SCIENCE REQUIREMENTS

NEPTUNE

DOCUMENT CONTROL SHEET

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RECORD OF ISSUE

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REVISIONS

Date	Nature of Change
16 Dec 2003	Minor OCS/SII revisions
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MISSION STATEMENT

To provide routine, real-time interaction via the Internet between and among a diverse scientific and educational community of land-based users and extensive suites of *in situ* instrumental sensor arrays. These arrays will be connected to a high-power and high-bandwidth infrastructure enabling numerous user-generated experiments designed to detect, characterize, sample and quantify variability across a broad range of ocean and earth processes.

1. SCOPE

This document will define the science requirements (usually called user requirements, and explicitly combining the design principles with the functional and performance requirements) for the NEPTUNE regional cabled observatory (hereafter, simply RCO). The RCO requirements are defined hierarchically. The top level requirements are intended to define the system functionality from the system stakeholder's (i.e., the science, education, and operational communities who will use the RCO, along with the funding agencies who will support it) perspective, and provide overarching principles to the engineering team designing the RCO. These are defined and refined through the construction of a wide range of use scenarios incorporating representative suites of sensors and platforms in close collaboration with a broad group of potential science users.The science requirements are then used to define the top level system architecture. From this architecture, the next lower level or subsystem requirements are derived which are a function of the specific design implementation. The requirements and architecture are refined iteratively through a system engineering process defined in Section 2.

The goal is for stakeholders to work with the RCO Engineering Team to define and take ownership of the science requirements through the RCO Project Scientist(s), who are responsible for maintenance of the Science Requirements Document. The Project Scientist(s) will work with the System Engineer and RCO Engineering Team to define the second and lower level requirements. Interactions between the engineering team and the stakeholders at every level of requirements definition is essential to ensure that the system as implemented meets science needs in a cost effective manner.

2. SYSTEM ENGINEERING PROCESS

A system is a collection of functional elements which work as a whole to perform some set of functions. It consists of a hierarchy of sub-systems which, taken together, comprise the system. System engineering is a management and engineering process which brings a system into existence. Its evolution into an engineering sub-discipline grew from management and integration challenges in increasingly complex technological projects, especially in the defense and aerospace industries. Neither the system engineering process nor its procedures are uniquely defined, although it has a set of common elements in any implementation. A common version is Military Standard 499B which is briefly outlined here.

The figure below is a top-level view of the Mil Std 499B system engineering process. It consists of three main stages:

1. Requirements Analysis
2. Functional Analysis/Allocation
3. Synthesis

along with a continuous, cross-cutting, System Analysis and Control phase.

