note: Budgetary Estimate for broad scope.	$0.46	PRR	Low	possible to shift outfitting to operator
3	ACCU	Eliminate ACCU certification requirement (or go to ACU - $1.745)	$4.68	Shipbuilder Construction Award	Low	useful to have monitoring tools but will always have manned engine room; worth a conversation
4	Ceiling Tiles	Eliminate use of ceiling tiles. Note: Lab Areas, Machinery Areas, Walkways. No alternate replacements.	$2.23	PRR	Low	Not essential
5	Small Boats	Delete small boats from fleet of available boats except for the regulatory required fast rescue boat	$1.85	PRR	High	community interest in small boat capabilities very high, but could shift costs to operator
6	Deck Heating	Delete deck heating	$3.20	Shipbuilder Construction Award	High	critical
7	Crane	Delete the portable crane on the aft working deck	$0.81	PRR	High	necessary equipment, could be provided by operator
8	Deck Sockets	Reduce the extent of 2x2 foot exterior deck socket grid to key areas only	$1.67	Shipbuilder Construction Award	High	always needed everywhere for maximum flexibility; could evaluate how strong sockets need to be - potential cost savings
9	Shipyard Earned Value Management (EVM)	Relax requirement for full use of EVM by the shipyard and their standard practice	$1.17	Shipbuilder Construction Award	High	contractor must personally be held responsible
10	Deck Gear	Reduce the extent of removable gear/equipment on the main deck, including having a limited number of removable bulwark sections	$2.43	PRR	High	allows for flexibility
11	Electric Growth	Reduce reserve growth in electrical distribution system from 20% to 10%	$11.21	Shipbuilder construction Award	Medium	nice to have overhead to grow but 10% margin is acceptable; could be switched to low with better design
12	Science Wireways	Reduce dedicated science wireways from two to one	$1.26	PRR	Medium	Scientists always want to wire things up, very useful
13	Entertainment System	Eliminate the entertainment system	$0.77	PRR	?	Not sure what this covers? Need greater specificity to rank.
14	Lab Deck Sockets	Reduce the extent of lab coverage for interior deck tie-down sockets	$0.44	PRR	High	always needed everywhere for maximum flexibility
15	Lab Outfitting	Reduce the outfitting requirements for the labs	$2.05	PRR	Medium	costs could be shifted to operator
16	Forward Stores Crane	Eliminate the forward crane	$1.88	PRR	High	needed for moving materials from forward deck to stores
17	Baltic Room Hoist	Eliminate the overhead hoist in the Baltic Room	$1.16	PRR	High	request greater clarity in use - related to CTD deployment and recovery? if yes, absolutely necessary
18	Furniture	Reduce the quality of furniture used in the staterooms	$0.43	PRR	High	If you don't do this now, it won't get done!
19	Vans	Reduce the number of vans that can be carried to the threshold level. Note: per van	$0.70	Shipbuilder Construction Award	Low	The PSPEC lists 20 (threshhold) and 24 (objective) 20-ft vans to be accomodated. Currently, space for 20 Lab Vans is allocated with 3 science containers in the Lab Van Garage, 2 on the AUV deck, 8 vans double-stacked in the hold, and the remaining vans located on the back working deck. We could have fewer vans in the hold, but prefer to maintain other vans at current number given the likelihood of projects that demand this heavy use of back deck located science containers, for example, drilling projects.
20	Spares	Reduce the level of onboard sparing	$2.57	PRR	?	Spares are critical but need to identify these items more specifically in order to rank
21	Meetings	Reduce the frequency of shipyard review meetings. Note per meeting	$0.13	Shipbuilder Construction Award	Low?	Unsure what this entails but is it possible to conduct some of the reviews via Zoom?
22	Staffing	Reduce the extent of project staff oversight at the shipyard and/or project staff (savings to shipyard contract and project overhead). Note: 10% reduction	$2.98	Shipbuilder Construction Award	High	High! Need oversight
23	Transducers	Owner supply transducers - eliminates the mark-up	$0.28	Post Shipyard Bid	Low?	This seems like a good idea, but is there a downside with regard to warranty or repair work?

24	Handling System	Owner supply cranes and A-frames- eliminates the mark-up	$0.20	Shipbuilder construction Award	Low?	This seems like a good idea, but is there a downside with regard to warranty or repair work?
25	Insurances	During cost negotiations, requirements for insurance and penalties could be reduced to transfer risk to the Owner-this transfer could cause a net cost increase if things do not go well. Note: Insurance only	$2.50	Shipbuilder Construction Award	Medium?	not sure of implications of this - need additional information
26	Battery	Delete battery system.	$2.24	PRR	Medium	Cost savings in the long term
27	Elevator	Delete personnel elevator	$1.62	PRR	High	Extremely beneficial moving heavy items between decks
28	Mammal Observation	Eliminate Mammal Observation and use the pilothouse	$3.25	Shipbuilder Construction Award	Medium	while desirable, can conduct marine mammal observations from bridge; how will this impact Meterologic Lab which was combined into MMO space?
