Appendix A: Site Design: Pioneer Mid-Atlantic Bight Array

CGSN Site Design:
Pioneer Mid-Atlantic Bight Array

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Coastal and Global Scale Nodes
Ocean Observatories Initiative
Woods Hole Oceanographic Institution

Revision History

Version	Description	ECR No.	Release Date
0-01	Initial Draft		
0-02	Formatting updates and minor edits		
0-03	Completed draft		
0-04	Updated mooring locations, Draft for PDR		
0-05	Updated to address PDR comments		
1-00	Initial Release	ECR-947	2023-02-06

Table of Contents

List of Figures

List of Tables

1.0 Purpose

The purpose of this report is to provide an overview of the planning process and array configuration decisions for the new Pioneer Mid-Atlantic Bight (MAB) Array. This overview will include site selection, array layout, mooring types, instruments, and mobile assets.

2.0 Reference Documents

Table 1: Reference Documents

Document ID / Source	Document Title
3210-00001	Pioneer MAB Regulatory Study
3210-00002	Pioneer MAB Desktop Study
3210-00003	Pioneer MAB Maritime Archeology Study
3210-00007	CGSN Site Characterization: Pioneer Mid-Atlantic Bight Array
3102-00026	Analysis of Pioneer MAB Coastal Surface Mooring
3102-00027	Analysis of Pioneer MAB Coastal Profiler Mooring

3.0 Definitions & Acronyms

CGSN	Coastal & Global Scale Nodes
EM	Electro-Mechanical
HIB	Hose Interface Buoyancy
MFN	Multi-Function Node
MAB	Mid-Atlantic Bight
NC DEQ	North Carolina Department Environmental Quality
NDBC	National Data Buoy Center
NES	New England Shelf
NSF	National Science Foundation
NSIF	Near Surface Instrument Frame
OOI	Ocean Observatories Initiative
OOIFB	Ocean Observatories Initiative Facilities Board
PM	Profiler Mooring
PMO	Program Management Office
SM	Surface Mooring
SW	Shallow Water Mooring
USACE	United States Army Corps of Engineers
VACAPES OPAREA	Virginia Capes Operating Area
WHOI	Woods Hole Oceanographic Institution

4.0 Site Summary

The Pioneer Array is proposed to be relocated in the spring of 2024 to a location off the coast of Nags Head in North Carolina. The preliminary plan is for the moored array to be constituted in a sideways "T" shape, with seven mooring sites between about 13 nautical miles (nm) and 45 nm offshore, outside of state waters (Figure 1). The Pioneer MAB Array will consist of:

- Three Surface Moorings located in 30 m and 100 m water depths
- Five Profiler Moorings located in 100 m and 600 m water depths
- Two Shallow-Water Moorings located in 30 m water depths

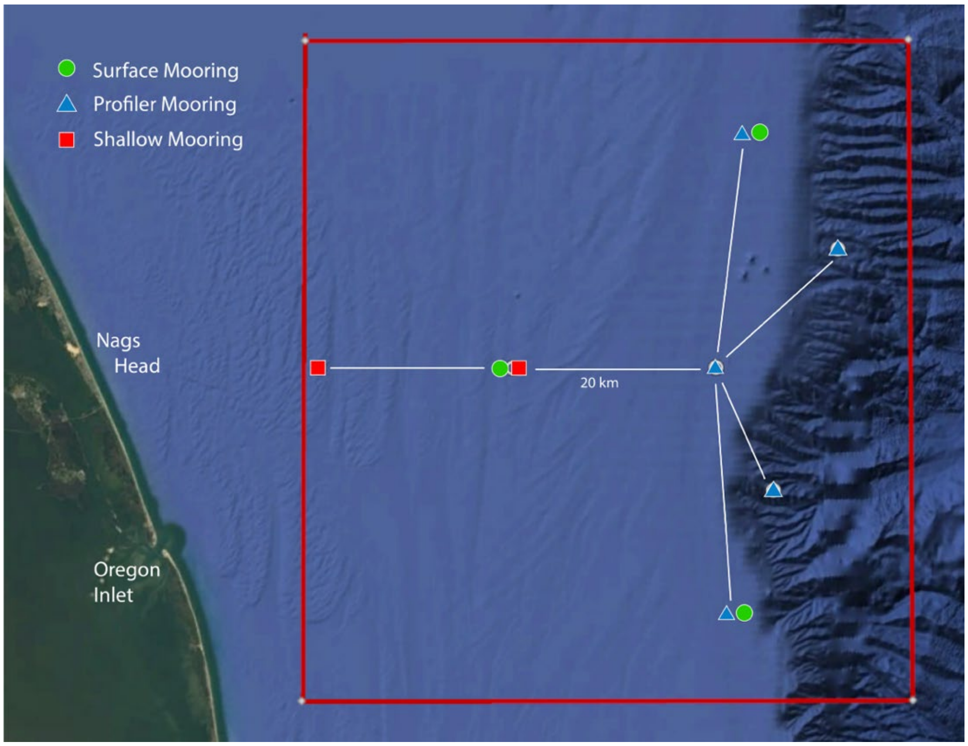

Figure 1: Pioneer MAB Proposed Array Layout

5.0 Timeline

- December 2020: The National Science Foundation (NSF) & Ocean Observatories Initiative Facilities Board (OOIFB) announce a participatory process for the potential selection of a new Pioneer Array location and request applicants for future Innovations Labs.
- January 2021: **Micro Lab #1** – Introduce Innovations Lab process, provide overview of existing Pioneer Array infrastructure and environment.
- March 2021: **Innovations Lab #1** – Science community explores possible locations for the Pioneer Array based on scientific questions that require an ocean observatory to advance knowledge.
- April 2021: NSF decision to re-locate Pioneer Array to Mid-Atlantic Bight.
- May 2021: **Micro Lab #2** – Introduce objectives and goals for Innovations Lab #2, provide technical considerations for relocation of existing Pioneer Array.
- June 2021: **Innovations Lab #2** – Science community discusses how the existing Pioneer Array sensors and platforms can be optimized to achieve science and education goals at the new site. Community also discusses what enhancements to the Pioneer infrastructure could be made.
- July 2021: CGSN kicks off relocation planning and engineering.
- April 2024: Planned first Pioneer MAB deployment.

6.0 Roles & Responsibilities

- **National Science Foundation (NSF):** Funds the operations and management of the Ocean Observatories Initiative. NSF also funded the Pioneer Array relocation process by supporting two Innovations Labs; attended the Innovations Labs, answered community questions on the decision process and selected NSF Innovations Lab 1 and 2 organizers and panelists.
- **Ocean Observatories Initiative Facilities Board (OOIFB):** Proposed and managed the Pioneer Array relocation decision process, including two Micro Labs and a two-phase (virtual) community workshop series called Innovations Labs.
- **NSF Panelists:** Interdisciplinary Innovations Lab participants selected by NSF. Served as members of the organizing committee, participated in selecting applications for Innovations Labs, attended all labs and provided subject matter expertise, provided recommendation for site selection following Innovations Lab #1, and provided feedback on community discussions in Innovations Lab #2.
- **OOI Program Management Office (PMO) and Coastal and Global Scale Nodes (CGSN):** Provided technical expertise on the existing Pioneer New England Sheff (NES) Array, answered question in the Innovations Labs concerning system capabilities, potential risks, and logistical considerations. Following the relocation decision, refining the Innovations Labs' recommendations to be operable and maintainable within existing budget constraints.

7.0 Community Input

Community input is a significant component of the Pioneer Array relocation process. Multiple approaches to receiving community input are exercised during an ongoing, multi-stage process, as summarized below. Every stage seeks interdisciplinary participation to the science community and other stakeholders to ensure the new array is suited to meet science goals. The first and second Micro Labs each drew over 80 participants to the virtual discussion. The cornerstones of the process were two Innovations Labs, supported by NSF and managed by the OOIFB. Each lab had over 30 selected participants from diverse areas of the ocean science community. Participants were selected with the goal of achieving a broad range of disciplines and professional expertise, career stage, gender, cultural background, and life experience. The Innovations Labs resulted in a report from OOIFB to NSF, and NSF subsequently provided relevant information to OOI about regional science themes and array design recommendations for relocation of the Pioneer Array to the MAB.

