University-National Oceanographic Laboratory System

Global Class

Oceanographic Research Vessel

Science Mission

Requirements

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University-National Oceanographic Laboratory System (UNOLS)

Science Mission Requirements for Ocean Class Oceanographic Research Vessels

These Science Mission Requirements (SMR) were developed as part of the Academic Fleet Renewal effort outlined in the Federal Oceanographic Facilities Committee (FOFC) report: *Charting the Future for the National Academic Research Fleet – A Long-Range Plan for Renewal* published in December 2001. Funding for development of the SMR is provided to UNOLS through NSF Cooperative Agreement number OCE-1922916 and through ONR Grant number N00014-19-1-2614.

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Preface

Global Class Research Vessel

Science Mission Requirements

The timely replacement of the academic research fleet is vital to oceanographic research in the United States. The ships age and become more expensive to operate and they become less capable as scientific missions evolve. Yearly fleet utilization data continues to illustrate how critically important the Global Class research vessels are to supporting critically important major oceanographic research projects, particularly ones supporting collaborative international programs. Recognizing the need to maintain a continued focus on readiness to upgrade / renew the Global Class element of the Academic Research Fleet, the Fleet Improvement Committee initiated the review and update of the Global Class Science Mission Requirements over the past few years.

While the process used to construct new ships is many faceted, the first step is the formulation of the Science Mission Requirements: the SMR. The SMR states with as much specificity as possible what attributes the ship must have to perform the science envisioned. For example, “What is the maximum sea state that a CTD cast can be taken in?” or “Is a core storage freezer needed and how big should it be?” The SMR provides a science capability framework for the steps between community input, vessel concept design, and final construction. It is not meant to serve as a final list of specifications, but as a list of science needs that may face prioritization during the funding, design and construction phases of building new Global Class vessels.

This document provides the best estimate of what the Science Mission Requirements are for a Global Class Research Vessel for the foreseeable future. The document represents the dedicated work of many people including the Global SMR Sub-committee, the Fleet Improvement Committee, the UNOLS Office, and many other contributing scientists and subject matter experts over the past few years. The Fleet Improvement Committee has reviewed and finalized the document. The final document has also been approved by the UNOLS Council.

Although Science Mission Requirements and technology change with time this SMR represents a community consensus of what a Global Class vessel should be capable of in the coming years. This document should be considered a living document that should be updated as new science requirements are identified and as new technical solutions become available.

This SMR should serve as the guiding document for concept designs, preliminary designs, and construction of Global Class Research Vessels.

We are deeply indebted to the following people who contributed significantly to this endeavor:

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Executive summary

The Global Class of general purpose research vessels is designed to support integrated, interdisciplinary research throughout the world's non ice-covered oceans, including ice-free waters in the polar regions. The primary requirement is a maximum capability commensurate with ship size to support scientific, educational, and engineering operations in all oceans, with improved over-the-side equipment handling, station keeping, and acoustic system performance while providing a stable laboratory environment for precision measurements.

These vessels should be designed to be reliable, cost effective, and flexible.They will support scientific (non-crew) parties as large as 45 persons, with a minimum of 22 plus the chief scientist in separate staterooms. Attention to the details of habitability and the design of crew and technician berthing should promote crew retention and the resulting expertise for supporting the scientific missions. The vessel should support expeditions up to 70 days and a total range up to 16,000 nautical miles (20,000 km) at optimal transit speeds. The ship should be able to sustain 12 knots through sea state 5 with fine speed control. The vessel must have effective dynamic positioning relative to a fixed position in a 45 knots wind, sea state 6 and 2 knot current.

The design should maximize the sea-kindliness of this vessel and maximize its ability to work in sea states 6 and higher. It is desirable for this vessel to be capable of maintaining scientific operations in approximately 75% of winter weather in the Pacific, Indian, and Atlantic Oceans. In sea state 5 the vessel should be fully operational for all but the most demanding deployments and recoveries.

The stern working area, with a minimum of 3,500 sq ft aft of deckhouses and total space equal to at least 4,500 sq ft, should be open and as clear as possible from one side of the ship to the other and highly flexible to accommodate large and heavy temporary equipment. In addition, a contiguous work area along one side should provide a minimum of 150 ft clear deck area along the rail. The area should be designed to provide a dry working deck with provisions for allowing safe access for deployment and recovery of free-floating equipment to and from the water.

Additional deck areas should be provided with the means for flexible and effective installation of incubators, vans, workboats and temporary equipment. There should be maximum visibility of deck work areas and alongside during science operations and especially during deployment and retrieval of equipment. Working deck space forward of the bridge should accommodate four 20 ft portable deck vans for instruments and sampling equipment requiring a wide field of view and clean wind sector with access to instruments and sampling equipment on the bow mast or tower. The bow mast should have ample space for science party-supplied meteorological sensors at a height of at least 16-20 m above sea level and capacity to mount power distribution and data interface equipment without interfering with smooth airflow over the bow.

Voice communications systems between the bridge, labs, working decks and machinery spaces should be designed to effectively enhance ship control during science operations.

The design of weight handling appliances to safely and effectively deploy, recover, and tow a wide variety of scientific equipment should be considered at the earliest stages of the design cycle. The entire suite of over the side handling equipment including winches, wires, cranes, frames, booms and other appliances should be considered as a system. Designs for over the side appliances and equipment should include innovative thinking and consider ideas that will reduce the amount of human intervention necessary for launch and recovery of equipment, both on wires and untethered, and that will control packages from the water to the deck, maximizing efficiency and safety during complex operations. This will enhance personnel safety, reduce manning level requirements, increase operability in heavier weather and protect science and ship's equipment. The winches should provide fine control and have maximum speeds of at least 100 m/min. Scientific coring operations should be supported. The ship should be capable of towing large scientific packages continuously for extended periods of time. A suite of modern cranes should be provided to handle large heavy equipment and that can reach all aft working deck areas. The capability of offloading vans and equipment weighing up to 30,000 lbs to a pier or vehicle when in port is desirable.

Total lab space should be approximately 4,200 sq. ft. including: Main Lab area designed to be flexible for frequent subdivision; smaller specialized labs (analytical; bio, etc.); separate wet lab/hydro lab located contiguous to sampling areas; climate controlled work space or chamber; and an Electronics/Data Analysis Lab. A high bay/hanger space for multiple purposes adjacent to the aft main deck should support protected setup and repair of equipment, sample sorting and other related functions. Flexibility and support for different types of science operations within limited space are the important design criteria for these vessels. Benches and cabinetry should be flexible and reconfigurable. A separate electronics repair shop/work space for resident technicians should be included. Storage space for resident technician spares and tools should be defined in the design and not part of usable laboratory space. There will be dedicated storage (science holds) and workshop space for science use. There should be accessible safe storage for chemical reagents and hazardous (non-radioactive) materials.

Lab areas need to have separate electrical circuits on a clean bus with uninterruptible power available wherever needed. Seawater systems should be designed to provide uncontaminated seawater to all science work areas and higher volume seawater to maintain on deck incubation experiments at ambient surface temperatures. The best available navigation systems will be provided for geo-referencing all data and for dynamic positioning and ship control as part of an integrated information system. Internal and external communications systems will provide high-quality voice communications and continuous high-speed data communications throughout the ship and with shore stations, other ships, aircraft, and data sources.

Space should be available on aft decks to carry eight standardized 8 ft by 20 ft portable deck vans that may be laboratory, storage, or other specialized use and up to two additional portable, possibly non-standard size, vans on superstructure and working decks is required. At least two 16-ft or larger rigid hull inflatable boats located for ease of launching and recovery using minimal crew is also required. The variable science load should be up to 200 LT.

The ship should be as acoustically quiet as practicable in the choice of all shipboard systems, their location, and installation. Propeller(s) are to be designed for minimal cavitation, and hull form should attempt to minimize bubble sweep down. Design criteria for noise reduction should aim to reduce radiated noise into the water that may affect biological research objectives, acoustic system performance, and habitability.

Heating, ventilation, air conditioning and lighting appropriate to berthing, laboratories, vans, and other interior spaces being served should be carefully engineered and designed to be effective in all potential operating areas.

A thorough evaluation of construction costs, outfitting costs, annual operating costs and long-term maintenance costs should be conducted during the design cycle in order to determine the impact of design features on the total life cycle cost. The design should ensure that the vessel could be effectively and safely operated in support of science by a well-trained but relatively small number of crew (ca. 20). Vessel accessibility should be addressed and maximized in order to make personal participation in research at sea available to more persons with disabilities. Global operations, available ports and shore-side services should be considered during the design process. In the context of energy efficiency and minimizing environmental impact, “green” technologies should be included in the design.

The Science Mission Requirements articulated in this document will require revisiting to validate and/or update them prior to commencing the acquisition of any new Global Class research vessels. Such action will be necessary given the rapid pace of technological advances and anticipated changes in scientific needs. It is recommended that the UNOLS Fleet Improvement Committee revisit these Global Class Science Mission Requirements every 3 years to ensure their continued relevancy and to minimize the amount of change and updating that may be necessary on initiation of efforts to acquire any Global Class research vessels.

Summary of Global Class Science Mission Requirements (SMRs)

Parameter	Capability or Characteristic
Accommodations and habitability	
Accommodations	Full crew, 2 Marine Technicians, and up to 45 non-crew personnel, with a minimum of 22 plus the chief scientist in separate staterooms
Habitability	Attention to details that ensure effective work and living spaces, including for persons with disabilities
Operational characteristics	
Operational area	All non-ice-covered ocean waters, including ice-free areas in the polar regions
Endurance	70 days (30 transit and 40 station)
Range	Up to 18,000 nautical miles at optimal transit speeds
Speed	12 knots sustainable through sea state 5
Sea keeping	Maximize ability to work in sea states 6 (4 to 6 m wave heights) and higher
Station keeping	Dynamic positioning relative to a fixed position in 45 knot wind, sea state 6, and 2 knot current
Track line following	Maintain a track line within ± 5 meters of intended track and with a heading deviation (crab angle) of less than 45 degrees with 40 knots of wind, up to sea state 6 (4 - 6 m wave heights), and 2 knots of current
Ship control	Design for maximum visibility and effective ship control
Ice strengthening	May be needed for work near 1st year ice
Over-the-side and weight handling	
Winches, wires, frames, and cranes	New generation oceanographic winches, frames, cranes, and other weight handling equipment that are integral parts of an equipment handling and deployment system. Winches should provide fine control (0.1 m/min under full load); maximum winch speeds should be at least 100 meters/min. Cranes that can reach all working deck areas and that are capable of offloading vans and equipment weighing up to 30,000 lbs to a pier or vehicle in port are desirable
Towing	The ship should be capable of towing large scientific packages up to 20,000 lbs tension at 6 knots, and 35,000 lbs at 4 knots. Winches should be capable of sustaining towing operations continuously for days at a time
Science working spaces	

Working deck	Stern working area - 3,500 sq ft minimum aft of deck houses open as possible. Contiguous waist work area along one side that provides a minimum of 150 ft clear deck area. Total amount of clear working area available on the main deck aft should be at least 4,500 sq ft. Foredeck work area – 1,800 sq ft minimum forward of the bridge, one level up from the bow weather deck for protection from over-washing seas and spray.
Laboratories	Total lab space should be approximately 4,200 sq ft including: Main Lab areas (2 at 1,000 sq ft each) designed to be flexible for frequent subdivision; Separate Wet Lab and Hydro Lab (400 sq ft each) located contiguous to sampling areas; Analytical Lab (500 sq ft); Electronics/Data Analysis Lab and associated users space (500 sq ft); two climate-controlled chambers/walk-in refrigerator/freezers (100 sq ft each); Electronics/Computer lab (300 sq ft) for resident technicians. High bay/hanger space for multiple purposes adjacent to the aft main deck;
Vans	Carry 12 standardized 8 ft by 20 ft portable deck vans and possibly non-standard size vans (1920 sq ft total) with appropriate power, data and comms connections to each van
Storage	Approximately 20,000 cubic feet of storage space that could also be used as shop or work space when needed would be desirable.
Science load	Variable science load should be 200 LT.
Workboats	At least two 16-ft or larger rigid hull inflatable boats located for ease of launch and recovery
Masts On deck incubations Marine mammal & bird observations	Design criteria are presented so these science operation areas are not overlooked
Science and shipboard systems	
Navigation Data network and onboard computing Real time acquisition Comms – internal Comms – external	Navigation, computing, voice and data communications, and cyber-security through the best available systems using current expert advice. Systems should be specified as close to actual delivery as possible.

Underway data collection & sampling	Promotes design of flexible and functional systems for data collection and sampling using advice from experts at the time of design and specification.
Acoustic systems	
Visiting science systems	Build in capability to accommodate a variety of equipment Ensure discharges do not impact science, health and environment.
Discharges	Ensure discharges do not impact science, health and environment.
Construction, operation & maintenance	
Maintainability	Ensure that the design and construction of these vessels consider the ability to maintain and operate the vessels within domestic and international regulations in a reliable and cost-effective manner.
Operability	
Life cycle costs	
Regulatory issues	

Mission statement and overall characteristics

The Global Class of general-purpose research vessels is designed to support integrated, interdisciplinary research throughout the world's ice-free oceans. The primary requirement is a maximum capability commensurate with ship size to support science, educational, and engineering operations in all oceans, with improved over-the-side equipment handling, station keeping, and acoustic system performance while providing a stable laboratory environment for precision measurements. These vessels should be designed to be reliable, cost effective, and flexible.

These ships are to serve as general-purpose research vessels. They will support larger scientific parties and greater flexibility in use of laboratory/deck spaces than are now available aboard the Ocean Class ships, and at a minimum be equivalent to the Global Class vessels they will replace. They should also be configured to accommodate ice-margin research, fisheries-related oceanography, underway survey operations or other specialized missions.

To accomplish these goals there are several features that should receive high priority during the early design cycle phases. These vessels should be acoustically quiet in terms of radiated noise so that hull mounted acoustic systems can function at their maximum capability. Seakeeping and station-keeping capabilities will be important design drivers as well. Education and public outreach are becoming an important function during research cruises and the personnel and equipment to carry out this mission should be considered during design. Paying attention to habitability issues such as noise control, vibration, ventilation, lighting, berthing needs, exercise facilities and aesthetics will also increase the effectiveness and health of the crew and science party.

The specification of scientific and operational equipment outfitting should be carefully planned and updated during the construction phase so that the vessel is delivered with the currently best-available technology and to meet evolving science needs. Expert scientific, technical, and operational groups should provide guidance and advice on design criteria for all key scientific and operational systems. Experience in the design of past research vessels as well as innovative new approaches should be used to provide designs that will serve the community well for three decades.

The ability to effectively maintain these vessels during full operating years with the smallest regular crew size meeting regulatory requirements should be a design criterion. A Full Operating Year for a Global Class research vessel is 260-300 days of dedicated science operations during a calendar year. Designs should also anticipate major machinery overhaul and replacement, as well as future improvements. Fuel efficiency and reliable machinery and equipment will serve to reduce the life cycle cost of these vessels. The design cycle should carefully consider the tradeoffs between initial acquisition costs and long-term operating costs.

Science Mission Requirements (SMR) - Overview

The purpose of the science mission requirements is to set down design features and parameters that should be used as guidelines during the various design phases. There are some areas where there will be tradeoffs between two or more desired capabilities. By allowing more than one concept design, the possibility of finding ways to minimize these tradeoffs will be enhanced. A key concept is that ship systems are completely integrated with the science mission for these vessels. Sample mission profiles are included in Appendix I to provide examples of how these vessels might be used. It is possible that not all requirements can be fully realized in any one design and it will be necessary to refine priorities during the design phases. Concept, Preliminary, and Construction design efforts should consider all elements in these requirements and make conscious decisions on how and if they can be addressed. These science mission requirements are organized with the following elements.

Mission Statement

Overview of SMRs

Size, cost, and general requirements

Accommodations and habitability

Operational characteristics

- Operational area
- Endurance
- Range
- Speed
- Seakeeping
- Station keeping
- Track line following Ship control
- Underwater Radiated Noise

Over-the-side and weight handling

- Over-the-side handling: winches, wires, cranes, towing, seismics, ROV support, AUV support

Science working spaces

- Working deck area
- Laboratories: Type, number, layout, construction, electrical, water, & air
- Vans, Storage, Science, Load, Workboats, Masts
- On deck incubations
- Marine mammal & bird observations

Science and shipboard systems

- Navigation
- Cybersecurity
- Data network and onboard computing
- Real time data acquisition system Communications - Internal & External
- U/W data collection & sampling, Acoustic systems, Geophysical Systems
- Project science system installation and power
- Discharges

Construction, operation & maintenance

- Maintainability, Operability
- Life cycle costs, Regulatory issues

Mission Scenarios

Science Mission Requirements - Details

Size and cost constraints (FOFC fleet renewal parameters)

The design phases will determine the overall size and cost of this vessel. However, the target size and cost were set in the 2001 Federal Oceanographic Facilities Committee (FOFC) Academic Fleet Renewal Plan and have served as the benchmark for the design of this class of vessel. In general, these vessels will serve the science demands for research throughout the world's non-ice-covered oceans, and large science parties consistent with multidisciplinary research.

The FOFC parameters were defined in 2001 as:

Endurance: 70 days

Length: 91 m (<300')

Range: 33,336 km (18,000 nm)

Science berths: 37

Cost: $72.5 million (This has been interpreted to mean the total cost for program management, design, construction, and outfitting in 2001 dollars).

These parameters are defined further by the science mission requirements described in this document. The specified range has the potential for driving the size of the vessel beyond what is economical and may be an area where compromise will be needed.