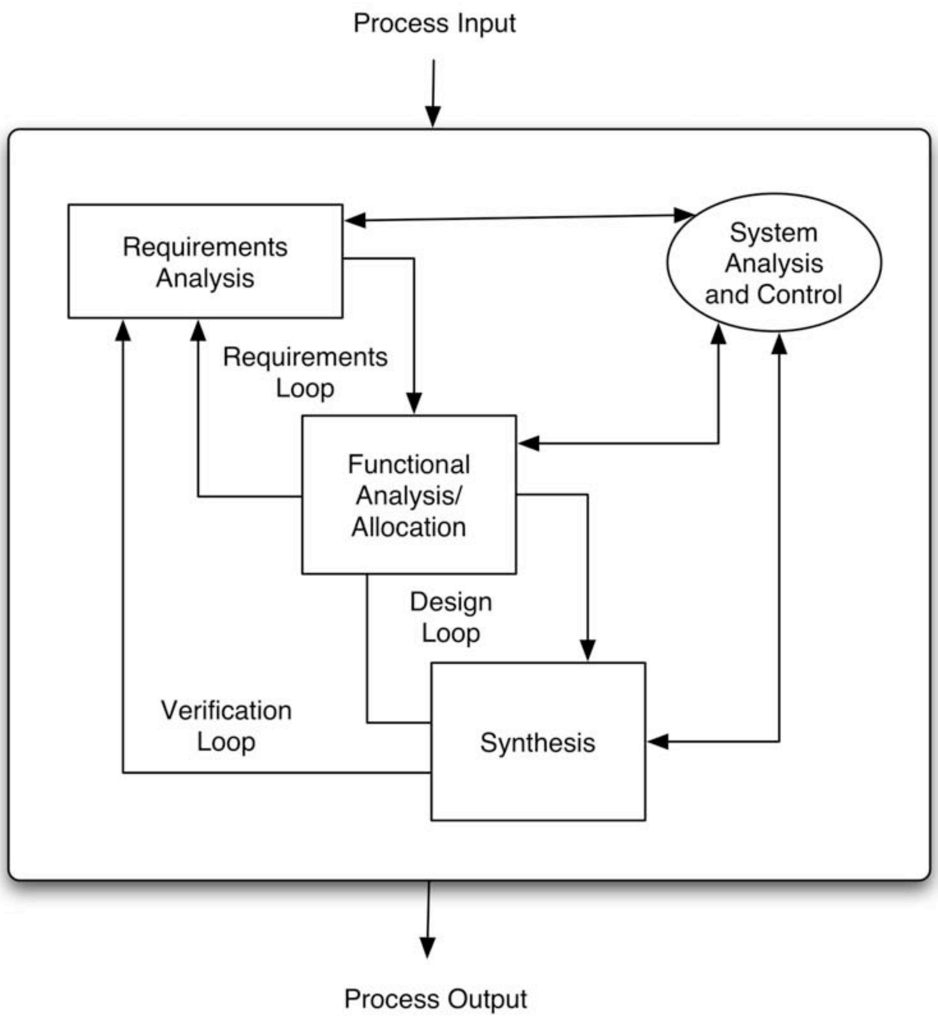

Figure 1. The system engineering process as defined in Mil. Std. 499B.

Requirements Analysis centers on two areas: user and performance requirements. The goal is to identify and define the set of functions that the system must do to meet the user requirements, and to place bounds on how well these functions must be carried out. These are usually called functional and performance requirements, respectively. In the context of the RCO, the functional and performance requirements, together with the design requirements given in Section 3, constitute the science requirements.

The second system engineering stage is Functional Analysis/Allocation, in which the objectives defined by the science requirements are decomposed into a set of lower-level functions, and performance allocations are applied to each of them. The functional interfaces and architecture flow from this process, which is iterative with the Requirements Analysis stage to ensure that the science requirements are being satisfied. The third system engineering stage is Synthesis, in which all elements of the functional design are transformed into a physical design. Synthesis begins at a concept design level, then passes on to a preliminary design level where high risk elements of the hardware and software are tested, and then passes to a detailed design level where full prototypes are constructed. This stage is also iterative with the preceding two stages to make sure that the required functionality is being provided and that the science requirements are being met.

The cross-cutting phase of the system engineering process is System Analysis and Control. This consists of a set of trade studies comparing the feasibility, performance, and cost of alternative technical approaches along with a set of over-arching tasks to manage risk, configuration, interfaces, and documentation.

3. DESIGN PRINCIPLES

The RCO will provide the infrastructure for a complete ocean observing system, and consists of a set of science nodes located on the seafloor and linked to each other, and to one or more shore stations, by a backbone fiber optic/power cable. The science nodes shall functionally encompass:

- A power network energizing both the infrastructure and all instruments on the network
- A communications network interconnecting all instruments with each other, with all shore stations, and with users via the Internet
- Reliable management of all elements of the infrastructure and all instruments on the observatory network
- The distribution of accurate time to user instruments
- Data dissemination and archiving functions
- Adequate security to prevent unauthorized tampering with the infrastructure, data, or instruments.

This will enable a user connected to the Internet anywhere in the world to communicate with, and (with appropriate permissions) to control instruments connected to the wet end of the observatory. To meet its scientific goals, the RCO shall be designed to allow four dimensional (three spatial dimensions and time) observations over the entire portion of the ocean basin selected for deployment.

The entire RCO design process must be guided by a set of overarching statements which comprise the design principles. Unlike the remaining parts of the science requirements, these can be specified a *priori* rather than being extracted from use scenarios, as they represent the overall RCO design philosophy. Further, this list should be as short as possible, both to simplify the design cycle and to avoid potential conflicts. The following order should not be construed as prioritization.

3.1. **Lifetime** The RCO shall operate, with appropriate maintenance, for a design life of at least 25 years.

3.2. **Cost** The RCO shall be designed to minimize the life cycle cost, defined as the sum of capital cost plus aggregate operating cost over the life of the system

3.3. **Controllability** The RCO shall allow all resources to be dynamically-directed where science needs and priorities dictate.

3.4. **Flexibility** The RCO shall be expandable, so that additional science nodes which meet the observatory reliability goals can be placed near or at locations of interest that may develop in the future.

