SCIENCE USER REQUIREMENTS

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Table of Contents

1. Purpose of this Document

The science user requirements (SUR) serve to define the desired functionality of the observing elements and the integrated network (i.e., the system). The intent is that these requirements clearly specify the needs of the users of the system, but do not specify (or restrict) the design approach. It is a living document that evolves throughout the life cycle of the OOI Network.

The Ocean Observatories Initiative (OOI) will advance the investigation of complex Earth and ocean processes by providing access to next generation (i.e., transformational) technologies to support interactive and adaptive observatory science. The OOI Network is to be an integrated network of interactive, globally distributed sensors with near real-time access providing scientists with unique opportunities to conduct multi-disciplinary studies of linked atmosphere-ocean-earth processes over timescales of seconds to decades, and spatial scales of millimeters to thousands of kilometers.

Advancing the understanding of how the complex physical, chemical, biological, and geological processes in the ocean, the atmosphere above, and the solid earth below interact requires simultaneous, interdisciplinary measurements on a broad range of temporal and spatial scales. Earth and ocean phenomena range from episodic, short-lived events (e.g., tectonic, volcanic, biological, severe storms), to subtler, longer-term changes or emergent phenomena in ocean systems (e.g., ocean circulation patterns, climate change, ocean acidity, ecosystem trends). The vision for the OOI is a permanent, interactive presence in the ocean to enable continuous observations of ocean processes year-round, in all weather conditions, from sea surface to sub-seafloor, at locations from the near-shore to the remote, open ocean.

The scientific requirements for the OOI trace back to guiding design principles and the research areas identified by the ocean research community in OOI planning documents appearing over the last decade, more recently in the National Research Council report, *Enabling Ocean Research in the 21st Century: Implementation of a Network of Ocean Observatories* (2003), the *Ocean Research Interactive Observatory Networks Report* (2004), the *Ocean Observatories Initiative Science Plan* (2005), and the OOI Science Prospectus (2007). Those topical areas are:

- Ocean-Atmosphere Exchange
- Climate Variability, Ocean Circulation, and Ecosystems
- Turbulent Mixing and Biophysical Interactions
- Coastal Ocean Dynamics and Ecosystems
- Fluid-Rock Interactions and the Subseafloor Biosphere
- Plate-Scale, Ocean Geodynamics

The OOI Science Prospectus (incorporated here by reference) reviewed those topics and linked the research needs to the required infrastructure to support those needs. The format used to illustrate those linkages was a traceability matrix. Ten example questions were taken from a much larger pool of scientific questions to show how the requirements for observations, sensors, sampling, data transmission, and sensor control trace to the proposed infrastructure and high-level requirements. The traceability matrices pointed to common requirements for observations, sensors, and sampling. Those common requirements, along with additional infrastructure or node-specific requirements provide the foundation for this version of science user requirements.

The guiding principles which also serve as a basis for user requirements are:

- Continuous observations at time scales of seconds to decades.
- Spatial measurements from millimeter to kilometers.
- The ability to collect data during storms and other severe conditions.

- Two-way data transmission and remote instrument control.
- Power delivery to sensors between the sea surface and the seafloor.
- Standard sensor interfaces.
- Autonomous underwater vehicle docking capability for download and battery recharge.
- Access to facilities to deploy, maintain, and calibrate sensors.
- Effective data management system that provides open access to all.

1.1 Organization of Requirements

Requirements are specified as location requirements, general science requirements, measurement objectives, and associated instrument and sampling requirements. All requirements are assigned an identification number for reference purposes and are binned by infrastructure element, i.e., Coastal-Scale Nodes, Global-Scale Nodes, and Regional-Scaled Nodes. For the Coastal-Scale Nodes, some specific measurement objectives and associated instrument and sampling requirements are listed separately for the Endurance Array and the Pioneer Array. Instrument and sampling requirements are associated with measurement objectives by way of referencing the measurement objective identification number.

References to core sensors are those specified in core sensor tables in the OOI Preliminary Network Design document, incorporated here by reference. The Cyberinfrastructure user requirements are those that enable the science of the OOI system. Science User Requirements will be maintained in a Dynamic Object Oriented Requirements System (DOORS) database and will be linked to the Systems Requirements document forming the basis for design and testing of the OOI system.

2. Coastal-Scale Nodes (CSN) Goal

The Coastal-Scale Nodes (CSN) will support long-term and high space-time resolution observations to understand the physics, chemistry, ecology, and climate science of key regions of the complex coastal ocean. The scientific goals include providing observations of phenomena such as: variability in complex eastern and western boundary current systems; coupling between coastal physics and biology, including nearshore fisheries and biological regime shifts; coastal carbon budgets; terrestrial-oceanic transport of carbon, nutrients, sediments, and fresh water; shelf, shelfbreak and slope exchanges; and coastal hazards such as storms, tsunamis, and hypoxia.

2.1 CSN Location Requirements

Coastal margins are subject to a range of forcing and transport mechanisms such as storms, river plumes, offshore jets, upwelling/downwelling events, and density flows. Many of these are focused or aligned by local topography, and variability in coastal systems is pronounced in the direction perpendicular to the shore. The challenges in locating CSN infrastructure are to adequately sample across the shelf while assessing along-shore variability and to incorporate specific localized effects and still characterize regional, margin-scale phenomena and transports. There are also regional differences in shelf width and geomorphology, wind regime, buoyancy and sediment inputs, tidal characteristics, boundary currents, and anthropogenic pressures. Placing the assets of the CSN in locations with contrasting characteristics will maximize its utility and engender greater interest in the research community. The location requirements are:

ID	Description
CSN-L-1	The Endurance Array will be located on the continental shelf and slope of the U.S. Pacific Northwest. The shelf in this region is narrow, subject to persistent wind-driven upwelling, influences large buoyancy inputs (e.g., the Columbia River) and an energetic eastern boundary current. This is an area with substantial inter-annual variability forced by fluctuations in patterns of ENSO and variations in circulation of the North Pacific (e.g., PDO).
CSN-L-2	The Pioneer Array will be located on the continental shelf and slope of the Middle Atlantic Bight, south of Massachusetts. The continental shelf is relatively broad with a well-defined shelfbreak front. The region is subject to distributed buoyancy input, variable winds, and intermittent intrusions of Gulf Stream rings and meanders. The array will be positioned at the climatological shelfbreak front.

