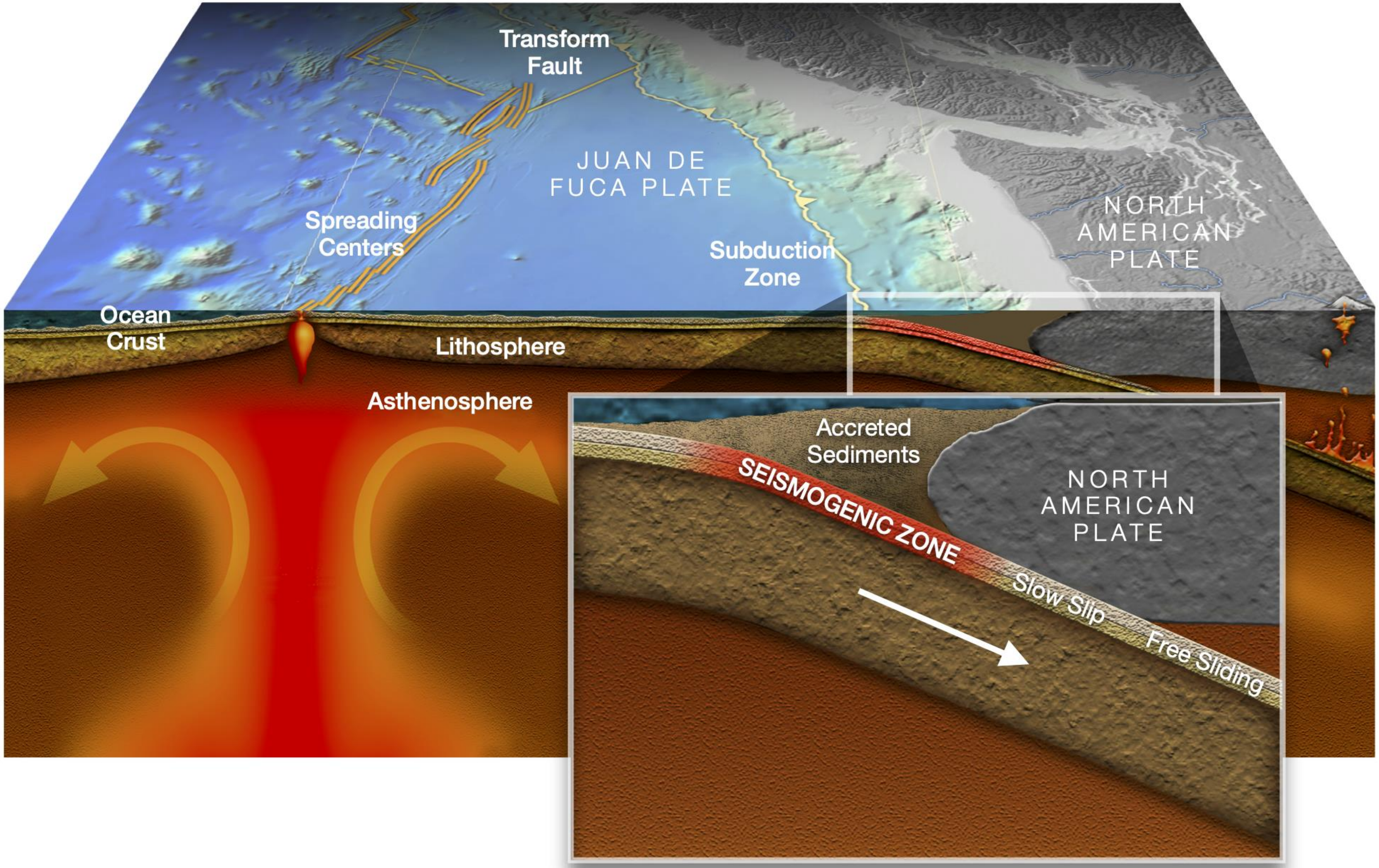
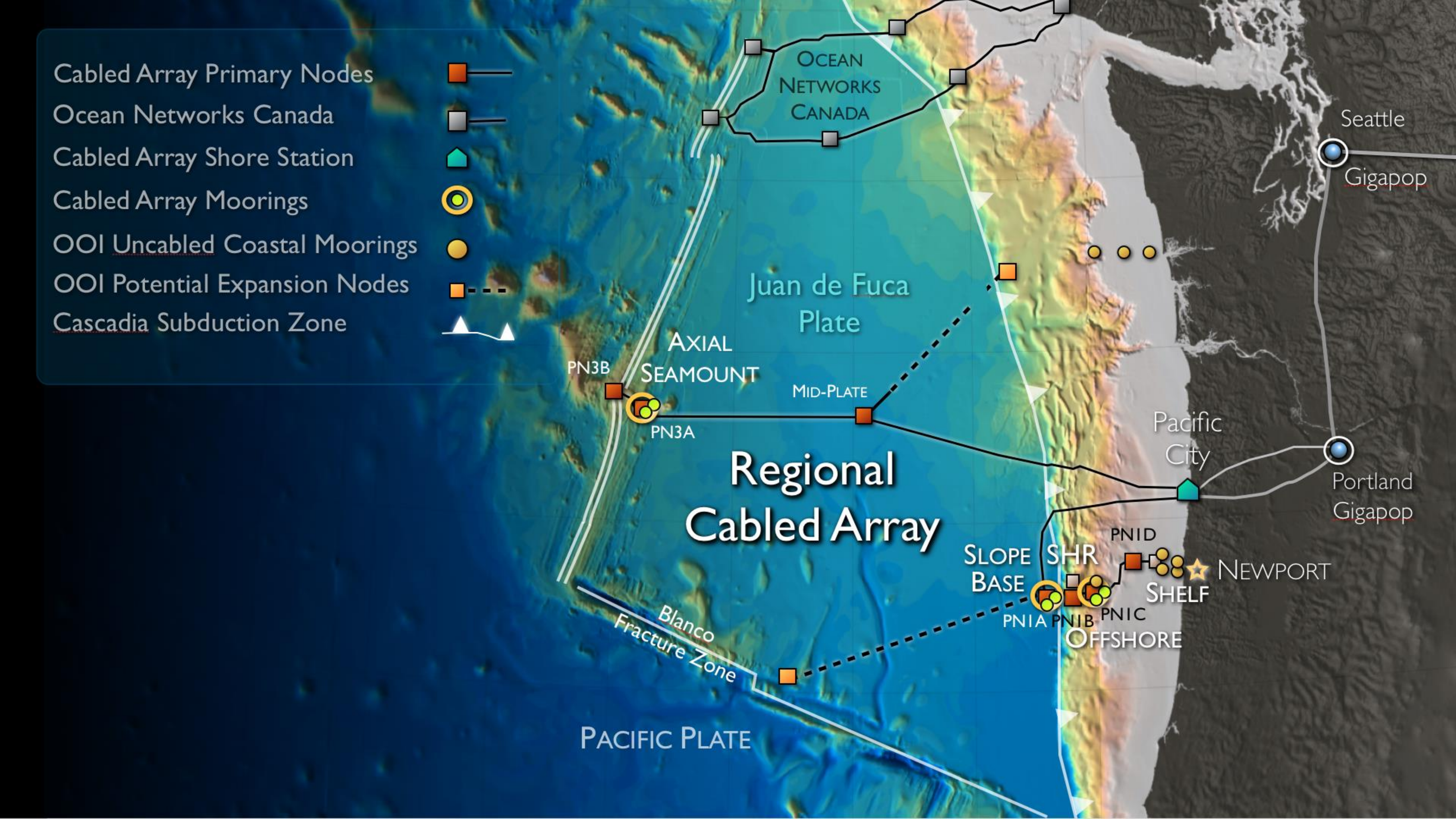
Enhancing the OOI Regional Cabled Array for subduction zone studies: The Cascadia Offshore Subduction Zone Observatory (COSZO)

William Wilcock

2024 MSROC Annual Community Meeting
Alexandria
Dec 8, 2024

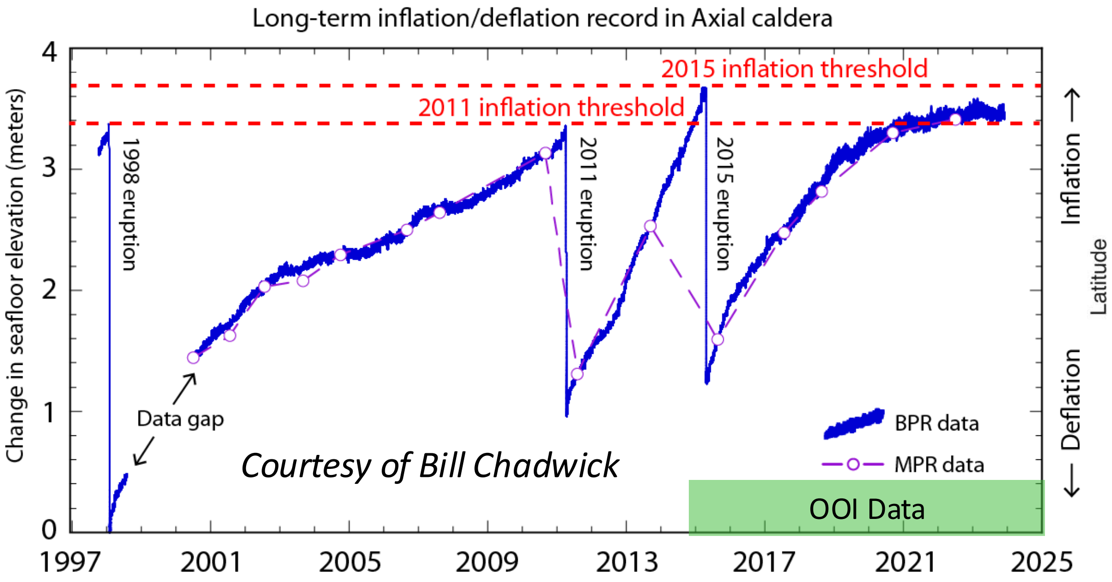

Transform
Fault
JUAN DE
FUCA PLATE
NORTH
AMERICAN
PLATE
Spreading
Centers
Subduction
Zone
Ocean
Crust
Lithosphere
Asthenosphere
Accreted
Sediments
SEISMOGENIC ZONE
NORTH
AMERICAN
PLATE
Slow Slip
Free Sliding