3.5. **Extendability** The RCO shall support individual instruments or clusters of instruments at sites up to 100 km away from the science nodes with possibly reduced power and communications capability and reliability.

3.6. **Upgradeability** The RCO shall be upgradeable to accommodate future technology improvement.

3.7. **Reliability** The primary measure of RCO reliability shall be the probability of being able to send data from any science instrument to shore and/or to other science nodes, exclusive of instrument functionality.

3.8. **Futurecasting** The RCO shall have functionality and performance significantly beyond that required to support current use scenarios so that experiments and instruments that may reasonably be anticipated to develop over the expected life of the facility can be accommodated.

3.9. **Open Design Principle** The RCO hardware designs and specifications shall be freely and openly available, and all software elements shall be based on open standards to the greatest extent possible..

4. FUNCTIONAL AND PERFORMANCE REQUIREMENTS

4.1 LOCATIONS OF SCIENTIFIC INTEREST

Through a community workshop (Regional Cabled Observatory Network (of Networks) or RECONN; http://www.geo-prose.com/projects/reconn_report.html) held October 7-10, 2003, the US scientific community endorsed a Juan de Fuca plate location for the first RCO.

Through two workshops and follow-up action, NEPTUNE Canada has identified and prioritized a set of locations of scientific interest for Phase 1 of the RCO as shown in Figure 2. These sites are contained in a Request for Proposals that is currently out to industry. How many of these nodes will be contained in Phase 1 is unknown pending industry RFP responses and subsequent NEPTUNE Canada decisions.

Comparable evaluation and prioritization of the remaining RCO nodes has not occurred. Figure 3 shows a preliminary concept for their location, although this should be regarded as notional rather than final at this time. Further refinement through community meetings and input is expected prior to installation of Phase 2 of the RCO.