1. **Micro Labs:** The OOIFB used these meetings to introduce the Innovations lab process to the science community, as well as provide a timeline for activities. The existing Pioneer NES Array infrastructure was also presented. Initial thoughts on science themes and questions were also requested from the science community.

2. **Innovations Labs:** Applications for participation were requested by the NSF. The Innovations Labs were supported by NSF and managed by the OOIFB. CGSN provided information on existing infrastructure, instruments, and mobile assets to support community discussions. In Innovations Lab #1, ad-hoc, interdisciplinary teams from multiple institutions pitched potential locations for the Pioneer Array. In Innovations Lab #2, following selection of the MAB location by NSF, participants were placed in interdisciplinary teams to discuss science themes, array layout, instrument allocation, and mobile asset usage.

3. **Focus Group:** Following the kickoff of relocation activities by CGSN, an interdisciplinary Focus Group was created to review and provide feedback on engineering and science questions posed by the CGSN operations and management team. The scope of Focus

Group feedback included consideration of science drivers, array design, instrumentation, and sampling plans. The Group and/or individuals were also asked to answer questions or provide input on specific issues in their area of expertise at other times during the process. In addition to providing breadth and depth of cross-disciplinary expertise from active researchers, the membership list sought to ensure a mix of early career and senior participants, gender equity, representation of regional institutions, inclusion of OOIFB members, and inclusion of Innovations Lab participants.

a. Kendra Daly, University of South Florida, Professor, Biological Oceanography; zooplankton ecology and marine food webs; long history with OOI; OOIFB Chair; Innovations Lab organizer.

b. John Wilkin, Rutgers University, Professor, Marine and Coastal Sciences; physics/modeling; familiar with OOI; member of original NES Pioneer focus group; Innovations Lab participant; OOIFB member.

c. Harvey Seim, University of North Carolina, Professor, Marine and Environmental Sciences; physics/observations; familiar with OOI; PI in the PEACH project; Innovations Lab panelist.

d. Sophie Clayton, Old Dominion University, Asst Professor, Ocean and Earth Sciences; physics/biogeochemistry; familiar with OOI; Co-Chair, OOI Biogeochemical (BGC) sensor working group; Innovations Lab participant.

e. Hilary Palevsky, Boston College, Asst Professor, Earth and Environmental Sciences; biogeochemistry, carbon cycle and climate; familiar with OOI; Co-Chair, OOI BGC sensor working group.

f. Tammi Richardson, Professor, University of South Carolina, Biological Sciences, biology and ecosystems, phytoplankton, Innovations Lab panelist.

g. Erin Meyer-Gutbrod, University of South Carolina, Asst Professor, Earth, Ocean and Environment, marine ecosystems, population dynamics, Innovations Lab participant.

h. Emily Eidam, Oregon State University, Asst Professor, Earth, Atmospheric and Ocean Sciences, sediment transport, plumes, Innovations Lab participant.

4. **Subject Matter Experts:** Where necessary, Subject Matter Experts (SMEs) were sought out to support the generation of specifications or requirements for the new array. As examples, SMEs were requested to provide feedback on:

   - Appropriate data units, expected measurement levels, and potential sampling rates for new sensors,
   - Mooring locations and spacing,
   - Mobile asset tracklines and appropriate sensor measurements dependent on location of line.

5. **Ocean Modeling Input:** The relocation process also benefited from discussions with John Wilkin (Rutgers University) and Ruoying He (North Carolina State University). Their ocean modeling results were found to be relevant to the moored array design and mobile asset trackline issues being assessed by CGSN.

8.0 Site Selection

Innovations Lab #1 focused on the development of pitches from various teams on potential new locations for the Pioneer Array. There were 32 selected participants from multiple institutions as well as the NSF, NSF Panel, OOIFB, OOI PMO, and CGSN for a total of 47 participants. Eight (8) pitches were made during the Innovations Lab, see Table 2below.

Table 2: Innovations Lab #1 Participant Pitches

#	Pitch	Location	Collaborators
1	Canyon Influences on Shelf Biogeochemistry	Juan de Fuca Canyon	• University of Washington • Northwest Indian Fisheries Commission
2	A Gulf of Mexico Multidisciplinary Shelf-slope Observing Array	Gulf of Mexico	• OceanGeeks LLC • Florida Institute of Oceanography • University of Southern Mississippi • Texas A&M University • Louisiana Universities Marine Consortium • Georgia Tech University • University of South Florida
3	Southern Mid-Atlantic Bight	Cape Hatteras to Norfolk Canyon	• North Carolina State University • Old Dominion University • East Carolina University • Virginia Institute of Marine Science • Bureau of Ocean Energy Management • University of North Carolina
4	Gulf of Alaska Array	Gulf of Alaska	• University of Alaska, Fairbanks
5	A Taste of the Gulfstream: Relocating to the Charleston Gyre	South Atlantic Bight	• Old Dominion University • Virginia Institute of Marine Science • University of North Carolina • North Carolina State University
6	Ecosystem Responses to Shelfbreak and Canyon Exchange Processes in a Changing Ocean: Southern New England	New England Shelf	• Woods Hole Oceanographic Institution • Massachusetts Maritime Academy • Northeastern Regional Association of Coastal Ocean Observing Systems • Bristol Community College
7	Puerto Rico/Virgin Islands Passage Throughflow: A Tropical Overlay of Science and Broader Impacts	Puerto Rico & Virgin Islands	• OceanGeeks LLC • University of South Florida
8	Coastal Upwelling Experiments and Simulations	Central California	• Monterey Bay Crescent Ocean Research Consortium (consortium of 27 institutions and agencies)

Following the Innovations Lab #1, the NSF Panel provided a ranking of the various locations based on intellectual merit, science drivers, and ability to achieve goals in a 5-year deployment. NSF requested budget and technical feedback from CGSN to support the decision process. In April 2021, NSF announced that the Southern Mid-Atlantic Bight was selected as the new location. The location is now named Pioneer Mid-Atlantic Bight (MAB) Array.

9.0 Science Themes

During the Micro Labs and Innovations Labs #1 and #2, participants were asked to contribute to a “virtual wall” of science questions within several themes. Input to the science questions was organized for Innovations Lab #2 based on:

- Several broad themes derived from the overarching OOI Science Themes,
- Prior theme contributions from Innovations Lab #1, and
- Information on research interests provided by participants from the registration process.

For informational purposes, the six OOI Science Themes are:

- Climate variability, ocean food webs, and biogeochemical cycles
- Ocean-atmosphere exchange
- Coastal ocean dynamics and ecosystems
- Turbulent mixing and biophysical interactions
- Global and plate-scale geodynamics
- Fluid-rock interactions and the sub-seafloor biosphere

Not all contributions to the virtual wall were phrased as science questions, and the input could be more accurately described as a collection of topics relevant to coastal ocean science as seen through the filter of the OOI Science Themes and the Pioneer Array relocation process. Over 140 entries to the virtual wall were provided by Innovations Lab participants. A review of the Innovations Lab input revealed over 120 science topics plus approximately 20 topics describing relevant technology and instrumentation.

The full list of topics was presented at Innovations Lab #2, which included 34 selected participants. After presentation, review and discussion, the participants voted on the science topics. Topics with two or fewer votes were not considered to represent a consensus among the participants. This resulted in 23 “highly ranked” topics with three or more votes, including three “top-ranked” topics with six or seven votes. A review and consolidation of the “highly-ranked” topics revealed several similar or common elements:

- Mechanisms of cross-shelf exchange,
- Influence of the shelfbreak front and jet,
- Influence of the Gulf Stream,
- Sub-mesoscale dynamics, and
- The links between ocean dynamics and higher trophic levels.

Less common elements considered important due to their unique applicability to the region were:

- Freshwater plumes,
- Canyons, and
- Methane seeps.