2.2 CSN General Science Requirements

System-wide and CSN-specific general requirements (collectively referred to as Coastal Global Scale Nodes or CGSN requirements) are provided in the OOI System Requirements Document (SRD). In addition to CGSN general requirements listed in the SRD, the following general science requirements also apply to the CSN:

ID	Description
CSN-SR-1	The CSN will have the capability to support power and data transmission requirements for designated core sensors (refer to core sensor tables in the Preliminary Network Design document) and capacity for future sensors and instrumentation.
CSN-SR-2	Cabled and locally-generated power resources will be re-allocatable among attached modules, science nodes, sensors, instruments, and AUVs as commanded.
CSN-SR-3	System will, where possible, accommodate continuous data transmission from sensors and 2-way, real-time communication for sensor control.

ID	Description
CSN-SR-4	System capability for bi-directional communication and dynamic command/control among sensors, users, and operators.
CSN-SR-5	The operational status of the CSN shall be logged and publicly available.
CSN-SR-6	Data and associated metadata will be available consistent with the OOI Network Data Policy.
CSN-SR-7	Sensors to be deployed on the CSN so as to minimize interference among sensors, and provide high bandwidth communication and accurate time base.
CSN-SR-8	Minimize data and communication latencies.
CSN-SR-9	The CSN will, where necessary, buffer data streams in-situ to allow processing and/or later transmission at the maximum available telemetry rate. Buffering will be optimized such that the maximum amount of data are telemetered with minimum latency.
CSN-SR-10	CSN infrastructure noise levels (acoustic, electric, and magnetic) shall be fully characterized, documented, and publicly available.
CSN-SR-11	Capability to isolate instruments, sensors, and extension interfaces from power, communications, and time distribution systems.
CSN-SR-12	The CSN will have internal data storage capacity of 6 months.
CSN-SR-13	The CSN will have the ability to accommodate expansion of the network infrastructure (e.g., additional science nodes, arrays, moorings, instruments, and mobile assets) over its operational life.
CSN-SR-14	The CSN will have the ability to accommodate additions to the sensor suite over the operational life.
CSN-SR-15	The CSN must operate to allocate power appropriate to instrumentation and sensor requirements, and minimize downtime and impact to the network caused by sensor or infrastructure failure.
CSN-SR-16	Schedules for planned maintenance that affect user instruments or data streams shall be available to instruments and users in a timely fashion.
CSN-SR-17	Instrumentation and sensors maintainable at 6-month intervals.
CSN-SR-18	The projected amount of downtime during maintenance operations shall be available to instruments and users in a timely fashion.

2.3 CSN Measurement Objectives

ID	Description
CSN-MO-1	Time series of surface meteorological observations suitable for estimation of bulk air-sea fluxes of momentum, heat and moisture as well as direct covariance measurements of momentum and buoyancy fluxes.
CSN-MO-2	Observations of turbulent mixing and gas exchange at the sea surface.
CSN-MO-3	Time series observations of dynamic processes and structure in the surface mixed layer and upper ocean.
CSN-MO-4	Time series observations of surface to near seafloor distribution and variability of standard hydrographic properties, currents, mixing, and biogeochemical parameters such as carbon, other particulate and dissolved materials, optical properties, estimated phytoplankton biomass, and primary production.
CSN-MO-5	Observations of bottom boundary layer dynamics, currents, dissolved properties, community respiration, suspended particulate characteristics.

2.4 CSN Instrument and Sampling Requirements

ID	Description	Reference
CSN-SR-19	Provide high quality, high resolution observations of: air temperature; specific humidity; barometric pressure; wind speed and direction, wind stress; shortwave radiation; longwave radiation; sea surface temperature and conductivity; precipitation; surface waves.	CSN-MO-1
CSN-SR-20	Surface platforms with power and communications to accommodate sensors for surface meteorology and direct covarient fluxes: thermistor, hygrometer, barometer, sonic anemometer, pyranometer, pyrgeometer, in-water temperature/conductivity, rain gauge, motion sensor.	CSN-MO-1
CSN-SR-21	Provide high quality, high resolution observations of: pCO2 in air; sea surface pCO2; pH, dissolved oxygen.	CSN-MO-2
CSN-SR-22	Surface platforms with power and communications to accommodate sensors for CO2 and O2 exchange: IR gas analyzer, in-water pCO2 analyzer, pH, DO sensor.	CSN-MO-2
CSN-SR-23	Surface platforms with sufficient physical stability to support, protect, and operate instrumentation and sensors in open ocean conditions.	CSN-MO-1,2
CSN-SR-24	Provide high quality observations of the upper 150 meters with high vertical and temporal resolution of the following parameters: temperature, conductivity, pressure; horizontal current velocity (shear); vertical velocity; pCO2; pH; dissolved oxygen; penetrating solar radiation; chlorophyll-a, optical backscatter, colored dissolved organic matter (CDOM), photosynthetically available radiation (PAR), optical attenuation and absorption, nitrate.	CSN-MO-3
CSN-SR-25	Provide high quality, high vertical resolution observations from near surface to near seafloor for parameters as listed in CSN-SR-24.	CSN-MO-4,5
CSN-SR-26	Moorings with capabilities to support instrumented, autonomous profilers and fixed depth instrumentation/sensors for water column observations.	CSN-MO-2, 3, 4, 5
CSN-SR-27	Water column sensors for sampling/observation requirements: conductivity-temperature-depth (CTD), fixed and profiling current meters, pCO2 sensor, pH, DO, profiling spectral radiometer, transmissometer, Chl-a/CDOM fluorometer, PAR radiometer, multi-channel spectrophotometer, nutrients (nitrate, nitrite, phosphate, silicate).	CSN-MO-2, 3, 4, 5
CSN-SR-28	Moorings equipped with profilers capable of sampling the water column from surface to near bottom at high-vertical resolution.	CSN-MO-3, 4, 5
CSN-SR-29	Profilers should accommodate the core sensor package (see core sensor tables in the Preliminary Network Design document).	CSN-MO-1, 2, 3, 4, 5
CSN-SR-30	Capability to sample the upper water column (0-150 meters) in vertical profile with resolution of sub-meter to meter intervals.	CSN-MO-2,3
CSN-SR-31	Capability for multiple upper water column profiles per day (up to 8 profiles per day).	CSN-MO-2,3
CSN-SR-32	Capability to sample from 150 meters depth to near seafloor at meter to 10-meter intervals.	CSN-MO-2, 3, 4, 5