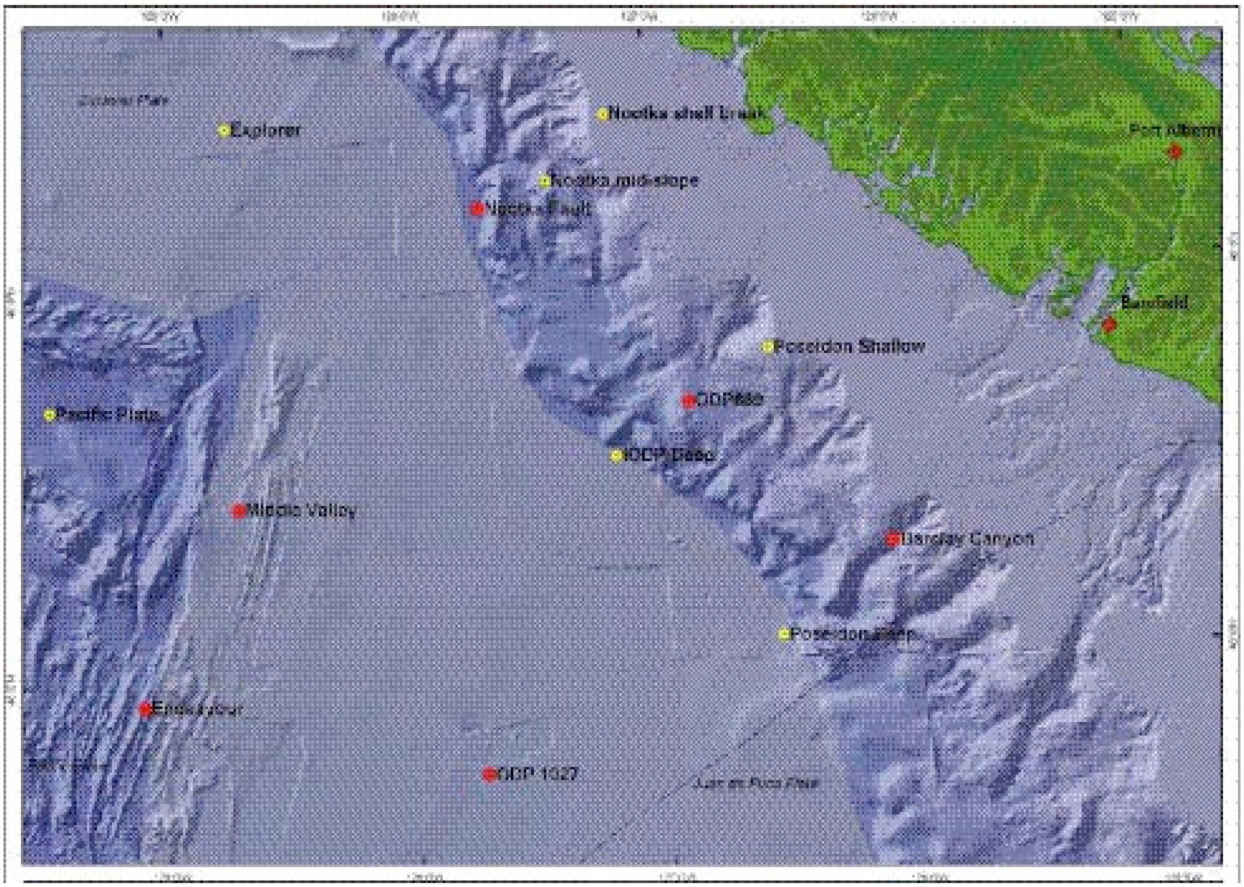

Figure 2. The locations of RCO Phase 1 nodes as prioritized by NEPTUNE Canada in 2004. The red dots indicate the location of primary nodes which meet all of the science requirements, while the yellow dots are the location of secondary nodes which may be served by extension nodes. The dashed line delineates the boundariy of the Exclusive Economic Zone.