29	Centerboard	Delete the centerboard and have all sonars hull mounted	$2.67	Shipbuilder Construction Award	High	quality of data from hull mounted sonar systems enhanced by centerboard
30	Atmospheric Lab	Eliminate the atmospheric lab at the base of the foremast and provide the data network connections only	$2.78	PRR	High	important scientiific lab
31	Meteorological Lab	Eliminate the meteorological lab	$2.87	PRR	High	important scientiific lab
32	Unmanned Aerial Vehicle (UAV)	Reduce the size of UAV's that can be supported so the UAV deck, hanger and associated support footprint reduced	$1.97	Shipbuilder Construction Award	High	will reduced size eliminate the possibility of landing a helicopter? If yes, then maintain size such that helicopter landing is possible. This opens up 2-ship operations for helicopter support of land and ice-based field work.
33	Lounge/Library	Go with the threshold requirement only for lounges and library	$3.61	Shipbuilder Construction Award	Medium	seems reasonable
34	Conference Room	Eliminate the conference room	$1.15	Shipbuilder construction Award	Low	could a single large room with a divider function as combined lounge/conference room on the 01-deck?
35	Spa	Eliminate the Spa and reduce to minimal polar code requirements only	$2.34	PRR	Low	not essential
36	Mess Deck	Reduce the mess deck size from seating at least 60 to 45	$1.96	Shipbuilder Construction Award	Low	under most working conditions, given shifts, likely that seating for 45 is adequate
37	Science Office	Eliminate the science office.	$1.10	PRR	Medium	clarify science office - is this the space for the Marine Lab Tech on the main deck or for the MPC on the 01-deck? Both spaces are used heavily
38	Ice Class	Reduce to PC4 ice class rating	$23.49	Shipbuilder construction Award	High	key feature of ARV will be its icebreaking capability
39	Endurance	Reduce the range/endurance by 10% to 15%	$8.90	Shipbuilder Construction Award	Medium	From the 2019 report "Endurance of >70 days (threshold) / >90 days (objective) underway and 17,000nm without replenishment. Average annual operational tempo of 250-300 days."
40	Ship's Office	Delete the ship's office (reception)	$1.15	Shipbuilder Construction	Low	not essential
41	Baltic Room Door	Eliminate the side shell opening door to the Baltic Room and associated boom and use the side A-frame for CTDs	$4.25	Shipbuilder construction Award	High	CTD is one of the most commonly used piece of equipment on the ship
42	Fixed Shaft	Use fixed shafts versus azimuthing drives	$16.50	Shipbuilder Construction Award	High	the azimuthing drives provide better maneuverability than fixed shafts?
43	Lab Space	Eliminate some lab space. Note:10% reduction.	$5.60	Shipbuilder Construction Award	High	with greater capacity for scientists, lab space should not be reduced; space on NBP already used to capacity on interdisciplinary cruises
44	Coring	Reduce core length threshold and objective to 30 and 40m respectively. (Currently 40 and 50m)	$1.00	Shipbuilder Construction Award	Medium	objective of 40 m acceptable
45	Habitability	Lower habitability requirements from Hab+	$5.64	Shipbuilder construction Award	Medium?	Having some interior berthing is acceptable but we need more information on other changes that would take place by lowering from Hab+. Would this impact acceptable niose levels for example?
46	Ice Trials	Do not conduct ice trials until in Southern Ocean	$4.03	Builder’s Trials	?	Where would the ice trials take place instead of Southern Ocean? Uncertain of impact.
47	Warranty Period	Reduce warranty period and deliver ARV earlier. Note: 10% reduction	$3.20	Shipbuilder construction Award	High?	Maintaining the warranty period as is provides a safety net for troubleshooting
48	Science Trials	Reduce science trials and move to R&RA	$2.80	Builder’s Trials	High	Science trials critical to test out all equipment and instrumentation
49	Crew	Operate vessel with USCG minimum crew number.	$2.30	Vessel Operator Award	High	for safe working conditions need adequate staffing
50	Science Technicians	Conduct science trials with minimum science technicians onboard	$0.50	Builder’s Trials	Medium	run the risk of not identifying problems with some systems if expertise not on board
51	Warranty Drydock	Do not return to US for shipyard warranty work	$3.87	Shipbuilder construction Award	Medium?	not sure of implications of this - need additional information
52	Ceremonies	Reduce or eliminate commissioning ceremonies	$1.00	PRR	Low	not essential
	Total Deductions	**(10% of baseline = $98M)**	**$159.19**	**-**		