ID	Description	Reference
CSN-SR-33	Capability for multiple surface to bottom water column profiles (maximum number is depth dependant).	CSN-MO-2, 3, 4, 5
CSN-SR-34	Capability to adjust profiling intervals and speed throughout the water column i.e., operate in sampling mode over smaller and/or fixed depth intervals.	CSN-MO-3, 4, 5
CSN-SR-35	Two-way, near-real time communications, where possible, to adjust sensor sampling rates and other sensor and instrument parameters.	CSN-MO-1, 2, 3, 4, 5
CSN-SR-36	Accommodate and integrate instrumented mobile platforms such as profilers, autonomous underwater vehicles (AUVs), and gliders into the design of fixed infrastructure.	CSN-MO-3, 4, 5
CSN-SR-37	Instrumented autonomous vehicles (AUVs and or gliders) with capability to extend spatial coverage along and across the shelf.	CSN-MO-3, 4, 5
CSN-SR-38	Moorings with benthic modules or nodes to supply power and communication to seafloor instrumentation and sensors.	CSN-MO-4,5

2.5 Measurement Objectives: Endurance Array

ID	Description
	All CSN measurement objectives listed plus specific objectives listed below.
CSN-MO-6	A permanent coastal observatory to provide continuous and coherent multi-disciplinary measurements to resolve long-term trends while providing temporal resolution to observe episodic events and resolve rapidly varying processes.
CSN-MO-7	Permanent cross-margin line(s) of moorings to provide observations of cross-shelf and along-shelf variability over seasonal, interannual, and climatic time scales.
CSN-MO-8	Provide high power and communications bandwidth via cable connections to shore.
CSN-MO-9	Observations of pelagic and benthic organisms, and site-specific events.
CSN-MO-10	Additional capability for power and bandwidth to support future observations (i.e., accommodate the potential of additional sensors) such as zooplankton and other nekton biomass and size class, biogeochemical processes and sediment-seawater exchange, high definition visible images, seafloor imaging, sediment transport, etc.

2.6 Instrument and Sampling Requirements: Endurance Array

ID	Description	Reference
All CSN instrument and sampling requirements listed plus specific requirements listed below.		
CSN-SR-39	A line of at least 3 moorings offshore of Newport, OR to be placed at depths ranging from 25 to 500 meters, at sites representative of conditions on the inner shelf, middle shelf, and continental slope.	CSN-MO-6-8
CSN-SR-40	High power and communications furnished to at least 2 moorings via electrical-optical (EO) cable extension of the RSN cable to support power-demanding sensors with real-time, high bandwidth data communication.	CSN-MO-6-10
CSN-SR-41	A line of at least 2 moorings offshore of Grays Harbor, WA to be placed at depths ranging from 25 to 150 meters, at sites representative of conditions on the continental shelf.	CSN-MO-6,7

ID	Description	Reference
CSN-SR-42	Moorings with benthic nodes to support required instrumentation and sensors, and additional modules or instrumentation.	CSN-MO-8,9
CSN-SR-43	A sustainable operational lifetime of 25 years.	CSN-MO-6
CSN-SR-44	Collection of visible images via camera deployed at benthic node.	CSN-MO-9
CSN-SR-45	Instrumented gliders with capability to extend observations up to 500 km along-shelf.	CSN-MO-7

2.7 Measurement Objectives: Pioneer Array

ID	Description
All CSN measurement objectives listed plus specific objectives listed below.	
CSN-MO-11	A relocatable array of instruments and sensors optimized to focus on high spatial (vertical and horizontal) resolution of continental shelf processes.
CSN-MO-12	Array to be designed to resolve shelf transport processes and ecosystem dynamics.
CSN-MO-13	Array to be configured and instrumented to provide multidisciplinary, synoptic measurements spanning the shelfbreak at high temporal and spatial resolution.
CSN-MO-14	Fixed moorings to be augmented by instrumented AUVs and gliders.

2.8 Instrument and Sampling Requirements: Pioneer Array

ID	Description	Reference
All CSN instrument and sampling requirements listed plus specific requirements listed below.		
CSN-SR-45	The Pioneer Array will be designed for a sustainable, operational lifetime of 3-5 years from the time the full array is commissioned.	CSN-MO-11
CSN-SR-46	Upon completion of first deployment, the array will be reconfigured and deployed at a TBD location.	CSN-MO-11
CSN-SR-47	The array will be located to span the shelfbreak front (determined by climatology).	CSN-MO-12,13
CSN-SR-48	Benthic nodes with capability to support power and communication requirements for sensors, instrumentation, and at least one AUV docking station.	CSN-MO-14

3. Global-Scale Nodes (GSN) Goal

The Global-Scale Nodes will support air-sea, water-column, and seafloor sensors operating in remote, scientifically important locations and provide data and near-real time interaction to diverse communities of scientific and educational users. The scientific goals are to provide sustained and simultaneous atmospheric, physical, biogeochemical, ecological, and seafloor observations at fixed locations in support of research into: air-sea interactions and gas exchange; processes at critical high latitude sites; the global carbon cycle; ocean acidification; and global geodynamics.