Draft is a design element that should be considered carefully as the size of the vessel evolves. The 19-foot draft of the AGOR-23 vessels is desirable for operations in continental shelf waters and to allow shallow depth mounting of ADCP transducers. On the other hand, a deeper draft could increase sea-keeping capabilities (which is a high priority for these vessels) and allow for increased endurance. Access to normal ports of call should be considered so the operation of this vessel is not restricted because of a draft that precludes all but a few ports.

Cost will be a significant factor influencing the design, construction, and outfitting of these vessels. The budget and funding mechanisms available to the sponsoring agency for this vessel will determine the total budget for design, construction, and outfitting.

The FOFC plan set this number at approximately 50 million dollars per vessel in 2001 dollars including project management, outfitting, preliminary design, detailed design, and construction. The cost constraints and likely projected new Global Class project costs should be carefully examined, edited and updated by persons with knowledge and experience in the design and construction of oceanographic research vessels including representatives from the Regional Class Research Vessel, Ocean Class Research Vessel, and the R/V *Sikuliaq* construction projects as may be available. Long term operating costs should be considered carefully in the design process so that decisions are not made that would drive up the yearly operating and maintenance costs.

Accommodations & Habitability

Accommodations

Up to 45 non-crew personnel in two-person staterooms with every attempt to keep the number at the upper end of the range is highly desired. Non-crew berths should permit 22 plus the chief scientist in single staterooms. The number of crew and therefore the total complement will be determined by the Coast Guard Certificate of Inspection, the support requirements for the scientific mission and ship's technical systems, particularly IT needs, and proper maintenance of the vessel.

The design of accommodations needs to be for optimum habitability for the normal science party size, but with the ability to expand to larger science party sizes when needed. Supporting infrastructure would be designed around the largest possible complement and longest planned cruise durations. Shower and toilet facilities should support no more than four people per unit when there is a normal size of science party. Staterooms should be designed to optimize the available space. Providing adequate storage, washbasins, and limited workspace should be attempted in the design. Additional storage and larger workstations could be provided in common space elsewhere. Provisions should be made to accommodate gender imbalance.

The maritime crew and resident technicians should be berthed in single person staterooms to the maximum extent possible in order to promote crew retention and the resulting expertise for supporting the scientific mission.

The non-crew personnel (i.e., the Science Party) would consist of the personnel from the various scientific programs, the assigned marine technicians, technical support personnel for certain types of instrumentation (e.g. JASON II group, OBS groups, coring groups, etc.), foreign observers, education and outreach personnel, and anyone else not part of the maritime crew.

Habitability

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

Common areas (non-working spaces) include a fitness facility, lounges, a conference room and the galley. The fitness facility is considered quite important and should be adequately sized for a variety of exercise methods, some of which require open spaces for movement. Fitness equipment should be ample, durable and located in one or more dedicated spaces noise-isolated from staterooms. Conference room design must consider noise levels and infrastructure to support remote conferences (video and audio).

HVAC specifications as follows:

- Temperature ranges and environmental conditions: Maintain temperatures in normally occupied spaces (A/C spaces) of at least 70 degrees F in the heating season and 72 degrees or lower in the cooling season. Other spaces can have relaxed requirements based on the use of the space. Use SNAME Technical and Research Bulletin No. 4-16 for guidance. Environmental conditions range from a minimum air temperature of -20 degrees F or less and seawater temperature of 32 degrees F in winter and a maximum dry bulb air temperature of 100 degrees F (82 degrees F wet bulb) and seawater temperature of 90 degrees F.

- Relative Humidity percentages: Laboratories require a non-condensing environment and shall have a relative humidity of 50% relative or lower. Other A/C spaces shall have a relative humidity of 55% or lower.
- Rate of air exchange: Use SNAME T&R Bulletin No. 4-16 for guidance.

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

Staterooms shall be sound insulated to limit noise between cabins as much as possible for privacy. Airborne noise specifications should be developed using an experienced shipboard noise consultant.

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

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

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

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

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

Operational characteristics

Operational area

The intended operational area is, essentially, all navigable non-ice-covered waters of the World Ocean, including ice-free areas in the polar regions. The design process should consider a broad range of impacts accompanying this requirement, and examine trade-offs.

Endurance & range

Total endurance should be 70 days, providing the ability to transit for 30 days at cruising speed and for 40 days of station work (see station keeping and towing). Some mission profiles will require continuous underway survey or towing operations at speeds from 4 knots up to the normal cruising speed. The ability to conduct this type of cruise for up to 50+ days is desired. The design process should consider the impacts on engines, water-making capability, food and fuel storage, and other factors when on station or moving at slow speeds for extended periods of time.

Up to 18,000 nautical miles (33,336 km) total range at optimal cruising speed is desirable. A minimum of 15,000 nautical miles at optimal cruising speed is required. Range should be maximized without sacrificing sea-keeping ability and without driving the size and cost of the vessel beyond available funds.

Speed

14-15 knots maximum speed at sea trial in calm seas and 12 knots sustainable through sea state 5 (1.25 – 2.5 m wave heights) is desirable. An optimum cruising speed of at least 12 knots is desired but should not come at the cost of decreased sea-keeping ability, excessive fuel consumption, or excessive noise.

Speed control in sea state 5 or less (< 2.5 meters wave height) should be 0.1 knot in the 0-6 knot range and 0.2 knot in the 6-14 knot range.

Seakeeping

Seakeeping capabilities should permit work in rough seas of the higher latitude oceans (e.g., Labrador Sea, N. Atlantic, and waters of the Antarctic Circumpolar Current).

The vessel should be fully operable in SS 5 and for most routine operations in SS 6. Vessel motions should be minimized through hull design, weight control and the use of passive or active anti-roll devices such that personnel can safely work in the SS 6 or greater.

Safety of equipment operation and deployments should be a primary consideration.

Station keeping

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

Dynamic positioning relative to a fixed position in 35-knot wind, sea state 5, and 2 knot current. The maximum excursion allowed should be ± 5 meters (equal to navigation accuracy) from a fixed location for operations such as bore hole re-entry through sea state

4 at best heading and up to ± 20 meters at best heading through sea state 5. DP system design and operation should minimize noise, vibration, and adverse effects on the operation of acoustic systems as much as possible, and these issues should be evaluated early in the design process. The DP system should have outputs for interfacing with science systems.

Performance is more important than ABS certification.

Track line following

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

Ship control

A chief requirement for ship control is maximum visibility of deck work areas and alongside during science operations and especially during deployment and retrieval of equipment. This should be accomplished with a direct view to the maximum extent possible and enhanced with closed circuit television systems. Portable hand-held control units or alternate control stations could also be used at various locations that enhance visibility and communications with the working deck during over the side equipment handling. The functions, communications, and layout of the ship control station should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude, and positioning should be integrated with scientific information systems. Voice communication systems between the bridge, labs, working decks, and machinery spaces should be designed to effectively enhance ship control during science operations. Also, an integrated bridge management and collision avoidance system should be provided to help ensure safe and efficient science operations in traffic congested coastal waters. Autopilot and DP systems should be integrated with sophisticated control settings that allow appropriate response levels for the type of work being conducted. These systems should also be designed to enhance manual control of the vessel whenever needed.

Underwater radiated noise

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

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

Over-the-side and weight handling

Over-the-side handling

The design of weight handling appliances to safely and effectively deploy, recover, and sometimes tow a wide variety of scientific equipment should be considered at the earliest stages of the design cycle so that they are based on required science performance requirements and are integral in the earliest layout of spaces. The entire suite of over the side handling equipment including winches, wires, cranes, frames, booms, and other appliances should be considered as an integrated system and should be engineered and designed by a single contractor/manufacturer. Design specifications and safe working loads should consider the breaking strength of the intended wires and cables in accordance with applicable standards such as 46 CFR 189.35 and the UNOLS Research Vessel Safety Standards.

Designs for over the side appliances and equipment should include innovative thinking and consider ideas that will reduce the amount of human intervention necessary for launch and recovery of equipment, both on wires and untethered, and that will control packages from the water to the deck. These over-the-side appliances and equipment should also be located so that deployment of equipment is unlikely to result in entanglement with the ship's propeller(s). Heave compensation and other techniques designed to minimize stress on cables and equipment should be included in designs of these systems. These systems should be developed to enhance personnel safety, reduce manning level requirements, increase operability in heavier weather, and protect science and ship's equipment.

Suggested considerations may include:

- Side weight handling appliances or frames should be designed to handle the loads for piston coring (e.g., 9/16 inch 3 x 19 wire) including the capability to support giant piston coring or WHOI long coring and have an appropriate safe working load (possibly at least 35,000 lbs).
- The Stern Frame should be designed for a dynamic safe working load of 30,000 lbs. through its full range of motion, and it must be structurally engineered to handle 1.5 times the breaking strength of cables for which it will be used for research (such as the up to one inch the tether for large ROV systems, which may have up to 120,000 lbs breaking strength).

The stern A-frame should have a 25-ft minimum horizontal and 25-ft vertical clearance from the attachment point for the block to the deck. At least a 12-ft inboard and outboard reach is required. It is desirable to be able to support long coring, such as the WHOI Long Core system, in which case other design parameters specific to long core deployments should be incorporated in the stern A-frame design. Consideration should be given to an A-Frame design that incorporates a forward maintenance position to facilitate changing blocks and wire leads.

Portable weight handling appliances should be located to work with winch and crane locations, but be able to be relocated as necessary. The design of frames and other weight handling equipment should allow removal to flush deck foundations.

The capability to carry additional over the side weight handling appliances along working decks from bow to stern should be included in the design.

Control stations(s) need to give the operator protection, provide operations monitoring, and be located to provide maximum visibility of over the side work.

The need for any human-rated systems should be identified early in the design process.

A facility capable of launching, recovering, and servicing a CTD and rosette shall be incorporated into the design in a manner that will facilitate its operation and enhance safety of the operators. This shall include a system for launching and recovering the rosette that is capable of operating in accordance with the sea state conditions as stated in the section of this document titled “Sea-keeping” and which minimizes the need for “tag” lines or physical, hands-on control by the operator. Once recovered to the main deck, the system shall move the rosette into an area that is protected from weather and over-washing seas to allow scientists to sample the water bottles in a safe and sheltered environment.

Winches and wires

The vessels should be designed to operate with the newest generation of oceanographic winch systems that are an integral part of the equipment handling and deployment system. The winches should provide fine control (0.1 m/min under full load); maximum winch speeds should be at least 100 meters/min; and constant tensioning and other parameters, such as speed of wire, should be easily programmable while at the same time responsive manual control must be retained and immediately available at any time.

Manual intervention of winch control should be available instantly for emergency stop and override of automatic controls. Wire monitoring systems with inputs to laboratory panels and shipboard recording systems should be included. Wire monitoring systems should be integrated with wire maintenance, management, and safe working load programs. Local and remote winch controls should be available. Remote control stations should be co-located with ship control stations and should be located for optimum operator visibility with reliable communications to laboratories and ship control stations. Winch control and power system design should be integrated with other components of over-the-side handling systems to maximize safety and protection of equipment in heavy weather operation and to maximize service life of installed wires. Adequate provisions for connecting slip rings and the ship's power and data network to the E-M and F-O cables should be included in the design. Electric drives and motors should be used whenever possible.

Three hydrographic-type winches capable of handling up to 10,000 meters of wire, rope, electromechanical, synthetic, or fiber-optic cables having diameters from 1/4" to 1/2" should normally be installed. Winches should be readily adaptable to new wire designs with sizes within a range appropriate to the overall size of the winch.

A heavy winch complex capable of handling 12,000 meters of 9/16" wire/synthetic cable (“wire rope”) and/or 10,000 meters of 0.68" electromechanical cable (up to 10 KVA power transmission) or 0.681” fiber optic cable should be permanently installed. This complex is envisioned as one or two winches with the possibility of multiple storage drums that could be interchanged in port. Consideration should be given during design to comparison of alternative systems for efficacy and efficiency of research support, such as individual winches vis-à-vis a traction winch with two or more storage drums that can be used interchangeably. Winches should be adaptable to new wire/cable designs including synthetics within a range appropriate to the overall size of the winch. At least one winch should be capable of supporting operations over the stern and starboard side and one should also be capable of supporting operations through the moon-pool.

Winches handling fiber-optic cable should allow storage of the cable under lower tension unless new technologies in wire construction allow otherwise. This would include winches for both 0.681” and smaller cables.

Provision should be provided for additional special-purpose winches (e.g., clean sampling, pumping, multi-conductor) which may be installed temporarily at various locations along working decks. A look-ahead forecast of winch sizes and power requirements should be considered during the design phase in order to establish reasonable limits based on the vessel size.

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

Wire fairleads, sheave size, and wire train details need to be integrated with the general arrangement as early in the design process as possible in order to increase the possibility of limiting wire bends and overly complicated wire train. Sheave sizes, number, and locations should be designed to maximize wire life and safe working load. It should be possible to fairlead wires from permanent winches over the side or over the stern.

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

Fresh water washdown capability shall be incorporated into the winch arrangement to enable rinsing of winch wires during normal winch operations.

If support for the Long Coring Facility is intended, the deck should be designed to accommodate the Long Core Winch with it’s synthetic cable and associated fairlead blocks to a frame likely mounted on the stern A-Frame (or this should be designed into the A-frame).

Cranes

These vessels should include onboard cranes capable of reaching all areas of the working deck including the mid-ship upper decks to move cargo, science equipment, and capacity to move a loaded 20-foot intermodal container on and off the vessel. A suite of modern cranes should be provided to handle the required cargo loads and should be integrated with the entire over-the-side handling system. The main heavy lift cranes should be considered at a minimum FWD 30,000 lbs @ 40ft and Main, AFT 50,000 lbs @ 60ft.

The highest-rated crane needs to have the capacity and reach to service a Geotechnical drilling rig. One or two cranes that provide the capability to reach all working deck areas and that are capable of offloading vans and equipment weighing up to 20,000 lbs to a pier or vehicle in port is desirable. This will generally mean being able to reach approximately 20 feet beyond one side of the ship (usually starboard) with the design weight. At least one crane should be able to deploy buoys and other heavy equipment weighing up to 10,000 lbs up to 12 feet over the starboard side at sea in sea state 4 or 5 if possible. At least one crane should be articulating in order to keep the load close to the crane head.

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

A provisions crane needs to be located in such a way as to not interfere with cargo, or science mobilization operations.

Towing

The ship should be capable of towing large scientific packages up to 20,000 lbs tension at 6 knots, and 35,000 lbs at 4 knots. Winch control should allow for fine control (± 0.1 meters/min) at full load and all speeds. Winches should be capable of sustaining towing operations continuously for days at a time.

Towing operations include mid- to low-load operations with mid-water equipment such as towed undulating profilers, single and multiple net systems, and biological mapping systems. Other systems may involve larger loads and spike loads such as deep towed mapping systems, bottom trawls, camera sleds, and dredges. The vessel should be capable of towing multi-channel seismic streamer and air guns, and include the ability to tow short streamers off both the port and starboard stern.

Seismics

The science objectives require capability to acquire marine seismic reflection and refraction data to meet a range of targets from the shallow sediment section to deep crustal and upper mantle structure. The crustal/mantle targets have the most impact on required infrastructure. Based on current needs as identified by the seismic user community, the vessel should have the power, infrastructure, and deck space to configure and deploy a tuned large volume 6600-in^3 array seismic source as well as a 15 km long multi-channel hydrophone array. The vessel will need adequate power to tow the deployed gear at speeds of 3.5-4.5 kts. Large built-in seismic air compressors will be needed capable of supporting the 6600-in^3 array (R/V *Marcus G. Langseth* has two 3,300 CFM compressors for this function). The vessel will also need adequate deck space to store, configure and deploy large OBS arrays (e.g. 60-100 instruments). State-of-the-art seismic data logging and navigation systems will be needed for multi-channel work including GPS and acoustic based positioning of source and hydrophone receivers elements. Onboard computing resources adequate to cover the data storage and onboard seismic processing will also be needed.

ROV support

The ship must be able to host and deploy/recover Remotely Operated Vehicles (ROV) and

Autonomous Underwater Vehicles (AUV), both with a wide variety of capabilities. Adequate deck space for up to four ROV support vans and dedicated launch and recovery systems along with sufficient deck and tie down hardware strength to accommodate the loads created with ROV/AUV systems will be required for the largest currently available systems. A hangar bay with climate control for staging ROV/AUV operations will not only facilitate these operations but many others as well. The capability to support JASON operations can be used as a guiding example; the U.S. National Deep Submergence Facility provides up-to-date documents with support requirements for these systems.

Other considerations include how and where cables should go over the side, how and where free-swimming vehicles should be recovered (e.g. moon pool, cable dock, open water maintained by the ship), and how subsea vehicles will be navigated. For AUV/ROV operations the stern frame should be designed for a dynamic safe working load of 30,000 lbs. through its full range of motion, and it must be structurally engineered to handle 1.5 times the breaking strength of cables up to one inch, such as the tether for large ROV systems (up to 120,000 lbs. breaking strength). The stern A-frame should have a 15-ft minimum horizontal and 25-ft vertical clearance from the attachment point from the block to the deck. At least a 12-ft inboard and outboard reach is required.

Unmanned Aircraft Systems (UAS) support

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

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

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

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

Science working areas

Working deck area

A stern working area with 3,500 sq ft minimum aft of deckhouses, open and as clear as possible from one side to the other, is required. In addition, a contiguous waist work area along one side (starboard preferred) that provides a minimum of 150 ft clear deck length along the rail should be available. This area will allow for long core capability like the WHOI Long Core system (up to 45 meters) or more conventional 20-meter piston coring and other operations. A minimum width of twelve feet is needed for coring operations and the overall width of the waist deck should be wide enough to accommodate all planned operations. The total amount of clear working area available on the main deck aft should be maximized and equal to at least 3,500 sq ft.