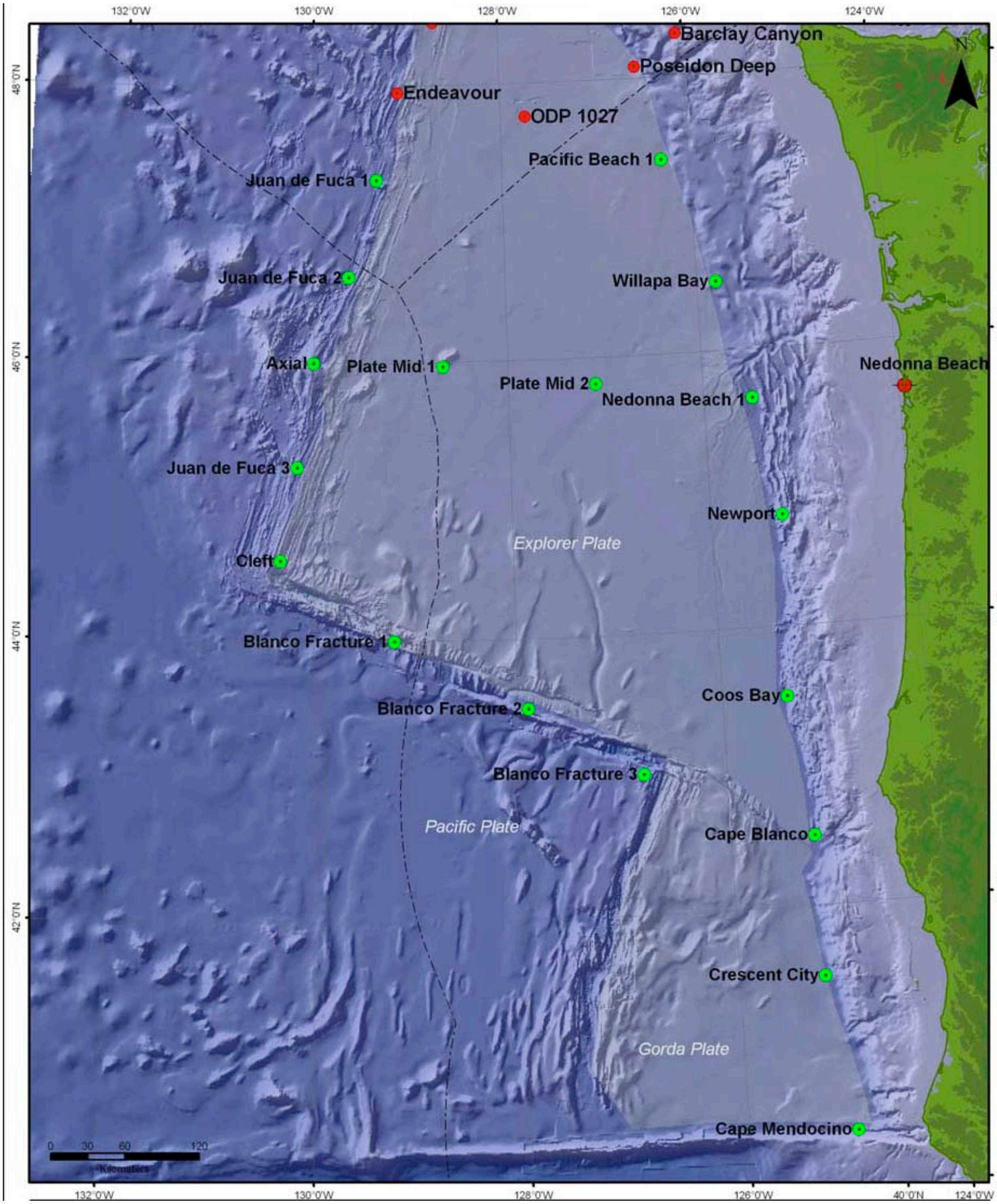

Figure 3. Notional locations of RCO Phase 2 nodes (green), along with selected Phase 1 nodes (red). The dotted line is the boundary of the Canadian and US Exclusive Economic Zones.

4.2 POWER NETWORK

4.2.1. The power network shall provide the maximum average continuous user power equally to all nodes, with a goal of 5 kW.

4.2.2. The power network shall provide the maximum peak user power to as many nodes as possible, with a goal of 10 kW.

4.2.3. The power network shall be in a known state upon power up.

4.2.4. The power network shall be able to detect and localize infrastructure problems, including (but not necessarily limited to) shunt faults or breaks of the backbone cable, high resistance faults, and node power system failures.

4.2.5. The power network shall isolate failed sections of backbone cable or failed nodes such that the remaining operational nodes can function normally.

4.2.6. The power network shall provide voltage and current monitoring functionality adequate to detect and localize infrastructure and user instrument problems, including (but not necessarily limited to) over-current faults in user and infrastructure loads and ground faults.

4.2.7. The power network shall allow power delivery to all nodes and science ports to be scheduled and prioritized.

4.2.8. All pressure cases, including support frames or assemblies electrically connected to them, shall be DC isolated from all signal and power circuits in the RCO.

4.3 DATA COMMUNICATION NETWORK

4.3.1. The data communication network shall provide an aggregate backbone data rate of at least 8 Gb/s.

4.3.2. Each data communication node subsystem shall provide an aggregate instrument data capacity of at least 1 Gb/s exclusive of overhead for system functions such as (but not necessarily limited to) framing or re-transmission due to errors, at all times during the observatory life cycle.

4.3.3. The data communication network shall be in a known state upon power up.

4.3.4. Each data communications node subsystem shall automatically reconfigure itself to suppress fault propagation, and shall automatically recover from faults.

4.3.5. Each data communication node subsystem shall be monitored and controlled over the data communication network using standard protocols.

4.3.6. Each data communication node subsystem shall be monitored and controlled over a high reliability, auxiliary channel.

4.3.7. The data communication network shall be remotely re-configurable so that data transmission to and from each node can be scheduled and prioritized.

4.3.8. Each data communication node subsystem shall support a maximum data rate from each instrument of 100 Mb/s, and for at least one instrument or secondary node at 1 Gb/s, using standard Internet protocols, including (but not necessarily limited to) TCP/IP and standard application layer protocols.

4.3.9. The data communication network shall facilitate intra-node, peer-to-peer communication by user instruments with the minimum possible latency commensurate with inter-instrument propagation delay.

4.3.10. The data communication network shall facilitate inter-node peer-to-peer communication by user instruments with the minimum possible latency commensurate with direct inter-node propagation delay.

4.4 TIME DISTRIBUTION NETWORK

4.4.1. The RCO shall support the Network Time Protocol (NTP) over the data communications system.

4.4.2. At each primary node, the RCO shall provide time accurate to 1 μs corrected for latency and jitter.

4.4.3. Each primary RCO node shall provide all connected secondary nodes with time accurate to 1 μs corrected for latency and jitter.

4.4.4. Each RCO primary and secondary node shall provide all connected instruments with time accurate to 1 μs corrected for latency between node and instrument.

4.4.5. All time signals shall be traceable to a recognized international standard, with UTC being preferred.

4.5 NODE-INSTRUMENT INTERFACE

4.5.1. The standard physical interface (hereafter called science connector) to the RCO for science instruments shall be a single electrical wet-mateable connector which is accessible by standard remotely operated vehicles (ROVs) or manned submersibles, including all present academic deep submergence assets.