3.1 GSN Location Requirements

The criteria for the location of Global Sites include: high scientific value with impact to a broad range of disciplines, the location's contribution to a global network (e.g., OceanSITES, DART, TAO), prioritizations from previous community planning efforts, and occupation of sites beyond the reach of present technology. High latitude, remote sites where less observing capability exists are also considered a priority, as are sites considered representative of ocean basins and/or biogeographic provinces. The requirements for location of Global sites are as follows:

ID	Description
GSN-L-1	Locations with high science value in Pacific and Atlantic Oceans.
GSN-L-2	Sites in contrasting ocean provinces.
GSN-L-3	Sites for which in situ data would be considered transformational.
GSN-L-4	Sites requiring advanced buoy or platform technology to acquire observations.
GSN-L-5	Sites that would serve as strategic locations for the benefit of science and "proof of concept" for highly capable, physically stable buoy or platform designs.
GSN-L-6	Selection of sites should address as many of the above requirements as possible.

3.2 GSN General Science Requirements

System-wide and GSN-specific general requirements (collectively referred to as CGSN requirements) are provided in the OOI System Requirements Document (SRD). In addition to CGSN general requirements listed in the SRD, the following general science requirements also apply to the GSN:

ID	Description
GSN-SR-1	The GSN will have the capability to support power and data transmission requirements for designated core sensors (see core sensor tables in the Preliminary Network Design document) and capacity for future sensors and instrumentation.
GSN-SR-2	Power resources will be re-allocatable, where possible, among attached modules, science nodes, sensors, and instruments as commanded.
GSN-SR-3	System capability for bi-directional communication and dynamic command/control among sensors, users, and operators.
GSN-SR-4	The operational status of the GSN shall be logged and publicly available.
GSN-SR-5	Data and associated metadata will be available consistent with the OOI Network Data Policy.
GSN-SR-6	Sensors to be deployed on the GSN so as to minimize interference among sensors, and provide high bandwidth communication and accurate time base.
GSN-SR-7	Minimize data and communication latencies.

ID	Description
GSN-SR-8	The CSN will, where necessary, buffer data streams in-situ to allow processing and/or later transmission at the maximum available telemetry rate. Buffering will be optimized such that the maximum amount of data are telemetered with minimum latency.
GSN-SR-9	The GSN will have internal data storage capacity of 12 months.
GSN-SR-10	GSN infrastructure noise levels (acoustic, electric, and magnetic) shall be fully characterized, documented, and publicly available.
GSN-SR-11	Capability to isolate commandable instruments, sensors, and extension interfaces from power, communications, and time distribution systems.
GSN-SR-12	The GSN will have the ability to accommodate expansion of the network infrastructure (e.g., additional sites, science nodes, moorings, instruments, and mobile assets) over its operational life.
GSN-SR-13	The GSN will have the ability to accommodate additions to the sensor suite, including changes in data rates, over the operational life.
GSN-SR-14	The GSN must operate to allocate power appropriate to instrumentation and sensor requirements, and minimize downtime and impact to the network caused by sensor or infrastructure failure.
GSN-SR-15	Schedules for planned maintenance that affects user instruments or data streams shall be available to instruments and users in a timely fashion.
GSN-SR-16	Instrumentation and sensors must be robust enough to be maintained at routine 12-month intervals.
GSN-SR-17	The projected amount of downtime during maintenance operations shall be available to instruments and users in a timely fashion.

3.3 GSN Measurement Objectives

ID	Description
GSN-MO-1	Time series of surface meteorological observations suitable for estimation of bulk air-sea fluxes of momentum, heat and moisture as well as direct covariance measurements of momentum and buoyancy fluxes.
GSN-MO-2	Observations of ocean wind waves and swell, flow structures within the upper ocean, upper ocean turbulence, and other exchange processes at the air-sea interface and upper ocean during severe storms (i.e., high wind, waves, sea spray).
GSN-MO-3	Observations of turbulent mixing and gas exchange at the sea surface.
GSN-MO-4	Time series observations of dynamic processes and structure in the surface mixed layer and upper ocean.
GSN-MO-5	Time series observations of surface to near seafloor distribution and variability of standard hydrographic properties, currents, mixing, and biogeochemical parameters such as carbon, other particulate and dissolved materials, optical properties, estimated phytoplankton biomass, and primary production.
GSN-MO-6	Observations of bottom boundary layer dynamics, dissolved properties, community respiration, suspended particulate characteristics.
GSN-MO-7	Observations of the global sound field to detect earthquakes, nuclear explosions, track marine mammals.
GSN-MO-8	Observations of global seismicity.
GSN-MO-9	Capability to support investigations of global heat content and large-scale thermal variability.

ID	Description
GSN-MO-10	Capability to support observations of atmospheric aerosols.
GSN-MO-11	Capability to support observations of BSRN compliant direct and diffuse solar radiation.

Note: All sites will not be capable of supporting all objectives.

3.4 GSN Instrument and Sampling Requirements

ID	Description	Reference
GSN-SR-18	Provide high quality, high resolution observations of: air temperature; specific humidity; barometric pressure; wind speed and direction, wind stress; shortwave radiation; longwave radiation; sea surface temperature and conductivity; precipitation; surface waves.	GSN-MO-1,2
GSN-SR-19	Surface platforms with power and communications to accommodate sensors for surface meteorology and bulk fluxes: thermistor, hygrometer, barometer, sonic anemometer, pyranometer, pyrgeometer, in-water temperature/conductivity, rain gauge, motion sensor.	GSN-MO-1,2
GSN-SR-20	Provide high quality, high resolution observations of: pCO2 in air; sea surface pCO2; pH, dissolved oxygen.	GSN-MO-3
GSN-SR-21	Surface platforms with power and communications to accommodate sensors for CO2 and O2 exchange: IR gas analyzer, in-water pCO2 analyzer, pH, DO sensor.	GSN-MO-3
GSN-SR-22	Surface platforms with sufficient physical stability to support, protect, and operate instrumentation and sensors in open ocean conditions.	GSN-MO-1,2
GSN-SR-23	Provide high quality observations of the upper 150 meters with high vertical and temporal resolution of the following parameters: temperature, conductivity, pressure; horizontal current velocity (shear); vertical velocity; pH; dissolved oxygen, chlorophyll-a, optical backscatter, colored dissolved organic matter (CDOM), optical attenuation and absorption. nitrate.	GSN-MO-4,5
GSN-SR-24	Provide high quality, high vertical resolution observations from sea surface to near seafloor for parameters as listed in GSN-SR-23.	GSN-MO-4, 5, 6
GSN-SR-25	Moorings with capabilities to support instrumented, autonomous profilers and fixed depth instrumentation/sensors for water column observations.	GSN-MO-4, 5, 6
GSN-SR-26	Water column sensors for sampling/observation requirements: conductivity-temperature-depth (CTD), fixed and profiling current meters, pCO2 sensor, pH, DO, profiling spectral radiometer, transmissometer, Chl-a/CDOM fluorometer, multi-channel spectrophotometer, nitrate.	GSN-MO-4, 5, 6
GSN-SR-27	Moorings equipped with profilers capable of sampling the water column at high-vertical resolution.	GSN-MO-4,5
GSN-SR-28	Profilers should accommodate the core sensor package (see core sensor tables in the Preliminary Network Design document).	GSN-MO-3 to 5
GSN-SR-29	Capability to sample the upper water column (0-150 meters) in vertical profile with resolution of sub-meter to meter intervals.	GSN-MO-3,4