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

All working areas should provide 1-8 UNC (1 inch diameter, 8 threads per inch - SAE National Coarse Thread) threaded inserts on two-foot centers with a tolerance of ± 1/16" on center. The bolt down pattern should be referenced to an identifiable and relevant location on the deck to facilitate the design of equipment foundations. The inserts should be installed and tied to the deck structure to provide maximum holding strength (rated strength should be tested and certified). Tie down points should be provided for any clear deck space that might be used for the installation of equipment including the foredeck, 01 deck, bridge, and flying bridge and should extend as close to the sides and stern as possible.

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

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

The use of a moon pool can be considered. The use of wood or synthetic decking material to protect equipment, promote draining of water, and to provide for safer footing should also be considered.

The working deck forward of the bridge should accommodate four 20 ft portable lab vans for measurement systems requiring a wide field of view and for access to instruments and sampling equipment on the bow mast. The deck should be fitted with threaded inserts on two-foot center, as on other working decks. Free deck space forward of the lab vans of about 600 sq. ft. should be planned for deck-mounted atmospheric instruments such as aerosol filter samplers, lidars, upward-looking radiometers, cloud or rain radars, and infrared sea surface temperature sensors. This location should provide a relatively unobstructed view of the sky. Additional space on top of the pilothouse can also be used for this purpose.

Other deck areas should be provided with the means for flexible and effective installation of incubators, vans, workboats, and temporary equipment. (See relevant Mission Scenarios in Appendix 1 for details)

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

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

Laboratories

Number, type, and size

A large portion of the lab space should be located in two large labs that can be reconfigured, partitioned, and adapted to various uses to allow for maximum flexibility. This flexibility is an important design criterion. The remaining labs should be specialized for functions such as computer/electronics, wet lab, analytical lab, and temperature-controlled rooms.

To the largest extent possible, labs should all be located on the same deck adjacent to each other and adjacent to the main working deck areas. None of the labs should be located such that they serve as general passageways. Doors and hatches should be designed to facilitate installing large equipment, loading scientific equipment, and bringing equipment to and from the deck areas. Door sills should be temporarily removable.

The total lab space should be approximately 4,200 sq. ft. (dimensions below are approximate guidelines):

Two main lab areas (1,000 sq. ft. each) should be designed to facilitate large set-ups but be flexible for frequent subdivision providing smaller specialized lab areas. With respect to flexibility, they would accommodate both wet and dry areas so they should have sinks and fume hoods. Lighting levels should be controllable and programmable.

A separate wet lab (400 sq. ft.) for processing samples (e.g., filtration) is to be located contiguous to CTD/rosette launching and sampling areas. This would be complemented with another “hydro” lab (400 sq. ft.) for immediate analyses of samples.

A dedicated computer/data acquisition lab (500 sq. ft.) should be dry and separated as much as possible from sources of electronic noise. It may include a central watch standing space that should accommodate visiting science equipment as well as normally installed equipment. Provisions for remote displays in other labs should be part of the lab design.

Lighting levels should be controllable and programmable.

A separate electronics repair shop/work space (300 sq. ft.) for resident technicians that includes provision for repair bench space for visiting technicians is required. Storage space for resident technician spares and tools should be defined in the design so that it is not taken from usable laboratory space.

A dedicated, physically secure location for the shipboard server is desired and should be provided as a part of the ship design, either in lockable equipment racks in the computer/data acquisition lab or a separate lockable compartment (100 sq. ft.). A properly designed server space should include the following characteristics:

- Remote displays should be used to provide control and monitoring of systems in the computer rooms.
- Reliable, uninterruptible clean power to the equipment, backed by batteries and redundant power sources.
- Its own isolated filtering HVAC system with an environmental alarm system (temp and humidity).
- Adequate space in the front and the back of the equipment racks for easy access of the equipment into and out of the racks, and to allow servicing of the equipment while underway.

A high bay/hanger space (500 sq. ft.) for multiple purposes adjacent to the aft main deck should be included. This space should support protected setup and repair of equipment, sample sorting, and other related functions. CTD/rosette storage/sampling should be accommodated in this space.

Two climate-controlled workspaces/chambers (100 sq. ft. each) are required. In the past, these have been called walk-in refrigerator/freezers, and while they can be used as such for storage, they should also be rudimentary labs including the capability to temporarily install work benches. These areas should be usable for other purposes when not needed as a climate-controlled space. This space should be capable of controlling temperature to ± 0.5°C and as low as –10°C. Lighting levels should be controllable and programmable. In this chamber, space is needed for which incoming air can be controlled, i.e. where a filter for cleaning the air could be installed, and/or where temperature and humidity can be regulated. Network and communications support should be provided.

Design of HVAC systems should be integrated with designed partitioning of laboratory spaces so that temperature control can be achieved. Lighting control should also consider partitioning plans.

Refrigerator/freezer space (100 sq. ft.) should be built into the lab space with provisions for temporary additional space. Two units with similar configuration, and refrigeration equipment capable of maintaining temperatures between –15°C and 10°C (these temperature requirements should be verified during design) would allow for flexible use by science projects needing freezer and/or refrigerator space. A –80°C freezer should be available.

Layout and construction

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

Refer to the section on habitability for guidance on the importance of lighting, air circulation, etc.

Labs should be fabricated using materials that are uncontaminated and easily cleaned. Furnishings, HVAC, doors, hatches, cable runs, and fittings must be planned to facilitate maintaining maximum lab cleanliness. Spaces and materials that may trap chemical spills should be avoided. Lab safety equipment to include but not limited to emergency eye stations and showers, fire equipment, etc. are required near stations such as fume hoods and or chemical handling workspaces.

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

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

Through the design process, minimize the incursion of ship facilities (e.g., air handlers, gear lockers, and food freezers) into the lab space.

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

Locations for a fume hood with explosion proof motors in each of the main labs, and one in the wet, hydro and analytical labs should be included in the laboratory layouts. Exhaust ducting, electrical connections, and sink connections should be permanently installed in place to allow for easy installation and removal of fume hoods. Fume hood locations should accommodate hoods at least four feet wide.

Sinks should allow for flexible installation, removal, and provision for additional sinks when needed. At least two locations in the wet lab, one each in the hydro and analytical labs, and three locations in each of the main labs (some of which are located with the fume hoods discussed above) should be provided with stubbed out plumbing at convenient locations. Similarly, stubbed out plumbing shall be provided for a sink in each of the climate-controlled workspaces. More locations can be provided if possible. Drains should be designed to work at all times under operating conditions that create various trim and list conditions, with pitch and roll, etc. Drains should be capable of being diverted over the port side, into holding tanks, or to the normal waste system, and should allow for continuous discharge of running seawater. Sinks should be large enough to accommodate five gallon buckets and the cleaning of other equipment.

Continuing present UNOLS practice, work with radioactive materials should be restricted to radiation lab vans that remain isolated from the interior of the vessel.

All labs, including the climate controlled workspaces shall have deck drains that work under all operating conditions that create various trim and list conditions, with pitch, roll, etc.

Electrical

Each lab area is to have a separate electrical circuit on a clean bus with continuous ‘household’ quality power. There should be two 110V outlets per linear foot of bulkhead. Delivery capability of at least 40-volt amperes per square foot of lab deck area is required (the amount of power needed will be verified at the time of design). Un- interruptible power should be available throughout all laboratory spaces, bridge/chart room, and science staterooms. The use of modular UPS design can be considered.

Separate circuits should be available for tools and other equipment that will not interfere with clean power circuits. Use current IEEE 45 or equivalent standards for shipboard power and wiring and current IEEE standard for UPS and clean power specifications.

Electrical service for the labs should include:

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

There should be dedicated science wire-ways with dedicated transits to all science and instrumentation locations, including locations at the bow, at the seawater intake locations, and at winches. There should be two color-coded science wire-ways; one is for permanent science equipment and the other for temporary science equipment.

Science wire ways should be separated from power and other signal cables. There should also be non-energized wiring installed and dedicated to supporting project science systems (appropriate gauge and number of conductors determined during design phase). Provisions for easy installation and removal of temporary wiring should be made.

Water and air

Clean hot and cold potable water should be provided to sinks and equipment in labs and on deck. A constant supply of seawater shall be provided to all laboratories, including the climate-controlled workspaces, as well as on weather decks for incubators. A seawater supply shall also be provided to instrumentation for production of 18 megohm water (e.g., Millipore Milli-Q) is required. Ship’s water made with commercial reverse osmosis equipment is not adequate without further treatment. Space or equipment for adequate clean water (18 megohm) supply should be provided.

The ship’s service compressed air supply (@100 psi) should be available on working decks and in the labs and have the ability to add filters as needed. Clean dry air needs are to be handled by bottled air or user supplied filter systems. Volume of air and whether or not a continuous supply will be required should be considered during the design stages in order to ensure that installed compressors are properly rated. The need to support high volume or specialized air requirements such as for seismic work, driving air powered pumps, or

SCUBA tank recharging should be clearly specified and carefully considered early in the design process. Provisions for removable fixtures in the lab spaces designed to secure compressed gas tanks should be included.

Portable vans

Deck space is required for carrying at least 12 “UNOLS Standard” lab vans or equivalent on the main aft deck plus the aft areas of decks above the main deck and on the working deck forward of the bridge. Space for 8 vans on the aft decks may be used for specialized lab space (e.g. working with radioisotopes, trace metal-clean space and/or other environmentally controlled conditions), or operator-supplied support vans for specialized ROVs, coring, or drilling equipment, storage of mooring supplies, etc. Deck area forward of the pilot house for four additional lab vans, sited to provide the best feasible degree of protection from heavy seas, will support atmospheric and meteorological instrumentation requiring a wide field of view or a clean air sampling sector.

All container locations intended to support laboratory vans should have AC power as follows: 30 amps 480 VAC 3-phase and 40 amps 240 VAC 3-phase. 30 amps 110 VAC single phase may also be required, but usually can be provided by panels in vans from step down transformers. In addition to power, the tie-down locations should have fresh water and seawater lines; gray water line; compressed air, and data and communications hook-ups, including for the ship’s emergency notification system.

In addition to the laboratory vans, capacity to carry at least 4 standard containers (including, for example, frequently-accessed storage vans, equipment flat racks) in an accessible deck location.

Science storage

Science storage on a Global Class ship is critical given the large number of scientists, the long missions, and the likely event that a previous or upcoming cruise may need to have some of their gear stored on board (e.g., due to Customs restrictions for some materials, difficulties shipping hazmats or other logistical constraints). It is critical that this space not be shared with ship’s gear due to incompatibilities (e.g., rusty steel, grease) and ill-defined boundaries (i.e., from observation, ship’s equipment tends to encroach on the science storage spaces). However, ship’s technical spares (e.g., sampling bottles, rosettes) are science equipment. Thus, the types of storage and area for each are:

- storage for ship technician science gear (500 sq. ft. but doesn’t have to be in one room)
- reagent/chemical and hazardous materials storage (2 x 200 sq. ft. to ensure no incompatible materials are stored). This is intended for longer term storage and must be complemented by short-term use of hazardous materials cabinets in the laboratories. Scientific chemical waste should also be stored in these spaces.
- storage for spares and boxes for scientist-provided science gear. The ability to load and remove large, heavy items and to properly secure them in the storage area should be provided. (2500 sq. ft; ideally in two spaces, one on the main deck for easiest access)
- storage for compressed gas cylinders from the science teams (100 sq. ft.). This space should be placed on the main deck near the main labs and is for longer term storage or gas spares. This space is supplemented by secure racks distributed throughout the ship’s labs. This is a frequently overlooked aspect of ship’s lab design, but is a vital safety issue;

- storage for batteries including proper lithium battery safety storage.

Science load

A variable science load of 200 LT is required. This load would include science-related equipment, supplies, and instrumentation not normally installed on the vessel. Examples are mooring equipment, ROV systems, temporary winches, rock and mud samples, lab equipment, temporary cranes or frames, vans, and extra workboats. Items that would not be included are regularly installed winches (permanent and removable), Stern A-Frames, other normally installed handling equipment, rescue boats, and ship's workboats.

To prevent losing this variable science load to the inevitable growth in light ship displacement, a service life allowance of approximately 5% additional load capacity should be included in the design. The ship's ballast system should have the capacity and capability to compensate for a changing science load during a cruise.

Workboats

Small workboats are increasingly being used to conduct supplemental research activities that are made away from the mother ship. A growing need, for example, is for agile, efficient small boat operations in support of autonomous devices deployed from or recovered by a ship. This requires adequate space, siting, and facilities to support safe, quick, functional launch and recovery. Efficiencies count: small boat operations can be limited due to involvement of crew and technicians needed for other concurrent operations. Yet programs relying upon work with autonomous vehicles can sometimes benefit from having more than one boat in the water. Conditions for small boat operations are frequently challenging, and choice of small boat design should consider suitability for work in rough seas.

At least two 16-ft or larger rigid hull inflatable (foam collar or semi-rigid) boats should be located for ease of launching and recovery with minimal crew. With respect to the latter, semi-automated and rapid deployment systems such as the "Miranda Davit" should be considered. The ship design should also include the capability to carry and deploy a scientific workboat 25-30 ft LOA outfitted specially for supplemental operations at sea.

Required rescue boats may be capable of serving as a science workboat with careful planning. Otherwise, workboats will be required in addition to any IMO/USCG required rescue boats.

Masts

The ship shall have a permanently mounted foremast equipped with an instrument platform at a height of at least 16-20m above sea level (or a height that is twice the height of the foredeck above the waterline, whichever is greater) for permanent atmospheric and meteorological sensors, designed to minimize the influence on airflow by the ship's structure as much as possible, with space for up to 5 additional science party-supplied sensors.

The foremast should be provided with 2 x 20 Amp clean power circuits and weatherproof connection to the ship's network, ideally utilizing a system of patch cables to facilitate connectivity between the mast, laboratories and bridge over dedicated, closed networks (the patch cable system on RV Sikuliaq is a good example of this feature).

The foredeck at the base of the mast should have a weather-tight feed-through block permitting passage of cables and sampling tubes to below-deck spaces, and these spaces should also have clean power and ship-wide network access via the patch-cable system described above.

The main mast shall be provided with yardarms within 2m of the mast top capable of supporting five scientific packages each weighing 100 pounds and measuring 2 feet wide by 2 feet long by 3 feet high. This mast should have a clear view of the sky and sufficient space to mount multiple GPS antennas, meteorological sensors and optical instrumentation. The mast design shall incorporate a standing platform for personnel working aloft of sufficient size for safely installing and servicing instruments on the yardarms.

Mast safety systems for personnel working aloft should be carefully engineered during the initial design of the mast and should facilitate access to equipment aloft in calm sea state conditions.

Care should be taken that sewage or fuel tank vents are not located near the van locations or foremast.

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

On deck incubations and optical equipment/instruments

Design of deck layout and science infrastructure should include consideration for carrying out a certain amount of deck incubation or optical experiments without interfering with other deck operations. This deck area must receive as much unobstructed sunlight as possible. At the same time, the weight of wet incubators may need to be considered for decks that are high above the baseline. Specifying deck area to be used for these experiments early in the design process will help to ensure that other design decisions do not have a negative impact on providing this capability and will ensure that the required services are provided. Other important design considerations are that a continuous flow of near surface seawater at ambient temperatures (< 1 °C above ambient) is available with adequate flow (e.g., minimum 50 gals/min) using a dedicated system (i.e. not fire pump or flushing pump) in order to maintain the proper temperature for the experiments.

The advice and input of expert scientific user groups should be sought as part of the design process to ensure current requirements are met.

Marine mammal & bird observations

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

Science and shipboard systems

Navigation

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

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

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

Cyber-security

As recommended in the NSF Large Facilities Manual NSG 17-066, cyber-security measures include:

- Cyber-Security Plan - Plans for maintaining security of data, hardware, and networks during all stages of project life cycle,
- Code Development Plan - Plans for writing, testing, and verifying, deploying, and documenting software, including configuration control during the stages of development, and
- Data Management Plan - Plans for managing data, including infrastructure, archiving, open data access plans, etc.

Attention to cyber-security issues, at all stages from design through operation, is required to reduce vulnerability to cyber threats of both information technology (IT) and operational technology (OT) systems.

Cyber-security on a large global-ranging vessel faces challenges due to the complex interplay of its mechanical (physical plant and environmental systems), control, and navigational systems - each typically IT and OT intensive - and the IT needs of the large, diverse science teams which typically change over between cruise legs. A Global Class research vessel should be considered a high-risk environment for cyber-security issues. Attention to cyber-security issues should aim towards mature, proven approaches following vetted guidelines, embracing an appropriate amount of standardization and consolidation of effort in order to address cyber-security challenges in an effective and practical manner.

Cyber-infrastructure risk assessment, technical requirements and costs (both initial cost and continuing costs of hardware, software, maintenance, upgrades and operations) should be carefully considered and periodically evaluated during the planning, design, construction, and testing phases.

Data network and on-board computing

High-speed data processing facilities capable of handling large data sets for rapid processing, display, evaluation, and archiving are needed. It should also include receiving real-time updates of the ship's navigation data and disposition of the X-band radar data for analysis by the science party.

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

A data presence system shall be capable of local (ship-based) data processing and further visualization of real-time data with the potential for a shore-side component.

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

Real time data collection, recording, and display

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

Internal communications

Internal communications include phones, PA, entertainment systems, ship alarms, some bridge communications, via LAN, voice and CCTV connections throughout laboratories and living spaces, preferably via fiber-optic network distributed throughout the vessel.

