The Bio/Chem/Analytical Lab is on the port side between the Hydro Lab and the Electronics Lab. This lab supports a variety or disciplines in a configurable space but it is also located furthest from the live animal/wet spaces to better isolate fixatives and other chemicals. It also two large fume extraction hoods.

Numerous commenters have found that the Electronics Tech Lab, which is just forward of the Biology Lab, is larger than needed, and the Biology Lab may be enlarged as volume is removed from the Electronics Tech Lab.

The Hydro Lab has close proximity to the Baltic Room, Main Lab and Bio/Chem/Analytical Labs, The science seawater system serves the Water Wall with fixed flow through sampling instrumentation and contains a climate-controlled space for a Salinometer Room. . Attention was spent to ensure that the space was large enough to accommodate both current and future flow through instrument needs as well as mission specific instruments while maintaining a configurable lab space. It also has both a small and large fume extraction hood. Based upon comments, the Hydro Lab has been designed larger than the PSPEC's minimum area requirement.

Both the Hydro Lab and the Biology Lab have direct access to the large central hallway with direct access to the aft Science Reagent and Hazardous Material Storage Locker.

The Computer/Electronics Lab is on the port side, opposite the SOC, and has easy access to the Main Lab and to the central hallway. The Computer/Electronics Lab is a configurable dry space to support scientific electronics, instruments and sensor assembly, servicing and trouble shooting. It has bench space to support CTD assembly, battery charging, acoustic release servicing, camera/video systems and other housed assemblies. Workbenches are modular and may be used to secure workpieces. It also has printers and over-sized plotters along with a video/photo editing works station and a 3-D printing workstation.

The Microscope Room has space for three microscopes, including a Keyboard, Video, and Mouse (KVM) to support each. A small Chem locker is provided for reagents and other chemicals., and the Microscope Room is directly adjacent to the central hallway with immediate access to the exterior HazMat locker. The microscopes will be installed on vibration isolation tables. The room is located in a place of minimal motion and with the ability to darken the space for fluorescence or photographic needs.

The Baltic Room is accessed by a 6ft double door into the Wet Lab, the Main Lab, and also onto the Starboard Working Deck. It is the primary deployment and recovery area for water sampling rosettes. The CTD LARS is deployed through a door through the hull side. The Baltic room is expected to be a wet space, and as such has substantial deck drains, washdown facilities, as well as the standard 2' x 2' bolt down grid. There is an overhead viewing area for the Baltic Room in the ship's reception area, and the space available has been optimized for many hands to access the CTD concurrently when it is recovered. The CTD LARS and CTD winch may be operated from the Baltic Room Control, which has unobstructed view of the starboard waterline as well as a commanding view of the Baltic Room operations. Backup controls for the CTD LARS and CTD Winch are available from the main winch control cab.

The Wet Laboratory is located aft of the Baltic Room for transfer of scientific samples from the Side A-Frame and Starboard Working Deck. The wet lab has oversize drains and may be equipped with a sill-less roll up door aligned with the Starboard A-Frame to facilitate operations involving the Starboard Working Deck, including trace metal operations utilizing a portable trace metals winch with specialized sheaves. The other laboratories are located on the port and starboard side of the vessel forward of the Baltic Room. All of the main deck labs are designed to facilitate accessibility for disabled science crew members. Double doors to facilitate equipment loading/unloading are provided for all science spaces located on the main deck. As required, the laboratories listed below are located on the main deck with access to the working deck area and a 72-inch-wide longitudinal passageway for access between the working deck area and the science spaces.

The Aquarium is aft of the Wet Lab, with a 6 ft double door connecting them. The Aquarium also has a 6 ft door accessing the Starboard Working Deck. It is the wettest space accommodating large and small free flowing aquaria with large direct access to the starboard working deck and service from the science and incubator seawater systems. It will have a grated deck and sediment traps for efficient drainage during sampling and processing efforts.

All the equipment required by PSPEC is installed. As with the Wet lab, the space is expected to be muddy, and is designed with the intent to be easily cleaned.

There are two identically sized cold labs, measuring 8ft wide and 20ft deep. Each have work benches, seating, and shelving for storage of samples. Both may be cooled as low as -20F.