4.5.2. Each science node shall provide at least 10 such science connectors.

4.5.3. The instrument interface at each science node shall provide each science connector with:

- An IEEE 802.3 10/100baseT Ethernet data connection
- A power source capable of delivering the maximum continuous node power at a maximum voltage of 400 VDC
- A power source capable of delivering a reduced level of continuous power at 48 VDC
- A high accuracy time signal capable of being corrected for latency between the node and the instrument.

4.5.4. At least one high data rate instrument/secondary node interface (hereafter called extension interface) at each science node shall support:

- A wet-mateable fiber optic connector (hereafter called extension connector)
- An extension of the IEEE 802.3z 1000baseF Ethernet standard or equivalent capable of at least 100 km distance capability
- A power source capable of delivering the maximum continuous node power at a maximum voltage of 400 VDC
- A two-wire power supply capable of delivering the maximum continuous node power at a voltage of at least 2 kVDC
- A high accuracy time signal that can be corrected for latency between the node and the instrument/secondary node.

4.5.5. Each instrument or extension interface in the RCO shall incorporate the ability to disconnect and isolate it from the power, data communications, and time distribution systems.

4.5.6. Each instrument or extension interface shall function in a "plug and work" mode such that an instrument may be placed in service by simply plugging it in.

4.5.7. Each instrument connected to the RCO shall incorporate dynamic metadata storage.

4.5.8. Instrument metadata shall be maintainable by the instrument owner or operator, and shall be continuously accessible to the RCO data management system.

4.5.9. A sensor interface for incorporation into any instrument shall support the instrument interface, standard serial protocols (e.g., RS232/ 422 or RS485), standard voltages (e.g., 5 and 12 V) for sensors, and metadata storage and service.

4.5.10. Each science or extension connector shall be expandable using one or more secondary interfaces to allow each science node to interface to hundreds of instruments.

4.5.11. It shall be possible to monitor each node power bus to detect fault conditions, including (but not necessarily limited to) ground faults or over-current conditions.

4.5.12. It shall be possible to set the ground fault threshold on each node power bus.

4.5.13. It shall be possible to set the over and short circuit current on each science or extension connector.

4.5.14. It shall be possible to isolate a faulted science or extension connector without impact to other science or extension connectors.

4.5.15. Neither instruments nor the interface to them shall use seawater as a return path for current.

4.6 OBSERVATORY AND DATA MANAGEMENT

4.6.1. An observatory management system (OMS) which monitors and controls all interactions between either distinct elements of the infrastructure or elements of the infrastructure and instruments/users shall be provided.

4.6.2. The OMS shall be fault tolerant.

4.6.3. A failure in the OMS shall have no impact on the operation of the RCO.

4.6.4. The OMS shall be capable of unattended operation.

4.6.5. The OMS shall detect and flag warnings, alarms, or other anomalous conditions in all active components of the RCO.

4.6.6. A mechanism to log and serve status information about the RCO shall be provided by the OMS.

4.6.7. The OMS shall maximize user control of RCO resources subject to controls to protect the infrastructure and other users from interference.

4.6.8. A web-based interface to the OMS shall be provided

4.6.9. All interactions between an instrument/user and the OMS shall be logged.

4.6.10. A process for the orderly shut down of the entire system shall be provided by the OMS.

4.6.11. A process for the orderly shut down of individual science nodes shall be provided by the OMS.

4.6.12. A process for the orderly shut down of individual science instruments shall be provided by the OMS.

4.6.13. A data management system (DMS) which coordinates data flow between instruments and users shall be provided.

4.6.14. The DMS shall support real-time data access.

4.6.15. A web-based interface to the DMS shall be provided.

4.6.16. The DMS shall support one or more data archives that are either part of the RCO infrastructure or external to it.

4.6.17. All data flowing to a shore station from instruments connected to the RCO shall be archived and freely available, subject to special provisions for instrument development and/or quality control.

4.6.18. Metadata shall be associated with all data.

4.6.19. Metadata state change shall be flagged.

4.6.20. Metadata shall be stored with all data.

4.6.21. The data archive(s) shall use standard data and metadata formats.

4.6.22. The DMS shall be able to access data external to the data archive(s).

4.6.23. The data archive(s) shall store information about data quality with all data.

4.6.24. The data archive(s) shall support and store data products, including but not limited to event, feature and pattern detection-processed data products.