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

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

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

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

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

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

External communications

Primary high speed Internet access will be provided by a Very Small Aperture Satellite (VSAT) system. A location for installing a 2 to 3 meter VSAT or similar actively stabilized antenna will be provided in the design with a full-sky view. Consideration should be given to installing the VSAT antenna at the top of the Main Mast as is currently done on the AGOR-23 Class research vessels to ensure full-sky view at all times.

Locations for satellite, cellular, and other line of sight antennas should be clear and as high as possible. The design should minimize interference between systems, provide for installation of additional systems, and ease of maintenance as much as possible.

Provisions for some permanently installed wiring from temporary antenna mounting locations or from permanently installed antennae to the laboratories to facilitate user-installed antennae or receiving equipment should be included.

Design should include capabilities for acoustic communication with submersibles, data buoys, and underwater sensors based on currently utilized technology as well as the ability to tie underwater data transmission and voice signals with other communications systems. Provisions should be included for changing or installing underwater acoustic transducers as needed.

Design should also provide locations for installing temporary antennae, including antenna to receive direct satellite readouts of environmental remote sensing data. External communications systems should be completely integrated with internal voice and data systems to the maximum extent possible.

The technical specifications for all external communications should be re-evaluated at final design time to consider recent technical developments, IMO cyber security requirements, and evolving scientific needs, such as telepresence support, which is increasingly used to enhance and expand research capabilities.

Underway data sampling and data collection

The infrastructure and space for continuous underway sampling and data collection for as many ocean and atmospheric parameters as possible should be included in all design phases and construction details. This would include, but not be limited to surface (or near surface) seawater temperature, salinity, fluorescence, chemical, and biological measurements. Uncontaminated seawater with a flow of >100 L/min should be supplied to laboratories, vans, and several key deck areas. The system should be designed with the following criteria:

- Minimize the time lag between intake and sampling location (sensor suite and/or lab sinks). If more than one intake is installed, ensure that the intake being used is flagged in the data stream.
- Provide underway seawater taps on at least 4 sinks in lab-accessible spaces (although the more access points the better should be the rule). This will allow users to configure for either continuous or discrete sampling of underway seawater according to their needs. Additional access points should be provided in sinks in other labs (chem labs, trace metal labs, wet lab, and ability to access underway seawater from labs in vans on deck). While these sinks will not be used exclusively for underway seawater sampling this arrangement provides the option for cruises that will utilize underway flows extensively for a variety of sampling. User-supplied sensors that would be installed near sinks include flow cytometers, LISST (laser-based particle imaging), and cavity ring down systems for measuring gasses (CH_4 and N_2O) and pCO_2. All of these could be installed next to a sink with seawater access. It is important to minimize the time between water intake and delivery of the intake to the sink.
- The underway system should be designed so that additional sensors (user- supplied or ship-supplied and not requiring a sink) can be mounted in close proximity to the ship's 'standard' CTD-fluorometer package and coupled to a debubbler. The likely suite of additional sensors would include optical sensors (backscatter, transmissometer, additional fluorescence sensors), nitrate (suna or ISUS), pH (Seabird), O_2 (SBE 43 or optode-based), and pCO_2. Although these additional sensors could be standalone with their own data logging, the underway system should be designed to allow the voltage or ASCII serial output to be recorded and merged with the ship's underway data feed. It is important to minimize the time between water intake and delivery to the sensors.
- Maintenance of the underway sampling system is critical for obtaining high-quality data. The system should be designed to conduct periodic (approximately daily) back-flushes with freshwater or a dilute bleach rinse, to prevent accumulation of growth/biofilms in the underway plumbing. The system should have the ability to access coarse strainers for conducting daily rinses. This can be done by bifurcating the inflow so that one side can be taken out of line for cleaning. Provisions for changing pumps, valves, and piping when necessary should be included in the design. Provisions for connecting multiple

users in addition to semi-permanent equipment should be provided. A backup or alternate system should be considered. There should also be provision to discharge water over the side and not into holding tanks. Design of seawater systems should be integrated with instrumentation requirements and should be conducted with review and input by expert user groups.

A separate, higher volume seawater source with temperature control or high enough flow to maintain ambient surface seawater temperature for incubations should be provided. Sea chest location and maintenance should be designed for proper operation on a continuous basis. This system should be separate from firefighting, ballast, and ship service saltwater systems, or designed as part of a flexible and redundant seawater supply system that allows operation of ship's service systems without interfering with science operations.

Finally, provisions for sampling trace metal-clean, uncontaminated, and ambient temperature seawater while underway at all speeds should be included in the design. Currently, this is typically done with towed "fish" from a midship boom with clean tubing and a trace metal-free pump, plumbed into a clean van or ship's lab.

Acoustic systems

The infrastructure to support a suite of shipboard acoustic sensors will be needed and requirements should be included in all design phases and construction details. The shipboard acoustics system includes deep and shallow multibeam, echosounder, sub-bottom profiling, and ADCP with the following features and characteristics:

- Deep Ocean multibeam bathymetric mapping system.
- Shallow Water multibeam bathymetric mapping system.
- 38 kHz and 75 kHz Acoustic Doppler Current Profilers, and if space permits, a 150 kHz or 300 kHz system for use in shallow water.
- State of the art swath sub-bottom profiling system
- 3.5 kHz Sub-Bottom Profiler, CHIRP or Parametric Narrow Beam
- 12 kHz Echosounder.
- Bioacoustic Sonars – 38, 120 and 200 kHz transducers as a minimum, 18 and 70 kHz desired in addition.
- Ultra-short baseline (USBL) underwater systems positioning transponder.
- 12 kHz Acoustic Release transponder.
- Hydrophones and Hull-mounted Underwater Cameras.
- At sea transducer maintenance capability wherever possible.
- Possible use of a gondola or drop-down keel to minimize effects from bubble sweep down on acoustic sensors. The drop keel option provides additional science capability for the installation of mission specific equipment without a dry dock and does not increase the ship's draft.
- Other hull design elements to minimize bubble sweep down.
- Noise and vibration mitigation engineering to minimize SONAR interference.

Geophysical systems

The infrastructure and space for continuous underway geophysical data collection for sub-seafloor parameters will be needed including for a shipboard installed gravimeter and support for towed magnetometer operations. The science mission objectives require periodic use of both low energy and high energy marine seismic sources for reflection and/or refraction studies. The vessel should have the power and infrastructure to deploy seismic gear, including towed multichannel streamers at speeds of 3.5-4.5 kts. This capability also includes onboard, below main deck seismic air compressors and associated delivery systems capable of supporting large volume (e.g., 6600 cu. in.) airgun source arrays.

Project science system installation

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

The electrical system capacity and design should consider provisions for the cruise variable connection of systems with large electrical motors or power demands. Provision for multiple simultaneous connections should be possible for 480V 3-phase, 208 – 240V 3-phase, and single phase, and 110V single phase with up to 50 amps service for vans, laboratories, and on deck. Final design specifications should take into consideration common electrical requirements for currently used and planned equipment, and excess capacity should be designed-in to the maximum extent possible.

Discharges and waste

All liquid discharges from sinks, deck drains, sewage treatment systems, cooling systems, ballast pumps, fire fighting pumps, and other shipboard or science systems should be on the port side aft of midship, with tanks capable of holding normal discharges for a minimum of 48 hours. Design should allow for zero discharges on the starboard side, including deck drains, when required during normal operations.

A well thought out waste management plan should be developed during the design phases so that these vessels can prevent, control, or minimize all discharge of garbage and other wastes at sea. The use of all appropriate and best available systems and methods such as compactors, incinerators, vacuum toilets, low flow showers, oily water separators, efficient marine sanitary devices, recycling, adequate holding tanks, and others should be used to prevent, reduce, and control waste discharges. The location of garbage storage areas should be well defined. The vessel should be designed and equipped so that it can effectively adhere to all local, state, federal, and international (MARPOL) pollution regulations, to prevent contamination of science experiments, protect the environment, and to ensure the health and safety of embarked personnel.

An on-deck hazardous storage capability for chemicals plus a holding capability for class C waste should be provided. Provisions for low-level radioactive waste storage will be incorporated in the radiation vans.

Discharges of engine exhaust, tank and sewage system vents, exhaust from fume hoods, and ventilation systems should be designed so they do not re-enter the ship's interior or ventilation systems, and so they can all be directed away from the ship at the same time with proper placement of the relative wind (i.e. all on the port side aft). Exhaust and air system discharges should be separated from sensor locations as much as possible.

Construction, operation & maintenance

Green ship

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

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

Maintainability

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

Operability

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

Life cycle costs

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

Regulatory issues

The impact of USCG and international regulations on the design and outfitting of these vessels should be carefully considered.

Americans with Disabilities Act (ADA) Provisions

Vessel accessibility should be addressed in order to make personal participation in research at sea available to disabled persons. The design should include considerations for accommodating features that would allow increased access by individuals with disabilities. For example, designs should consider applicability, incorporation and impacts of the ADA Guidelines for Ocean Class vessels that are included as Appendix V.

Appendix I: Mission Scenarios

The following mission scenarios are designed to show the types of work the Global-Class vessels may carry out. In some cases, these scenarios illustrate how scientists currently adapt to existing vessels and point out areas that might suggest design features to accommodate science project equipment. They do not represent all possible scenarios and are intended to serve as examples. Distances are in nautical miles (nm).

Mission Scenario 1:

Type of work:	GEOTRACES-type Basin Survey		
# in science party:	37+		
Time of year:	Year round		
Area of operations:	Pacific, Atlantic, Indian Oceans basins		
Dist. from nearest port:	500-2000 nm	**Transit speed:**	12 knots.
Dist. Survey/towing:	6,000 nm	**Towing/survey spd:**	12 knots.
Days on station	**Days towing/survey**	**Days transit**	**Total days**
35	25 (during transit)	30	65
Major or special equipment:	7 science vans; trace metal clean winch, A-frame, rosette; towed clean fish; in situ pump deployments on Vectran cable (full depth); atmospheric sampling.		
Scientific Objectives:	The international GEOTRACES program seeks to identify processes and quantify fluxes that control the distributions of key trace elements and isotopes in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions. Sampling of the water column is conducted for standard hydrography (salinity, temperature, nutrients), mixing tracers such as chloro-fluorocarbons, and radioactive isotopes, and dissolved and particulate trace elements and their stable isotopes using specialized non-contaminating sampling equipment and procedures. Particles are also collected using in situ pumps. Samples from the underlying sediments are collected for these same parameters, as are atmospheric aerosols and precipitation. All cruises are highly interdisciplinary, require large amounts of deck and lab space utilizing special sampling equipment, and have a large number of science personnel, and thus only Global Class vessels meet the requirements.		

Mission Scenario 2:

Type of work:	GO-SHIP		
# in science party:	28-35+		
Time of year:	Year round (“best for expected sea and ice conditions”)		
Area of operations:	Global - Pacific, Atlantic, Indian, Arctic Ocean basins		
Dist. from nearest port:	up to ≈2000+ nm	**Transit speed:**	11-12 knots
Dist. Survey/towing:	n/a	**Towing/survey spd:**	n/a
Days on station	**Days towing/survey**	**Days transit**	**Total days**
	n/a	typically 13-43+	38-95 (not including port days)
Major or special equipment:	2-3 science vans; A-frame or boom; large 36-place rosette with ancillary instruments; underway seawater system with ancillary measurements; ADCP; ARF global ship standard met package		
Scientific Objectives:	Highest accuracy global measurements covering the ocean basins from coast to coast and top to bottom, with approximately decadal resolution of the changes in inventories of heat, freshwater, carbon, oxygen, nutrients and transient tracers, so that climate and associated biogeochemical changes can be tracked with enough parameters and spatial coverage to constrain state estimation and inform predictive modeling of Earth’s climate. 24/7 ship operations require station-keeping (ca. 4-5 hours per station) with the ship’s bow into the wind and attention to minimizing roll and CTD cable tension fluctuations. Extensive on-board water sample analyses for a variety of parameters heavily use all ship laboratory facilities.		

Mission Scenario 3:

Type of work:	OOI/Moorings		
Number in science party:	15-35		
Time of year:	Spring, Summer, Fall		
Area of operations:	Global and coastal research arrays		
Dist. from nearest port:	50-1000 nm	**Transit speed:**	10 knots
Dist. Survey/towing:	N/A	**Towing/survey spd**:	N/A
Days on station	**Days towing/survey**	**Days transit**	**Total days**
14	N/A	8	22
Major or special equipment:	ROV Jason, Heavy Lift winch, TSE spooler, 2-3 vans, DP, trawl winch, large crane and A-frame, ample deck space for buoys, anchors, cabled packages		

Mission Scenario 4:

<table>
<tr><td>Type of work:</td><td colspan="3">Climate, Meteorology, Air-Sea interaction, Wave Physics</td></tr>
<tr><td>Number in science party:</td><td colspan="3">25</td></tr>
<tr><td>Time of year:</td><td colspan="3">all</td></tr>
<tr><td>Area of operations:</td><td colspan="3">All, including high latitude and polar seas in sea state 7+</td></tr>
<tr><td>Dist. from nearest port:</td><td>Entire ocean basin</td><td>Transit speed:</td><td>12 kts</td></tr>
<tr><td>Dist. Survey/towing:</td><td>na</td><td>Towing/survey spd:</td><td>na</td></tr>
<tr><td>Days on station</td><td>Days towing/survey</td><td>Days transit</td><td>Total days</td></tr>
<tr><td>40</td><td>na</td><td>25</td><td>65</td></tr>
<tr><td>Major or special equipment:</td><td colspan="3">Extensive use of foredeck and bow mast space for radars, lidar, radiometers and met equipment, and aerosol/chemical measurements.</td></tr>
<tr><td>Scientific Objectives:</td><td colspan="3">Projects of this type focus on tropospheric meteorology from mesoscale or larger circulations (e.g. Madden Julian Oscillations or Atmospheric Rivers) to microscale boundary layer properties; cloud physics and precipitation; transfer of heat, momentum and trace gases between the ocean surface layer and atmosphere; wave physics; and aerosol/chemical properties of the surface atmosphere.

Atmospheric projects typically make limited use of the main deck and A-frame facilities, but are often conducted in collaboration with science teams who do use these areas extensively. Ship operations require station-keeping with the ship's bow into the wind or slow transect legs into the wind. Some studies may focus on high wind and heavy sea conditions.</td></tr>
</table>

Mission Scenario 5:

Type of work:	MG&G - Coring		
Number in science party:	20-25		
Time of year:	Year round		
Area of operations:	All, including high latitude		
Dist. from nearest port:	Entire ocean basin	**Transit speed**	12 kts
Dist. Survey/towing:	N/A	**Towing/survey spd:**	N/A
Days on station	**Days towing/survey**	**Days transit**	**Total days**
30-40		15-25	45 -65
Major or special equipment:	Piston/gravity/multicore etc cores (including long piston core), adequate winch and wire capability, adequate length clear side deck for deploy and recovery, lab space for core splitting, core description lab or science vans for multi-sensor track, camera, geochemistry		
Scientific Objectives:	Projects of this type support the study of Earth history and dynamics as recorded in the chemical, mineralogical, geological and physical properties of ocean sediment samples. Sediment records are used for studies of temporal evolution of ocean chemistry, ocean circulation, sealevel, earth processes such as reversals in earth's magnetic field, and history and nature of geologic events including volcanic eruptions, earthquakes and submarine landslides.		

Mission Scenario 6:

Type of work:	MG&G – Seismics		
Number in science party:	20-25		
Time of year:	Year Round		
Area of operations:	All, including high latitude, ice-free conditions for streamer work		
Dist. from nearest port:	Entire ocean basin	**Transit speed:**	12 kts
Dist. Survey/towing:		**Towing/survey spd:**	4-5 kts
Days on station	**Days towing/survey**	**Days transit**	**Total days**
N/A	40	25	65
Major or special equipment:	compressors, airgun array, streamer reels, data acquisition system, adequate deck space for deployment, recovery, computer lab for data processing		
Scientific Objectives:	Projects of this type focus on characterizing the structure and geophysical properties (e.g. Vp, density, porosity) of ocean sediments, crust, and mantle for studies ranging from global tectonics, to geohazards, to paleoclimate. Targets include offshore sediment transport, submarine landslides, magmatic processes at submarine volcanic systems, subduction zone properties, earthquake and tsunami hazard assessment, ocean basin evolution and past sea level change. Types of programs supported include active source studies making use of airgun array and ocean bottom seismometers or nodes, and multi-channel seismic studies making use of hydrophone streamer and airgun arrays. These projects typically make extensive use of the main deck with specialized equipment needed for streamer and airgun handling.		

Mission Scenario 7:

Type of work:	EXPORTS-type expedition (Process/ experiment ship-investigating the Biological C Pump)		
Number in science party:	34 - 35		
Time of year:	Spring and summer		
Area of operations:	Subarctic North Pacific and North Atlantic Oceans		
Dist. from nearest port:	500-2000 nm	**Transit speed:**	12 knots
Dist. Survey/towing:	10-100 nm	**Towing/survey spd:**	2-7 knots
Days on station	**Days towing/survey**	**Days transit**	**Total days**
26-28	26-28 (on site)	8 - 20	38-48
Major or special equipment:	4 science vans (1 TMC, 2 radiation, 1 general use); MOCNESS; small plankton nets; marine snow catcher (100-L capacity); trace metal clean winch; A-frame; ship's rosette; trace metal clean rosette; towed clean fish; neutrally-buoyant and surface-tethered sediment trap deployments and recoveries; wire walker; hand- and winch deployed optical instruments; acoustics (hull-mounted ADCP); Underwater Video Profiler (attached to rosette); small winch with a 1/4" wire and metering block for towing plankton nets.		