The Atmospheric Lab is on the 03 Deck forward, underneath the flight deck. Tubing runs from sampling locations on the Atmospheric Mast, directly above, to the atmospheric lab. The Atmospheric Mast is far forward on the ship, in clear air. The Atmospheric Mast includes a small platform with a 2' x 2' bolt pattern to support installation of scientific equipment as necessary. The detail design of the mast will occur in the Final Design Phase, and its exact height will be determined then, after the Stack Gas Analysis Study. The tubing routing from Mast to sampling equipment length and turns are minimized and tubing is easily accessed for cleaning either through mechanical means or by provided compressed air.

The Meteorology Laboratory is located on the 07 Deck above the Bridge collocated within the Marine Mammal Observation Room; this location is in close proximity of the main mast, minimizing the length and number of turns for routed cables and piping for sampling. Additional wireways are installed for installation of equipment on a mission by mission basis.

There are some areas of the laboratory outfitting and arrangement that will be further developed but these items are not of concern at this stage of the design, and will be developed as the design matures and VFI is available. Examples of areas that are still under development include the size of fixed counters and cabinets and details of modular sink installations and hood exhaust details.

In all, the Science Laboratory Arrangement has been designed to maximize communication and collaboration among scientists, and to ensure safety and efficiency of the work done in them.

7. Science Support Spaces

Details of the ARV science support spaces outfitting and arrangement are shown on the drawing 5E1-601-D001 Science Space Arrangement Drawing, Reference 6). At this stage of the design, no significant design trade-offs are required to integrate the science support spaces in the ARV design and there are no risks identified or areas of non-compliance related to these compartments. These Science Support Spaces have been arranged to provide ease of access from required Laboratory spaces, and effective isolation from Laboratories as necessary for safety and function. All of the Science Support Spaces meet SMR and Performance Specification requirements for area, volume and outfitting.

The Science Main Deck is served by the Main Centerline Hallway which reaches from the aft working deck to the large door accessing the Science Stores Area. The hallway is designed to allow mobility of a pallet jack from bow to stern of the ship. The large Science Stores space is provided forward of the collision bulkhead. The entrance to the Science Stores is adjacent to the Science Office.

The Electronic Technician Shop is located on the main deck. It provides work station/office and bench space and tooling for Electronic Technicians to test trouble shoot and repair sensitive electronic sensors, instruments and systems for both standard shipboard and mission specific needs. It is equipped with static dissipative mats or deck coatings and specialized electronic tools and test equipment.

The Liquid Nitrogen plant is located aft of the Cold Storage/Labs next to the stack. This location separates it from the Labs due to noise, but keeps it on the Main deck to improve safe and efficient movement of working quantities of liquid nitrogen.

The Server Room is oversized for the current electronics compliment. This space will not be wasted, rather it provides storage for electrical and electronics supplies but also provides space for anticipated future growth of the ship's server compliment.

The Sonar Transceiver Room is situated above the Sonar Cable Trunk. The space supports the large transceivers and provides ample wireways for both transducer cabling and power and network cabling. Additional wire trays are available to support temporary sonar installations or growth in the ships transducer and transceiver compliment. Several comments have directed that the Transducer Room should be moved to the 01 Platform. In the PDR phase this will be a primary goal as the exact requirements for fuel tankage and provision storage are refined.

The Autosal room is currently in the Hydro Lab and provides a dedicated steady controlled temperature space for salinometer sample processing and sample bottle storage. This space is in consideration to be moved to the Bio/Chem/Analytical Lab when the Transceiver Room is moved to the 01 Platform. This would further increase the size of both Hydro and Bio/Chem/Analytical Labs.

The Staging Bay is aft of the Aquarium Room on the starboard side of the ship, it has large doors accessing both the Starboard Working Deck and the Aft Working Deck. The Staging Bay provides a sheltered location to stage and maintain equipment between deployments. It can also be used to shelter mission specific equipment such as Trace Metal Clean (TMC) rosettes, gliders and small AUVs, drifters and mooring gear. This space has large lockers for rigging and lifting gear. The door to the Working deck is sized such that either of the large workboats may be partially brought through the door for maintenance or equipment installation on the Science Workboats in inclement weather. Both large doors into the Staging Bay are supported by the Starboard Main Crane.

The Changing Room is on the interior of the ship, on the port side of the Main Centerline Hallway. It includes large lockers and drying racks as well as benches, hanging hooks and cubbies. It is set up in a “locker room” style layout, allowing crew to move about without interrupting other crew who may be gearing up more slowly or coming off the deck. Two toilets are adjacent to the changing room. It is equipped with boot and glove driers.