ID	Description	Reference
GSN-SR-30	Capability for multiple upper water column profiles per day (up to 8 profiles per day).	GSN-MO-3,4
GSN-SR-31	Capability to sample from the 150 meters to near seafloor at intervals as small as meter to tens of meters.	GSN-MO-3 to 6
GSN-SR-32	Capability for multiple surface to bottom water column profiles (maximum number is depth dependant).	GSN-MO-3 to 6
GSN-SR-33	Capability to adjust profiling intervals and speeds throughout the water column i.e., operate in sampling mode over smaller and/or fixed depth intervals.	GSN-MO-3 to 6
GSN-SR-34	Two-way, near-real time communications, where possible, to adjust sensor sampling rates and other sensor and instrument parameters.	GSN-MO-1 to 11
GSN-SR-35	Accommodate and integrate instrumented mobile platforms such as profilers and gliders into the design of fixed infrastructure.	GSN-MO-2 to 6
GSN-SR-36	Instrumented gliders with capability for 1-year deployments.	GSN-MO-4,5
GSN-SR-37	Moorings with benthic modules or nodes to supply power and communication to seafloor instrumentation and sensors such as seismometers, hydrophones, up-looking current meters.	GSN-MO-6 to 8
GSN-SR-38	Mooring or platform with the physical stability, power, and communications to accommodate future additions of air-sea sensors such as: surface skimming sonars; upper mixed layer sonars; sensors for aerosol scattering, absorption, optical particle counters, and size distribution; phased array radar for atmospheric wind profiling; nephelometers, LIDAR, BSRN compliant radiometers.	GSN-MO-2, 10, 11
GSN-SR-39	Mooring or platform capability to support future instrumentation and sensors, such as very low frequency acoustic sources, hydrophones, etc.	GSN-MO-7,9

4. Regional-Scale Nodes (RSN) Goal

The Regional-Scale Nodes (RSN) will enable oceanic plate-scale studies of water column, seafloor, and sub-seafloor processes using high-powered, high-bandwidth instrument arrays cabled to shore. The science goals of the RSN are to support investigations into the structure of Earth's crust; the interaction of the Juan de Fuca Plate with its neighbors; geophysics of subduction zones and transform faults; seismicity, magmatism, and deformation across the Plate and Cascadia Subduction Zone; water, heat, and chemical fluxes of hydrothermal systems connecting the sub-seafloor with the water column above; gas hydrate formation and life in extreme environments; benthic ecosystems; ocean circulation, and current systems at gyre boundaries; turbulence and mixing; and biogeochemistry and ecosystem dynamics. The RSN will enable science at each node, and at the same time across all OOI nodes, connecting coastal scales to global scales in one network.

4.1 RSN Location Requirements

Planning for a regional cabled observatory spanned a decade of effort, including ten workshops and meetings to define the many scientific and technical issues that could be addressed with a network of cabled sensors. An NSF-supported workshop held in 2003 considered the choice of location as a balance among science themes served and the logistical issues of the engineering, construction, and maintenance of a cabled observatory [see the *Regional Cabled Observatory Network of Networks* (RECONN) report, March 2004]. The Northeast Pacific in the region of the Juan de Fuca Plate was recommended as having the greatest potential benefit to broad research themes, to span coastal to global scales of observation, to link with other observing programs (e.g., NEPTUNE Canada, EarthScope), and favorable proximity to domestic ports to support operations. The requirements for location of node infrastructure are as follows:

ID	Description
RSN-L-1	Node locations should be jointly optimized to serve multiple science topics and themes, and maximize science return.
RSN-L-2	Locate infrastructure at all major plate boundaries on the Juan de Fuca Plate to support real-time observations of phenomena associated with gas hydrate formation, a transform plate boundary, a spreading ridge and active submarine volcanoes, sub-seafloor biogeochemistry and hydrothermal processes, a subduction zone, and mid-plate location suitable for measurements of stress propagation, crustal scale hydrogeology, and intraplate deformation.
RSN-L-3	Locate infrastructure to support surface to seafloor measurements of physical, chemical and biological processes associated with the larger ocean circulation, mixed layers at the surface and bottom, mixing associated with topography and internal waves, and the eastern boundary current systems; the infrastructure shall form a spatial array from which gradients and interior and boundary conditions can be estimated.
RSN-L-4	Nodes located to form a spatial array linking the OOI coastal (Endurance Array), North American (EarthScope), to global scale (Station Papa, other OOI global sites, MARS, ALOHA, NEPTUNE Canada, etc.).
RSN-L-5	Primary nodes to be placed to ensure safest possible location for backbone infrastructure to reach secondary nodes that maximize science return.
RSN-L-6	Node locations to be consistent with prioritizations and justifications established during the Conceptual Network Design process.
RSN-L-7	Locate Node N1 to provide access to Hydrate Ridge.
RSN-L-8	Locate Node N2 to provide access to the Blanco Transform Fault.
RSN-L-9	Locate Node N3 to provide access to Axial Volcano.