Mission Scenario 8:

Type of work:	BIO/MG&G Deep submergence studies, benthic habitats, vents, seeps		
Number in science party:	25-35		
Time of year:	Year round		
Area of operations:	All		
Dist. from nearest port:	Entire ocean basin	**Transit speed:12**	12 kts
Dist. Survey/towing:		**Towing/survey spd:**	1-2 kts
Days on station	**Days towing/survey**	**Days transit**	**Total days**
Major or special equipment:	ROVs and/or AUVs and associated support vans		

Appendix II: SMR Process and Participants

Part of UNOLS, the Fleet Improvement Committee (FIC) regularly updates the U.S. Academic Research Fleet Improvement Plan (https://www.unols.org/sites/default/files/Fleet_Improvement_Plan_2019_Final_191009.pdf) and amongst its recommendations, the first one is, "*Determine a course for building future global vessels capable of supporting large (>30 researchers) interdisciplinary or discipline-focused science*." With this in mind, the FIC appointed a sub-committee in May 2017 to develop the Science Mission Requirements for new Global-Class research vessels, the first step in designing and building a research vessel. The Global SMR Sub-Committee consisted of:

- Gregory Cutter, Chair, Old Dominion University
- Byron Blomquist, University of Colorado, Boulder
- Suzanne Carbotte, Lamont-Doherty Earth Observatory, Columbia University
- Clare Reimers, Oregon State University
- James Swift, Scripps Institution of Oceanography, University of California, San Diego
- Research Vessel Operators:
- Zoltan Kelety, Scripps Institution of Oceanography, University of California, San Diego
- Ethan Roth, University of Alaska

The process included gathering information through written online surveys of past Global R/V users (January 2018; Appendix 3), the general oceanographic community (May 2018; Appendix 4), and research vessel operators/professionals (October 2018; Appendix 5). The other information collection was conducted directly with the oceanographic community through town hall meetings at international meetings (2018 Ocean Sciences Meeting; Appendix 6; and 2018 AGU Fall Meeting; Appendix 7). In compiling the information and preparing the SMR report, information on international global-class research vessels was also examined for examples and insights (Appendix 8).

Appendix III: Survey of Past Global-Class Research Vessel Users

This was the first survey we conducted and was focused on users who had sailed on existing Global-Class vessels in the prior 5 years (the time frame was to avoid comments on retired vessels). The UNOLS Office chose the people sent the survey based on cruise participation lists. The survey was sent on 4 January 2018 and responses were requested by 2 February 2018; 41 responses were received. The survey questions are below, followed by a numerical summary of the responses and Global SMR Committee analyses of the comments provided by the survey respondents.

Survey Questions
Q1 Please indicate your current career status:
Q2 Please provide a 2 to 3 sentence description of your field of study.
Q3 Is the current maximum science berthing capacity of global-class ships (~36) sufficient for your work now and in the future?
Q4 Are the available laboratory space, deck area and science storage space on global-class ships generally sufficient for your work now and in the future?
Q5 Is the standard suite of scientific support instrumentation on global-class vessels sufficient for your current work (e.g. acoustical profiling & mapping systems, meteorological instruments, underway seawater measurements, CTD or other lowered instrument packages, sample collection and storage facilities, etc.)? What other standard scientific systems might be required in the future to provide broad support for all research cruises on global-class ships?
Q6 Are the network and other technical systems on global class ships sufficient for your work now and in the future (e.g. intra-net connectivity on the ship, internet connectivity and bandwidth to external sites, mapping and GIS capabilities, desk space and support for personal workstations, navigation systems, time servers, clean power, etc.)?
Q7 Are the winch, A-frame, crane and small-boat operations capabilities of global-class ships sufficient for your work now and in the future?
Q8 Are the general handling characteristics of global-class ships with respect to dynamic positioning for over-the-side operations and stability in heavy seas sufficient for your work now and in the future?
Q9 Please mention any additional capacity or capability you feel is lacking in the current global fleet or may be required to meet future scientific objectives in your field.

Results and Analyses

Q1. Please indicate your current career status.

# Responses (% total)	Status
0 (0%)	Graduate Student
0 (0%)	Post-Doc
0 (0%)	Early Career (0-5 yrs since PhD)
7 (17%)	Mid Career (6-15 yrs since PhD)
30 (73%)	Senior Scientist (16+ yrs since PhD)
4 (y%)	Other

Responses to ‘Other’ included: 16+ yrs since M.S.; 38+ yrs in navy as chief scientist and expedition leader; retired; and ROV program manager.

Q2. Please provide a 2 to 3 sentence description of your field of study.

# Responses (% total)	Field of Study
10 (24%)	Marine Geology
7 (17%)	Biological Oceanography
11 (27%)	Chem./Geochem./Biogeochem. Oceanography
2 (5%)	Physical Oceanography
5 (12%)	Ocean-Atmosphere-Climate Interaction
6 (15%)	Other

Responses included in 'Other' are: naval/defense; OOI project manager; paleoclimate; DSV operations; and marine engineering/instrumentation (2 responses).

Q3. Is the current maximum science berthing capacity of global-class ships (~36) sufficient for your work now and in the future?

# of Responses	Response
36 (88%)	Yes
5 (12%)	No
Comments indicating a need for more berths:	
4	More berths needed for large, multi-PI, multi-discipline projects
1	Adequate for science, but more berths would better support educational activities

Survey respondents seem satisfied with berthing capacity for their own work, but several indicated that large collaborative projects like GO-SHIP or GEOTRACES and most polar cruises often equal or exceed the 36-person berthing limit.

Q4. Are the available laboratory spaces, deck area and science storage space on global-class ships generally sufficient for your work now and in the future?

# of Responses	Response
37 (90%)	Yes
4 (10%)	No
Comments regarding adequacy of science labs/deck/storage	
5	Deck space is limiting factor for portable vans and equipment (ROV, Seismics, etc).
4	Sufficient space for containers is important, e.g. carrying gear for prior/future legs.
1	Quality of lab furnishings and facilities could be better
1	Science storage space should not be reallocated for other purposes (gym, ship stores, etc.)
1	Sikuliaq deck elevator is a nice feature
1	More storage and lab space needed for large, multi-PI, multi-discipline projects

Responses indicated a general satisfaction with space currently available for research operations on global class ships. Most comments focus on available deck space and the need to accommodate more containers, both for storage and for lab/technical work spaces. In the future, large multi-PI projects may require more space than currently available.

Q5. Is the standard suite of scientific support instrumentation on global-class vessels sufficient for your current work (e.g. acoustical profiling & mapping systems, meteorological instruments, underway seawater measurements, CTD or other lowered instrument packages, sample collection and storage facilities, etc.)?

# Responses	Response
23 (58%)	Yes
17 (43%)	No
Comments on desirable new capabilities (overlap with Q8):	
4	support for seismic reflection studies should be maintained
2	better underway seawater sampling infrastructure (cleaner, higher flow, chilled)
2	CTD cameras/video & high-bandwidth data cabling for lowered/towed systems
2	easier installation of cruise-specific acoustic sensors (drop keel, straza tower, moon pool)
2	support for USBL acoustic positioning
2	underway ocean profiling systems beyond just temperature and salinity (e.g. SeaSoar)
1	ADCP enhancements (e.g. lowered, 600 kHz, 38 kHz systems)
1	meteorological systems should be higher quality and better maintained
1	seafloor mapping systems tuned for different depths
1	parametric sub-bottom profiling
1	more freezer & fume hood space
1	pump profiling systems
1	CTD handling system for high sea state conditions
1	AUVs to compliment CTD profiling
1	synthetic cable for winch ops.
1	recharging and communication infrastructure for self-contained equipment (e.g. LADCP)
1	temperature-controlled room for salinity instruments
1	capacity to meet increased demand for water volume and sensor mounting on CDT rosette
1	mulit-frequency echo sounder and plankton imaging systems
1	real-time visualization of sensor data to facilitate adaptive sampling

The intent of this question was to survey opinion about the most common science support infrastructure on Global class ships. The majority of responses (58%) indicated general satisfaction with ‘standard’ support. Many responses also suggested new capabilities that should be considered ‘standard’ on future vessels, as summarized on the table above.

Q6. Are the network and other technical systems on global class ships sufficient for your work now and in the future (e.g. intra-net connectivity on the ship, internet connectivity and bandwidth to external sites, mapping and GIS capabilities, desk space and support for personal workstations, navigation systems, time servers, clean power, etc.)?

# of Responses	Response
11 (27%)	Yes

30 (73%)	No

This question received the largest percentage of negative responses. Comments to this question were varied, but fall into several broad categories:

Internet connectivity: It is unsurprising that network capacity was a focus of the majority of responses. The survey comments indicate a general need for better, faster and more reliable internet connectivity both on-ship and for ship-to-shore communications. Better internet is desired to support multiple needs including:

- to receive shore-based data to aid in site selection
- to take advantage of other near-real time observations
- to support transfer of video to shore for telepresence and outreach needs
- for specific data collection activities such as piloting autonomous platforms (gliders and wavegliders).
- by science technicians for troubleshooting equipment problems.
- by scientists and technicians to maintain their other ongoing professional commitments on shore
- as a quality-of-life issue, with poor internet connectivity contributing to the challenges of recruiting and retaining skilled engineers and others for routine deployment to sea.

Other IT Infrastructure: Respondents also commented on the continued need for clean power and sufficient data storage as well as space and connectivity for personal workstations. The ship design should include functional cable trays, pass throughs and network patch boxes to efficiently route data, power and signal cables across the ship (i.e. to bridge, labs, deck, bow tower). There were also comments regarding the need to anticipate changing technology in the coming years and that any new ship design will need to be flexible enough to easily incorporate any new technologies.

Navigation: One respondent commented on needs for geodetic quality GPS receivers as part of the ship's mapping support system.

Work Space: Respondents commented on computer lab outfitting and the need for adequate desk and chair space as well as to ensure that benches and chairs are functional and comfortable. Computer labs should be well separated from wet labs or other sources of corrosive contamination.

Q7. Are the winch, A-frame, crane and small-boat operations capabilities of global-class ships sufficient for your work now and in the future?

# Responses	Response
24 (65%)	Yes
13 (35%)	No

Winches: Four responses to this question specifically mentioned the need for improved CTD handling systems capable of safe operation in heavy sea conditions. Tension control and heave compensation were also mentioned as desirable features in new winch systems.

One respondent noted that it "would be useful to have both a mechanical wire capability, for dredging for example, and a fiber optic cable capability, for deep-towed sonars and ROV's available on the same cruise. Heave-compensated winches would be useful for some instruments like cameras".

Another noted that it would be very beneficial to have embedded .681 EOM cable and winch, with tension control and active heave compensation, A-frame rated to breaking strength of the installed cable.

A-Frames: An expanded range of motion both outboard and inboard were mentioned as desirable features for A-frames, in addition to the option of an overhead winch and a minimum 35,000 lb working load. One comment indicated the Sikuliaq A-frame was particularly good.

Cranes: Crane provisions need attention. A user noted that there is a need to "deliver large, heavy science payloads to the seafloor". (User noted: "The oil and gas industry has created a market for very capable, albeit expensive, crane systems. These systems include high reach, heave compensation, and synthetic rope lines with 3000m plus reach.") Basic crane functions were also noted: "ship's crane [should lift] a fully loaded 20' container" and "cranes should be able to self-load and self-unload a 10T container." One comment also noted that "articulated cranes capable of delicate launch and recovery are needed". Another respondent noted "giant cranes are great for loading containers, but small, knuckle cranes are often more effective for science uses".

AUV/ASV launch and recovery systems are a key system component. A dedicated, smaller crane/handling system for AUVs/ASVs would add to the ship's science capability. Operations with multiple UUVs should be supported - 2 cranes and an A-frame - plus two small boats.

Small Boats: Another comment mentions better, easier access to workboats (e.g. similar to the Ronald H. Brown emergency boat) for glider work, mooring access, etc. Another respondent noted "small boat for science use should be something that works, not an afterthought". And another noted: "With increasing use of autonomous instrumentation, it would be good to think of ways to recover instruments more quickly than with the work boat (jet ski?)." Another user noted that for some operations two small boats were needed and that small boats should include on-board power - like a small generator - for ROV operations.

There was also a request for "capacity on more ships for human occupied submersible operations". Similarly, "As we have only one A-frame that can handle DSV Alvin, we lose the ability to use Alvin when Atlantis goes in for its mid-life overhaul or maintenance that is more than a month. If a major problem occurs like a blown engine, which has happened in the past, then we are short one global vessel and/or the ability to use Alvin."

Q8. Are the general handling characteristics of global-class ships with respect to dynamic positioning for over-the side operations and stability in heavy seas sufficient for your work now and in the future?

# Responses	Response
34 (83%)	Yes
7 (17%)	No

Most respondents to this question were happy with the handling capabilities of the current global fleet. Specific responses indicated a desire for improvements in recovery and deployment of CTDs, ROVs and AUVs in heavy weather conditions (5 responses). Three comments indicated a desire for improved position and heading stability in high winds and heavy seas (3 responses). One comment indicated a desire to support the 100T weight load of Jason in 'single body mode'. And one mentioned redundancy in the DP system to limit risk of single point failures.

Q9. Please mention any additional capacity or capability you feel is lacking in the current global fleet or may be required to meet future scientific objectives in your field.
This was an open-ended question, but some suggestions were mentioned in multiple responses, with some overlap with responses to prior questions:

- ROV support winches below deck & built-in ROV support infrastructure, including 480V power outlets on deck, larger hangars, storage space (2 responses).

- Acoustic positioning (USBL) and acoustic communications (ACOMMS) support for remotely operated vehicles and subsurface sensors (2 responses).
- Continued availability of infrastructure for deep seismic survey work (4 responses).
- Continued and expanded support for extended, large-scale, collaborative science projects (3 responses), including: increased science berthing capacity (ideally above the waterline to minimize excessive noise), adequate ‘quality of life’ facilities (library, lounge, gym), 48 hr.+ waste water storage capacity to limit station time lost during ‘pump the bilge’ runs (provision for an on-board waste treatment system is also an option here).
- Better support for upper ocean profiling (upper 20m of water column) and clean sampling systems to limit interference from the ship’s hull (2 responses).

Other individual suggestions included:

- Heave compensated winches
- Avoid using inappropriate materials like particle board in lab construction.
- Support for diving operations and human operated vehicles (PICES/ALVIN).
- Single berth accommodations for engineers and support staff to improve recruiting and retention of critical staff.
- Improved synchronization of profiling sonars & multibeam sonars.
- Gravimeters and magnetometers as standard equipment.
- Marine mammal observers post as necessary support infrastructure on seismic cruises.

Appendix IV: Ocean Science Community Survey

The second survey was for the entire ocean science community and was conducted using Survey Monkey. The link to the survey was sent using the UNOLS_NEWS email list maintained by the UNOLS Office. The email announcement was sent on 17 April 2018 and the survey closed on 17 May 2018; 120 responses were received. The survey questions are below, followed by a numerical summary of the responses and Global SMR Committee analyses of the comments provided by the survey respondents.

Note: In this Appendix a survey response in the form "XX (YY%) indicates that there were XX responses with this choice, received from YY percent of the total survey respondees.

Survey Questions

**1. Please indicate your current career status:*

- Graduate Student
- Post-Doc
- Early Career Scientist (0-5 years since Ph.D. or equivalent)
- Mid-Career Scientist (6-15 years since Ph.D.)
- Senior Scientist (16+ years since Ph.D.)
- Other (please specify)

**2. Have you ever used a Global Class ship to support your oceanographic research?*

- Yes
- No

**3. Will your future oceanographic studies require Global Class ships?*

- Yes
- No

**4. Please provide a 2 to 3 sentence description of your field of study.*

5. Is the current maximum science berthing capacity of global-class ships (~36) sufficient for your work now and in the future?

6. Are the available laboratory space, deck area and science storage space on global-class ships generally sufficient for your work now and in the future?

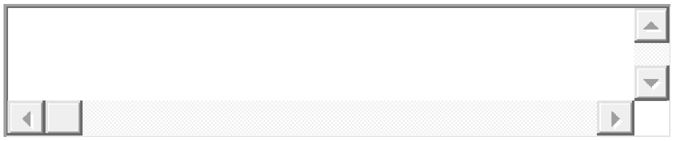
7. Is the standard suite of scientific support instrumentation on global-class vessels sufficient for your current work (e.g. acoustical profiling & mapping systems, meteorological instruments, underway seawater measurements, CTD or other lowered instrument packages, sample collection and storage facilities, etc.)?

8. What other standard scientific systems might be required in the future to provide broad support for all research cruises on global-class ships? Are there specific ROV/AUV infrastructure needs over current capability? What are the anticipated needs for geophysical studies in the future that could be accomodated on a global class ship?

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

10. Are the winch, A-frame, crane and small-boat operations capabilities of global-class ships sufficient for your work now and in the future?

11. Are the general handling characteristics of global-class ships with respect to dynamic positioning for over-the-side operations and stability in heavy seas sufficient for your work now and in the future?



12. Please mention any additional capacity or capability you feel is lacking in the current global fleet or may be required to meet future scientific objectives in your field.

Results and Analyses

Q1 Please indicate your current career status

# of Responses	**Response**
18 (15%)	Graduate Student
8 (7%)	Post-Doc
12 (10%)	Early Career Scientist (0-5 years since PhD or equivalent)
22 (18%)	Mid-Career Scientist (6-15 years since PhD)
52 (43%)	Senior Scientist (16+ years since PhD)
8 (7%)	Other

Q2 Have you ever used a Global Class ship to support your oceanographic research?