Considering the original six OOI Science Themes, accommodating common elements of the highly ranked Innovations Lab science topics, and accounting for unique regional characteristics resulted in three overarching regional science themes for the Pioneer MAB Array:

- **Dynamics of shelf-slope exchange**, including Wind forcing, frontal instability, and Gulf Stream influences.
- **Biogeochemical cycling and transport**, including carbon, nutrients, and particulates, and considering the ecosystem response to cycling and transport.
- **Extreme events**, including major storms, hurricanes, and freshwater outflows

10.0 Array Layout

Following the science theme discussions, the Innovations Lab #2 participants were broken into groups by regional science theme. They were then tasked with generating a diagram depicting what areas of the MAB could best address the OOI Science Themes, and by extension the MAB regional science themes. Figure 2shows a composite regional map showing the areas of interest grouped by science theme as generated by all of the groups.

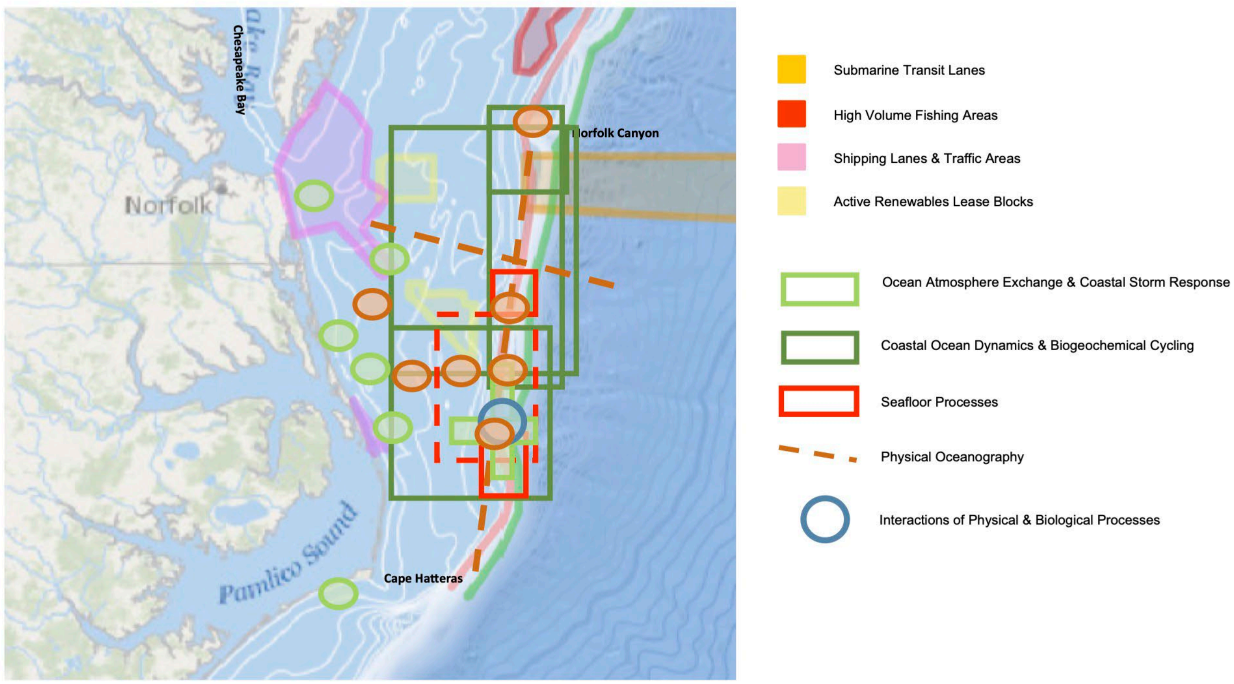

Figure 2: Overlapping Areas of Science Themes

The Innovations Lab Panelists then recommended an area of interest where all themes overlapped and where conflict with other seabed users could most easily be mitigated. This map was presented to the participants for discussion and to layout the mooring infrastructure (Figure 3).

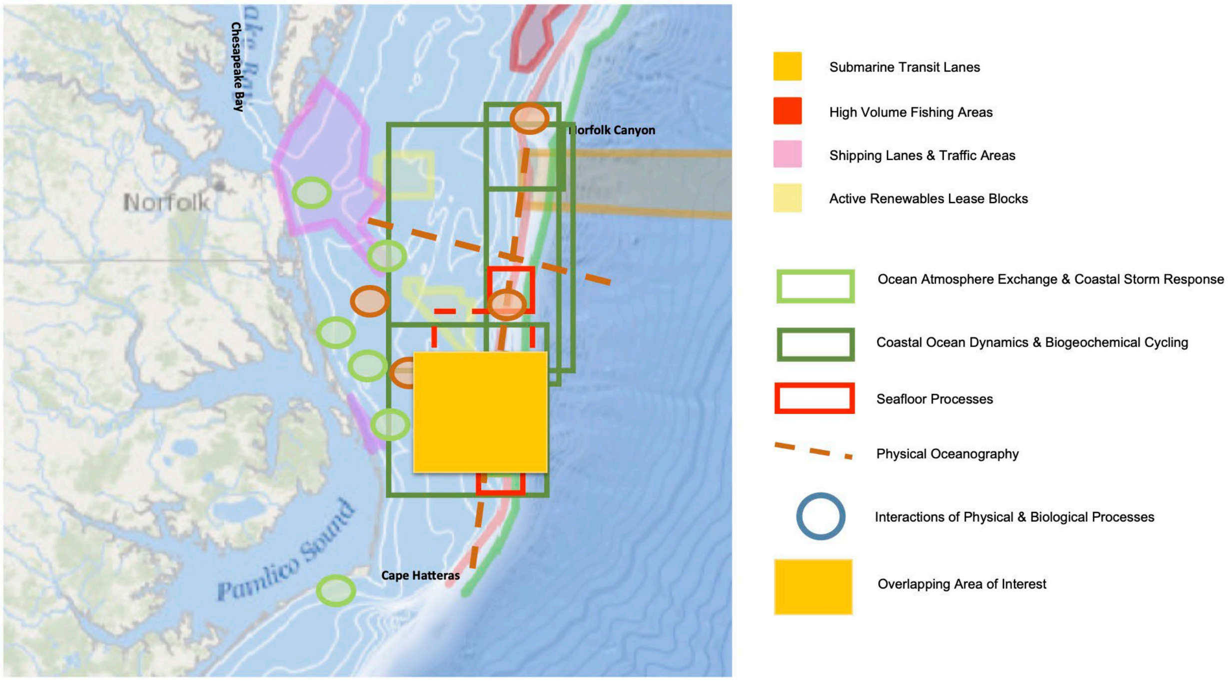

Figure 3: Scientific Overlapping Area of Interest

The participants were then placed into four (4) interdisciplinary teams. They were asked to layout the existing Pioneer mooring infrastructure (surface & profiler moorings) in an array they believed was best suited to answer the themes previously discussed. The participants were provided with the existing mooring designs, environmental operating limits, and instrument allocations. The teams were also asked if additional infrastructure was required, which they should add to their layouts.

The four teams generated the layouts shown in Figure 4 through Figure 7.