ID	Description
RSN-L-10	Locate Node N4 to provide access to the Cascadia Subduction Zone.
RSN-L-11	Locate Node N5 to provide access to the mid-plate region of the Juan de Fuca Plate.

4.2 RSN General Science Requirements

System-wide and RSN-specific general requirements are provided in the OOI System Requirements Document (SRD). In addition to RSN general requirements listed in the SRD, the following general science requirements also apply to the RSN:

ID	Description
RSN-SR-1	The RSN primary nodes will have the capability to support power, data transmission, and timing requirements for designated core sensors (see core sensor tables in the Preliminary Network Design document) and for future sensors and instrumentation.
RSN-SR-2	The system must accommodate continuous data transmission from sensors and 2-way, real-time communication for sensor control.
RSN-SR-3	System capability for bi-directional communication and dynamic command/control among sensors, users, and operators.
RSN-SR-4	The system must be able to dynamically allocate limited resources (e.g., power) taking into account science policy and priorities.
RSN-SR-5	The operational status of the RSN shall be logged and publicly available.
RSN-SR-6	Data and associated metadata will be available consistent with the OOI Network Data Policy.
RSN-SR-7	Minimize latency throughout the network to enable robotic control and timely response.
RSN-SR-8	Precise and accurate time shall be served to support all sensors including wave-based sensing methods (e.g., seismic, acoustic, and electromagnetic) as well as for extending communications and navigation infrastructure.
RSN-SR-9	RSN infrastructure noise levels (acoustic, electric, and magnetic) shall be fully characterized, documented, and publicly available.
RSN-SR-10	Sensors to be deployed so as to minimize interference among sensors.
RSN-SR-11	Calibration of RSN core sensors will be maintained with explicit documentation on procedure, schedule, and evaluation.
RSN-SR-12	Sensors will be serviced or replaced on schedules so that data gaps are minimized.
RSN-SR-13	Sensors and assemblies, and less reliable infrastructure (e.g., mechanical devices) will be constructed and installed so as to minimize interference with the system or other sensors during deployment, servicing, and replacement.
RSN-SR-14	Capability to disconnect and isolate instruments, sensors, and extension interfaces from power, communications, and time distribution systems.
RSN-SR-15	Geotechnical properties of the sediments at each RSN location shall be publically available.
RSN-SR-16	The RSN will have the ability to accommodate expansion of the network infrastructure (e.g., additional science nodes, junction boxes, extension cables, water column moorings, mobile platforms) over its operational life.

ID	Description
RSN-SR-17	The RSN will have the ability to accommodate additions to the sensor suite at any node location over the operational life.
RSN-SR-18	The RSN must operate to allocate power appropriate to instrumentation and sensor requirements, and minimize downtime and impact to the network caused by sensor or infrastructure failure.
RSN-SR-19	Schedules for planned maintenance that affects user instruments or data streams shall be available to instruments and users in a timely fashion.
RSN-SR-20	The projected duration of downtime during maintenance operations shall be available to instruments and users in a timely fashion.
RSN-SR-21	The RSN will manage the acoustic and electromagnetic spectrum of the infrastructure and sensors with respect to potential interferences, with guidance from the advisory structure.

4.3 RSN Measurement Objectives

ID	Description
RSN-MO-1	Capability to detect and measure phenomena such as: volcanic tremor, seismic events, slow tremor, strong motion, pressure changes, and tidal perturbations.
RSN-MO-2	Measure temporal and spatial scales of seismic activity and impacts to crustal hydrology; collect observations to understand the nature and causes of intraplate deformation; measure temporal and spatial scales of sub-seafloor hydrology and pressure transients, anisotropy, velocity and attenuation.
RSN-MO-3	Measure the spatial and temporal variability of temperature, chemistry, hydrothermal and pore fluid flow in subsurface, black smoker, cold seep, and plume environments.
RSN-MO-4	Provide observations of gas hydrate formation/dissolution, bubble formation, compaction, compression, tidal loading, thermal perturbations, lithification, carbonate formation, and exchange.
RSN-MO-5	Provide capability to support visual observations of macrofaunal community distribution in seep and vent environments.
RSN-MO-6	Provide for future capability to support observations of the composition and concentration of microbial material in subsurface, vent, pore fluid, seep, and plume environments.
RSN-MO-7	Provide the regional seismic measurements that complement on-shore seismic arrays as well as on a larger scale the global seismic network.
RSN-MO-8	Provide measurements of turbulent mixing and exchange of heat, gases, and particulate and dissolved materials from sea surface to seafloor.
RSN-MO-9	Measure turbulent mixing at the water-seafloor boundary in areas of rough topography and up through the water column.
RSN-MO-10	Time series observations of structure and dynamics of physical and biological properties in the mixed layer and upper ocean.
RSN-MO-11	Observe the meso- and larger-scale structure and dynamics in the RSN area, bridging spatial and temporal scales between coastal and global scales for the science themes of Climate Variability and Carbon Cycling, and Ocean Circulation, Mixing, and Ecosystems.
RSN-MO-12	Observe nekton (i.e., fish and marine mammals) and measure abundance, species classification, and biomass flux.

ID	Description
RSN-MO-13	Time series observations of surface to near seafloor distribution and variability of standard hydrographic properties, currents, mixing, and biogeochemical parameters such as carbon, other particulate and dissolved materials, optical properties, estimated phytoplankton biomass, and primary production.
RSN-MO-14	Observations of bottom boundary layer dynamics, currents, dissolved properties, community respiration, suspended particulate characteristics.