# of Responses	**Response**
111 (93%)	Yes
8 (7%)	No

Q3 Will your future oceanographic studies require Global Class ships?

# of Responses	Response
111 (93%)	Yes
8 (7%)	No

Q4 Please provide a 2 to 3 sentence description of your field of study.

# Responses (#)	Field of Study
11 (9%)	Marine Geology
2 (1.7%)	Biological Oceanography
5 (4%)	Chemical Oceanography
12 (10%)	Physical Oceanography
11(9%)	Ocean-Climate Interaction
4 (3%)	Geochemistry
12 (10%)	Biogeochemistry
42 (36%)	Seismology/Geophysics
2 (1.7 %)	Marine Macrobiology & Ecology
9 (8%)	Marine Microbiology & Ecology
1 (<1%)	Education
6 (5%)	Other

Q5. Is the current maximum science berthing capacity of global-class ships (~36) sufficient for your work now and in the future?

# of Responses	Response
104 (88%)	Yes

4 (3%)	No
Comments regarding adequacy of science labs/deck/storage	
5 (4%)	Adequate for science, but more berths would support educational needs

Survey respondents indicated that for most projects the current Global class berthing capacity is sufficient to meet the needs of the research community. However, this capacity is often fully used in particular for AUV or ROV cruises, and for multi-disciplinary, multi-program expeditions. The comments about insufficient berthing for instructional /educational use are significant and the potential importance of instructional activities to future demand of Globals should be considered in decisions requiring berthing capacity.

Q6 Are the available laboratory space, deck area and science storage space on global-class ships generally sufficient for your work now and in the future?

# of Responses	Response
89 (75%)	Yes
14 (12%)	No
Comments regarding adequacy of science labs/deck/storage	
10	More aft deck space, more deck space for ROV, coring, mooring ops, OBS/OBEM sensors, seismic gear, for simultaneous operations
4	More storage space w/access to main deck, more space for vans
3	More lab space/sinks and drains for wet biochem work (growing importance of ‘omics')
1	Longer rail access, good side lift capability for long coring
1	Better provision for MET instruments (foredeck space, larger foremast with data/power cable connections)

Most responses indicated a general satisfaction with space currently available for research operations on global class ships. A number of responses (14) indicated more main deck/van storage would be desirable to support, for example, future large array OBS or OBEM studies, seismic imaging gear, or surveys with multiple simultaneous operations like coring and AUV/ROV operations. 3 respondents commented on adequacy of lab space and sinks and drains. Future trends in biogeochemical and genomic/proteomic studies may require additional wet chemistry lab space and this community should be surveyed in future for details on required needs. Two respondents commented on likely changes in future needs as handling systems and the type of systems deployed are evolving rapidly. Lab design and outfitting will need to evolve in the future with anticipated increases in automation.

Q7 Is the standard suite of scientific support instrumentation on global-class vessels sufficient for your current work (e.g. acoustical profiling & mapping systems, meteorological instruments, underway seawater measurements, CTD or other lowered instrument packages, sample collection and storage facilities, etc.)?

# Responses	Response
59 (50%)	Yes
42 (36%)	No
Comments regarding standard suite	
14	More standardization in network cabling, 480V & clean power, underway seawater/MET instrumentation (including pCO2) and much improved QC/calibration procedures needed across all ships
12	Need deep-water MBES systems, should be designed for state-of-art MBES and ADCP surveys (reduced bubble sweep and noise, gondola or drop keel, better technician training and support)
3	Improved heavy lift (synthetic cable) and more robust CTD handling systems, synthetic wire to better support coring
2	Walk in reefers/freezers @ 4C & -20C as standard
3	Multi-frequency ADCP in all ships (OS150 & OS38), lowered ADCP (on CTD or other?), and higher-freq ADCP for better upper water column observations.

The intent of this question was to survey opinion about the most common science support instrumentation on Global class ships. Many respondents commented on the need for multibeam sonars designed for deep water mapping (EM122), which are not currently available on all vessels. Several comments indicated a desire for more underway pCOs systems, bioacoustic sonars and other biogeoscience sensors, as well as multi-frequency and lowered ADCP's. Responses also suggested new capabilities that should be considered 'standard' on future vessels (e.g. ROVs, gliders), leading to overlap in responses with Q8. The majority of responses (50%) indicated general satisfaction with the 'standard' sensor suite. The other comments span a range of topics and some responses focused on operational rather than design concerns. For example many respondents commented on the lack of proper maintenance and calibration of sensor data (eg flow-through water sensors, MET sensors), which greatly limits their utility for science. Issues with maintenance and adequate knowledge of acoustic systems and their operation including subbottom systems were mentioned. With the loss of seismic capability with Langseth retirement, many comments concerned the need for adequate support for seismics work as part of fleet capability.

Q8. What other standard scientific systems might be required in the future to provide broad support for all research cruises on global-class ships? Are there specific ROV/AUV infrastructure needs over current capability? What are the anticipated needs for geophysical studies in the future that could be accommodated on a global class ship?

# Responses	Response Comments
37	seismic deep penetration capability, large built-in compressors, deep penetration airgun arrays, long streamers, capability for high res seismic
4	seismic portable high resolution, P-cable
5	geophysical instrumentation, gravity, magnetics, high-res subbottom profilers eg TOPAS
10	support for coring capability, long core (50 m)
6	modern sonars, EK80
22	AUV/ROV, with needed handling infrastructure, expanded instrument packages
9	UAVs, drones, gliders
16	other instrumentation/infrastructure

The most common response regarding needed scientific systems was for ability to support seismic studies, given that the fleet will be without any capability for deep penetration reflection and refraction seismics after retirement of the Langseth in 2021. The second most commented on capability concerned ROVs/AUVs. Respondents also discussed projected increased need for drones and a larger fleet of gliders, for improved coring capability, new kinds of sonars, as well as other desired capabilities summarized below.

Active Source Seismics: Over a third of respondents (41) emphasized the need for any future global class ship to support seismic acquisition and in particular deep penetration seismic reflection and refraction. This was the most common theme of the survey response to this question regarding needs for other standard scientific systems. The needed capability includes for 3D surveys, as well as for long-offset streamer (8-12 km) studies. Built in compressors, large linear airgun source arrays (6000 cu in), space for streamer reels and streamer/airgun handling gear with sufficient deck space will be needed. Portable systems could provide some capability. Ability to deploy portable shallow seismic penetration high-resolution systems and for P-cable studies will be needed. Capacity to deploy bottom streamers with acoustic and 3-component sensors, and vertical streamers for seismic imaging was also discussed.

ROVs/AUVs/: Community respondents expressed strong support for expanded access to ROVs and AUVs. This will require sufficient deck space and appropriate launch and recovery devices, communication and monitoring systems. Respondents desire more choice in ROVs/AUVs, more modularity for ROV/AUV infrastructure, access to ROVs to inspect and service seafloor equipment, and suggest resident AUVs on ships. USBL transducer(s) and modem(s) for AUVs/ROVs are needed and ability to do untended/over the horizon AUV operations via ASV. There is a desire for more deep water ROV (6000-10000m)/AUV capabilities and ROVs/AUVs capable of precision sediment sampling, and with better methods for sampling organisms.

Unmanned Aerial Vehicles/Drones/Gliders: There were a number of comments concerning the need to support the use of drones. This capability is expected to become increasingly important for surface ocean observations. Storage, launch, and retrieval are critical and will need some development activity to support routine operations. More drones and equipped small boats that can be used simultaneously with a large ship are needed and support for unmanned underwater and aircraft systems needs to be developed fleet wide. Unmanned Aerial Vehicles/Systems that have the endurance of over 15+ hours with instrument payloads of over up to 10-15 kg are needed with MET sensors (including wind speed, air temperature, humidity, longwave radiation, solar radiation). The same UAVs can provide additional instrument capabilities that are not currently feasible from ships, such as hyperspectral visible imaging (i.e., ocean color). A number of respondents commented on the need for a larger pool of gliders, along with glider capable handling gear and better launch and recovery methods for gliders.

Coring: A number of respondents commented on the need for enhanced coring capability, in particular to enable long cores (50m) to be recovered as well as capability to easily acquire 20-25 m piston cores. The capability to conduct coring operations with cameras is needed. Onboard facilities for handling recovered cores are also needed including for sediment washing and core splitting, core description software, SCHSML and MSCL facilities, scanning XRF and xray capabilities like that onboard the Joides Resolution, and CT scanning and micro CT scanning capabilities.

Sonars: Needs for diverse sonar systems were indicated including for multi-frequency "bioacoustic" echosounders (e.g. the current EK-80) for biological and water column mapping and high resolution and deepwater multibeam swath sonar for seabed mapping. Modern subbottom profiling systems like those Kongsberg provides (SBP21, TOPAS,) were identified as a need as well as side-scan sonars. Multiple ADCPs from 300 kHz to 38 kHz are desired. Modular wells on the hull for innovative acoustic sensors were suggested.

Other instrumentation needs discussed included:

- Capability for doing ‘omics’ work on board: clean labs, computational bandwidth
- Cold temperature van or onboard lab
- Contamination-free lab space
- Clean seawater sampling systems; seawater flow thru systems with multiple intakes (and piping systems that are clean, neutral and easily repairable.
- LN2 generators for MBIO work
- Advanced flow-through seawater sensors
- A towable CTD frame (with a high frequency ADCP) for doing tow yos between stations
- CTD’s with a broader, interdisciplinary sensor suite
- Trace metal rosettes and supporting clean winch system and a winch/wire that can safely manage a 36-place rosette
- Methane and CO2 surface water sensors, underway pCO2 sensors
- Radars, lidars, sounding instruments, and capability for flux measurements for studying linkages between the ocean and atmospheric boundary layers
- Gravimeters
- Magnetometers.
- High-resolution 3D differential GPS navigation such as the Starfire subscription system as standard instrumentation.

Q9. Are the network and other technical systems on global class ships sufficient for your work now and in the future (e.g. intra-net connectivity on the ship, internet connectivity and bandwidth to external sites, mapping and GIS capabilities, desk

space and support for personal workstations, navigation systems, time servers, clean power, etc.)?

# Responses	Response
61 (52%)	Yes
48 (40%)	No
Comments regarding need for increased connectivity, technical systems	
10	To support outreach and education activities, enable transfer of real time data streams, transfer of video
6	To support data file transfer for onshore evaluation, shore-based processing to inform survey selection
12	To access external sites to aid in site selection, to receive shore-based data to aid in site selection, to support collaboration with onshore scientists,
5	Enable adaptive sampling, enable access to other near-real time observations e.g. accessing satellite imagery in real-time is often key to targeting on site sampling efforts.
5	Telepresence
2	To support at-sea ops with multiple groups and measurement platforms
1	For troubleshooting equipment problems

Approximately half (61/52%) of respondents indicated that current network systems were adequate for their science needs. Many noted that faster bandwidth would be helpful, in particular for outreach, but in general the network capability on recent cruises is considered adequate. A number of respondents noted that increased capabilities would be useful but not at the expense of scientific capability. The impact of increased IT support on science capability needs to be considered across the fleet.

Somewhat less than half of respondents (48/40%) indicated network capabilities are currently inadequate, with comments focused on the need for faster and more reliable internet connectivity both on-ship and for ship-to-shore communications. Community survey comments largely mirrored those received from the Global-class chief scientist survey with better internet desired to support multiple functions as summarized in the Table above.

There were many comments regarding the need for increased network connectivity to support telepresence and outreach. Outreach for scientific programs is currently highly dependent on real time data streams which can require high bandwidth to transmit. Telepresence is an emerging technology that is likely to become more commonplace to support on-shore scientist participation, outreach, and other broader impact-related activities. There was a suggestion that a fully integrated telepresence infrastructure be developed to support a "plug and play" option if telepresence is funded for a cruise. Another respondent noted that “outreach, among other reasons, is enough to warrant better internet connectivity while at sea - we can reach so many more people, and field work is often the most exciting aspect of our jobs for the outside world to see.”

Two respondents commented on the need for onboard integration of mapping and GIS technologies with the ship's navigation to aid in real-time survey planning where the science party can visualize the local seafloor bathymetry with survey lines and the data as it is acquired.

Two respondents commented on cyber security concerns which are becoming increasingly important as ship-to-shore and shore-to-ship networking is increasing. Easy, secure, two-way communication protocols, which are uniform across the fleet, need to be developed. Another respondent commented on the need for more onboard computational power and data storage “our imaging system currently generates 10's to 100's of TB of data so we are potentially seeing critical limitations in bandwidth, and need for onboard processing and mapping that will require significant computing power and platforms (e.g. GPU vs CPU).”

Respondents also commented on the desire for more (comfortable) computer work spaces including more ergonomic chairs and lab benches. Adequate desk space for scientists or a bigger library to work in equipped with screens to watch/follow ongoing operations (CTD, ROV, mapping) are needed.

Q10 Are the winch, A-frame, crane and small-boat operations capabilities of global-class ships sufficient for your work now and in the future?

# Responses	Response
71 (60%)	Yes
26 (22%)	No
Comments regarding ship infrastructure needs for equipment handling	

7	Configuration of winches and A-frames to support marine seismics
10	A-frame, winch and wire needs to support coring ops including long coring, also dredging
4	support for mid-ship deployments
2	Fiber optic cable for deep-tow surveys
2	multiple cranes/winches for simultaneous ops
13	Other: support for seabed drilling & dredging, improved small boat operations, clear water sampling from bow, support for automated systems, etc

60% of respondents stated that current capabilities for equipment handing on the global class ships are generally adequate for their needs. Many comments (10) concern the need for improved A-frame, winch and wire capability to support coring operations and in particular for long coring. Access to new generation synthetic wire is needed as well as improved pull-out capabilities to support deep water operations (>6 km) and modifications for operations in hot climates. Access to fiber optic cable for deep-towing operations would enable real time data streaming from towed instruments. Many respondents (7) also commented on the need to maintain the configuration of winches and cranes adequate to support marine seismics.

A number of comments concerned the need to deploy amidship as well from the fantail (eg. amidship for ROVs, CTD casts, near-surface net tows and from fantail for deep trawls (MOCNESS, etc), large buoy and mooring work) and for availability of multiple cranes and winches to support deployment and simultaneous operations of multiple instruments. Other comments included need for larger A-frames (like on Sikuliaq) and winches capable of handling larger equipment, higher loads (>6 tons) and dynamic loads. Some ability for clean water sampling from the bow would be useful. Better systems for launch/recover of workboats are needed. Two comments were received on the need for infrastructure capable of handling future science systems that will be increasingly automated for deployment off our ships. One respondent noted that a remotely operated or autonomous surface craft with an ADCP and a winch deployable from global class RVs would be a huge benefit.

Q11 Are the general handling characteristics of global-class ships with respect to dynamic positioning for over-the side operations and stability in heavy seas sufficient for your work now and in the future?

# Responses	Response
85 (72%)	Yes
15 (13%)	No
Comments regarding dynamic positioning	
9	Improvements needed for operations in rough seas, globals OK, capability of regionals is not adequate
5	Current capability adequate but as technology improves, fleet must keep up with any improvements in positioning
3	Bubblesweep issues need to be addressed
4	Other: DPS is needed, Z drive thrusters compromise geophysics

The majority of respondents indicated that the handling characteristics of modern global-class ships with respect to dynamic positioning are adequate for their current and future anticipated work. However, several indicated that improved capabilities to keep station in challenging sea states are desired and would make increasingly important regions like the Southern Ocean more accessible for more of the year. Respondents noted the need to deploy and recover AUVs, ROVs, moorings and other floating instruments in higher sea states. To better support drilling or piston core operations in heavy seas, passive heave compensation would be useful. Several respondents noted that bubbles associated with DP systems negatively impact acoustic systems and this needs to be addressed in future ship design. One respondent commented on the negative impacts for underway geophysical surveys of using Z-drive thrusters for main propulsion. Current ships have little keel and hence limited ability to track straight lines well. Compensation with the Z-drives to maintain survey tracks leads to the ship following an uneven meandering course which degrades geophysical surveys (e.g. multibeam, sidescan). Controllable pitch propellers with stern thruster should be evaluated as an alternative to Z-drives or Azipods. Other respondents noted the importance of good crew training in ship handling to support survey operations including station keeping in more challenging operational conditions.

Q12 Please mention any additional capacity or capability you feel is lacking in the current global fleet or may be required to meet future scientific objectives in your field.

Comments

37	Access to marine seismics
8	Need more global class ships, more berths, ships capable of Polar ops
9	Ship Design: Green ship technology, support for bow mounted instrumentation, adequate deck space for vans and instrumentation, habitability, quiet engines, improved transit speeds, telepresence
7	Access to ROVs, submersibles, UAVs/drones and IF to support them
8	Support for sampling: need for long piston coring, improvements for uncontaminated seawater and air sampling, trace metal clean systems, fume hoods, increased need for data intensive sampling
5	Acoustics: transducer portability, bubble mitigation, access to processing software
4	Other: Directional wave spectra observations, Doppler radar & lidar

Comments reiterated many of the desired capabilities described in response to prior survey questions. The majority of comments received (37) concern the need to maintain capability for active source marine seismics, which is fundamental for marine geoscience research. The compressors, airguns, streamers and handling gear for acquisition of high resolution and deep penetration seismics are needed within the fleet. A number of respondents commented on the desire for more global class vessels generally, including for Polar research, to support large science parties and to accommodate multiple concurrent projects and suites of analyses while at sea "Future research frontiers, such as studies of the interaction between marine organisms and their chemical environment will literally require the operation of dozens of projects concurrently at sea". In terms of overall ship design, respondents commented on needs for adequate deck space for vans and large suites of instruments (eg. OBS/OBEM senors), support for bow-mounted instrumentation, adoption of green technologies, and habitability issues, including better physical recreational spaces and noise control.