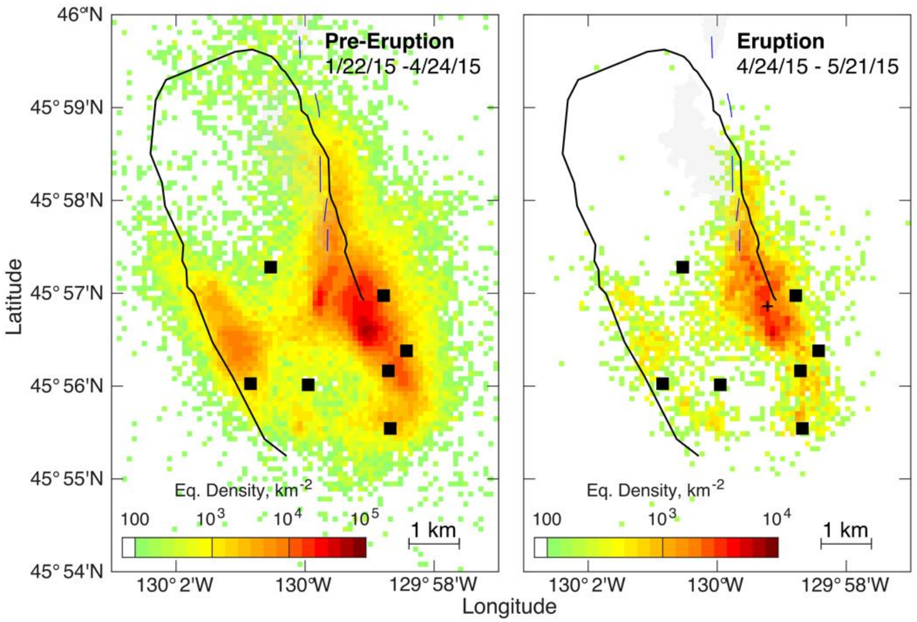


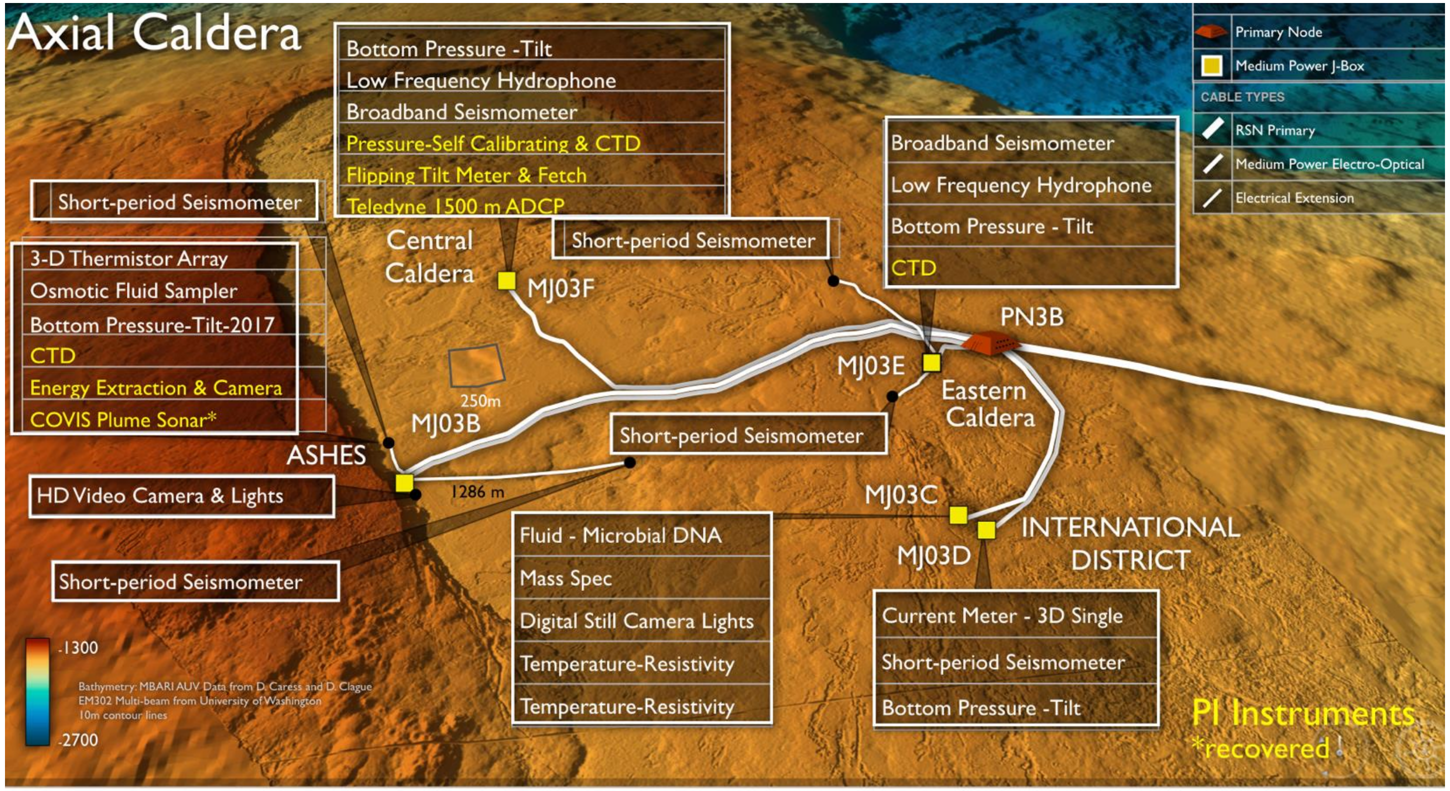
Cabled Array Primary Nodes
Ocean Networks Canada
Cabled Array Shore Station
Cabled Array Moorings
OOI Uncabled Coastal Moorings
OOI Potential Expansion Nodes
Cascadia Subduction Zone
Ocean Networks Canada
Seattle
Gigapop
Juan de Fuca Plate
Axial Seamount
PN3B
PN3A
Mid-Plate
Pacific City
Portland Gigapop
Regional Cabled Array
Slope Base
SHR
PN1D
Newport
Shelf
PN1A
PN1B
PN1C
Offshore
Blanco Fracture Zone
Pacific Plate