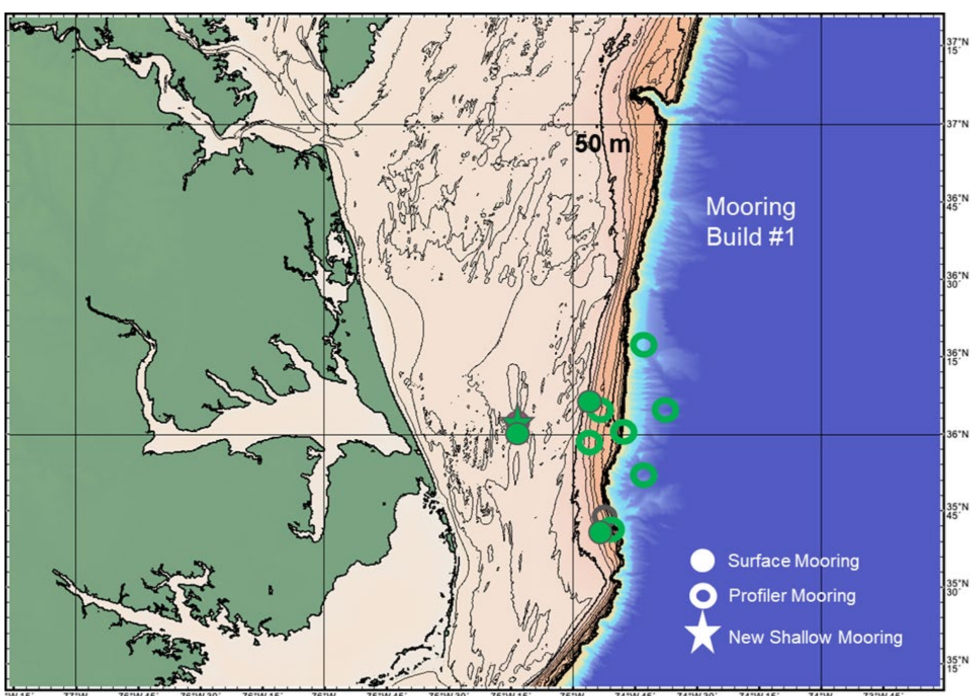

Figure 4: Innovations Lab Mooring Layout #1

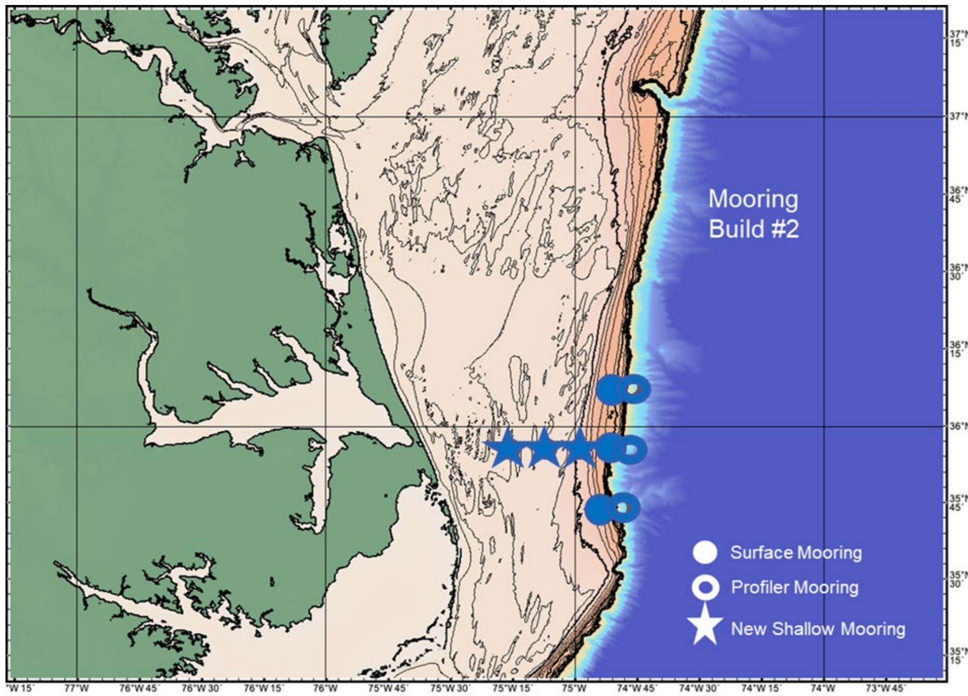

Figure 5: Innovations Lab Mooring Layout #2

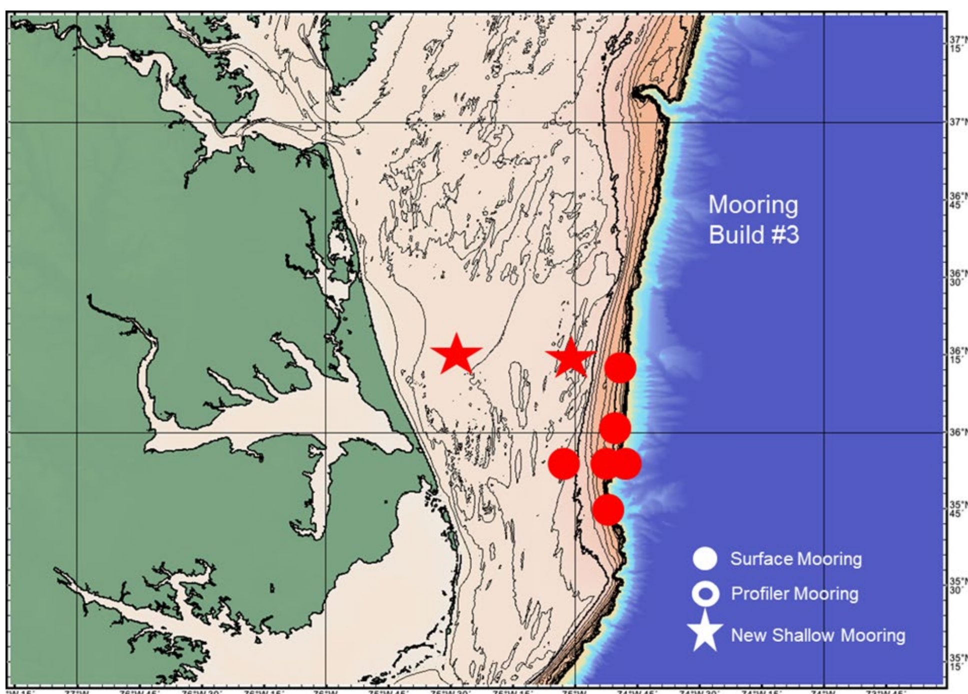

Figure 6: Innovations Lab Mooring Layout #3

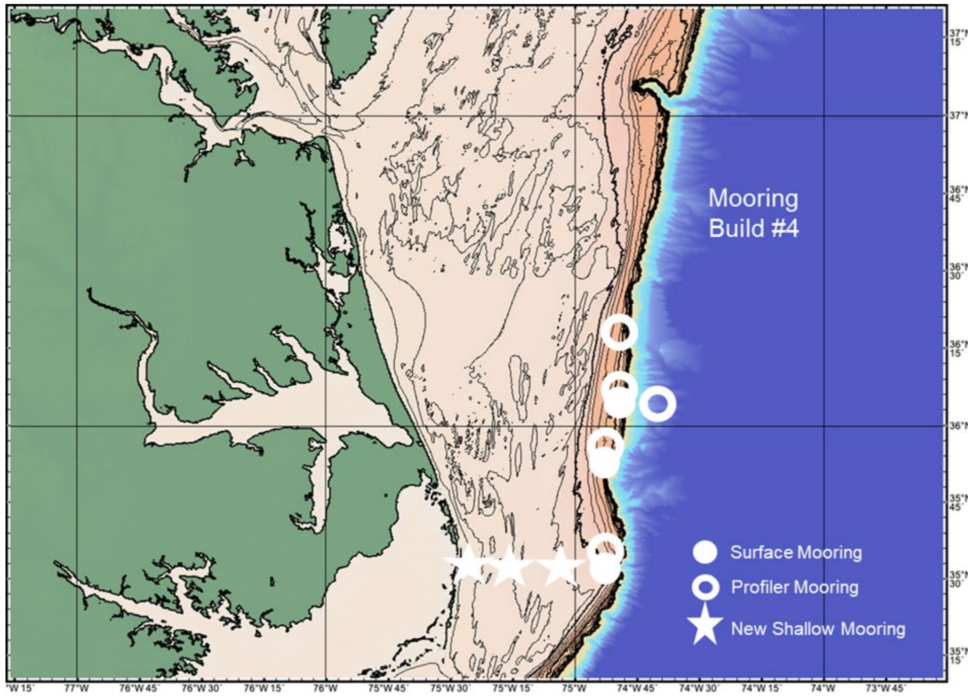

Figure 7: Innovations Lab Mooring Layout #4

Following review and discussion, the participants were asked to vote on the preferred array layout. The layout with the most support among the participants was “Mooring Build #2”. This layout included:

- 3 x surface moorings
- 3 x profiler moorings
- 3 x shallow moorings

The Innovations Lab Panelists then generated a consensus mooring layout based on the existing infrastructure. This mooring layout maintained a recommendation for shallow water moorings, although it was recognized that shallow water moorings would be in ~30 m water depth and that Pioneer does not currently include that specific infrastructure. Thus, implementation of shallow moorings was considered a recommendation to be evaluated by the operators. This layout was presented to the participants for discussion and comment (Figure 8). The Panelists then met with the NSF and agreed the consensus array design represented the layout to move forward with for planning and potential refinement based on CGSN assessment and engineering review:

- 3 x surface moorings
- 5 x profiler moorings
- 2 x shallow moorings

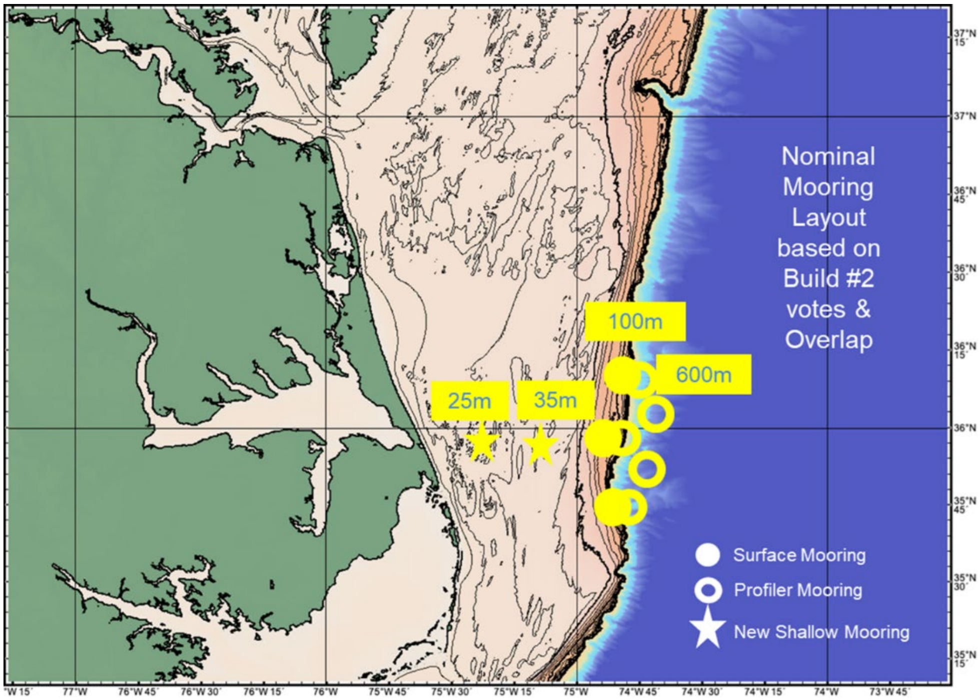

Figure 8: Innovations Lab Final Mooring Layout

Following kickoff of the planning and engineering phase in July 2021, CGSN reviewed several sources for potential conflicts with the proposed mooring locations. These included:

- Fishing Activity
- Military Operations & Training Areas
- Vessel Traffic & Traffic Schemes
- Offshore renewable energy lease areas
- Submarine Cables
- Wrecks & Obstructions
- Corals

The array was found to be:

- Outside of high revenue fishing areas (Figure 9);
- Inside a single military operating area (VACAPES OPAREA), outside of submarine transit areas, and outside of regulated air corridors (Figure 10);
- Outside of proposed fairways and traffic schemes – however, the shallow moorings were adjusted to maintain a minimum of 1km separation (Figure 11);
- Outside of proposed wind farm leases (Figure 12);
- Distant from known submarine cables (Figure 13);
- Distant from charted unexploded ordinance or wreck areas (Figure 14);
- Outside of charted coral habitats (Figure 15)