The limited access to ROVs at present within the ARF is viewed as science limiting and increased access is desired, with suggestions of at least shallow-water capable ROVs on all ARF vessels. Increased telepresence along with increased ROV access could "revolutionize efficiency per use-day of these prize assets". Improved capability to use drones and other Unmanned Aerial Vehicles with longer endurance (> 15+ hours) and higher instrument payloads (> 10-15 kg) are desired. In terms of sampling needs, comments reiterated the desire for long piston core capability, greater capacity for uncontaminated seawater delivery and non-disruptive pumps (rather than standard impeller pumps), and provisions for reliable sampling of uncontaminated air isolated from ship engine exhaust. A number of comments reiterated the need for better support of acoustic systems, with attention to near-field bubble noise mitigation, as well as standard access to processing software. One survey respondent noted that with appropriate facilities (e.g. a transducer well airlock), many smaller transducers can be swapped in and out regularly and transducer mounts should be designed for easy installation/removal at the dock without use of divers. Other comments included desire for directional wave spectra observations, Doppler radar and lidar capabilities, silent engines to access EEZ waters, and faster transit speeds to improve efficiency of science.

Appendix V: Survey for RV Professionals

Marine Superintendents, Masters, Chief Engineers, Marine Superintendents, Port Engineers, Marine Technicians, and R&D Engineers

This was the last survey and it was directed towards the various research vessel personnel who could operate a future Global-Class ship. It was done using Survey Monkey, distributed on 23 October 2018 with a deadline of 19 November 2018; there were 15 responses. The survey questions are below, followed by a numerical summary of the responses and Global SMR Committee analyses of the comments provided by the survey respondents.

Survey Questions.

Q1 This survey is anonymous, but we need a general description of your background and expertise (e.g., Marine Superintendent - 10 years; Marine Technician - 5 years; Ship engineer - 15 years; Port engineer - 7 years; Chief Mate - 5 years; etc.). Please indicate your position and years of service:

Q2 Sonar gondola are a means of reducing bubble sweep-down and thus improved scientific output, so from the scientific perspective a positive feature. However, it means a deeper draft of two feet, reduced fuel efficiency, and potential issues with dry docking. Please comment on the disadvantages of such systems from an operator's perspective in comparison to improved science?

Q3 Speed: Is it adequate that the ship be capable of a sustained speed of at least 14 knots in calm seas at full load (including service life allowance) at 80 percent of propulsion plant maximum continuous rating (MCR)?

Q4 Should vestibules be mandatory on the weather ends of passageways?

Q5 Should vestibules be mandatory at interface of labs and weather decks?

Q6 Structural: The Ocean Class is designed such that working decks, working deck van stowage locations and the staging bay are exposed cargo decks with a uniform design load of 767 lb/ft2 over the entire working deck area. Additionally, the aft and starboard working decks are designed to accept a 110 long ton load at a density of 1500 lb/ft2 located anywhere on the working deck. Deck plating in the working deck and staging bay region is not less than 20.4 lb/ft2 plating (0.50 inches). Is this adequate for future Global Class?

Q7 Bulwarks: Is it adequate to have bulwarks on the starboard side and aft working decks that are removable in six foot sections?

Q8 The current state of art is integrated propulsion and hotel load electrical bus. Is there any compelling reason to split these buses and reduce propulsion efficiency?

Q9 What anti-piracy and ship security features should be included in the design?

Q10 Essential requirements for any unattended machinery space (UMS) Ship to be able to sail at sea are enumerated in the SOLAS 1974 Chapter II-1, regulations 46 to regulation 53. Should ACCU designation be mandatory for the future Global Class?

Q11 Should waste heat evaporators producing 110% of daily required fresh water production be considered mandatory? If not waste heat evaporators, what device for fresh water production is recommended?

Q12 Under the Polar Code, Category A ship means a ship designed for operation in polar waters in at least medium first year ice, which may include old ice inclusions. Category B ship means a ship not included in category A, designed for operation in polar waters in at least thin first year ice, which may include old ice inclusions. Category C ship means a ship designed to operate in open water or in ice conditions less severe than those included in categories A and B. What is the correct designated polar category for a future Global Class research vessel from an operator's perspective to accomplish current and future science needs?

Q13 Should state-of-art waste treatment for blackwater be considered mandatory for future Global Class research vessels?

Q14 Please mention any other design features you feel would make the greatest contribution to improved crew safety and enhanced livability/morale.

Q15 Winches & handling systems: With logic-controlled electric drive winches becoming more commonplace, are traction systems still necessary? Is it suitable to run different cable types through the same warping heads on a traction winch to meet the demand for diverse applications that require a wide range of load and torque? Since spooling techniques have greatly improved, could one make the argument that any cable storage drum could instead be configured as a direct-drive winch and allow for more wire pathways overboard, therefore increasing the vessel's capability? Would a winch package like this then also open the door to utilizing tension members more safely that vary in construction such as synthetic versus steel wire rope? Can a synthetic tension member incorporate electrical and optical cables, and still be used in a similar fashion as steel cable in terms of terminations, spooling, bending/kinking characteristics, and abrasion resistance? How does all this play out in the capacity of load handling systems such as cranes and booms?

Q16 Lowered hydrographic systems: Is there a next-generation hydrographic instrument package that could replace conventional vessel-supported CTD systems to increase operational efficiency? For example, fast-repetition-rate and moving-vessel profilers already exist, but this does not address the problem of collecting water samples. How would the chemistry be impacted if water were pumped through tubing integrated into the winch cable and interfaced into a laboratory environment via a fluid-filled rotary joint? Are there other ways to design and integrate a fast CTD profiler and water sampler into a vessel?

Q17 Bolstering geophysical studies: How can we address the technical challenges in integrating active source seismic capability (e.g. multichannel 3D and 2D long streamer, and large-source seismic refraction), as well as long-coring capabilities, into a general-purpose vessel? Will the technology progress to make this more feasible, or does the solution lie more within vessel design and infrastructure?

Q18 Sonars & radars: How can a vessel achieve low-power, high-resolution remote sensing for seafloor mapping, sub-bottom profiling, water current velocities, biomass ecology, ocean waves, and sea ice detection? Consider novel techniques such as parametric arrays, modulated ultrasound, synthetic aperture, or even passive methods that utilize innovative signal and image processing methods.

Q19 Underway measurements: Global Class vessels are increasingly expected to support permanent installations of complex instrumentation for meteorological and underway seawater measurements, as well as navigation sensors. Some examples include a mass spectrometer, optical scattering tools, CO2 analyzer, and wave radar. The data quality is often directly affected by factors such as sensor location, field of view, water/air intake, plumbing material, pump type, climate control, etc. It is also important to consider accessibility for ease of maintenance and calibration. What general features could be designed into a vessel to better accommodate aspects that would augment its role as a "floating observatory"? Consider items like mast structures and platforms that minimize blockage, sea chests that do not clog with ice, as well as how to balance modular laboratory space for science users while maintaining adequate room for sensor installations.

Q20 Computing power: What are the pros and cons of using microcontrollers and single-board computers versus clusters and parallel computing for the acquisition and processing of scientific data? How can we meet memory and storage requirements for recording and logging large volume datasets? How will changes in the form factor of servers and similar industrial hardware affect space requirements?

Q21 Communications & networking: How does a Global Class vessel leverage satellite communications to meet the demand for adequate Internet bandwidth? Is it a matter of buying more bandwidth from Intelsat and installing more antennas on the vessel? What are the tradeoffs between using VSAT (Ku-, C-, Ka-band) versus L-band systems, and how do block converters play a role in determining antenna size and capacity? What approach would ensure continuous coverage with uninterrupted connectivity and low latency? Is there any advantage to having more than one Earth station interface with a vessel? If the ship's network was subdivided so that different types of traffic (for example – downloading satellite imagery, uploading scientific data, bidirectional personal use) were prioritized, could this optimize usage by routing through multiple communication systems simultaneously?

Q22 Virtual science presence: In order to alleviate the issue of limited science berthing, what do you envision the role virtual presence can play in conducting large scale multidisciplinary science missions? Comment on the effectiveness of telepresence thus far. Datapresence is an important component of the RCRV project. How does this differ conceptually from telepresence? How can GIS, data visualization, real-time processing, and automated analysis contribute to the tangibility of virtual science?

Q23 Mother ship concept: Consider a vessel designed to incorporate a fleet of autonomous underwater and aerial vehicles that can operate independently of the ship via wireless/acoustic communications. A moon pool and flight deck could provide a seamless platform for launch and recovery, while an operations center allows for piloting and acquisition of remote sensing products. Elaborate whether this could be a viable approach to fulfill science mission and operational requirements.

Q24 Navigation and seakeeping: The maritime industry is moving towards more automation of ships. We have integrated bridge systems where sensor data is broadcast over a network and systems such as ECDIS, ARPA, and dynamic positioning are interconnected. While maintaining IMO certification, how would you foresee better integration between key features of select science systems and a bridge system? Some examples include a modern vessel giving remote DP control to a ROV operator; Helmsman display provided to the bridge for mapping surveys; satellite/radar imagery overlaid on a GIS map server to aid in ice navigation. How do you maintain an appropriate level of security and implement isolation of critical systems while not inhibiting functionality to users?

Q25 Please mention any additional capacity or capability you feel may help to meet future scientific objectives.

Responses and Analyses.

Q1 This survey is anonymous, but we need a general description of your background and expertise.

Superintendent: 1

Port Engineer: 1

Vessel Master: 1

Electronics or IT Technician: 2

Marine Technicians: 10

Only a few respondents, but a good cross-section of ops and tech people with very broad experience. Many valuable and detailed responses to the survey.

Q2 Sonar infrastructure. All respondents felt that state-of-the-art support for sonar systems is mission critical. Science requirements for sonar probably outweigh any disadvantages related to ship performance or maintenance. Minimizing bubble interference can be addressed in a variety of ways: gondola, drop keel, hull design, or some combination of these. The specific approach will probably depend on other factors related to hull design and on anticipated maintenance requirements.

Q3 Speed. 14-15 kts is a reasonable cruise speed design goal. Slower than that is not desirable. Faster transits can increase the amount of time for science activities are thus desirable. Modern ship designs may allow higher cruise speeds without excessive fuel costs

Q4 and **Q5** Vestibules. No clear consensus on the necessity for these.

Q6 Deck Structural Specs. Current structural strength specs are adequate for work conducted on Global RVs. Strength specs for deck sockets should be conservative (and sockets should be on main and foredecks).

Q7 6 ft Removable Bulwarks. 6 ft sections work well and are easily maintained. Should be designed to minimize shipping water in heavy seas. Safety systems for open bulwarks should be robust. It's also desirable to encourage development of science ops that don't require removing bulwarks when possible.

Q8 Electrical Bus. Current design/engineering technology should permit the flexibility of an integrated bus without compromising science power.

Q9 Anti-piracy Provisions. A wide variety of active and passive security systems were mentioned in the responses to this question. In general, more secure exterior doors, remote door access control, RFID access card systems, distributed control/comms and better video camera coverage would valuable general security features as they will also enhance port security.

Q10 ACCU rating. No consensus about requiring this rating from the respondents.

Q11 Evaporators vs RO. Evaporators are a useful compliment to RO fresh water systems. The ship design should include both systems for maximum reliability. Provision for high purity water for science use should also be considered during design.

Q12 Polar Code. Most respondents felt Cat C is sufficient for a general oceanography Global RV. However, it might be wise to ensure the ship is capable of operating in/near light ice without risk of significant damage to hull or science packages since summer cruises to polar regions are likely for any future Global RV.

Q13 Waste Treatment. The ship design should incorporate state-of-the-art waste treatment. This is likely to be a standard/required feature in future. Some flexibility in treatment ops/requirements during blue water transits would be desirable.

Q14 Other Safety/Livability/Morale Enhancements. Among the responses, the most frequent were:

1) Much greater network bandwidth
2) Single occupancy berthing
3) Better facilities for exercise/workout
4) Omit ADA design requirements – not practical for typical ship ops
5) Safer deployment/recovery systems for small boat ops in rough seas
6) Advanced ship hull design to limit motion in rough seas and optimize work spaces

Q15 Winches and Cables. This question generated a mixed response with no clear endorsement for the latest technology. Modern systems may permit more flexible and convenient winch operations. Direct-drive systems for heavy lift jobs should be considered, but they aren't yet proven to reliably handle all ops. Likewise, for synthetic cables and electrical/optical data feeds.

Q16 Water Sampling and Lowered Systems. Again, mixed responses. No clear alternative to CTD for reliable water sampling, so it's likely it will always be necessary to support standard CTD ops. But, the ship winches, A-frame, etc. should be able to flexibly support towed systems, which may incorporate real-time water sampling.

Q17 Active Source Seismic Capability. From the responses it's not clear that future developments with seismic or coring technology will make it easier to accommodate these on a standard Global-Class R/V. Seems likely that vessel size and infrastructure will need to be specifically designed to support both these activities, at least as modular installations. This may well require larger ships than the current generation of Global-Class R/Vs.

Q18 Sonar and Radar. The consensus was that sonar systems should be state-of-the-art, and this needs to be a primary consideration in both hull and technical system design. Main mast design should anticipate installation and maintenance of large radars. It's worth considering use of novel techniques such as passive or synthetic aperture methods, but technical issues need to be addressed.

Q19 Provisions for Underway Measurements. A variety of oceanographic and atmospheric underway systems are now considered standard equipment on global RVs. Well-designed clean water sampling systems and co-located, dedicated lab space for underway seawater systems is desirable (below waterline). Sampling intakes at fore and aft are desirable. A robust, folding foremast is desirable for supporting a wide variety of standard met instrumentation and cruise-specific instrument installations. Foremast design criteria should locate met sensors in clean, undisturbed flow as much as possible.

Q20 Computing Power. Some consensus was that VM clusters are necessary to support computing needs. Ship design should conservatively consider power, space, cooling, access and cabling requirements for current state-of-the-art systems and plan for future expansion. Special attention to ship-wide cable runs is clearly critical during initial design and construction since it's problematic to expand this infrastructure after-the-fact.

Q21 Communications and Networking. It's clear that all R/Vs would like to have much more bandwidth than is currently available. Future design should prioritize a clear-sky view for all VSAT antennas. Multiple systems are desirable and the entire network design should be carefully considered and mocked up during the ship design phase.

Q22 Virtual Presence. As several responses mentioned, this is only feasible if current bandwidth limits can be overcome. Industry/military ships with more bandwidth are able to support virtual presence activities with current technology.

Q23 Mothership Concept. Most comments echoed the expectation that support for autonomous platforms will become more and more important in the future. Future ship design should plan to accommodate this fact, which may require additional storage and preparation space for the vehicles, specific deployment and retrieval systems (moon pools, custom small boat ops), dedicated undersea and airwave communications between the ship and remote vehicles, sufficient network bandwidth for 'data presence', etc.

Q24 Integrating Science Systems and Navigation and Seakeeping. The responses emphasized that integrating science systems with the ship's seakeeping systems is risky and, in most cases, unnecessary. Seismic surveys and perhaps recovery of drifting gear may be the exceptions.

Q25 Additional Capabilities.

1) Better small crane coverage over working decks

2) Network bandwidth; robust, accessible foremast; future-proof network cabling throughout the vessel. (Most of these were covered in prior questions).

3) Professional IT design and engineering during ship planning and construction phases (you get what you pay for).

Appendix VI: 2018 OSM Town Hall on Global Class SME – Meeting Notes & Slides

Ocean Sciences Meeting
Global Ship SMR Town Hall Meeting
February 12, 2018
Meeting Notes

Attendance List - https://www.unols.org/document/2018-global-ship-planning-ocean-sciences-town-hall-attendance-list

Town Hall Slides - https://www.unols.org/sites/default/files/201802OSM_TownHall_GlobalClassPlanning_final.pdf

Introductions: Greg Cutter opened the meeting and greeted everyone.

Background information regarding Research Vessel Design and Construction - Clare provided the steps of Research Vessel Design and Construction. Clare Reimers discussed the Research Vessel design cycle, following the path of the RCRV. Establishing Science Mission Requirements (SMRs) is key at the initial steps of Research Vessel Design and Construction. SMRs lead to Design Specifications, "if it's not in the specifications, it's not in the ship."

- The purpose of SMRs is to set down mission capabilities to be used as guidelines during the various design phases for a vessel class.
- A key concept is that ship systems are completely integrated with the science mission for these vessels.
- She stressed the role of the science community in informing the vessel planning.
- The design of the ship's core systems depends on the science missions the ship is intended to carry out.
- Clare described the SMR elements. The most basic aspects of the science support are accommodations, operational characteristics (payload, speed, endurance), over the side and weight handling, etc.
- Costs, energy efficiency, on the horizon technologies, operation and maintenance costs, regulatory requirements and classifications.
- It is possible that not all requirements can be fully realized in any one design. During later design phases priorities may be refined.

The Current Global SMR Process - Greg Cutter discussed the present Global SMR process, and that the town hall meeting was part of the early public dialog.

We are not designing a ship now.

"We need to have a 'folder in the drawer' that states the science community requirements for a Global class vessel".

Greg introduced the FIC Global SMR subcommittee members:

- Greg Cutter, Old Dominion U., Chair
- Byron Blomquist, U. Colorado, Boulder
- Suzanne Carbotte, Lamont-Doherty Earth Observatory, Columbia U
- Clare Reimers, Oregon State U.
- Jim Swift, Scripps Institution of Ocean.