A passage extends behind the Changing Room providing access to the Lab Van Garage. Here three Lab Vans are supported by a weather resistant vestibule. This allows each of these Lab Vans to be accessed without going onto the weather deck. A sill is provided forward of the van door openings and oversized scuppers are provided to evacuate any deck water that flows underneath the Lab Vans. The Lab Vans are protected from the weather by an 8ft overhang overhead. The Lab Van Garage provides a flexible and modular solution to support mission specific science processing or sampling needs.

The ARV is required to accommodate at least 20 scientific and laboratory vans. The current van storage plan includes two (2) positions forward on the aviation deck, eight (8) vans double stacked in the hold and ten (10), or more, positions on the main working deck. The Lab Van Garage is located in a sheltered location forward on the main working deck and can accommodate three (3) lab vans with direct access into the ship. This can support mission specific laboratory or storage needs, but Rad Vans or Cesium source Vans can only be supported on the main working deck, without direct access to the ship, to prevent potential contamination. 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 foreward and aft end of each container.

The vans stored within the Science Cargo Hold are served through the Science Cargo Hold hatch. Once the vans are stacked two high and dogged together, they will be elevated on the van roller track, and tugged to the port or starboard side. Once in position, the roller track will be lowered locally, allowing the two containers to be captured by the hold’s ISO locks. This process will be repeated for storage of all eight Science Cargo Hold containers.

This same passage provides access to the Marine Tech Shop and the Carpenter Shop, both on the port aft corner of the ship’s house. Both of these shops have direct access to the weather deck, and both have a 4ft overhang protecting these entrances from weather.

The Marine Tech Shop opens directly onto the main working deck and contains equipment and tooling to support the over-boarding, maintenance and repair of oceanographic systems and their associated rigging. Large gear lockers contain lifting, rigging and lashing gear. Tooling for repair and light fabrication is arranged within this space.

The Carpentry Shop opens directly onto the main working deck and contains tools and stock for fabrication in wood and plastics including field repairs/modifications, crate building for science samples, and other mission specific support needs. This space will have a dust collection system.

The Marine Mammal Observatory (MMO) is located on the 07 Deck, above the Bridge and includes the Meteorological Lab within. The MMO also includes an AloftCon station which when not in use provides adjustable captain’s chairs allowing a wide field of view forward. From within the MMO, a full 360 degree view of the ocean is provided.

8. Science Network Infrastructure

The Science Mission Network Infrastructure is a collaboration of the Cybersecurity Integrated Product Team (IPT) and Network Design Working Group to integrate the relevant ARV Performance Specifications, Reference 3), science mission needs, and lessons learned from prior vessel network designs. The Science Mission Network Infrastructure design is shown on the Shipwide Network Diagram. The network diagram is the primary design artifact for the ARV network design with the Science Mission Network being one of three networks overseen, in addition to the Vessel Network and the Guest Network.

The Science Mission Network electronics racks are co-located with the vessel electronics racks in the included in Servers and Server Heating, Ventilation, and Air Conditioning (HVAC) Room located on the main deck between Frames 13 and 18. Based on customer feedback, the electronics racks are located on the main deck in the vicinity of the Science Laboratories and Science Support Spaces to facilitate workflow and science wireway routing between the Science Mission Network electronics racks and science spaces. The size and arrangement of the Servers and Server HVAC Room will be evaluated in more detail as the ARV design matures.

9. Scientific Electronic Systems

The Scientific Electronic Systems are required by the ARV Performance Specifications, Reference 3), to support the ARV science mission. Many of the Science underwater sensors that perform poorly through ice windows were prioritized for the centerboard along with two large spare well to support future or mission specific transducer needs. The transducer foundations will be machined into a removable base or "shoe" attached to the bottom of the center board. This also better facilitates future arrangements or new systems as they become available. The centerboard design is described in more detail in Section 9.1. The arrangement of the underwater sensors is shown on the drawing 5E1-301-D101 Scientific Electronic Arrangement Drawing, Reference 7). There are several spare sonar transducer ports on the box keel and there will be space reserved within the transducer cable trunk for the installation of additional, redundant or future sensors. The hull includes a box keel which mitigates bubble sweepdown and ice tumble and reduces self-noise. This box keel redirects surface air ingested into the sea by wave action and the icebreaking bow shape away from the sensors and around the hulls waterline.