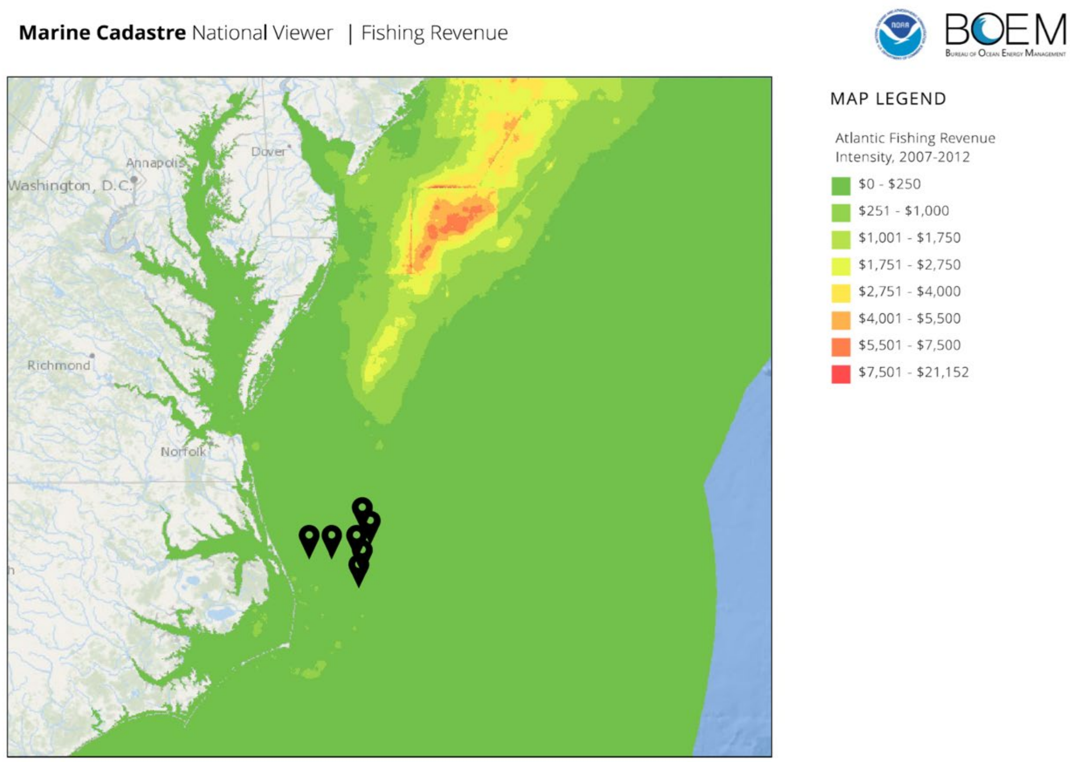

Figure 9: Fishing Revenue

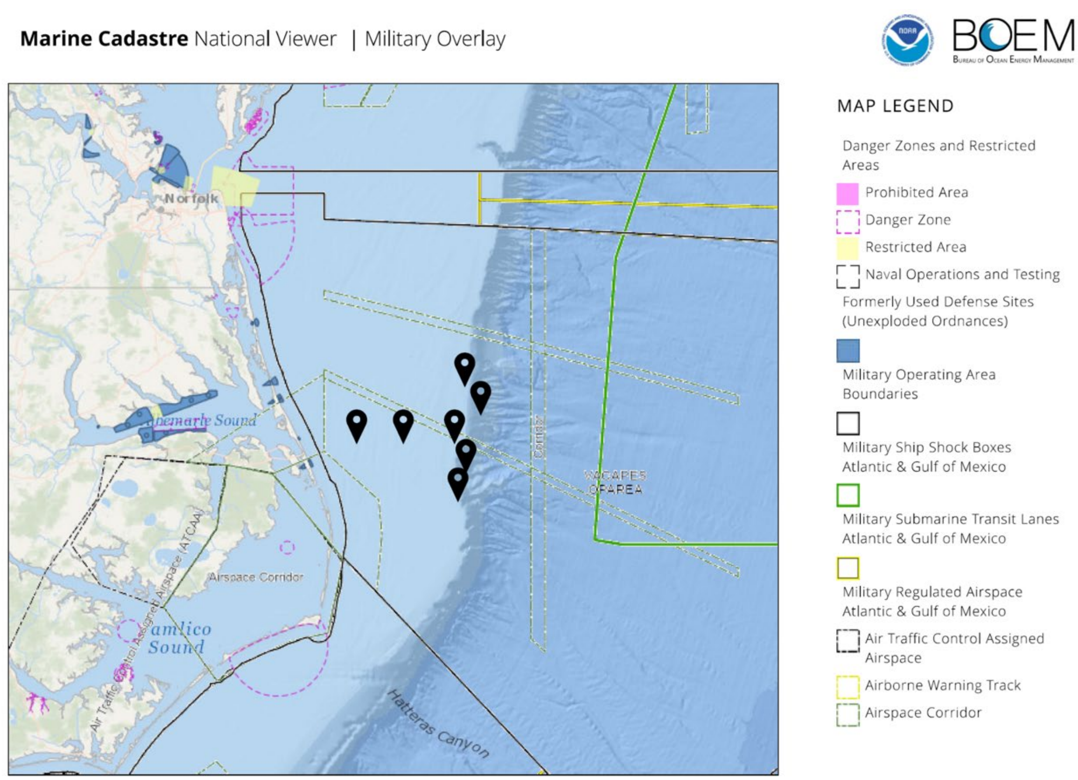

Figure 10: Military Areas

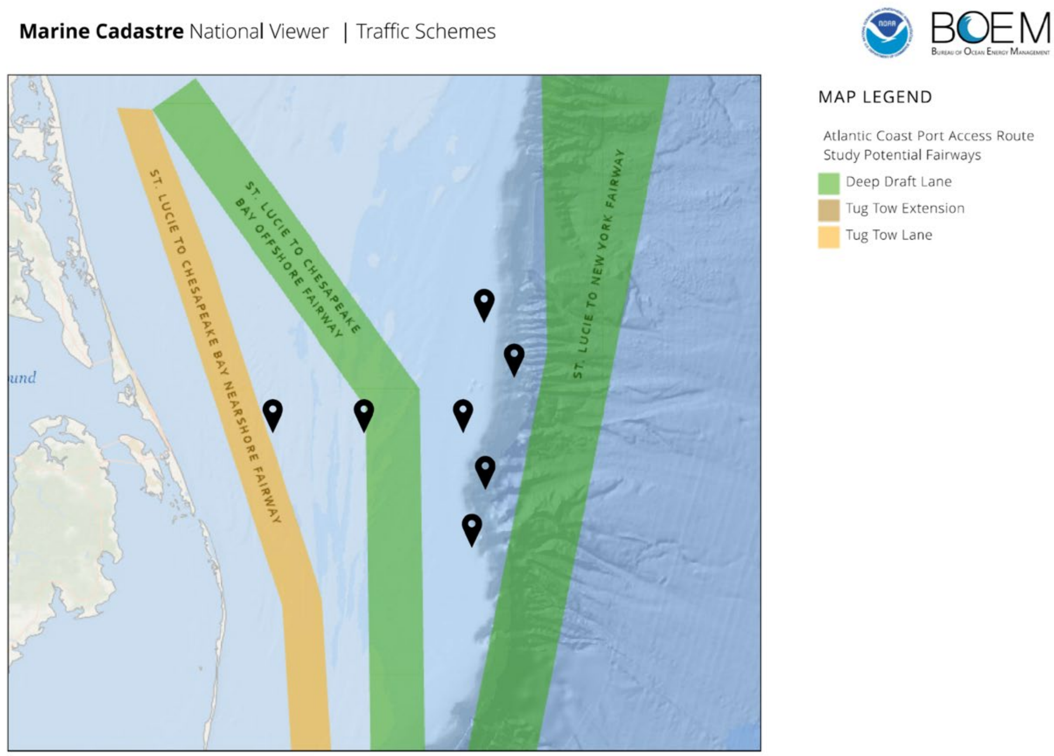

Figure 11: Proposed Traffic Schemes

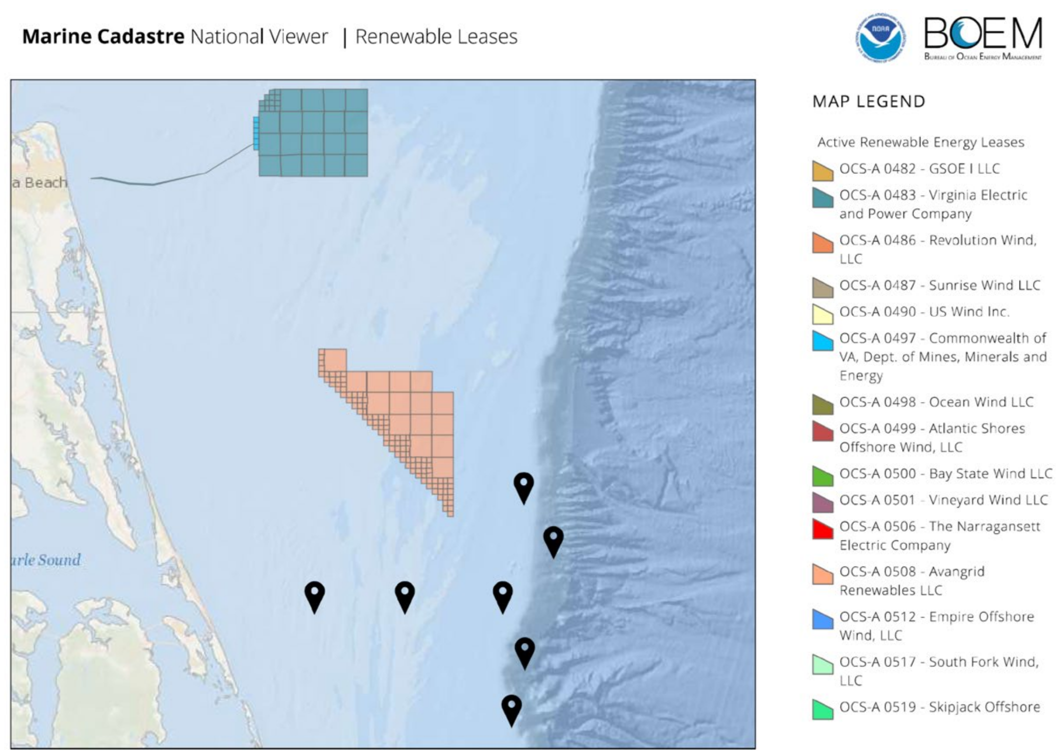

Figure 12: Planned Renewable Leases

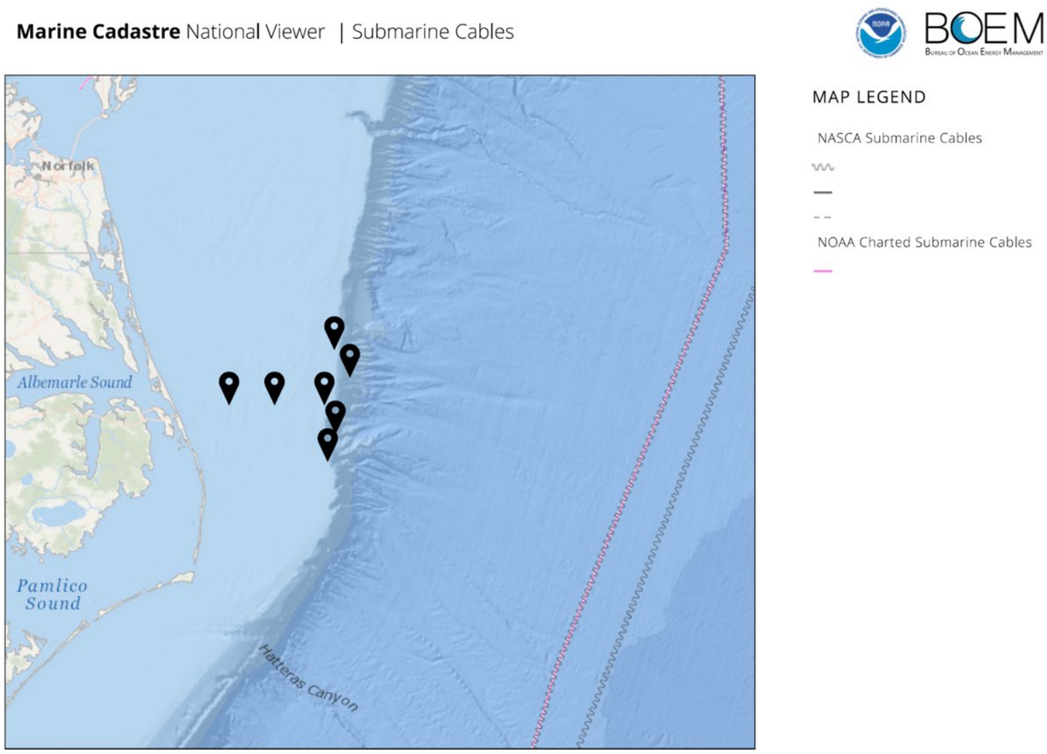

Figure 13: Submarine Cables

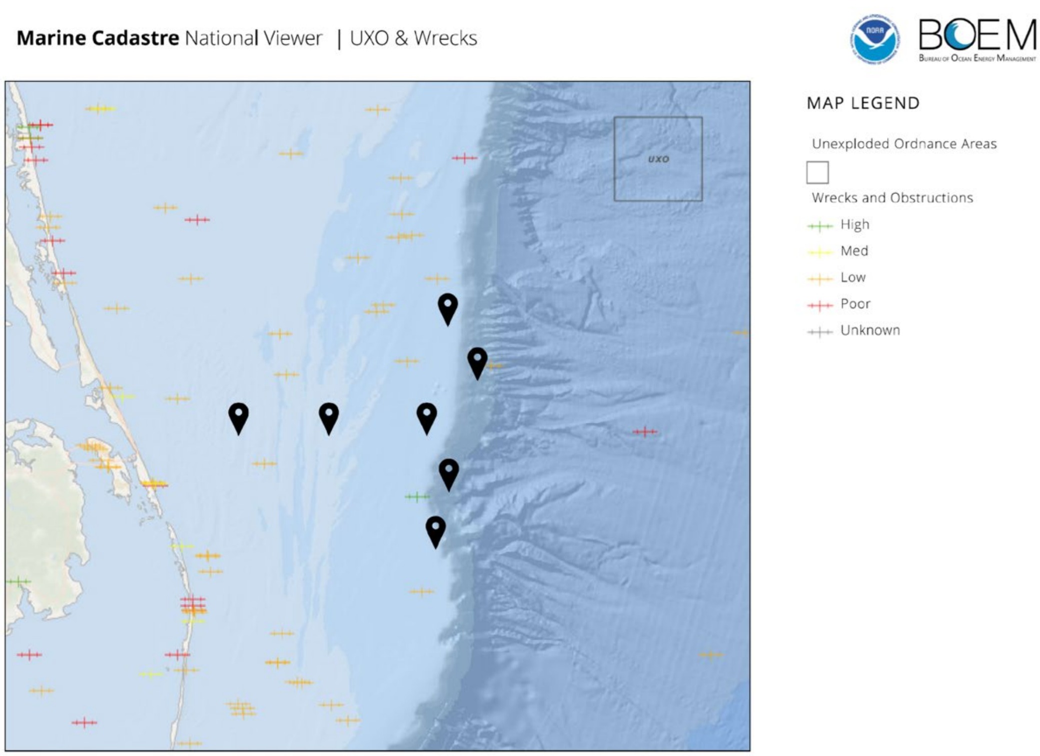

Figure 14: Known Unexploded Ordinance & Wrecks

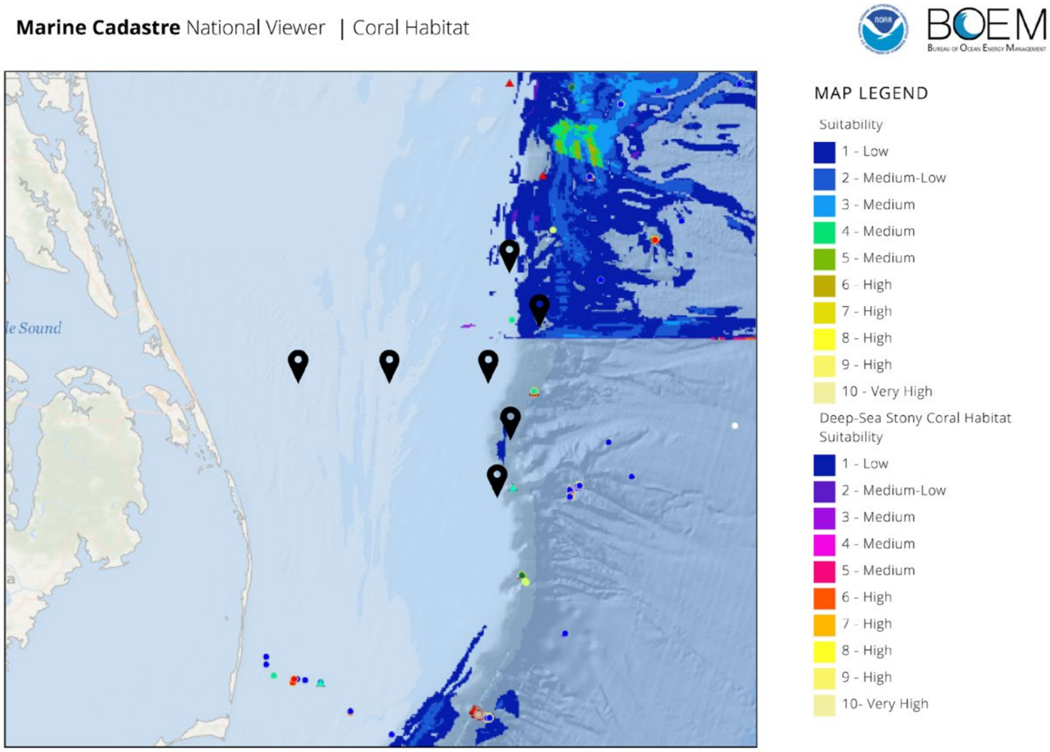

Figure 15: Coral Habitat

CGSN hired TetraTech in January 2022 to complete a regulatory study, desktop study, and marine archeological study. Final reports were completed in December 2022. TetraTech findings confirmed the CGSN array layout as feasible without any major risks. During the study:

- The United States Army Corps of Engineers (USACE) confirmed the array would fall under Nationwide Permit #5 and saw no major issues.
- The North Carolina Department Environmental Quality (NC DEQ) confirmed the array location was outside state waters and also did not see any major issues.
- The desktop study did not find any major physical or environmental risks and the marine archeological report confirmed that the planned layout did not impact any known wrecks.

During this time CGSN also discussed the mooring layout with the Focus Group and other SMEs. It was noted that oceanographic modeling and the desire for interdisciplinary observations at mid-shelf indicated the position of the central surface mooring would be best co-located near the central shallow water mooring, rather than on the 100 m contour with a profiler mooring. This new position will better distribute the heavily-instrumented surface moorings within the array, and will result in an "imbedded triangular array" made up of the three surface moorings to capture cross-shelf process and, potentially, freshwater outflows from the Chesapeake area. This layout was vetted with the Focus Group in September 2022 and resulted in the current mooring layout shown in Figure 16 and in Table 3.