Greg described the Global SMR charge, tasks, and process:

FIC Global SMR Subcommittee Charge: Develop a "Living" (easily modified) SMR for the next US Global Class Vessel

Tasks: Define Science Drivers

- Fleet Improvement Plan
- Evaluation of existing fleet – service life, scheduling, costs
- Existing and future individual PI to large program needs (Community Surveys, Town Halls, etc.)
- Agency needs and funding

SMR tasks – data gathering

- Examine existing SMRs for US Global and Ocean Classes
- Gather information on international Global fleet – size, endurance, berthing, deck/lab facilities, build and maintenance costs, etc.
- Lesson learned are very important
- Survey existing Global Class users, and captains and engineers.
- Survey the community and have open discussions via Town Halls such as this one

Global SMR timeline – The timeline can be 15 years before we see a new Global ship, but the plan is to start the process now. The process began in June 2017 and the subcommittee would like to have an SMR living document by July 2018.

Greg presented a brief summary of the "mid-point" (JHS term) of the survey responses. The survey feedback indicated that:

- Endurance and berthing – OK, but not less
- Lab and deck space – Labs OK, but a lot of comments on deck space
- Communications – broadband issues

Open discussion:

- Norm Nelson, UCSB– Asked who would own the ship(s). Reply – a builder hasn't been identified.
- Jules Hummon, U. Hawaii – She provides support for fleet ADCP systems. It is important that the new ships have "NO Bubbles!!!"
- Mark Abbott, WHOI – If it is going to be at least 10-15 years before the Global Ship is built. Who is going to drive the design? Who will be the sponsor? If we have to engage the Navy, it has to start now.

- Chris Sabine, U. Hawaii – It is good to talk to past users of the global ships, but we need to talk to future/new users.
- Peter Wiebe, WHOI – One of the new things coming down the pipe is a brand-new deep (2000m) towed body system that will need motion-compensated fiber optic winches. Make sure the winches are motion compensated. Finn (Rapp Winch) representative - "we can do this now and shops can be retrofit".
- Carin Ashjian, WHOI – Why did the survey close? Did not hear about it as a user. Regarding capabilities, we should remember that not all users require "big equipment", but for example, we do not design for towing nets and cameras off the side of a ship. The stern is not an ideal location for much of the work we do from the stern because large equipment (buoys, OOI, etc.) needs the stern from a big deck.
- Tamara, SIO – Are we retaining information from lessons learned on the ships we built recently? Clare – The FIC polls the community after new vessels enter service. Annette – UNOLS also tries to learn more about how effective the SMRs are in the designs of new ships.
- Jeff Condiotti, Kongsberg – Will there be a drop keel? Clare – This would come out of the SMRs.
- Curt Collins, NPS – Acknowledged the effectiveness/utility of these lab-accessible drop-down keels. Quietness should also be considered.
- Jon Alberts, UNOLS – As new Global ships are considered, it is important to keep the proposal pressure high for research that requires these ships. They won't get built unless there is a demand.
- Susan Haines (?), NOAA – They have large ships? Must have ships that have infrastructure to accommodate. NOAA has the vessel *Okeanos Explorer*. It is an exploration vessel and effective telepresence infrastructure and support is important. Is Telepresence requirements being addressed?
- Paul Wosack (sp?), OSU – Piston Coring operations require good sea keeping and station keeping. The loss of starboard side handling capabilities is astounding (compared to *Melville* and *Knorr*). We need to be looking at *Sonne* ("the best global ship in world at present").
- Mike Viccione (sp?), NOAA? – Would be good to have the capability to trawl very large nets on the large global ships. Clare – This is a science mission. Look at the federal agencies that support that type of work. Peter Wiebe (WHOI) emphasized this. Norwegian ships can tow fantastic mesopelagic trawling gear 'way outside US capability.'
- Chris Measures – He emphasized the need for many berths, nothing smaller than the current Global capacity. Multi-disciplinary research is labor intensive and requires large science parties. The German ships have lab containers below decks. This has worked well. Perhaps the new ships should have containers inside the vessel that could be used for berthing.
- Tina Toone (sp?), UCSD – She has worked with the Germans and they had extra lab space through use of containers. It works well. They also had on-board incubations. More space is needed for temperature controlled rooms. ROV teams are large. Ships must accommodate multi teams efforts. In summary, a lot of berths are needed.
- Mark Abbott, WHOI – Multi- disciplinary sciences are important. Need new ways to get multiple things in the water at the same time. Captains often only allow one or two things.

- Andrew Thurber, OSU – There is a need to reduce the number of people required to support over-the-side operations. US ships require more people than foreign vessels.
- Steve Ramp, private – How serious are we are about incorporating green technology in the new ships? We should do this. Clare – There is a Green Workshop on April 3-4. Bruce Corliss – We are making big strides over the last decade. This would be an opportunity to move that forward.
- Andrew Woogen, OSU – The need for sufficient technology support on the ships is vital. The ships are getting more sophisticated.
- Kristin Beem, OSU – It would be good to have single staterooms for technicians. It would provide more flexibility in terms of cruise participants. Sharing staterooms between the science party and tech groups requires gender considerations.
- Amanda Netburn, FAU – There is a separate effort through DeSSC on how to accommodated Telepresence for science. This needs to be considered in a new ship.
- Charles Roman, Battisti of Bergen, Norway – There is an important need for real-time data from the ships. Research groups need to show results quickly.
- Mark Abbott, WHOI – when you go through the SMR process – is science is the only driver, cost becomes a “feature.” There needs to be thought about the cost for building and operations. It is important to have that information sooner and later.
- Andrew Woogen (OSU) – There needs to be time for calibrations and Quality Assurance.
- Joe Resing (UW) – Could there be a trace metal capability? Yes
- Matt Durham, SIO – With the multi-disciplinary, multi-PI direction, the ships need flexibility so that everything can be accommodated. The ships need to allow for "everyone working off the side" on the same ship - need to allow for portable winches, etc.
- Norm Nelson, NASA – Very early on in the ship planning process, in NASA, a design/cost workshop is held.
- Carin Ashjian, WHOI – Will the draft SMR document be open for community discussion and suggestions. Yes.
- ?, SIO – Input from the ship captains is needed.
- Peter Wiebe, WHOI – The props need to have distance from the stern to avoid entanglement.

Closing Remarks – Greg Cutter thanked everyone for attending and providing feedback.

Appendix VII: 2018 Fall AGU Town Hall – Global Class SMR Minutes

2018 Fall AGU Meeting
Global-Class SMR Town Hall
Thursday, December 13th, 2018
Meeting Notes

Town Hall Slides - https://www.unols.org/document/2018-agu-town-hall-global-class-planning

Attendance – approximately 25 people

Greg Cutter presented the slide deck, Planning for the next US Global Class Research Vessel, Appendix YB.

Discussions –

- *Greg*: Based on our May community survey, generally the current global ships are just fine and meeting research needs.
- *Bill Landing*: *Revelle* is fine for Geotraces and programs that use all of the bunks. We will still have cruises in the future that require that same level of berthing.
- *Greg Cutter*: From the community survey, it was indicated that present berthing is fine; more berthing isn't needed.
- *Karen Stocks*: Cyberinfrastructure as a whole is expanding. There is more data being collected and this has to be stored.
- *Bill Landing*: Is bandwidth limited by cost or capability? *Bob Houtman*: cost.
- *Comment*: We need ships that are large enough to do seismic and coring at the same time. We need deck space.
- *Question*: There will be more satellites and bandwidth should become less expensive. Would that cut down on the berthing needs?
- *Comment*: The *Sonne* as a great example of a capable global ship. There is need for long coring. We need seismic as well.
- *Rob Sparrock*: Autonomous vehicle use will continue to grow; what does it mean to be a mother ship? This is an important area. *Craig Lee*: There is a broad range of vehicles – floats, gliders, large AUVs, etc. A lot of these platforms need more flexible platforms. You might have swarms of vehicles where you deploy them. From experience, it is good to use small boats to help support autonomous operations. What we need in a global vessel is purely general use – flexible and reconfigurable.
- *Greg Cutter*: In terms of acoustics, gondolas are an option. There are issues of draft. There are retractable keels that are very nice.
- *Rob Sparrock*: He would be interested in hearing about missions that they are doing now, that they might not be doing ten years from now. Will mapping be appropriate? In the future will it be done by AUVs? Can these be divested from the large ships?
- *Nick*: AUV *Sentry* enhances the capability of the ship. Technology growth is rapid, but it is not there yet. Old technology doesn't hang around.
- *Clare Reimers*: On a big platform, you can take laboratories to sea. In the future you might be able to do this. You could spend three months going around Antarctica with

your lab.

- *Greg Cutter*: It is valuable to have a Global Class SMR document in a file drawer (figuratively) and ready to pull out if the money materializes for construction. It is a long process. We need to be ready. This is also why it would be a living document.
- *Matt Erickson*: Was there a strong response to the survey by early career scientists? *Greg Cutter*: We collected the demographics. Most survey responses came from senior scientists. *Matt*: We should reach out to the early career scientists. *Greg*: we can look at this.
- *Bill Landing*: They tried to launch and land UAS (unmanned aircraft systems) from the *Falkor*. This is a growing area; has it been considered? *Greg*: yes.
- *Greg Cutter*: are there any programs in the initial stages that you have heard of?
- *Craig Lee*: EXPORTS was a large program. One of the challenges was having a 2-ship operation. It was required to provide ample berthing to carry out the science that was needed. They needed a lot of people with a lot of skills. This begs the need for large ships that are general purpose. *Bob Houtman*: We do have to keep an eye on cost.
- *Question*: Can berthing be expanded as needed, example – berthing vans? *Clare*: When additional people are added, you still need to deal with added waste, lab space, food, etc.
- *Dennis Hansell*: What about wire time? On a larger the ship, you still have limited wire time. Are we thinking about how to expand the capability in the limited amount of time? Is multitasking being considered? This is the constraint; even when you have 80 scientists, you still have one wire.
    - Then this begs having two medium sized ships
    - *Craig Lee*: There is an area of sample swapping.
- *Craig Lee*: There is also an issue of sea keeping. This makes the argument for larger, more stable platforms.
- *Greg Cutter*: The ocean class ships do well, but not as great as the globals.
- *Matthew Erickson*: Is science changing so that fewer people are needed? *Clare*: We are seeing we need more techs; systems are becoming more complex.
- *Rob Sparrock*: Are there discussions about the ice capabilities, giving the shrinking ice pack. Has this been considered? *Annette*: we are fortunate to have Jim Swift on this FIC subcommittee. He is also on the NSF Polar Research Vessel SMR committee, so we are getting feedback from him.
- *Rob*: Autonomous ships could work with globals.
- *Greg Cutter*: Please contact the subcommittee to share any additional feedback.

Appendix VIII – International Global Class Research Vessels

R/V Name	Country	Length, ft.	Range, nmiles	Endurance, Days	Scientists	Lab space, sq ft	Working Deck, space, sq ft	Laboratory Containers	Special features
Tan Kah Kee	China	255	10000	50	36	4380	4650	4+	drop keel for acoustics; portable clean sampling facilities
Dong Fang Hong 3	China	338	5000	60	82	6458	6565	7+	clean sampling facilities built in; seismic facilities
Pourquoi Pas?	France	353	16000	64	40	4500	6000	10	30m long coring
Investigator	Australia	308	10800	60	35			13	two drop keels + acoustics gondola; moon pool
Meteor	Germany	320	10000	50	30	4300		9	
Merian	Germany	310	10500	35	23			152	seismic facilities
Sonne	Germany	380	15600	52	40	5800	5900	10	seismic facilities
Discovery	UK	327	14000	50	32	4200	4700	7	
OOSV Hudson	Canada	87.9m	12719						oceanographic, geological and hydrographic
James Cook	UK	293	12000	50	30	3000		7	

Appendix IX: Sea State Definitions

#	Wind (kts)	Description	Sea State	Wave Ht (ft)	Effects at Sea
0	< 1	Calm	0	0	Sea like a mirror
1	1-3	Light air		<1/2	Ripples with appearance of scales, no foam crests, Smoke drifts from funnel.
2	4-6	Light breeze	1	½-1	Small wavelets, still short but more pronounced, crests have glassy appearance and do not break. Wind is felt on the face. Smoke rises at about 80 degrees.
3	7-10	Gentle Breeze	2	2-3	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses (white caps). Smoke rises at about 70 deg.
4	11-16	Moderate breeze	3-4	3-5	Small waves, becoming longer. Fairly frequent white horses (white caps). Wind raises dust and loose paper on deck. Smoke rises at about 50 deg.
5	17-21	Fresh breeze	4	6-8	Moderate waves, taking more pronounced long form. Many white horses (white caps) are formed (chance of some spray).
6	22-27	Strong breeze	5	9-12	Large waves begin to form. White foam crests are more extensive everywhere (probably some spray).
7	28-33	Near gale	6	13-19	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of wind.
8	34-40	Gale	6-7	18-25	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind.
9	41-47	Strong gale	7-8	23-32	High waves. Dense streaks of foam along the direction of wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	48-55	Storm	8	29-41	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense streaks along the direction of the wind. On the whole, the sea takes on a whitish appearance. Tumbling of the sea becomes heavy and shock-like. Visibility affected.
11	56-63	Violent storm	8	37-52	Exceptionally high waves (small and medium-sized ships might be for time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are blown into froth. Visibility greatly affected.
12	> 63	Hurricane/ typhoon	9	> 45	The air is filled with foam and spray. The sea is completely white with driving spray. Visibility is seriously affected.

Appendix X: Ship Motion Criteria

Source: Marintek

DESCRIPTION	CRITERIA RMS-Value	COMMENTS	REFERENCE
VERTICAL ACC.:			
Exposure: 0.5 hour	0.10 g	10% motion sickness incidence ratio (MSI)	ISO 2631/3
1.0 hour	0.08 g	(vomiting) among infrequent travelers	1987 &
2.0 hours	0.05 g	general public	1982
8.0 hours	0.03 g		
Simple Light work possible	0.27 g	Most of the attention devoted to keeping balance	Connoly 1974
Light manual work might be carried out	0.20 g	Causes fatigue quickly. Not tolerable for longer periods	Mackay 1978
Heavy manual work might be carried out	0.15 g	Limits in fishing vessel	
Work of more demanding type	0.10 g	Long term tolerable for crew	Payne 1976
Passenger on a ferry	0.05 g	Limit for persons unused to ship motions	Goto 1983
Passenger on a cruise liner	0.02 g	Older people. Lower threshold for vomiting to take place	Lawther 1985
ROLL:			
Light manual work	4.0°	Personnel effectiveness	Comsrock 1980
Demanding work	3.0°	Personnel effectiveness	Hosada 1985
Passengers on a ferry	3.0°	Short routes. Safe footing	Karppinen 1986
Passenger on a cruise liner	2.0°	Older people. Safe footing	Karppinen 1986
PITCH:			
Navy Crew	3.0°	Limits to avoid damage to personnel	Comstock 1980
Light manual work	2.0°	Personnel effectiveness	Hosada 1985
Demanding work	1.5°	Personnel effectiveness	Hosada 1985
HORIZONTAL ACC.:			
Passenger on a ferry	0.025 g	1-2 Hz frequency. General public	ISO 263/1
Navy crew	0.050 g	Non-passenger and navy ship	
Standing passenger	0.070 g	99% will keep balance without need of holding	Hoberock 1976
Standing passenger	0.080 g	Elderly person will keep balance when holding	Hoberock 1976
Standing passenger	0.150 g	Average person will keep balance when holding	Hoberock 1976
Standing passenger	0.250 g	Average person max. load keeping balance when holding	Hoberock 1976
Seated person	0.150 g	Nervous person will start holding	
Seated person	0.450 g	Persons will fall out of seats	

Appendix XI: ADA Guidelines for Global Class Vessels

Introduction

Although UNOLS vessels are not passenger vessels and fall under USCG Subchapter U Classification, vessels that support federally funded academic research should be equipped and arranged as feasible to accommodate persons with disabilities. Improvement of access to UNOLS vessels in the spirit of the ADA is focused to the scientific and living spaces in UNOLS vessels, including the working decks. The overall goal of providing accessibility for the disabled is the maintenance of a safe working environment and to provide as much a quality experience as practical within the confines of reasonable cost constraints. ADA accommodations should be considered during the earliest phases of the ship design process.

ADA Recommendations for Global Class Scientific Vessels

New Global Class research vessels should include as many of the following accommodations in scientific workspaces and living quarters as possible to conform to ADA while taking into account the size of the vessel and any special circumstances. A list of suggested design features for various scientific workspaces and accommodations is given below but it should not be considered exhaustive. A more complete listing with proposed specifications for large cruise vessels can be found on the website for ADAAG (https://www.access-board.gov/pvag/) but it should be recognized that many of the recommendations are not practical, and not mandatory, for research vessels.

The items recommended for consideration for ADA accommodations on Global Class UNOLS vessels are outlined in the UNOLS ADA Guidelines for Research Vessels (https://www.unols.org/sites/default/files/ADAGuidelines_for_UNOLS_RVs_Final_Feb08.pdf). This document covers both general recommendations (Section 2) and those specific to the Global Class vessels (Section 5). Some of the specified items may be difficult to accomplish and have large cost factors for some vessels within this class of vessel. It should also be understood that the specific design of the vessel would place constraints on the level of ADA accommodations that can be achieved. The (reference numbers) indicate the specific detailed requirements that are listed in Section 5 of the UNOLS ADA document.