The underwater sensors located on the hull plating are on the box keel,behind ice reinforced windows.. Additional underwater sensors are mounted on the centerboard which is able to be retracted and closed to protect the transducers from ice damage.. The Bottom Mapping Transceiver Room is located on the main deck, port side, directly above the Transducer Room. The location of the Transceiver Room is vertically aligned with the Deep Water Multi-Beam transducers to minimize the cable run length and cable bends required for routing between the transducers and the transceivers; this arrangement is in accordance with the manufacturer recommendations. The science underwater sensors are listed in Table 5. Descriptions of the sensor systems are in the following paragraphs. The desire to move the Transceiver Room to the First Platform is noted, and this will be a primary investigation as requirements for fuel and provisions are further refined.

As the ARV design continues to mature, and VFI is available, the science underwater sensor arrangement will be evaluated, including a hull form trade study and bubble sweepdown analysis to validate the sensor locations.

Below specific makes and models of these sensors are specified for reference; however, these manufacturer and models may be updated as new products become available.

9.1 Multi-Beam Echo Sounders

The multi-beam echo sounders include both deep water (10-8,000 m) and shallow water (3-3,600 m) multi-beam models.

The deep-water multi-beam echo sounder is the Kongsberg EM 124 one degree by one degree transmit and receive arrays. The EM 124 transducer arrays are fitted with titanium ice windows for protection from damage when the vessel is operating in ice-covered waters.

The shallow water multi-beam echo sounder is the Kongsberg EM 712 one degree by one degree transmit and receive arrays. The EM 712 is ice strengthened but is not capable of sustaining heavy ice breaking. For this reason the EM 712 is to be installed on the retractable centerboard, which will further increase its performance in open water conditions. The centerboard and the EM 712 may be deployed 10ft below the ship baseline, 3 ft below baseline, flush with the hull bottom, or protected inside the ship with a closure.

9.2 Sub-Bottom Profilers

The sub-bottom profilers are Kongsberg SBP 29 model which is a narrow beam, multi-beam profiler with a primary application to do sub-bottom imaging of sediment layers and buried objects under the sea floor. These profilers constitute a system that has a wide bandwidth (2-9 kHz) and narrow beams giving it improved penetration, cleaner data, and good angular resolution. The SBP 29 utilizes the EM 124 receive array so that only the SBP 29 transmit array is required. This allows the system to operate with wider beams when desired.

9.3 Acoustic Doppler Current Profilers

The Acoustic Doppler Current Profilers (ADCP) are Teledyne RDI for 38, 75, 150, and 300 kHz frequencies which can collect detailed maps of the distribution of water currents and suspended materials through the water column at depths 1000m and deeper. This sensor suite is helpful in applications including climate studies, mid-ocean frontal mapping, fisheries research and others. These sensors are clustered near each other on the box keel. Each are protected underneath a custom ice window that mimics water properties and allows low loss transmission of the ADCP through its protection. ADCP's perform well with minimal signal loss from behind composite ice windows and are suitable for placement in the Box Keel.

9.4 Marine Biology Echo Sounder/Sonar

The marine biology echo sounders and sonars are a suite of Simrad EK80 models. This suite includes individual 18, 38, 70, 120, 200, and 333 kHz transducers and is well suited for applications such as assessment of fish biomass and distribution, species identification and discrimination, plankton research, habitat mapping, behavioral studies, environmental research, and oil and gas detection. Notice that this installation exceeds PSPEC objective by including the 333 kHz transducer. This is included within this study for reference that the space is available for such an installation and may be eliminated if desired. These sensors are clustered on the bottom of the centerboard and are not provided with ice windows, as these sonars are sensitive to ice windows, and substantial resolution is lost.

9.5 Ultra-Short Baseline System

The Ultra-Short Baseline (USBL) system is the Kongsberg HiPAP 502P, a High Precision Acoustic Positioning System, designed for optimal positioning in both shallow and deep water of subsea objects such as AUVs, towed bodies or fixed seabed transponders. The ARV configuration for the USBL system uses a Classification Society approved gate valve to lower the USBL transceiver below the vessel keel when the system is operating and retract the transceiver inside the hull when the system is not in use to reduce drag, protect the system from ice damage, and for maintenance or repair. The system offers a wide range of transponder channels and cNODE transponder models for depths rating down to 11,000m.

9.6 Other Underwater Sensors

The hydrophones are Simrad PI Trawl model hydrophones and microphones dedicated for bottom and pelagic readings to communicate with deployed wireless sensors. The hydrophone monitoring system reception has a 50^o horizontal beam and 30^o vertical beam.

The ARV is also fitted with two (2) speed logs and a forward-looking sonar used for navigation and a forward-looking camera which may be used to observe bubble sweep down.

The centerboard has been designed to support installation of side looking sonars if these are desired. This capability is not required but may have added value.