4.4 RSN Instrument and Sampling Requirements

ID	Description	Reference
RSN-SR-22	Core sensors to be located appropriately to monitor local and regional seismicity, harmonic tremor, inflation/deflation at spreading centers, tidal pressure, differential pressure, sub-seafloor pressure, and impacts of local currents and ocean temperature on seismic signals.	RSN-MO-1, 2, 4
RSN-SR-23	Data acquisition must be low noise, high bandwidth, and have an accurate time base.	RSN-MO-1, 2,3,4,5,6,7
RSN-SR-24	The system must accommodate observations on temporal scales of milliseconds to years, up to decades.	RSN-MO-1, 2,3,4,5,6,7
RSN-SR-25	Sensor deployment must be at sites of active venting and hydrate formation and seepage.	RSN-MO-2, 3,4,5,6
RSN-SR-26	Water column profiling capability for temperature, salinity, pressure, currents, dissolved gases at N1 and N3; capability to support full water column sampling at all primary nodes.	RSN-MO-3, 4, 6
RSN-SR-27	Capability to support downhole observations.	RSN-MO-1, 2,4
RSN-SR-28	To obtain a plate scale distribution of seismometers, broadband seismometers must be placed at all major plate boundaries: subduction zone, transform fault, spreading center.	RSN-MO-1, 2, 7
RSN-SR-29	The system will provide at least millisecond timing for broadband sensors.	RSN-MO-1, 2, 7
RSN-SR-30	The system will provide timing of 0.1 millisecond to local seismic arrays.	RSN-MO-1, 2, 7
RSN-SR-31	Current meters to be placed adjacent to broadband sensors to evaluate possible noise resulting from current flow.	RSN-MO-1, 2, 3, 4
RSN-SR-32	Bottom pressure sensors shall be deployed adjacent to the broadband sensors to allow impacts of tidal forcing to be determined on the seismic record.	RSN-MO-1, 2, 7
RSN-SR-33	The RSN will have the capability to accommodate mobile platforms (AUVs, gliders, floats).	RSN-MO-3, 4, 6, 10, 11, 13
RSN-SR-34	Water column moorings at primary nodes (initially at N1 and N3) supporting fixed instruments and instrumented profilers with capability to provide real-time data streams from core sensors (see core sensor tables in the Preliminary Network Design document) from sea surface to near-seafloor.	RSN-MO-8, 9,10,11,12, 13,14
RSN-SR-35	Adjustable sampling intervals over vertical resolutions of centimeter to tens of meters.	RSN-MO-8, 9,10,11,13,14

ID	Description	Reference
RSN-SR-36	Ability to control profiling intervals and speeds over variable depths.	RSN-MO-8, 9,10,11,13,14
RSN-SR-37	Water column moorings must support a variety of sensors to measure water velocity and density, temperature and salinity, dissolved gases, biogeochemical and bio-optical properties, and nekton.	RSN-MO-8, 9,10,11,12, 13, 14
RSN-SR-38	Robust long-lived bottom instrument packages at all nodes to determine gravest vertical modes (i.e., barotropic velocity and 1st baroclinic mode) and gradients, ambient sound for multiple purposes, as well as local turbulence measurements.	RSN-MO-8, 9, 11, 13
RSN-SR-39	Specific locations of moorings and bottom packages at each node shall be based on specific science objectives and detailed analysis of local and surrounding bathymetry. Locations at each primary and secondary node will be reserved for a future surface mooring and an additional bottom package.	RSN-MO-8, 9, 10, 11,12, 13, 14
RSN-SR-40	Capability to acquire observations at frequencies of seconds to hours, for periods ranging from hours to decades.	RSN-MO-8, 9, 10, 11, 12, 13, 14
RSN-SR-41	Sensor packages and sampling with sufficient similarity to provide data continuity with the Coastal Endurance Array, Global node Station Papa, and other Global nodes.	RSN-MO-8, 9,10,11,13,14
RSN-SR-42	Provide the expansion capability necessary to support additional future sensors and platforms, with provision for the necessary mechanical mounting, electrical power, communications, and precise timing signals. This includes fixed sensors on the moorings and bottom packages, modified profilers/winches (more capacity and/or speed), and remotely controlled and autonomous vehicles.	RSN-MO-8, 9, 10, 11, 12, 13, 14

5. Cyberinfrastructure (CI) Goal

The OOI Cyberinfrastructure (CI) will be the backbone linking the broadly distributed, multi-scale network of observing assets (i.e., the physical infrastructure elements, sensors, and data) into an integrated coherent system of systems. The OOI CI will enable anyone—scientist, engineer, or educator—to have access to two-way interactivity, command and control, and resources (e.g., instruments, sensors, near-real-time data, historic data archives). The CI will permit mediation among different protocols, data streams, and derived data products. In accordance with the OOI data policy, calibrated and quality-controlled data will be made publicly available with minimal delay.

5.1 CI User Requirements

Refer to the OOI System Requirements Document (SRD) for system-wide and CI-specific general requirements. In addition to CI system requirements listed in the SRD, the following user requirements also apply to the CI:

ID	Description
CI-U-1	The CI shall support distributed resources and actors. A resource is any entity associated with an observatory that provides capability, and includes instruments, data, workflows, networks and more. An actor is an entity external to an observatory that interacts with it, and may be a scientist or a machine.
CI-U-2	CI source code developed by the CIIO shall be publicly available. The CI will be based on open software and standards to the maximum extent possible.
CI-U-3	The CI shall support real time, guaranteed delivery, pull mode, streaming and register to receive communication capabilities. Real time means minimum delay commensurate with latency on the channel. Guaranteed delivery means storage of a message until an acknowledgement receipt is received. Pull mode means storage of a message pending receipt of an explicit request for it. Streaming means an asynchronous, continuous format. Register to receive means that a given actor or resource must explicitly ask to receive a given stream, at which point it is sent directly.
CI-U-4	The CI shall facilitate the translation between specified message formats. The needs specificity to scope the requirement. OPeNDAP and NetCDF are obvious candidates. This requirement encompasses the provision of documented connectors to allow a user to provide transformer code to handle user-specified message formats.
CI-U-5	The CI shall provide for the sharing of resources subject to specified policies. The policies will be set by the OOI operators, and are constrained by resource providers and external entities such as the Navy.
CI-U-6	The resource catalog shall include information about physical samples. Physical samples means biological, chemical or geological samples retrieved from the seafloor or water column. This implicitly contains the requirement that metadata be associated with physical samples.
CI-U-7	The CI shall support links to non-OOI resource catalogs and metadata.
CI-U-8	The CI shall provide a standard set of tools to compose and execute processes.
CI-U-9	The CI shall facilitate the integration of multiple data streams or data sets into a single stream or set, including elimination of redundant entries.