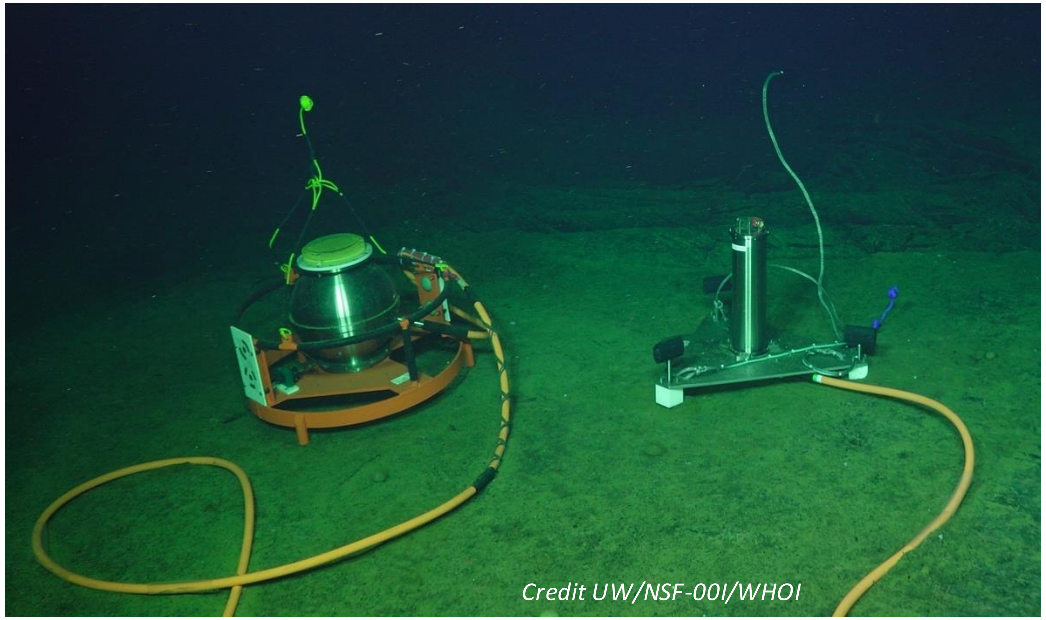
Axial Seamount

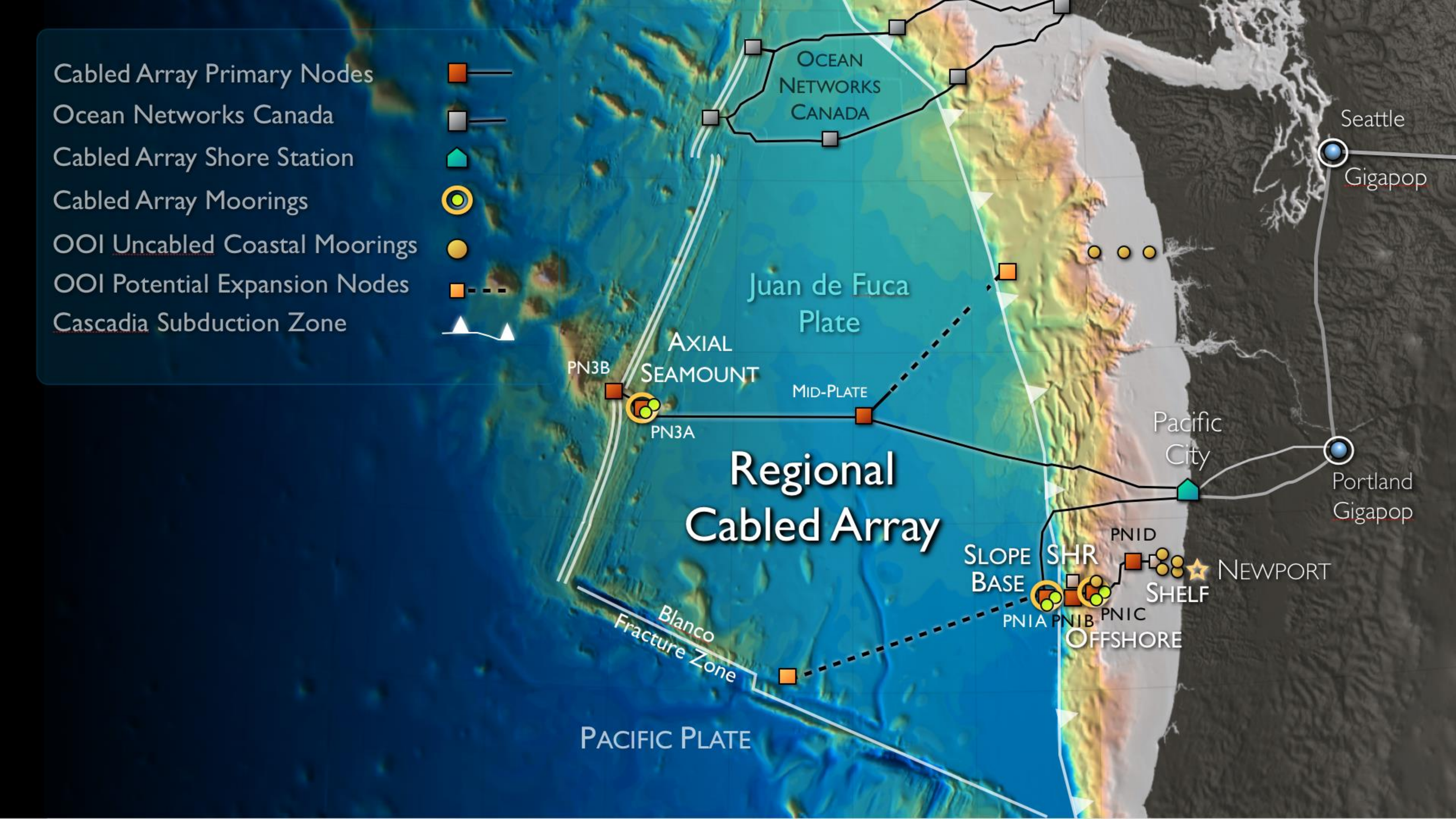
A critical mass of geophysical sensors











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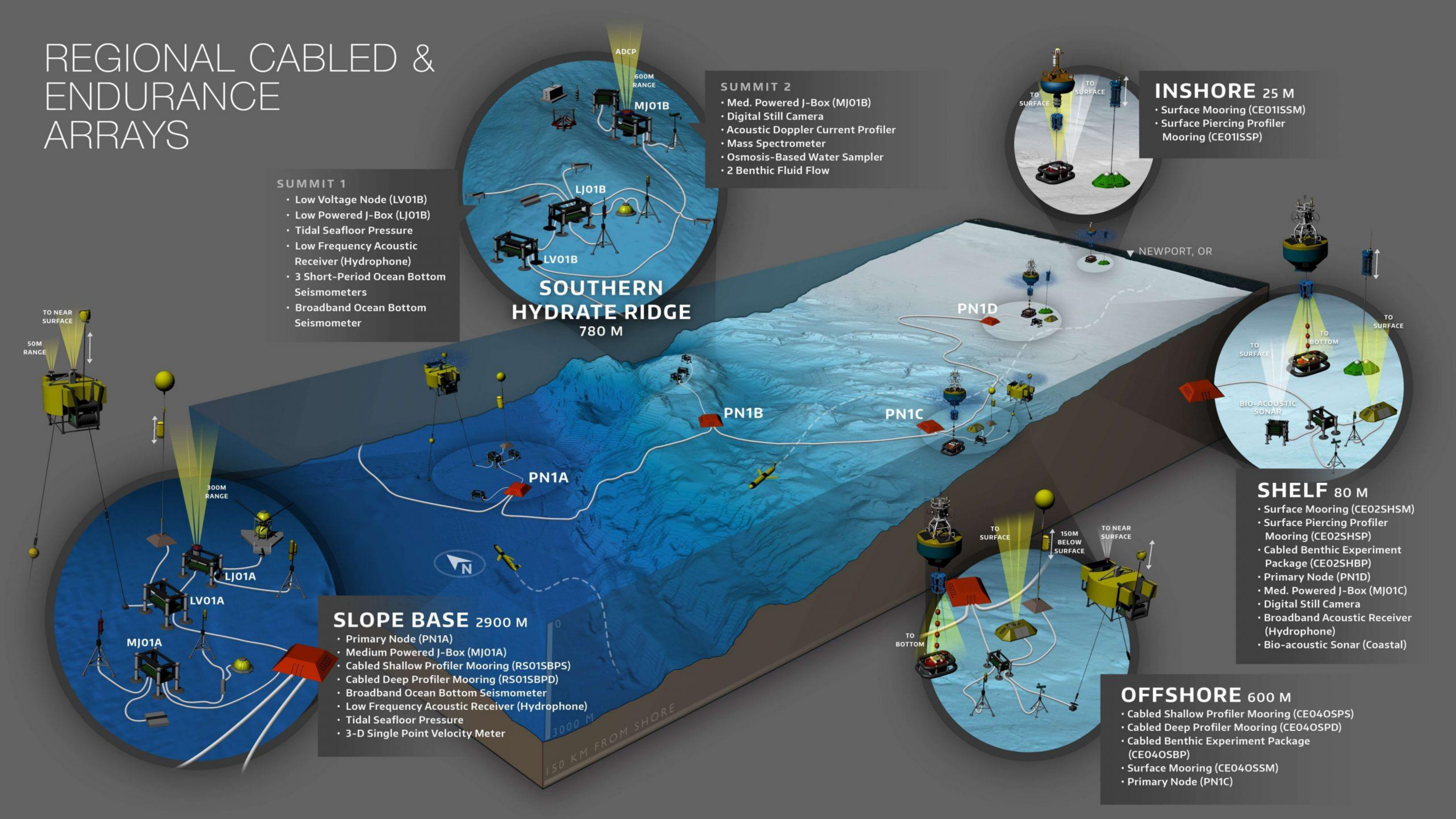
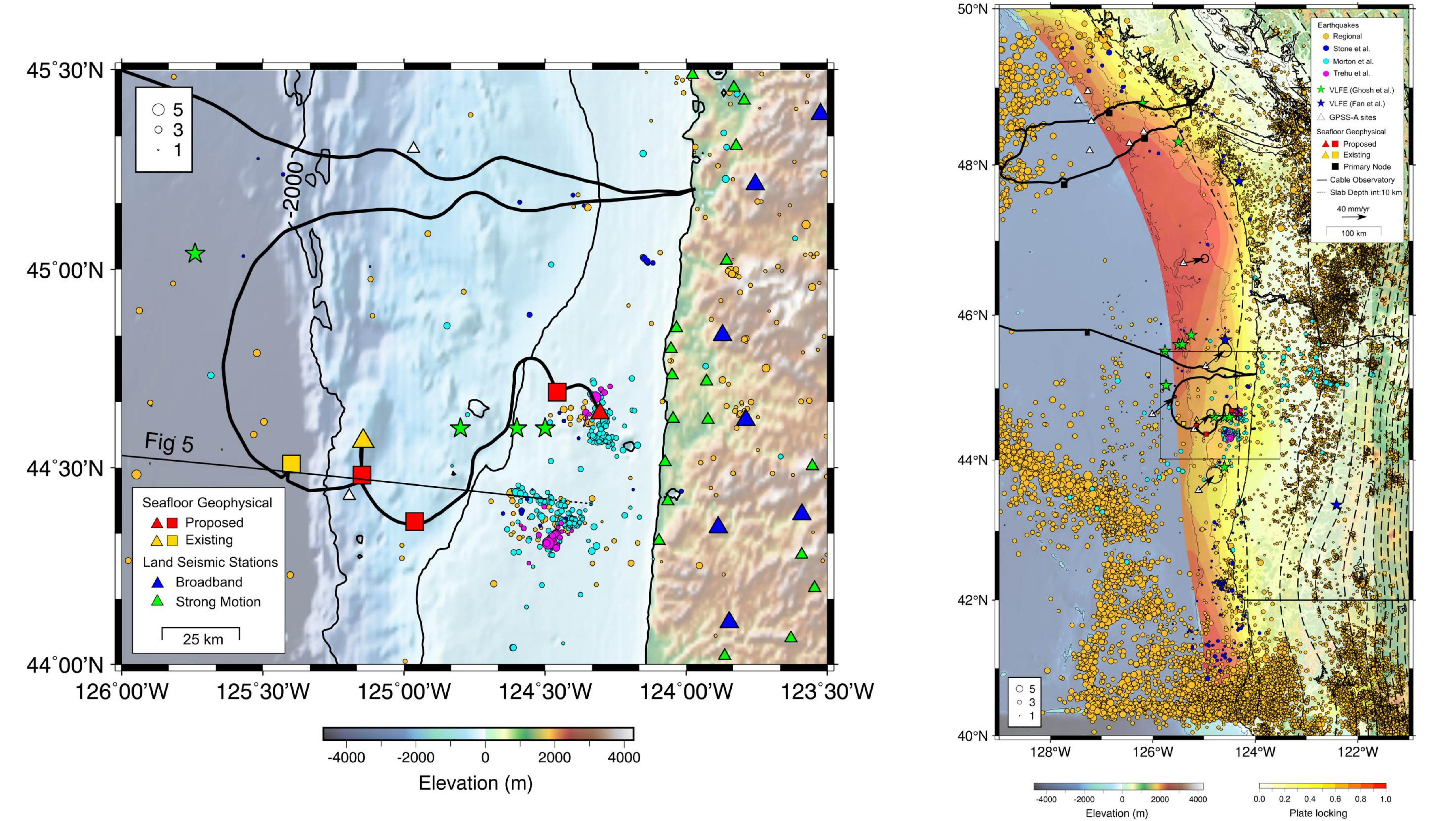
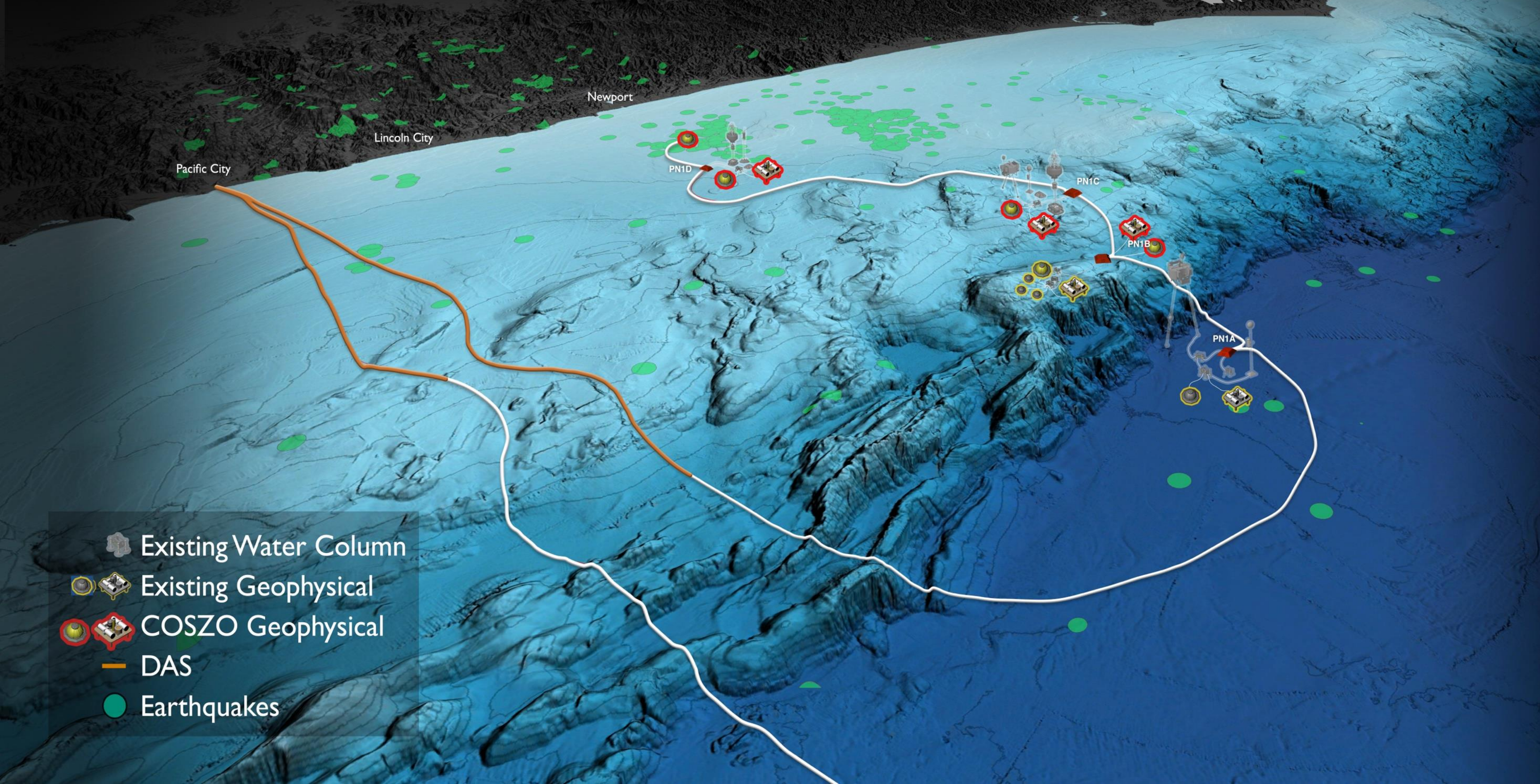


REGIONAL CABLED & ENDURANCE ARRAYS
ADCP
600M RANGE
MJ01B
SUMMIT 2
• Med. Powered J-Box (MJ01B)
• Digital Still Camera
• Acoustic Doppler Current Profiler
• Mass Spectrometer
• Osmosis-Based Water Sampler
• 2 Benthic Fluid Flow
SUMMIT 1
• Low Voltage Node (LV01B)
• Low Powered J-Box (LJ01B)
• Tidal Seafloor Pressure
• Low Frequency Acoustic Receiver (Hydrophone)
• 3 Short-Period Ocean Bottom Seismometers
• Broadband Ocean Bottom Seismometer
LJ01B
LV01B
SOUTHERN HYDRATE RIDGE
780 M
TO SURFACE
TO SURFACE
INSHORE 25 M
• Surface Mooring (CE01ISSM)
• Surface Piercing Profiler Mooring (CE01ISSP)
NEWPORT, OR
TO NEAR SURFACE
50M RANGE
PN1D
PN1B
PN1C
PN1A
TO SURFACE
TO BOTTOM
TO SURFACE
TO SURFACE
BIO-ACOUSTIC SONAR
300M RANGE
LJ01A
LV01A
MJ01A
N
SHELF 80 M
• Surface Mooring (CE02SHSM)
• Surface Piercing Profiler Mooring (CE02SHSP)
• Cabled Benthic Experiment Package (CE02SHBP)
• Primary Node (PN1D)
• Med. Powered J-Box (MJ01C)
• Digital Still Camera
• Broadband Acoustic Receiver (Hydrophone)
• Bio-acoustic Sonar (Coastal)
TO SURFACE
150M BELOW SURFACE
TO NEAR SURFACE
TO BOTTOM
SLOPE BASE 2900 M
• Primary Node (PN1A)
• Medium Powered J-Box (MJ01A)
• Cabled Shallow Profiler Mooring (RS01SBPS)
• Cabled Deep Profiler Mooring (RS01SBPD)
• Broadband Ocean Bottom Seismometer
• Low Frequency Acoustic Receiver (Hydrophone)
• Tidal Seafloor Pressure
• 3-D Single Point Velocity Meter
0
3000 M
150 KM FROM SHORE
OFFSHORE 600 M
• Cabled Shallow Profiler Mooring (CE04OSPS)
• Cabled Deep Profiler Mooring (CE04OSPD)
• Cabled Benthic Experiment Package (CE04OSBP)
• Surface Mooring (CE04OSSM)
• Primary Node (PN1C)


45°30'N
45°00'N
44°30'N
44°00'N
126°00'W
125°30'W
125°00'W
124°30'W
124°00'W
123°30'W
5
3
1
-2000
Fig 5
Seafloor Geophysical
Proposed
Existing
Land Seismic Stations
Broadband
Strong Motion
25 km
-4000
-2000
0
2000
4000
Elevation (m)
50°N
48°N
46°N
44°N
42°N
40°N
128°W
126°W
124°W
122°W
Earthquakes
Regional
Stone et al.
Morton et al.
Trehu et al.
VLFE (Ghosh et al.)
VLFE (Fan et al.)
GPSS-A sites
Seafloor Geophysical
Proposed
Existing
Primary Node
Cable Observatory
Slab Depth int:10 km
40 mm/yr
100 km
5
3
1
-4000
-2000
0
2000
4000
Elevation (m)
0.0
0.2
0.4
0.6
0.8
1.0
Plate locking

Cascade Offshore Subduction Zone Observatory (COSZO)



Science Questions

1. How does the locking of the Cascadia megathrust transition between the deformation front and the coastline off central Oregon?
2. Is there transient slip behavior – slow slip, tremor, and/or very low frequency earthquakes – offshore spanning the locked zone and its downdip transition? If so, might this be used to track the redistribution of stress on the megathrust, and possibly provide insight into precursory fault behavior?
3. How are the clusters of shallow earthquakes offshore linked to the megathrust?
4. What is the baseline deformation rate and fault slip behavior of the accretionary prism? This baseline information is critical for properly interpreting future transient deformation as precursory phenomena.