As the centerboard will not be readily accessible for post-delivery modification, there are two spare transducer ports, presenting opportunity to install special purpose mission sensors.

Table 5: Science Underwater Sensors

Description	Quantity	Model No.	Manufacturer	Notes
Deep Water Multi-Beam	1	EM 124	Kongsberg	Box Keel Mounted, Transmitter
Deep Water Multi-Beam	1	EM 124	Kongsberg	Box Keel Mounted, Receiver
Shallow Water Multi-Beam	1	EM 712	Kongsberg	Centerboard Mounted, Transmitter
Shallow Water Multi-Beam	1	EM 712	Kongsberg	Centerboard Mounted, Receiver
Acoustic Doppler Current Profiler (ADCP) 38 kHz	1	RDi	Teledyne	Box Keel Mounted
ADCP 75 kHz	1	RDi	Teledyne	Box Keel and Centerboard Mounted
ADCP 150 kHz	1	RDi	Teledyne	Box Keel and Centerboard Mounted
ADCP 300 kHz	1	RDi	Teledyne	Box Keel and Centerboard Mounted
Sub-Bottom Profiler 3.5 kHz	1	SBP 29	Kongsberg	Centerboard Mounted
Marine Biology Echo Sounder/Sonar 18 kHz	1	EK80	Simrad	Centerboard Mounted
Marine Biology Echo Sounder/Sonar 38 kHz	1	EK80	Simrad	Centerboard Mounted
Marine Biology Echo Sounder/Sonar 70 kHz	1	EK80	Simrad	Centerboard Mounted
Marine Biology Echo Sounder/Sonar 120 kHz	1	EK80	Simrad	Centerboard Mounted
Marine Biology Echo Sounder/Sonar 200 kHz	1	EK80	Simrad	Centerboard Mounted
Marine Biology Echo Sounder/Sonar 333 kHz	1	EK80	Simrad	Centerboard Mounted
Ultra-Short Baseline Transceiver	1	HiPAP 502P	Kongsberg	Box Keel Mounted
Speed Log	2	379814A	Kongsberg	Box Keel and Centerboard Mounted
Spare	4	TD50VLF	TBD	TBD Mounted
Acoustic Release Transponder 12 kHz	1	cNode	Kongsberg	Centerboard Mounted
Hydrophone	5	PI Trawl	Simrad	Box Keel and Centerboard Mounted
Forward Looking Camera	1	V-90	Dropshot 20/20	Centerboard Mounted
Forward Looking Sonar	1	SN-90	Kongsberg	Centerboard Mounted
Side Looking Sonar*	2	SN-90	Kongsberg	Centerboard Mounted

*Unrequired additional capability

9.7 Centerboard Design

The centerboard and centerboard trunk are required by the ARV PSPEC, Reference 3), to support the ARV science mission. The centerboard allows the scientific underwater sensors to be deployed below the vessel keel outside of the turbulent flow created by the vessel while underway to improve the functionality of the sensor readings. This arrangement also allows the underwater sensors to be raised above the vessel keel inside the centerboard trunk for protection from ice damage for vulnerable transducers when the vessel is operating in ice-infested waters.

These scientific underwater sensors are housed in the ARV centerboard:

Shallow Water Multi-Beam EM 712

- Marine Biology Echo Sounders 18, 38, 70, 120, 200, 333 kHz
- Speed Log
- Hydrophone
- Side Looking Sonar, Konsgsberg SN90
- Forward Looking Sonar, Konsgsberg SN90
- Underwater Forward-Looking Camera, Dropshot 20/20 -V90 or equivalent

The arrangement of the centerboard is shown on the drawing 5E1-301-D101 Scientific Electronic Arrangement Drawing, Reference 7). Notice that the side looking sonar and 333 kHz EK80 exceed requirements. If these are not installed at the time of delivery, it is recommended that the space and access should be reserved for this pre-planned product improvement.

The centerboard is designed to be deployed while the vessel is underway for science operations; therefore, the drag created by this appendage is important to consider with the overall vessel speed and resistance requirements for science operations. The overall size of the centerboard must be balanced to allow for adequate spacing of the transducers while minimizing overall drag. The NACA 0021 foil section was selected as the design point for the ARV centerboard – this foil section presents a low risk of stalling at the angles of attack expected when tracking a straight line over ground with a vessel crabbing angle. The underwater scientific sensor arrangement was optimized to have a footprint as small as possible with minimum required spacing between sensors to minimize obstruction and potential offset errors of the sensor readings. Based on the optimized sensor arrangement, the centerboard has a chord length (longitudinal direction) of 162 inches and thickness (transverse direction) of 56 inches.