4.6.25. The data archive(s) shall store selected data according to agreed upon protocols, including (but not necessarily limited to) compressed, sub-setted, or sub-sampled data.

4.6.26. The data archive(s) shall store and distribute model products associated with data.

4.7 SECURITY and ENVIRONMENT

4.7.1. The RCO shall accommodate the national security concerns of its sponsoring governments.

4.7.2. The OMS shall be able to validate that a particular science or extension connector is being used by an authorized instrument.

4.7.3. The security of the system from natural and man-made hazards shall be ensured through the use of (but not necessarily limited to) industry-standard cable engineering and burial practices, and the use of trawl-resistant design practices for all seafloor systems installed in waters that may reasonably be expected to be fished over the lifetime of the system.

4.7.4. The data communications network shall utilize best practice firewall protection from external aggression and the distribution of Internet viruses.

4.7.5. The power network shall incorporate backup power at all shore stations to ensure continuous operation in the event of a mains failure.

4.7.6. The shore stations shall incorporate protection from lightning strikes, power transients and surges, magnetic storms, and similar effects.

4.7.7. Equipment in the shore stations shall be earthquake resistant, with a goal of meeting standards for North American Earthquake Zone 4.

4.7.8. The wet infrastructure shall minimize acoustic noise radiated into the surrounding water, with goals (referenced to 1 μPa/Hz) of <50 dB from 1-50 Hz, <40 dB from 50-500 Hz, <30 dB from 500-5000 Hz, <20 dB from 5-10 kHz, and <10 dB above 10 kHz.

4.7.9. Fluctuating electric fields generated by the wet infrastructure shall be minimized, with a goal of 10 μV/m at 30 m range at frequencies below 1000 Hz, except near sea grounds where the goal may be ten times larger.

4.7.10. Fluctuating magnetic fields generated by the wet infrastructure shall be minimized, with a goal of 1 nT at a distance of 30 m at frequencies below 1000 Hz.

4.8 OPERATIONS

4.8.1. The RCO wet infrastructure shall be designed so that UNOLS Global Class vessels or equivalent and academic deep submergence assets can perform anticipated operations and maintenance procedures.

4.8.2. One or more portable simulators that emulate the instrument interface shall be available to users.

4.8.3. One or more portable simulators that emulate the extension interface shall be available to users.

4.8.4. An instrument verification facility that allows users to verify instrument functionality and compatibility with the RCO before deployment shall be provided.

4.8.5. One or more RCO testbeds for instrument and observatory operations development shall be provided.

4.8.6. The schedule for planned maintenance that will affect user instruments or data streams shall be broadcast to instruments and users in a timely fashion.

4.8.7. The projected amount of down time during maintenance operations shall be broadcast to instruments and users in a timely fashion.

4.9 RELIABILITY

4.9.1. At the 95% confidence level, the power network shall meet all requirements 99.9% of the time in a given year, excluding outages due to external factors and scheduled maintenance downtime.

4.9.2. At the 95% confidence level, the data communication network shall meet all requirements 99.9% of the time in a given year, excluding outages due to external factors and scheduled maintenance downtime.

4.9.3. At the 95% confidence level, the time distribution network shall meet all requirements 99.9% of the time in a given year, excluding outages due to external factors and scheduled maintenance downtime.

4.9.4. At the 95% confidence level, the observatory management system shall meet all requirements 99.9% of the time in a given year, excluding outages due to external factors and scheduled maintenance downtime.

4.9.5. At the 95% confidence level, the data management system shall meet all requirements 99.9% of the time in a given year, excluding outages due to external factors and scheduled maintenance downtime.

4.9.6. At the 95% confidence level, a given science or extension connector at a given primary science node shall meet all requirements 99% of the time in a given year, exclusive of outages due to external factors and scheduled maintenance down time.

4.9.7. At the 95% confidence level, a given secondary node shall meet all requirements 95% of the time in a given year, exclusive of outages due to external factors and scheduled maintenance down time.

4.9.8. At the 95% confidence level, the RCO shall have less than a 1% probability of system-wide failure in a given year.

4.9.9. All failures occurring in any 12 month interval shall be repairable during an annual 30-day repair period which will require less than 14 days of cumulative system down time.

4.9.10. At the end of the annual repair period, the RCO shall be restored to full functionality.