Science Requirements – 1 of 2

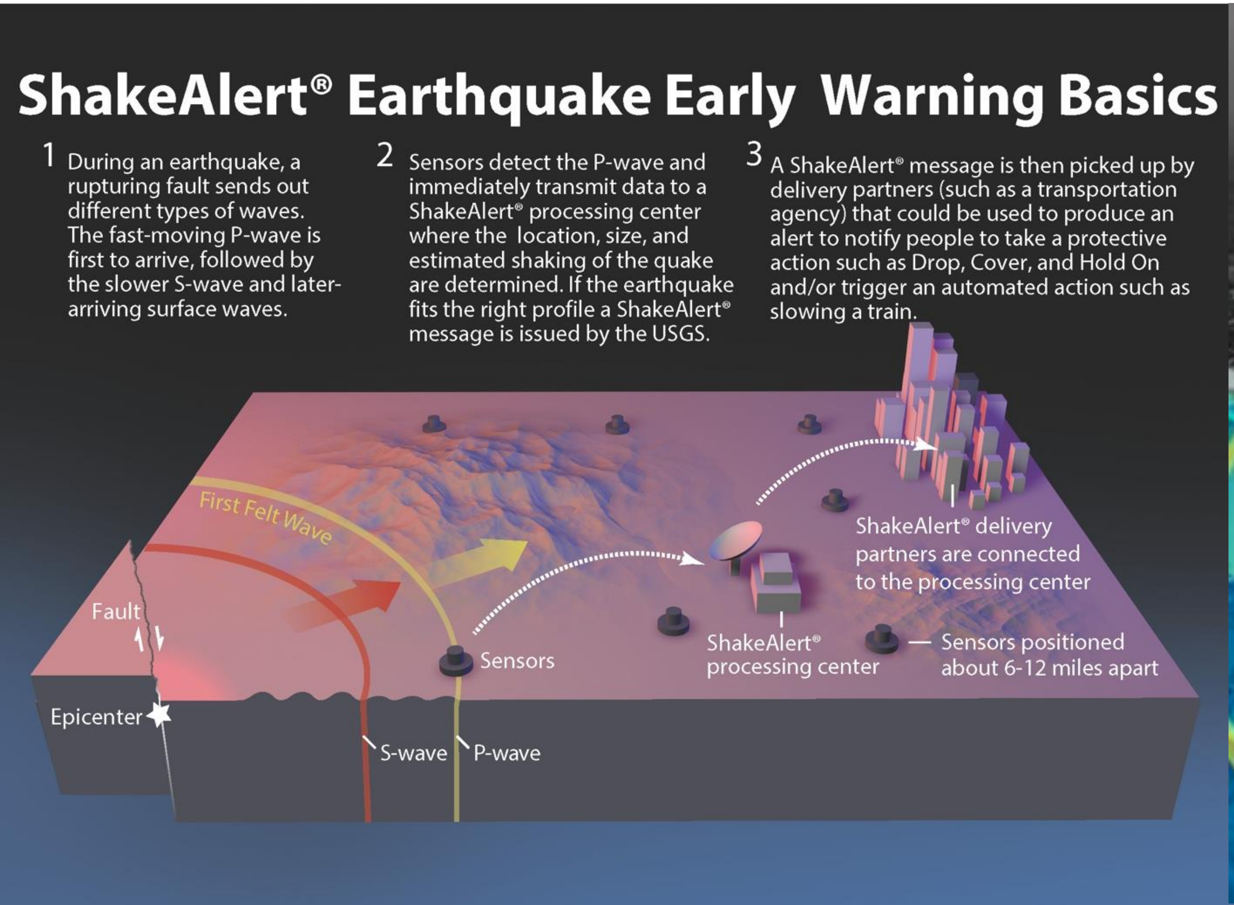
1. Collect high quality three-component broadband seismometer and strong motion acceleration time series at multiple locations across the subduction zone. These can be used to search for and localize shallow tremor signals and very low frequency earthquakes (Q. 1-2, Q. 4), characterize and accurately localize earthquakes of all magnitudes below the shelf (Q. 3), search for and localize very low frequency earthquakes (Q. 1, Q. 4), and measure temporal changes in the velocity structure of the accretionary prism (Q. 1-2, Q. 4).
2. Collect hydrophone and differential pressure gauge data that is collocated with the broadband seismometer to better distinguish between seismic signals such as tremor and acoustic arrivals such as T-phases (Q. 1-2, 4) and enable optimal corrections for tilt noise on vertical seismometer channels (Q. 2).
3. Collect high-resolution time series of calibrated pressure to measure secular vertical strain (Q. 1, Q. 4) and to detect slow slip events (Q. 2, Q. 4).

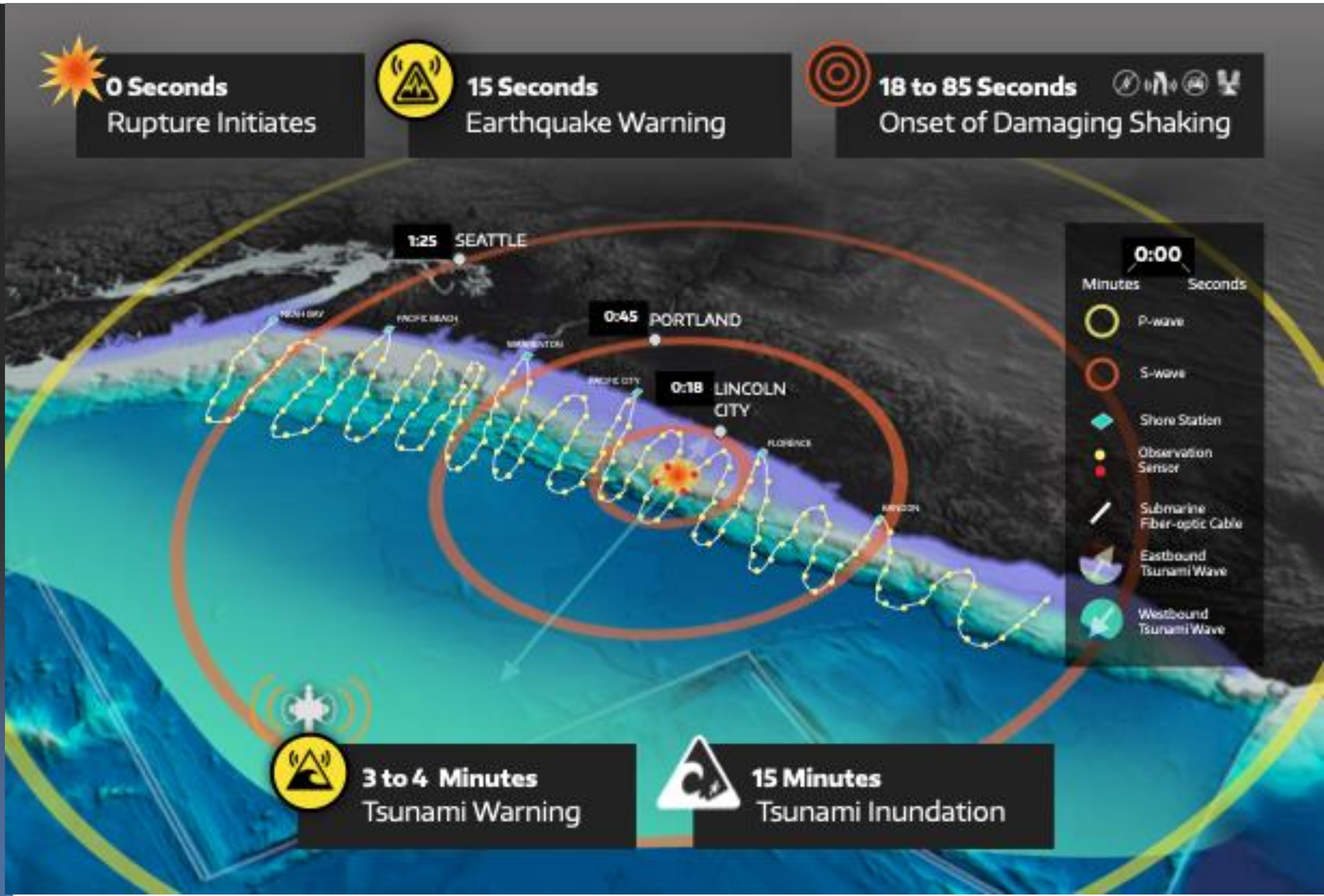
Science Requirements – 2 of 2

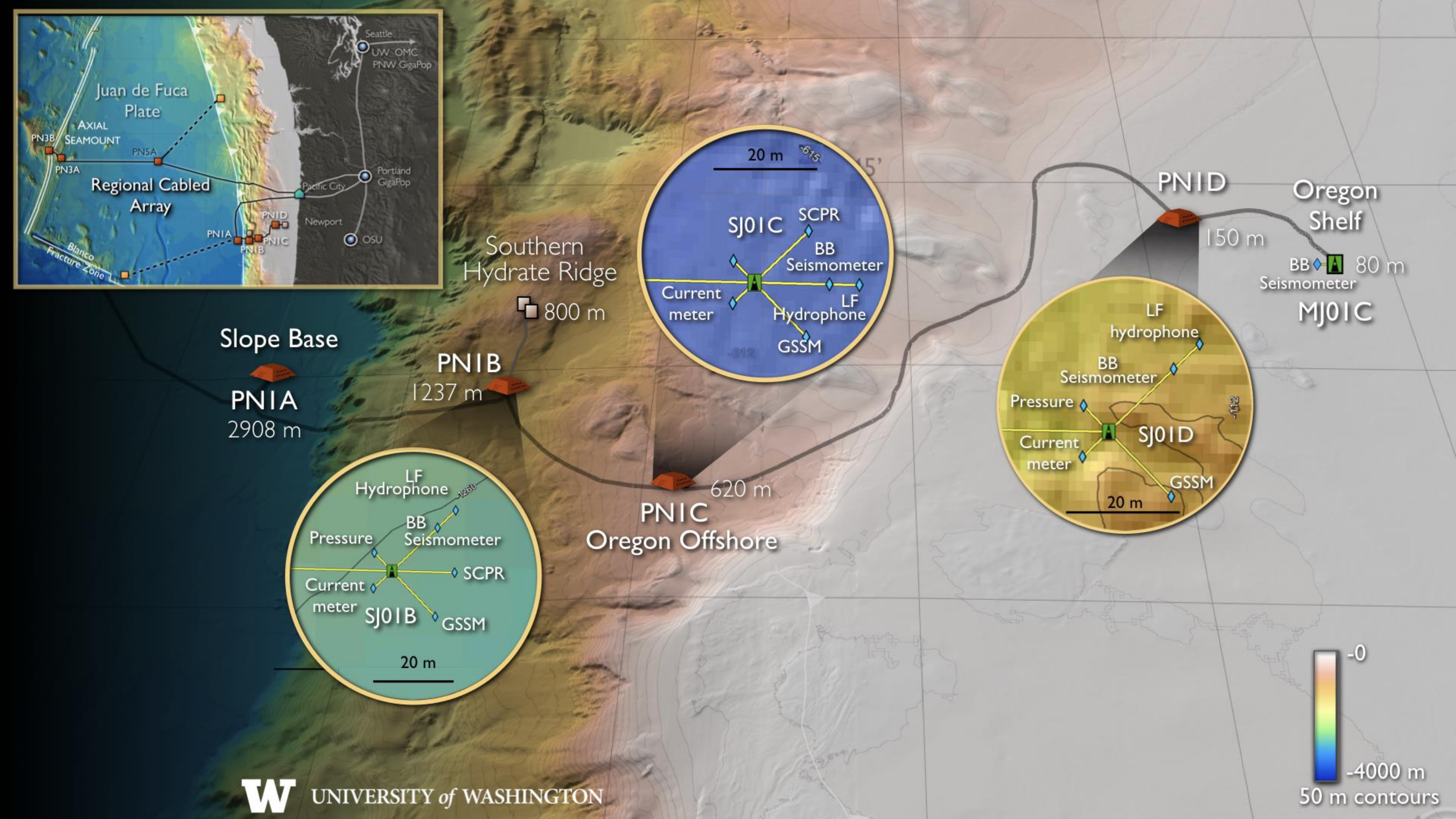
4. Collect high-resolution time series of uncalibrated pressure to search for and remove artifacts of pressure calibrations that might be confused with slow slip (Q. 2, Q. 4) and to support measurements of compliance that are sensitive to changes in seismic velocity structure (Q.1, Q. 4).
5. Make measurements of near bottom three-component ocean currents that can constrain oceanographic pressure gradients and thus contribute to pressure geodesy (Q. 2) and contribute to an understanding of seismic noise that might be confused with tremor (Q. 2).
6. Provide the flexibility to add additional Principal Investigator (PI) sensors, particularly those that are being developed for geodesy (Q. 1-2).
7. Ensure that all data and metadata are accessible to the scientific community in near real time (Q. 1-4)