The centerboard is raised and lowered within the centerboard trunk using a mechanical system with designed stops. The centerboard trunk will be larger than the centerboard. The centerboard is designed for three (3) down positions and one (1) maintenance position. The maximum deployed position of 10 ft. below the keel and to be retracted within the centerboard trunk so that the bottom fin position is no less than 35 ft. above baseline, and no less than 7 ft. above the waterline to allow for access for maintenance and calibration of the sonars. The centerboard trunk is fitted with an ice door to minimize damage from ice to the centerboard and underwater sensors when the centerboard is in the stowed and maintenance positions. The centerboard trunk is located adjacent to other multi-deck trunks such as the propulsion exhaust casing, lift trunk, and stair towers; this grouping of trunks minimizes the overall impact of the trunks on interior arrangements.

As the ARV design continues to mature, and VFI is available, the centerboard design and underwater scientific sensor arrangement will be developed in more detail.

9.8 Science Seawater System

The Science Seawater System consists of two (2) Scientific Seawater Pumps and two (2) Incubator Seawater Pumps installed to provide ambient temperature seawater to science laboratories, laboratory van sites, incubator locations, and the Aquarium Room as required by the ARV PSPEC, Reference 3). The location of the Science Seawater System components including the pumps, temperature probes, and Scientific Seawater Instrument Room is still under development at this stage of the design. The arrangement of the ARV Science Seawater System piping is shown on drawing 5E1-524-D001 Science Seawater Diagram, Reference 8). As the ARV design continues to mature, and VFI is available, the system design will be developed in more detail including location of key system components and verification of pump sizes based on the system arrangement.

The Science Seawater System materials must be corrosion resistant in seawater and as chemically neutral as possible to deliver science sampling water that is closely matched to ambient seawater conditions of the vessel when other scientific samples and data is collected. To improve the quality of the science sampling water relative to the ambient conditions, G&C is exploring the option to use debubblers (large debubblers at the intake manifolds or smaller debubblers within each science space), and also investigating ice separation systems. The piping material for the Science Seawater System is chlorinated polyvinyl chloride (CPVC); this material is immune to corrosion that results in pipe leaching for enhanced corrosion protection. Insulation is fitted for the science seawater system to limit the temperature change of water to 2 degrees Fahrenheit (^{o}F) or less from the inlet to point of use and insulation is fitted for the incubator seawater system to limit the temperature change of water to 1^{o}F or less from the inlet to point of use.

An audible/visual alarm system will be provided for the deck incubator system and live aquarium tanks.

10. Workboats

The ARV will support four science support small boats. Two 6-7m Rigid-Hull Inflatable Boats (RHIBs), one 10 m Science Survey Boat and one Landing Craft.

The diverse makeup of the small boat complement on ARV is necessary to support a broad range of scientific activities and observations off ship. The small boats are the primary method of access to water, land and sea ice for off ship scientific endeavors. The smaller RHIBs need to be simple, open, multi-use platforms that maximize space available for science equipment and personnel. The Scientific Work Boat will be outfitted with sampling and survey equipment and sonars with a requirement for a 12-hour endurance. The Landing Craft Work Boat will need to be a robust and capable solution, as it is the only method of transporting bulky science cargo from ship to shore.

Alternatives to traditional solutions should be considered that may better support operation in the rough and cold seas of Antarctica and the unimproved landing sites around the continent. Significant lessons learned have been realized in the program while working to improve small boat capability and access in the Palmer Station area. This experience has shaped and influenced capability, operation and maintenance of the small boats directly supporting US scientists and their efforts collecting scientific data on the water in Antarctica.

The ARV Project can leverage the knowledge and experience to date, from what is arguably the most diverse and capable scientific small boat program across Antarctica, in order to identify the safest and most effective small boat support solutions for the next generation Antarctic Research Vessel.

10.1 Science Small Boat characteristics

10.1.1 7m RHIBs open boat (2ea)

The ARV is equipped with two 7m RHIB support boats. These are particular useful in recovering gliders, tagging ceatations and for dive operations. These boats will be propelled by inboard diesel, outboard diesel, or electric drives. No gasoline engines will be required.

One of these RHIBs will be supported by a dedicated man rated launch and recovery davit. The other will have a deck cradle, which may be stowed on the 01 Boat Deck, or may be stowed on top of one of the Science or Stowage Vans and will be supported by the Port Main Crane.