ID	Description
CI-U-10	The CI shall facilitate offline operation. Users should be able to interact with the CI on a regular basis without the obligation to be always connected and online. This for instance includes batch data stream update and download for subscribed data resources. This also includes data caching and buffering while either a resource or the connected user/application is offline.
CI-U-11	The CI shall facilitate adding new resources and applications. New proposals and grants lead to new/updated hardware in existing observatories as well as to new observatories. The CI should be flexibly extensible with such resources.
CI-U-12	The CI shall provide resource-data connectors (analogous to APIs) to CI services. RSDs are required by external user applications that interact with CI services and provide user/organization specific extensions to common CI services and functionality.
CI-U-13	The CI shall provide synoptic time throughout the OOI observatories.
CI-U-14	The CI shall provide a catalog for all resources under CI governance.
CI-U-15	The CI shall provide the capability to discover all resources based on provided selection criteria. Selection criteria applies to resource descriptions, meta-data, parameters, location, observatory, etc. Discovery includes resources connected to the OOI observatories, as well as user provided electronic and data resources.
CI-U-16	The CI shall provide unique identification for resources, including data streams and data sets.
CI-U-17	The CI shall provide pointers from entries in the resource catalog to the resource subject.
CI-U-18	The CI shall provide pointers from entries in the resource catalog to their associated metdata.
CI-U-19	The CI shall bind metadata to all resources connected to an OOI observatory from inception to removal. This is a cradle-to-grave requirement to associate metadata with resources, but does not specify the metadata format or content.
CI-U-20	The CI shall incorporate information on citation and correspondence of resources into the bound resource metadata. Citation means statements about the use (including its outcome) of a given resource by another resource or actor. Correspondence means a statement of association between two or more resources.
CI-U-21	OOI-standard metadata shall include, but not be limited to, a complete description of behaviors, content, syntax, semantics, provenance, quality, context and lineage. Metadata standards will be externally imposed since the OOI is federally funded, but the OOI standard will probably need to go beyond them. Behaviors means the inherent characteristics of a resource (e.g., the range of sample rates that an instrument is capable of). Content means the characteristics of any externally-presented information provided by a resource (e.g., what an intrument measures, including calibration information). Syntax means a model for the resource content based on structure. Semantic means a model for the resource content based on meaning. Provenance means origin. Quality means information on the QA/QC status of a resource. Context means information about resource usage (e.g, the geographic location of an instrument). Lineage means information about the evolution of a resource (e.g, versioning of data due to QA/QC.

ID	Description
CI-U-22	The CI shall relate different data streams that are based on the same source data. It should be possible to identify different data streams that are based on the same instrument source data with possible but not necessary differences in sampling rate, quality of service parameters, meta-data annotations or post-processing algorithms applied.
CI-U-23	The CI shall offer data stream subscribers fallback options with similar data in case of original data stream unavailability. In case of temporary or permanent unavailability of the subscribed original data streams, the CI should offer data alternatives which are based on the same source data. If desired by the user, this fallback could be transparent.
CI-U-24	All data or data products associated with an OOI observatory shall be archivable. Whether or not to archive a given data set is a policy decision of the OOI operators that may be driven by economics.
CI-U-25	The CI shall facilitate the archival of versioned data. Versioning may occur due to changes in QA/QC state.
CI-U-26	The CI shall verify the accuracy of archived data throughout the OOI life cycle. This encompasses the requirement to verify that archived data accurately reflect the original, and that archived data are protected from loss due to media degradation or technology change.
CI-U-27	The CI shall ensure that archived data are up to date. This encompasses the requirement to make sure that the latest version of data is archived.
CI-U-28	The CI shall support notification of changes in resource state. State means behaviors or characteristics that persist (e.g., whether an instrument is on- or off-line, or changes in QA/QC state for archived data). Notification applies to subscribers of data streams.
CI-U-29	The CI shall facilitate publication of processed data streams as new data streams This includes data streams containing filtered, processed, aggregated data as well as model computation and simulation output. Such computed data streams should be treated similar to source data streams and have similar properties, including unique identification, catalog entry, meta-data etc.
CI-U-30	The CI shall provide subscription facilities to data streams. This includes data streams containing unprocessed source data as well as processed and aggregated data.
CI-U-31	The CI shall provide time zone conversion capabilities for subscribed data resources. Timed data in data streams should be automatically converted to users' preferred time zone if so desired.
CI-U-32	The CI shall provide resource access statistics The CI should keep track of resource access and usage and provide statistics based on this collected data to interested parties as data stream or on request.
CI-U-33	The CI shall provide data manipulation services including, but not necessarily limited to, re-projection, re-gridding, sub-setting, averaging, filtering, and scaling.
CI-U-34	The CI shall provide event triggered data services.
CI-U-35	The CI shall provide services to launch workflows in response to events.
CI-U-36	The CI shall facilitate the integration of multiple data streams or data sets into a single stream or set, including elimination of redundant entries.
CI-U-37	The CI shall provide web-based user interfaces. This should include a portal into the CI, and hence into the OOI observatories.

ID	Description
CI-U-38	The CI shall provide the capability to make OOI-standard metadata human readable.
CI-U-39	The CI shall facilitate the integration of user-friendly 4D data visualization tools.
CI-U-40	Web-based documentation for all components of the CI shall be available.
CI-U-41	A mechanism to incorporate user-suggested modifications to the CI shall be provided. The mechanism must include checks to ensure compatibility and consistency with observatory policies (e.g., security).
CI-U-42	The CI shall provide mechanisms to enforce user privacy policies. The policies will presumably be defined by the OOI contractors and NSF in consultation with representatives of the user community.
CI-U-43	The CI shall provide for the sharing of resources subject to specified policies. The policies will be set by the OOI operators, and are constrained by resource providers and external entities such as the Navy.
CI-U-44	The CI shall provide access to resources subject to use policy. The extent of access depends on explicit resource policies set by the OOI operators and resource provider. This particularly applies to accessing resources discovered in the resource catalog and affects
CI-U-45	The CI shall deliver messages with accuracy comparable to that of the Internet.