Earthquake and Tsunami Early Warning Requirement

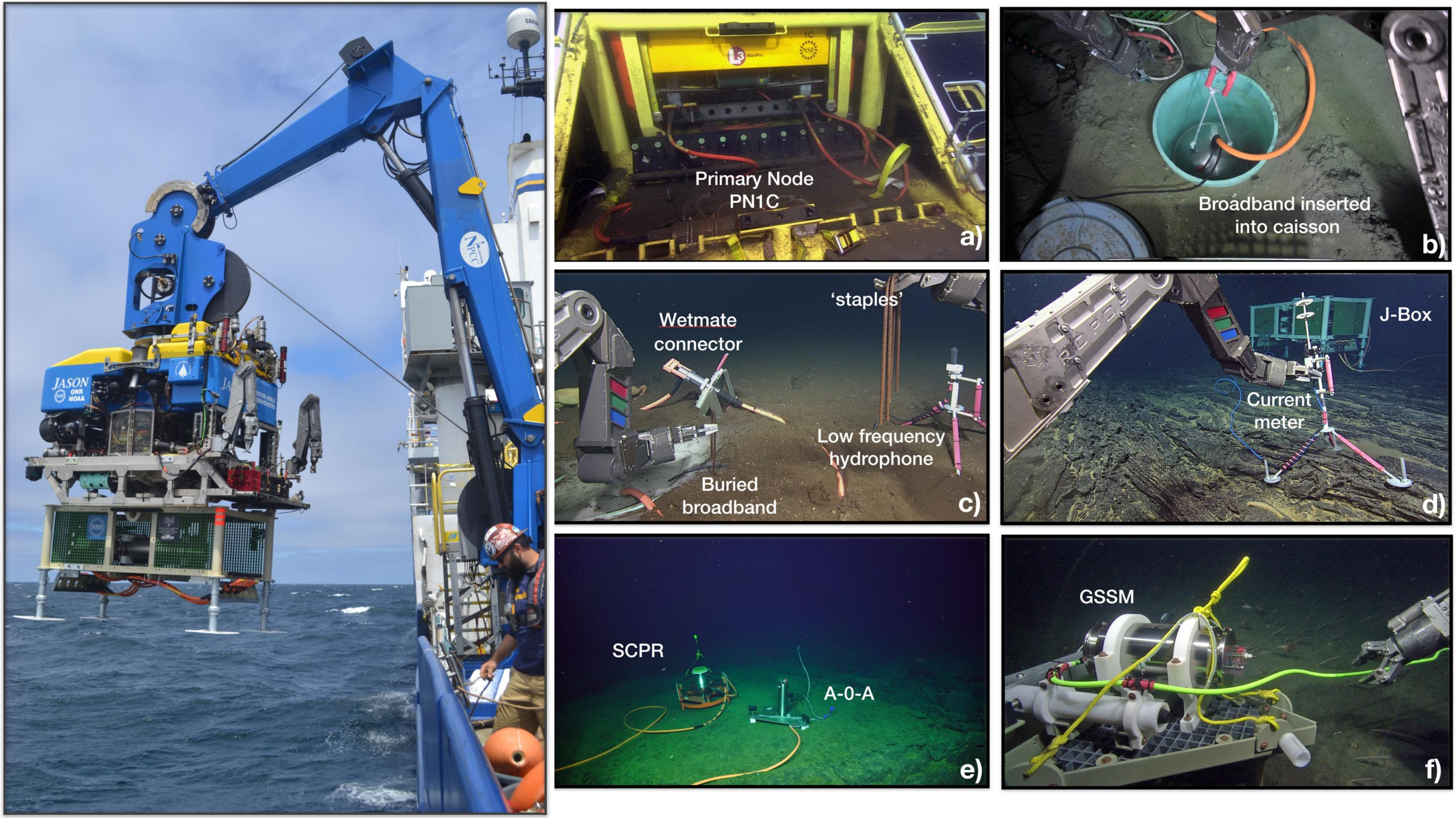
8. Deliver data to the shore station with a latency that meets the requirements of early warning.



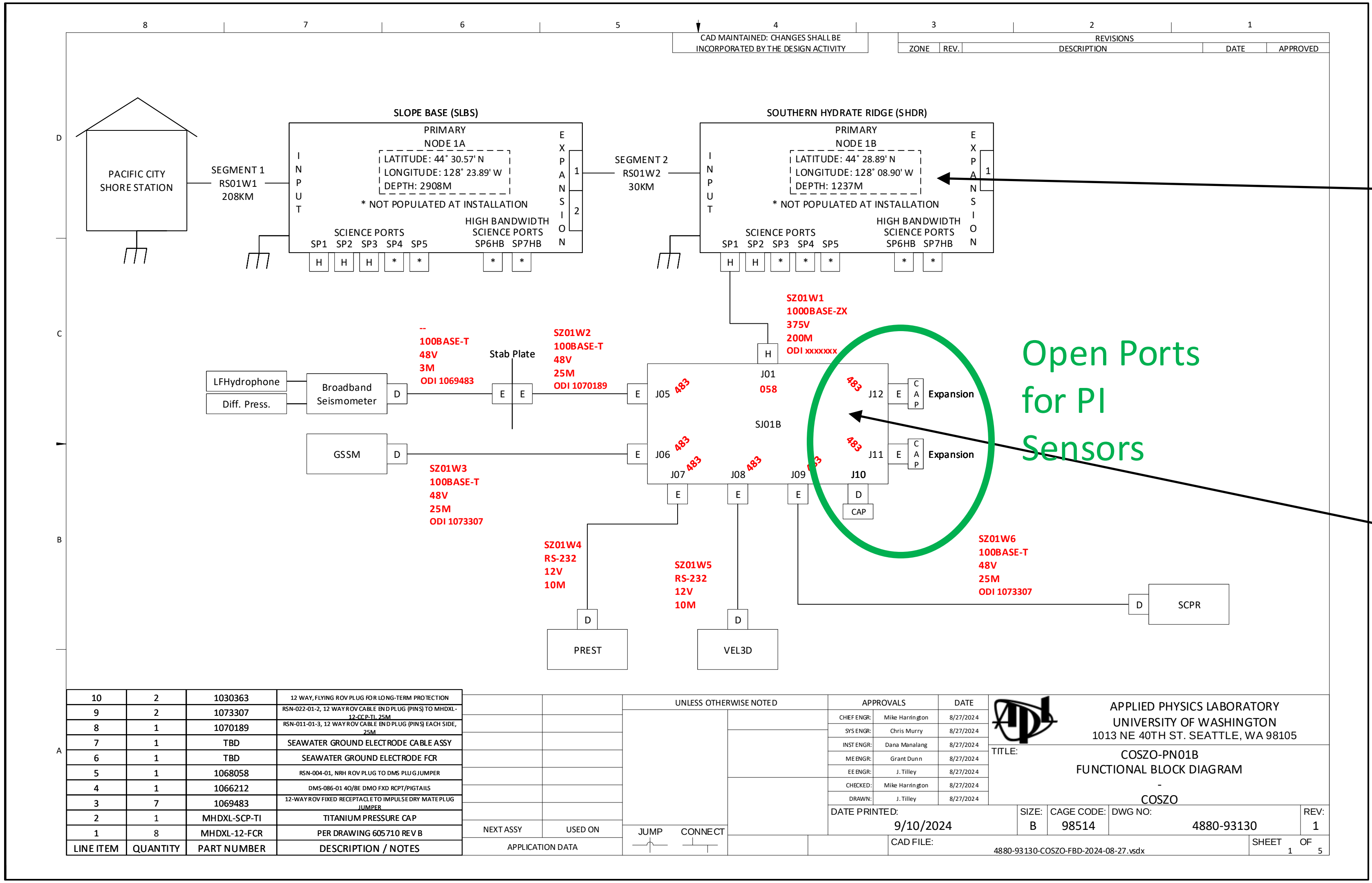




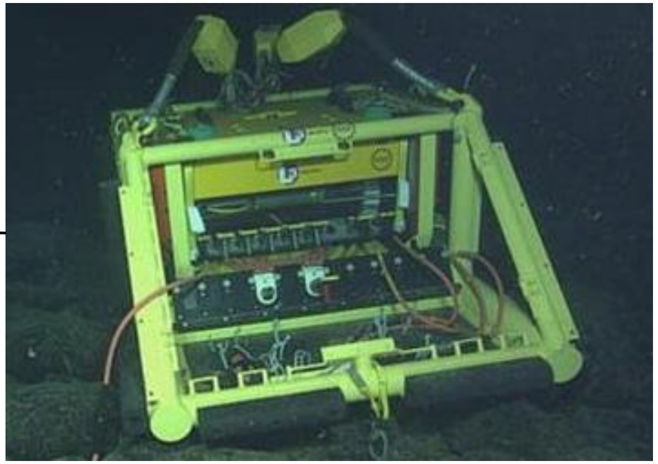
Seattle
UW OMC
PNW GigaPop
Juan de Fuca
Plate
Axial
Seamount
PN3B
PN3A
PN5A
Regional Cabled
Array
Pacific City
Portland
GigaPop
Newport
OSU
PN1D
PN1A
PN1B
PN1C
Blanco
Fracture Zone
Southern
Hydrate Ridge
800 m
Slope Base
PN1A
2908 m
PN1B
1237 m
20 m
SJ01C
SCPR
BB
Seismometer
Current
meter
LF
Hydrophone
GSSM
PN1C
Oregon Offshore
620 m
PN1D
150 m
Oregon
Shelf
BB
Seismometer
80 m
MJ01C
LF
hydrophone
BB
Seismometer
Pressure
Current
meter
SJ01D
GSSM
20 m
LF
Hydrophone
BB
Seismometer
Pressure
SCPR
Current
meter
SJ01B
GSSM
20 m
-0
-4000 m
50 m contours
UNIVERSITY of WASHINGTON

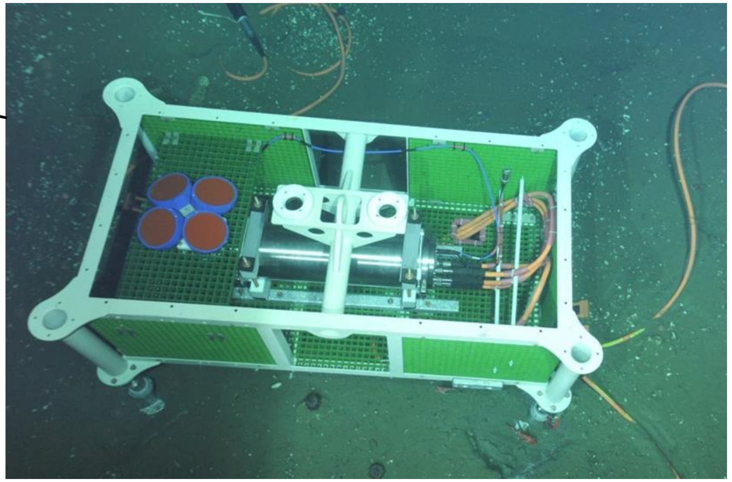

JASON
Primary Node
PN1C
a)
Broadband inserted
into caisson
b)
Wetmate
connector
'staples'
Low frequency
hydrophone
Buried
broadband
c)
J-Box
Current
meter
d)
SCPR
A-0-A
e)
GSSM
f)