10.1.2 Key 7m RHIB features and capabilities

- Matched/Interchangeable Hulls
- Air collar or similar fendering system for safety
- Consider diesel outboard, diesel hybrid or electric drive (no gasoline outboards)
- Multi-task role moving Pax and science support equipment on water, to sea ice or shore
- Open boat plan, bolt pattern, lashing points
- Low dead rise for improved beaching, multi-chined for maneuverability
- Aluminum hull with close scantling spacing and beaching pads for rocky and rugged landings
- Personnel lift rated
- Antennae arch for VHF/AIS/GPS antennae
- Simple low-profile control/steering station to maximize open cargo capacity
- Able to accept a removable bow pulpit for tagging, biopsy and close approach

10.1.3 Scientific Science Survey Launch

The Scientific Survey RHIB is the workhorse of the off-ship science operations. This includes a winch and A-Frame for towed operations, a sonar transparent well where sonar systems are installed, several scientific workstations, and a foam filled inflatable collar surrounding the hull's gunwale. This will be a twin engine boat, with either an inboard diesel, outboard diesel, or electric drive. The Scientific Survey Launch RHIB is highly maneuverable by virtue of its twin propulsors and is capable of being fitted with a Dynamic Positioning System. The RHIB will carry a suite of scientific instruments on its mast, including a cellular antenna for line-of-sight telemetry with the ARV and a StarLink or equivalent for over the horizon telemetry. The 10m RHIB is supported by a dedicated launch and recovery davit system located in a sheltered pocket on the 01 Boat Deck. The Scientific Survey Launch RHIB will have an onboard head and climate controlled cabin.

10.1.4 Science Survey Work Boat Features and Capabilities

- Air collar or similar fendering system for safety
- Consider diesel hybrid drive or electric (no gasoline)
- Research winch and stern a-frame (electric drive preferred) for towing and casting science packages. Plankton nets, Bongo nest, ECO rosette CTD
- Survey capability, multi-beam mapping (near shore/uncharted) capable
- Bio-acoustic survey, micro scale, (2-3 band EK-80) 38&120 kHz minimum
- Seismic support Chirp/Sparker, stream, survey grade GPS
- Full Nav Suite, Radar/Fathometer/AIS
- Cabin heat/head/fold down workstations for survey party/techs
- 2 crew 4 science/techs. Total of 6
- Bolt pattern and lashing points
- Keel cooler, no raw water in the boat to freeze
- Shore power/comms (boat power, block heaters, data line)
- Sonar well/ice window for transducer protection
- Cradle for storage when not in handling system
- On water support for glider ops, USV ops, close approach

10.2 Landing Craft Work Boat

The ARVs 10m Landing Craft is stowed on the 01 Boat Deck and is launched and recovered by the Port Main Crane. Its cradle may be installed on the top of one of the Science or Stowage Vans. The Landing Craft will have twin engines, either inboard diesel, outboard diesel, or electric drive. It will have onboard winches and a forward deploying launch gate. The pilot house will be set aft so as to support deployment of snow machines from the launch gate.

10.2.1 Landing Craft Features and Capabilities

- Air collar or similar fendering system for safety
- Consider diesel hybrid drive or electric (no gasoline)
- Transition challenge on an icy lee shore
- Consider non-traditional solutions to a traditional landing craft or augment with a transition solution
- Able to move bulky science equipment and portable sampling systems ashore (or sea ice)

- Able to move ashore equipment to establish a short-term Field Camp
- Able to transport science and tech pax and samples to and from shore

The ARV will support four science support small boats. Two 6-7m RHIB open boats, one 10m Science Survey Boat and one Landing Craft. The diverse makeup of the small boat complement on ARV is necessary to support a broad range of scientific activities and observations off ship. The small boats are the primary method of access to water, land and sea ice for off ship scientific endeavors. The smaller RHIBs need to be simple, open, multi-use platforms that maximize space available for science equipment and personnel. The Scientific Work Boat will be outfitted with sampling and survey equipment and sonars with a requirement for a 12-hour endurance. The Landing Craft Work Boat will need to be a robust and capable solution, as it is the only method of transporting bulky science cargo from ship to shore.

Alternatives to traditional solutions should be considered that may better support operation in the rough and cold seas of Antarctica and the unimproved landing sites around the continent. Significant lessons learned have been realized in the Program while working to improve small boat capability and access in the Palmer Station area. This experience has shaped and influenced capability, operation and maintenance of the small boats directly supporting US scientists and their efforts collecting scientific data on the water in Antarctica.