Functional Block Diagram (PN1B)

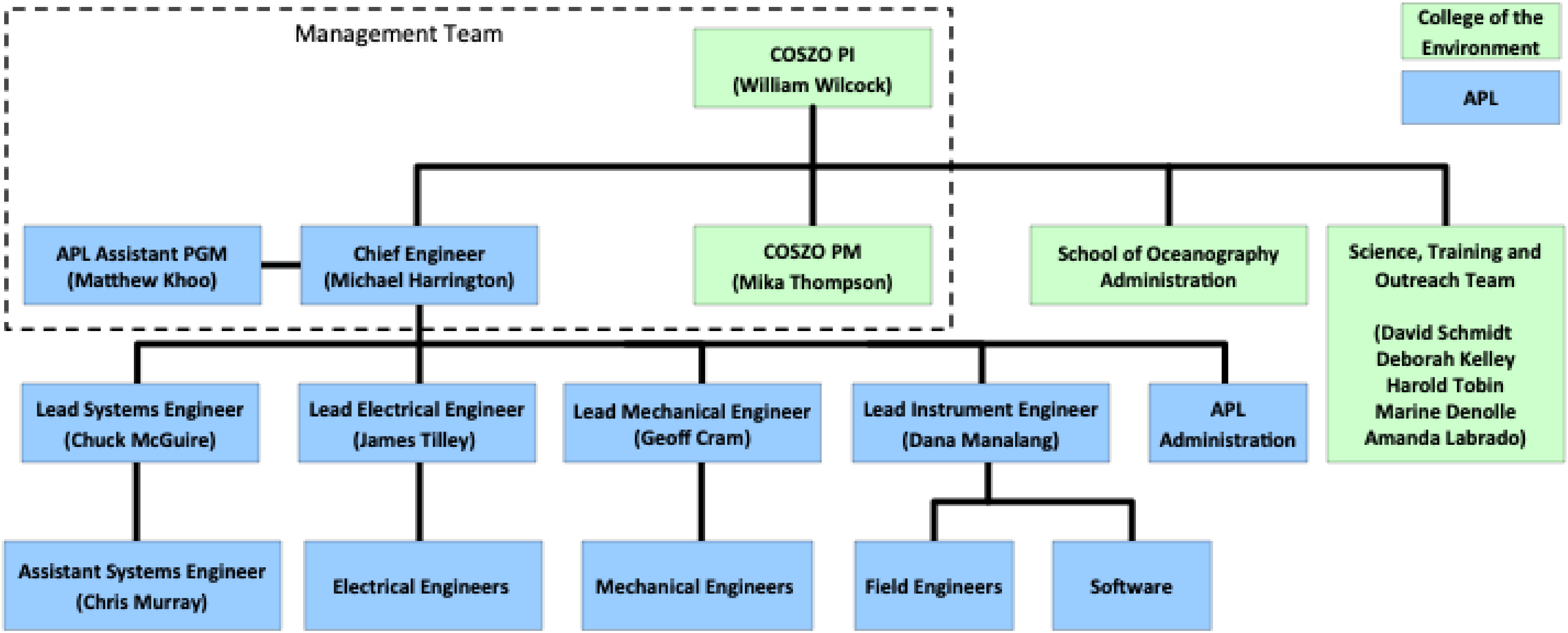


LINE ITEM	QUANTITY	PART NUMBER	DESCRIPTION / NOTES
10	2	1030363	12 WAY, FLYING ROV PLUG FOR LONG-TERM PROTECTION
9	2	1073307	RSN-022-01-2, 12 WAY ROV CABLE END PLUG (PINS) TO MHDXL-12-CCP-TI, 25M
8	1	1070189	RSN-011-01-3, 12 WAY ROV CABLE END PLUG (PINS) EACH SIDE, 25M
7	1	TBD	SEAWATER GROUND ELECTRODE CABLE ASSY
6	1	TBD	SEAWATER GROUND ELECTRODE FCR
5	1	1068058	RSN-004-01, NRH ROV PLUG TO DMS PLUG JUMPER
4	1	1066212	DMS-086-01 4O/8E DMO FXD RCPT/PIGTAILS
3	7	1069483	12-WAY ROV FIXED RECEPTACLE TO IMPULSE DRY MATE PLUG JUMPER
2	1	MHDXL-SCP-TI	TITANIUM PRESSURE CAP
1	8	MHDXL-12-FCR	PER DRAWING 605710 REV B

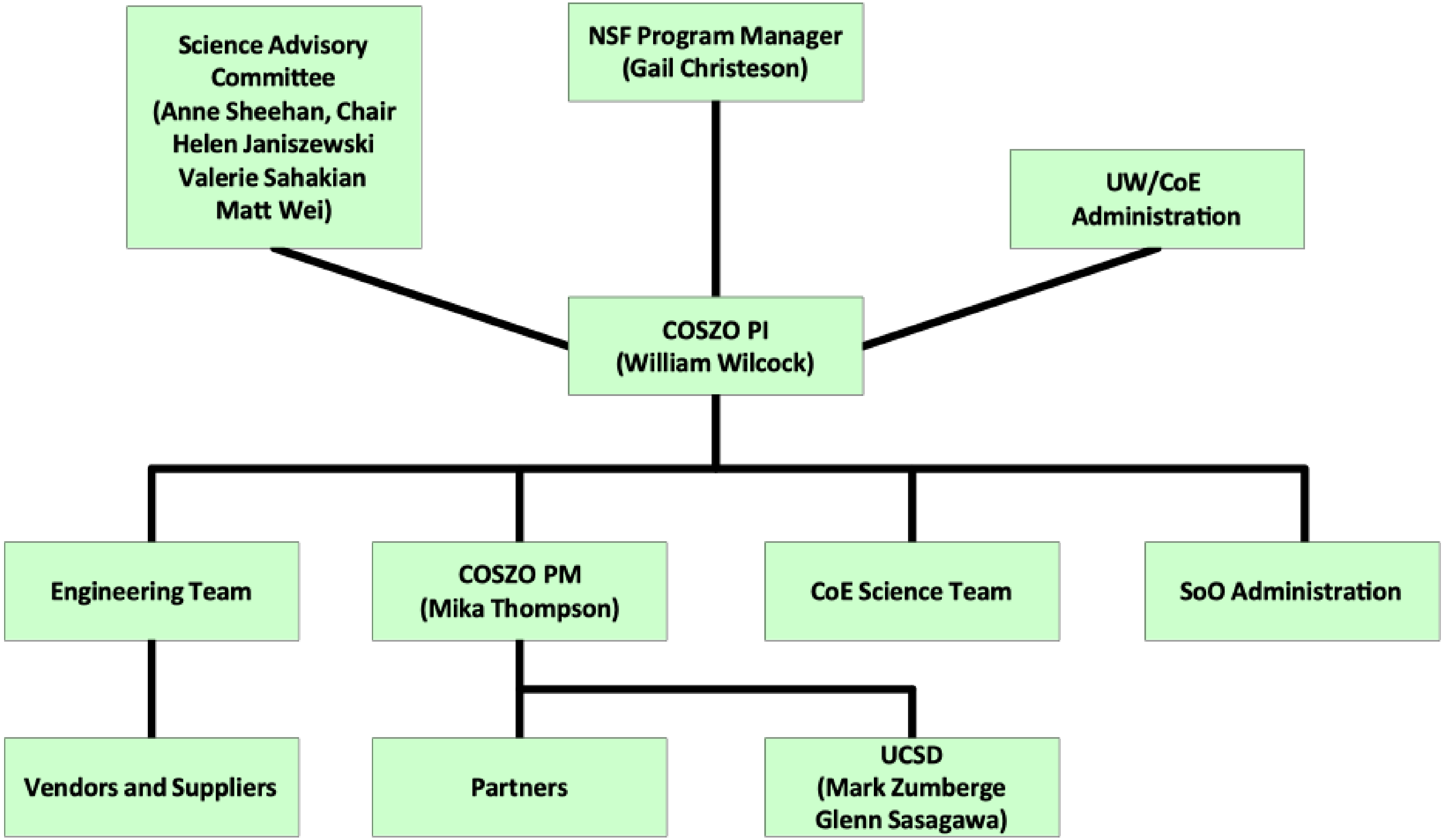




Internal Organization



External Organization



Science Advisory Committee

Anne Sheehan, Helen Janiszewski, Valerie Sahakian, Matt Wei (Chair)

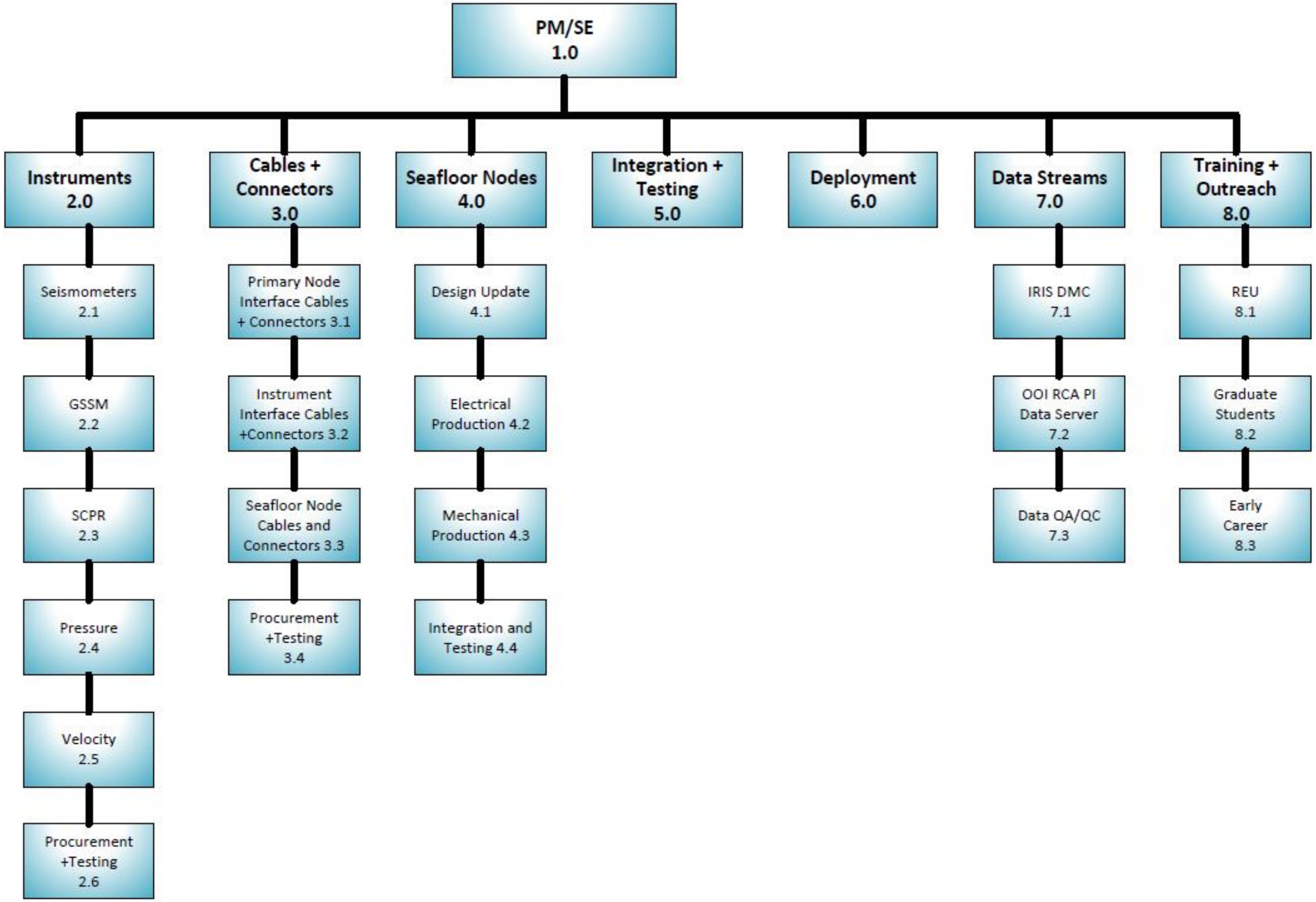
- Sensor specifications when there is a competitive RFP.
  - We enhanced the broadband seismometer to include a DPG
  - Pressure gauge to sample at 40 Hz
- Cost or schedule driven plans to descope the project.
- Management of delays in the installation.
- Data management and the development of derived data products.
- Assessments of data quality.
- An operations plan that meets the needs of the user community.
- Transitioning from construction to operations.
- Plans for the expenditure of unused contingency funds on either remedying deficiencies in the installed infrastructure or up-scoping to include additional seafloor infrastructure.

Project Timeline

- **Fall 2023** Award Received
- **Summer 2024** Seafloor Node Design Update Complete
- **Winter 2025** GSSM Build Complete
- **Winter 2025** Pressure & Velocity Sensors Received
- **Summer 2025** Seismometers + LF Hydrophones Received
- **Winter 2026** SCPR Build Complete
- **Winter 2026** Seafloor Node Production & Testing Complete
- **Spring 2026** Full Seafloor Systems Integration & Testing Complete
- **Summer 2026** Deployment
- **Spring 2027** Data Streams Quality Assessment Complete
- **Spring 2027** Early Career Workshop
- **Summer 2027** Commission
- **Fall 2027** Operations

GSSM – Geodetic and Seismic Sensor Module
SCPR – Self-calibrating Pressure Recorder

WBS (Work Breakdown Structure)



Instruments (WBS 2.0)

- **Seismometer, Strong Motion Acceleromter, Low Frequency Hydrophone & Differential Pressure Gauge (WBS 2.1)**
  - Trillium 360 Cabled Ocean Bottom Seismic Observatory - datasheet will soon be released.

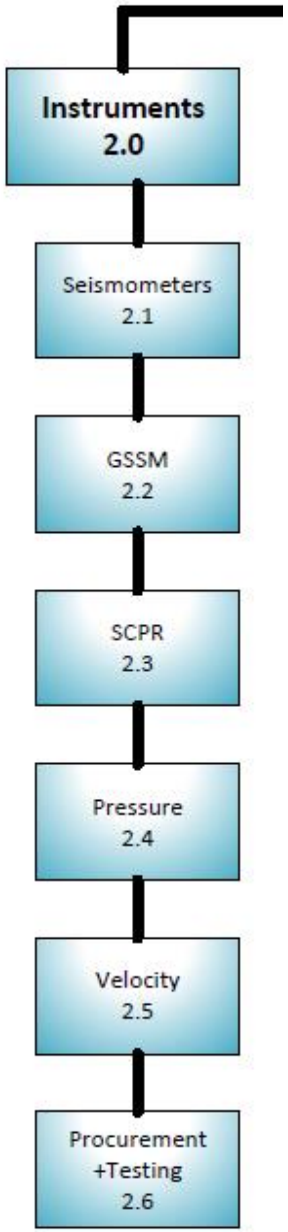
TRILLIUM 360
CABLED OCEAN BOTTOM SEISMIC OBSERVATORY

The **Trillium 360 Cabled Ocean Bottom Seismic Observatory** is an observatory-class cabled underwater solution that combines the proven technologies of the Trillium 360 Ocean Bottom broadband seismometer (OBS) with the Class A Titan accelerometer and the best-in-class Centaur datalogger to provide a single high-performance system optimized for tethered underwater seismic deployments. This Seismic Observatory enables new opportunities for streaming real-time data through an underwater, cabled network and an unparalleled range of noise floor and clip level.

Trillium 360
CABLED OCEAN BOTTOM SEISMIC OBSERVATORY

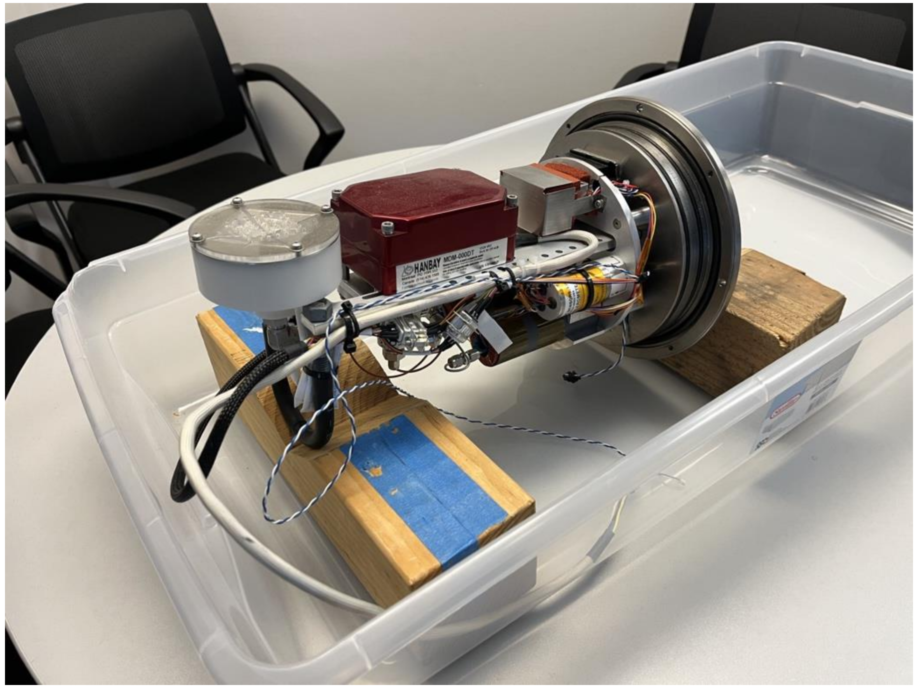
Key Benefits

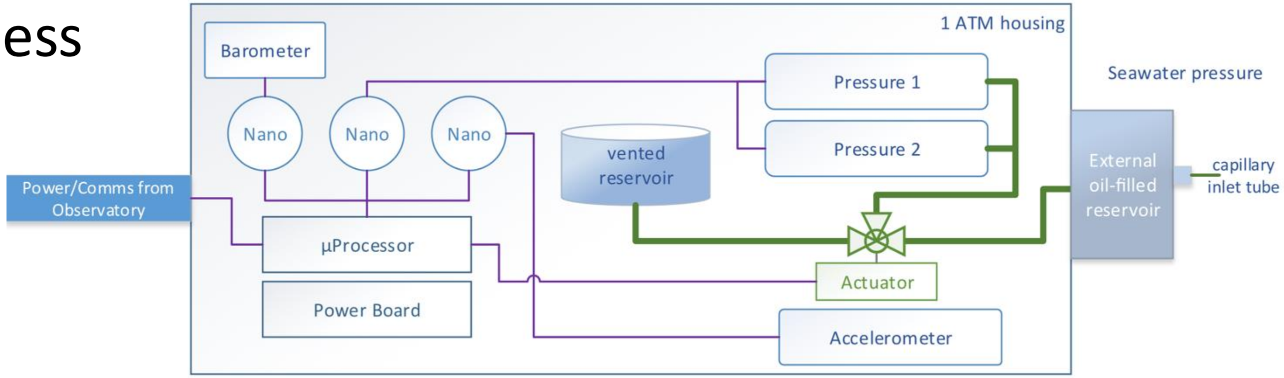
- Easy to use best-in-class datalogger
- Ability to acquire the highest quality of seismic data from a best-in-class broadband seismometer for high-value OBS networks

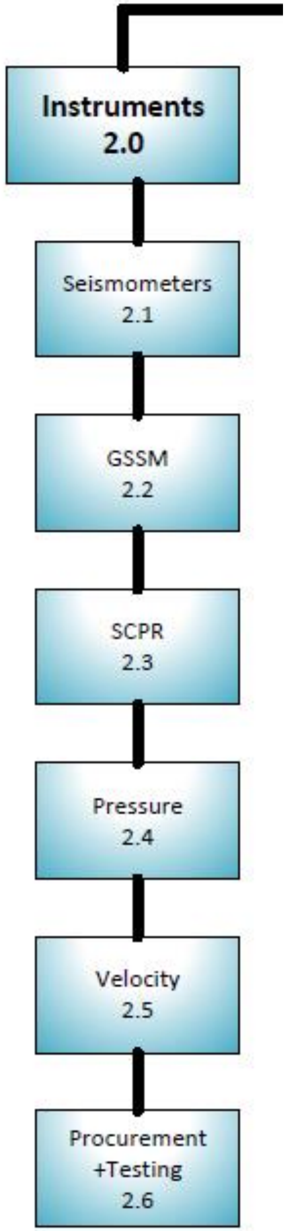


Instruments (WBS 2.0)

- **Geodetic and Seismic Sensor Module (GSSM, WBS 2.2)**
  - Updated electronics and accelerometers
  - Likely to use an HPLC value
  - Procurements in process





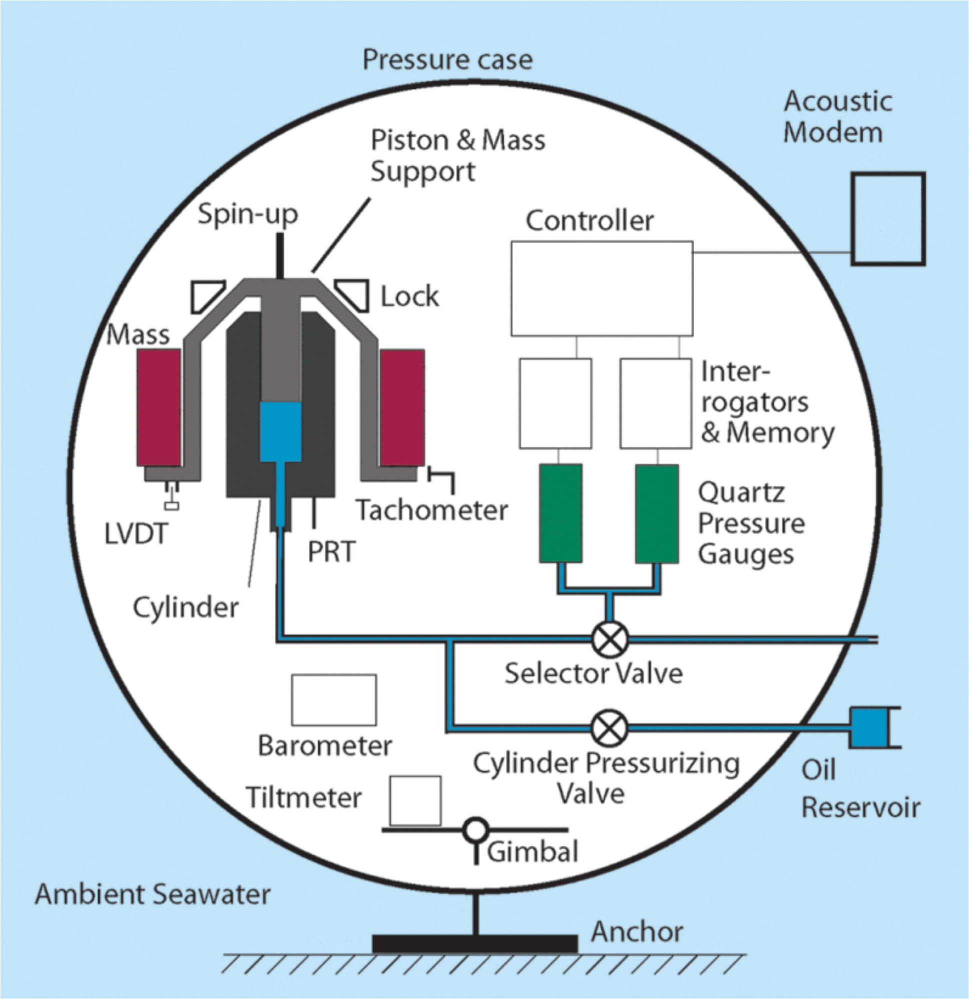


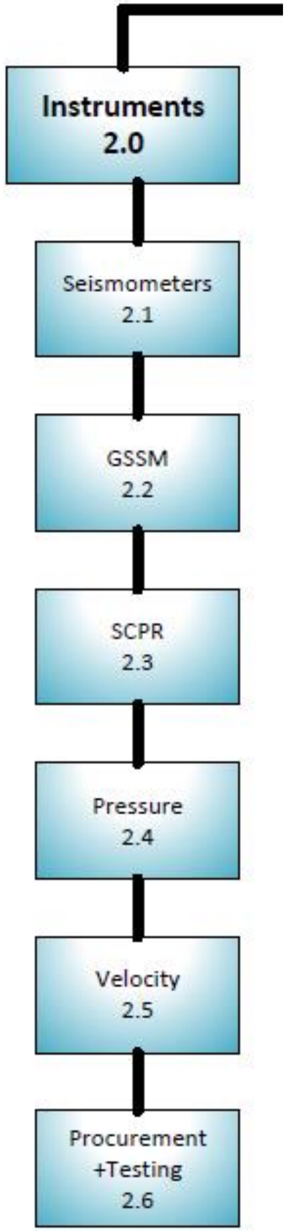
Instruments (WBS 2.0)