The ARV Project can leverage the knowledge and experience to date, from what is arguably the most diverse and capable scientific small boat program across Antarctica, in order to identify the safest and most effective small boat support solutions for the next generation Antarctic Research Vessel.

11. Design Trade-Offs

Two design trade-offs are described in more detail below to integrate the underwater sensors into the ARV design: hull form analysis, and centerboard design. At this stage, no significant design trade-offs are required to integrate other areas of the science systems.

11.1 Hull Form

The ARV is capable scientific research ship with icebreaking capability. Traditional hull forms for icebreaking are typically not desired for optimal performance for science operations (enhanced seakeeping at slow speeds, reduced bubble sweepdown for sensor performance). The design trade space for the ARV hull form therefore has two competing and opposed criteria that must be balanced as the design progresses. G&C has analyzed six (6) hull form variations to effectively balance hull form parameters of the ARV design with the competing criteria of icebreaking and science operations. Based upon additional understanding of the hull's icebreaking, bubble sweepdown, and open water performance, a further study of additional hull forms will be conducted in the post-PDR phase that will inform further testing.

11.2 Centerboard Design

To ensure optimum performance of the scientific sonar instruments, the team considered integrating a centerboard and centerboard trunk in the ARV design. G&C selected a single centerboard design over a twin centerboard design due to cost considerations and the added interior volume required to accommodate two separate centerboard trunks. A twin centerboard design may increase the total number of sensors capable of lowering below the keel, but the current single centerboard design satisfies the requirements, and this configuration is considered adequate.

12. Technical Risks, Areas of Non-Compliance, and Mitigation Measures

Bubble Sweepdown performance of the hull remains sub-optimal. This will be addressed in the Post-PDR phase of design with further CFD analysis and model testing.

The portable Aft Deck Working Crane is required to be installed on the Working Deck bolt pattern. This requirement has been called into question by our crane vendor and structural design team. This installation may require recertification by regulatory bodies each time it is moved. Additional vendors will be engaged in the Post-PDR phase to more thoroughly vet this requirement.

The two main cranes are currently sized to support significant lifts at maximum reach in sea state 5+. There is concern that this is a requirement for capability that will never be utilized in actual operations. Substantial weight and expense can be saved if this requirement is moderated.

Details of the working boats requirements have not been finalized and will be better fleshed out in the post-PDR phase.

13. Conclusions and Recommendations

The design and integration of science systems into the overall vessel design supports the successful science mission execution. The science systems integration is guided by the Performance Specification. As the ARV design continues to mature, and VFI is available, the design and integration of the science systems will continue and this report will be updated.

The ARV PDR design provides a significant advance in capability over current vessels across the spectrum of requirements. The ARV can explore previously inaccessible regions due to it's icebreaking capabilities and range. The Science Space Arrangements meet and exceed the requirements, provide for future growth, and provide for safe workspace, efficient workflow, and close proximity of workplaces. This carefully considered design allows for less fatigue, less risk of injury, and improved collaboration.

The deck equipment design allows for excellent accessibility, maintenance, and operability. The CDT and Piston Core LARS systems provide capabilities without precedent. A thorough examination of the winch requirements and limitations has led to a safe, efficient, and capable reeving arrangement. Active heave compensation is available on all of the winches, and through good reeving design, that capability may be extended to the Main Cranes. The man-rated cranes allow for deployment of crew of differing abilities onto the ice or into the workboats.

The compliment of Science WorkBoats are easily and safely deployed even in significant sea states, and the capabilities and efficiency of these workboats continues to evolve.

The ARV Preliminary Design has laid the foundation upon which the vision of an efficient, safe, and capable research ship may be realized. This design is poised make a significant advance is the scientific research capabilities of the National Science Foundation.

14. References

1) ARV Science Mission Requirements
2) NSF Research Infrastructure Guide (RIG)
3) ARV Performance Specifications
4) ARV Configuration Control Plan (CCP)
5) G&C Drawing No. 5E1-580-D001, Handling Systems and Scientific Package Deployment Drawing
6) G&C Drawing No. 5E1-601-D001, Science Space Arrangement Drawing
7) G&C Drawing No. 5E1-301-D101, Scientific Electronic Arrangement Drawing
8) G&C Drawing No. 5E1-524-D001, Science Seawater System Diagram
9) University – National Oceanographic Laboratory System (UNOLS) Research Vessel Safety Standards 11th Edition, November 2021