- **Self-calibrating Pressure Recorder (SCPR, WBS 2.3)**

Being build by our collaborators a SIO

Glenn Sasagawa
Mark Zumberge



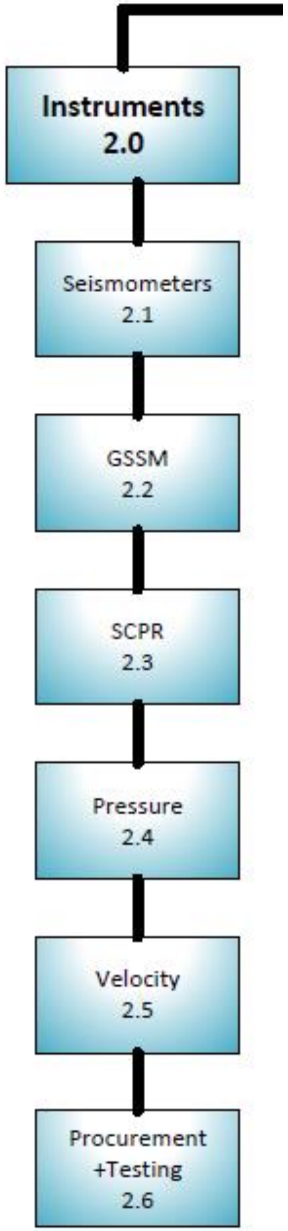


Instruments (WBS 2.0)

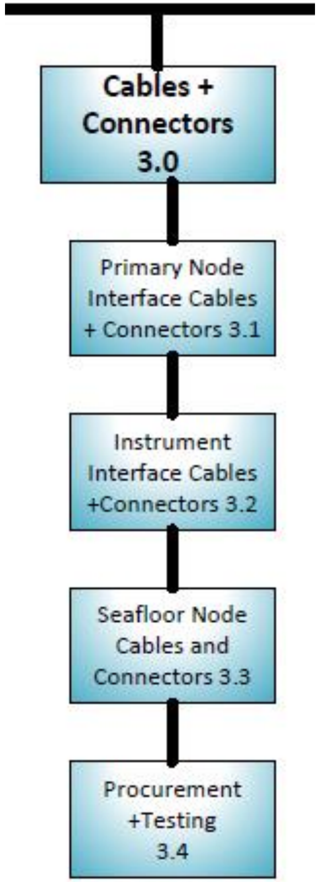
Pressure Sensor (WBS 2.4) & Current Meter (WBS 2.5)

- Paroscientific pressure gauge with units speced for highest accuracy at given deployment depths (accuracy is based on % of full-scale range)

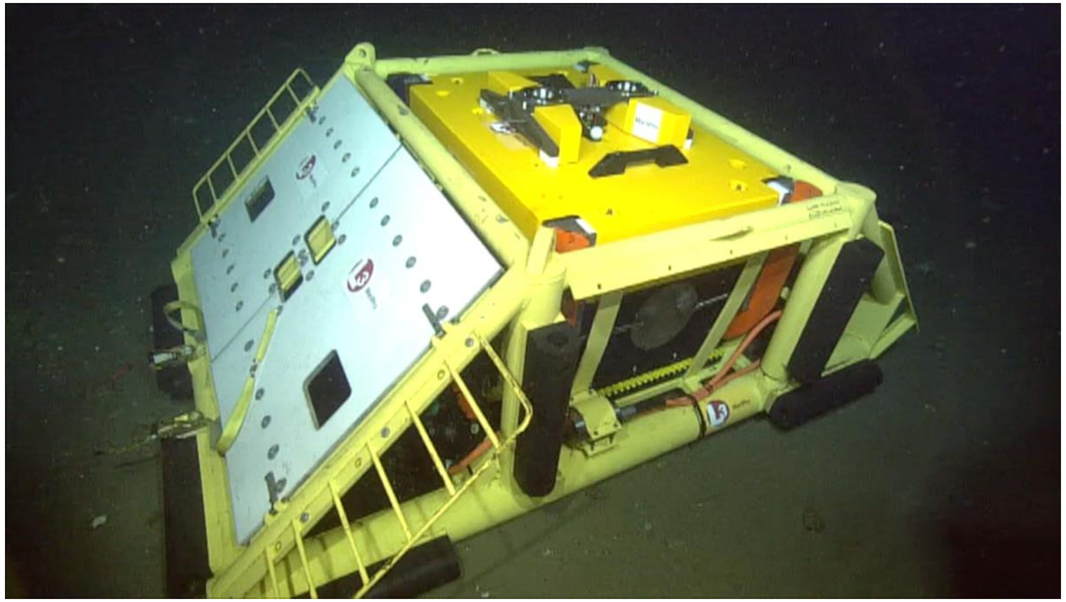
- Nortek Vector 3-component current meter is used on OOI-RCA benthic experiment packages, but is currently undergoing redesign due to part obsolescence



Cables + Connectors (WBS 3.0)



- **ODI Wet-Mate Connectors**

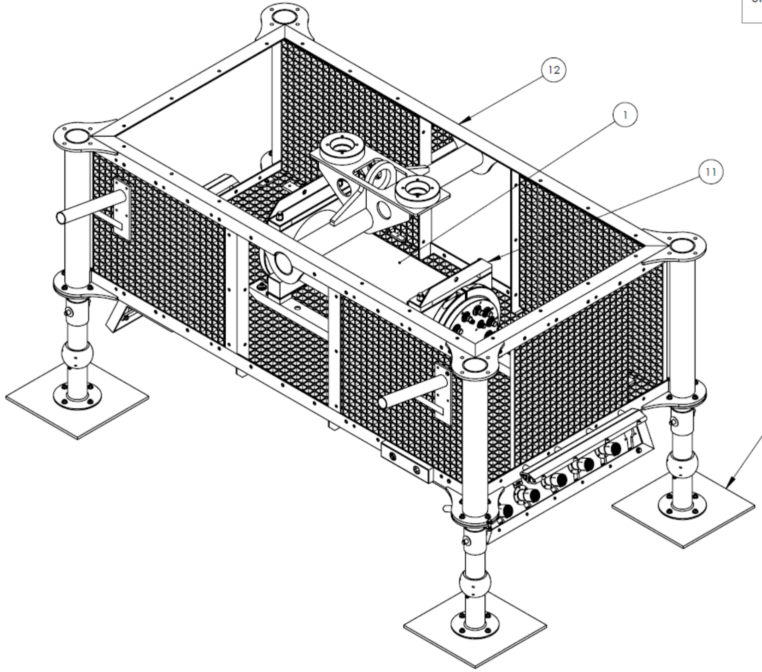


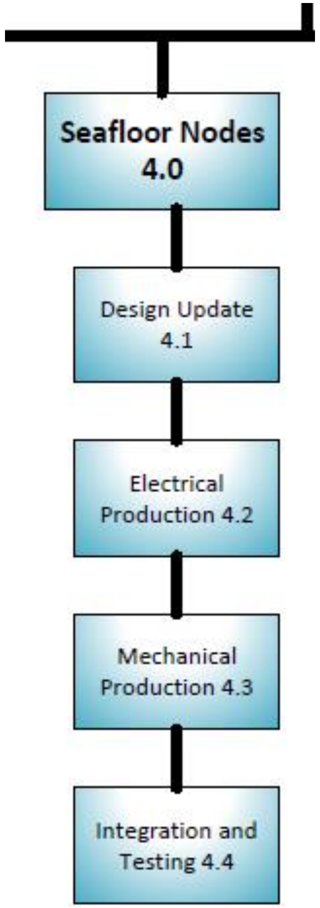
- **Various Dry-Mate Connectors**

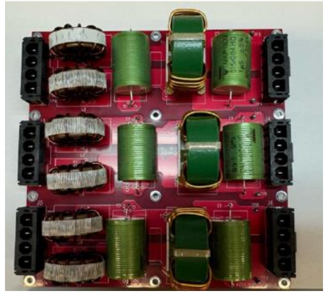
A lot of procurement challenges and long lead times but everything is in hand

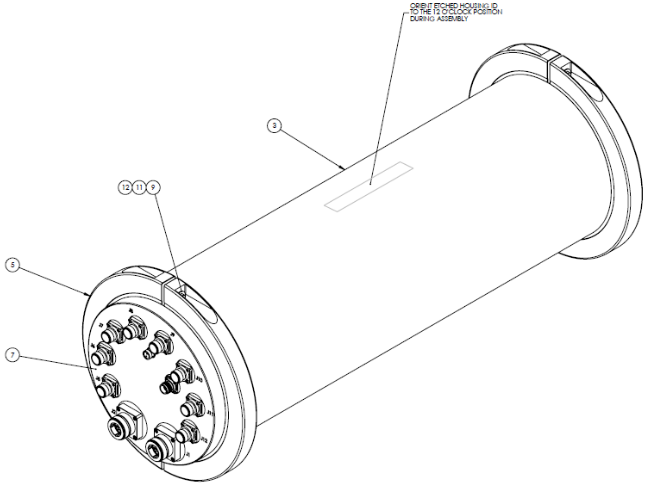
Seafloor Nodes (WBS 4.0)

- **Electrical Design**
  - Update 15-year old design to currently available components
  - Significant risks at outset re-design no in hanc
- **Mechanical Design**
  - Only minor modifications







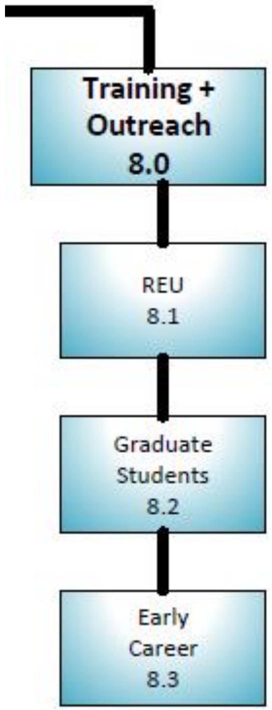


Training & Outreach (WBS 8.0)

1. Research Experiences for Undergraduates (REU) Program
   - 16 over 3-4 years to be integrated with
     - APL DINO-SIP (Diverse + Inclusive Naval Oceanographic Summer Internship Program)
     - SoO VISIONS 2024 Seagoing Expedition

2. Partial Support for 3 graduate Students (9 months each)
   - Contribute to Data QA and derived products
     - Calibrated pressure data
     - Seismometer noise
     - Ocean current meter data and links to geophysical data

3. Early Career Workshop
   - Goal is to help build a user community.
   - Spring 2027 after data streams are in place.



Data Archiving - OOI in general

Data Type	Core Sensors	PI-Added Sensors
Most Sensors	OOI Data Center	OOI PI NAS
Seismic (Velocity, SM, LF Hydrophone)	IRIS-DMC	
Pressure	OOI Data Center / IRIS-DMC	

Data Archiving – COSZO

Data Type	Core Sensors (Slope Base, Hydrate Ridge)	MSRI-1 (4 sites)
Seismic (Velocity, SM, LF Hydrophone, DPG)	IRIS-DMC	IRIS-DMC
Pressure Gauges (uncalibrated)	OOI Data Center	IRIS-DMC
Ocean Currents	OOI Data Center	PI NAS
Derived Data Calibrated pressure Others	 - PI NAS	 PI NAS PI NAS

Timeline for Transition to Operations

Date	Activity
Summer 2026	Installation
Fall 2026 /Winter 2027	Initial Quality Assessment
Spring 2027	Transition to Operations
Summer 2027	Potential installation of delayed components / repairs
Summer 2028	Potential installation of up-scoped infrastructure
Fall 2028	Infrastructure project complete

SAC 1st MEETING, Oct 24-25, 2024

Recommendations

- For up-scoping, prioritize ensuring instrumentation at the existing OOI nodes so that it meets COSZO specifications
- Ensure that the data is provided in a user-friendly format
- Add a data management and/or earthquake + tsunami early warning expertise to SAC
- Engage the community at meetings