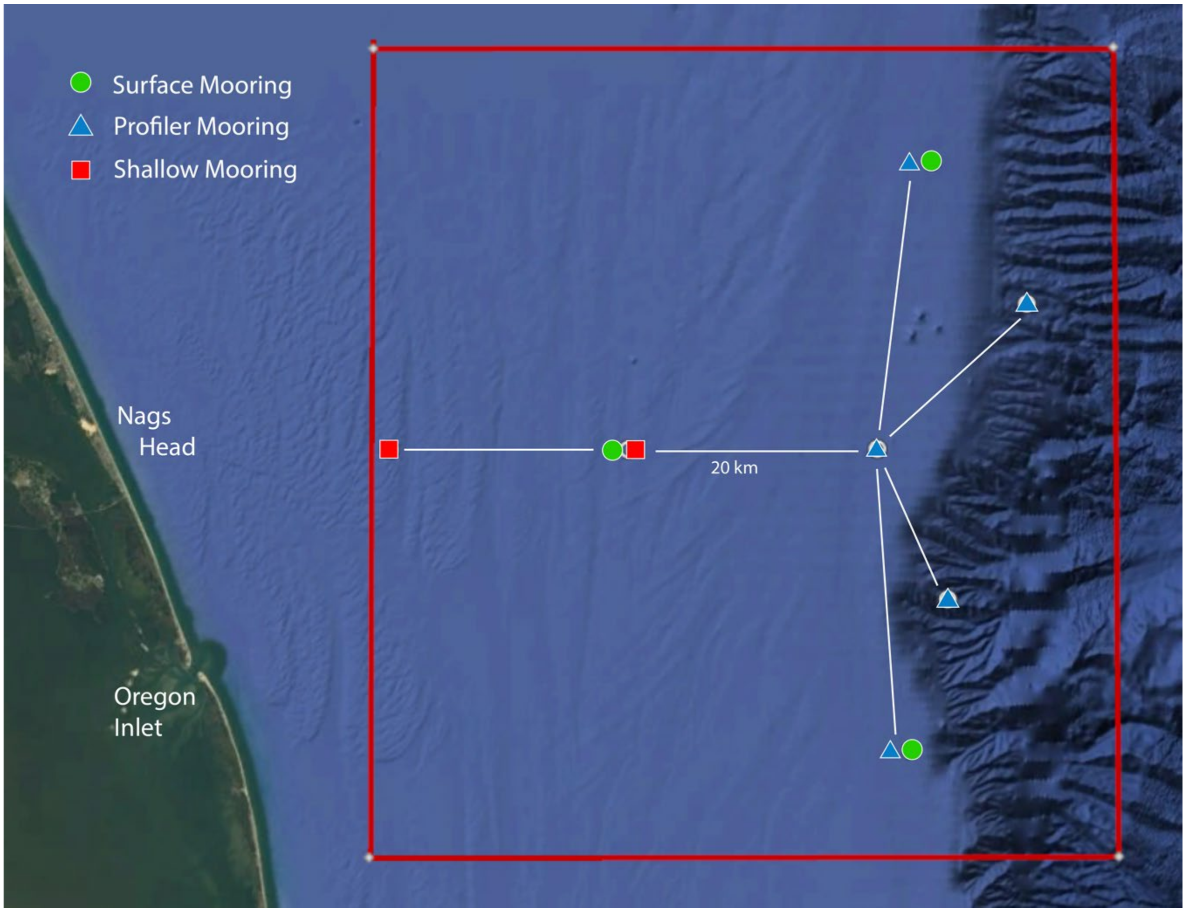

Figure 16: Current Array Layout

Table 3: Table of Planned Mooring Locations

Site	North		West		Depth (m)	Mooring Types	Notes
	lat (deg)	lat (min)	lon (deg)	lon (min)			
Western	35	57.00	75	20	30	Shallow Mooring	
Central	35	57.00	75	7.5	32	Shallow Mooring, Surface Mooring	Planned 2023 test mooring location
North	36	10.50	74	49.60	100	Profiler Mooring, Surface Mooring	
Eastern	35	57.00	74	50.74	100	Profiler Mooring	
Southern	35	43.50	74	51.18	100	Profiler Mooring, Surface Mooring	
Northeast	36	03.80	74	44.56	600	Profiler Mooring	Planned 2023 test mooring location
Southeast	35	50.20	74	49.45	600	Profiler Mooring	

11.0 Mooring Types

As part of the Innovations Lab #2, the groups who proposed the array layouts also reviewed individual mooring types. The existing infrastructure, Surface Moorings (Figure 17) and Profiler Moorings (Figure 18), were accepted by all groups but suggestions on instrumentation were provided, this will be discussed in Section 12.0. Each group also suggested mooring requirements for the shallow mooring. All groups recommended a shallow mooring design with near-surface, mid-water and seabed measurement capabilities.

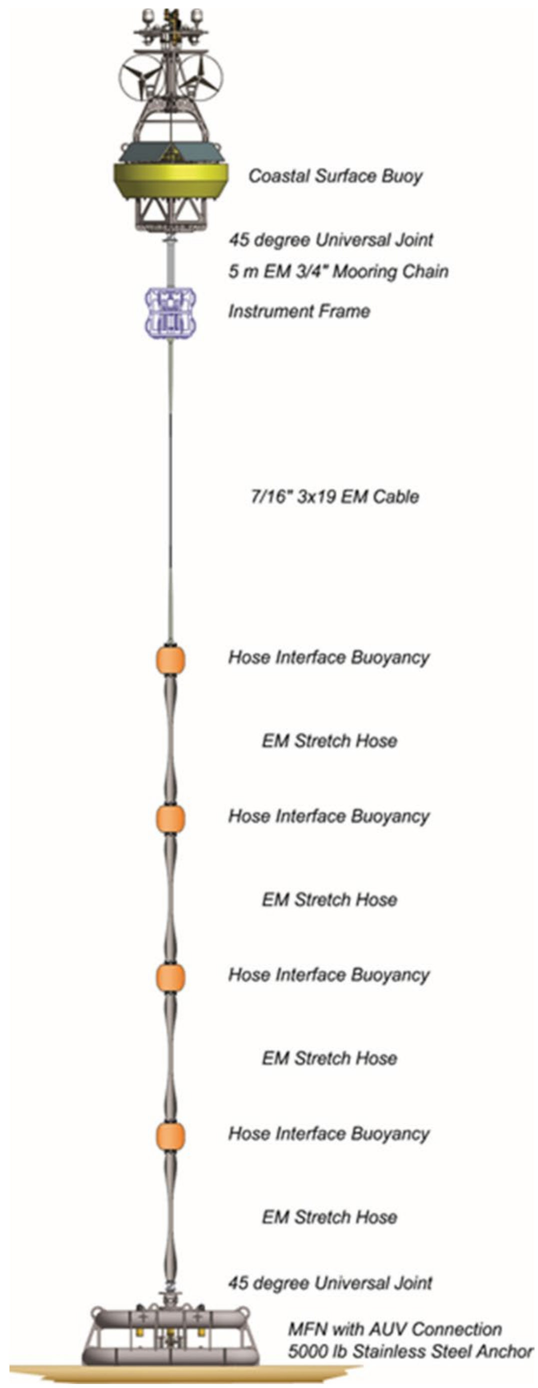

Figure 17: Pioneer Coastal Surface Mooring

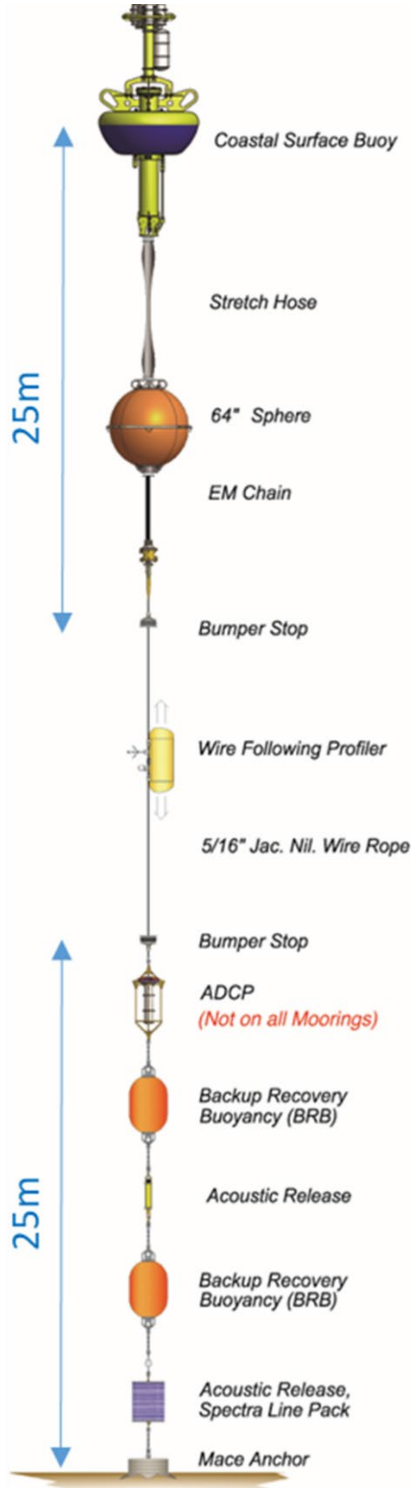

Figure 18: Pioneer Coastal Profiler Mooring

Mooring analyses were completed for both the Coastal Surface Mooring and the Coastal Profiler Mooring. Based on the analyses, no major re-design for the MAB environment is required. For further information, please review the mooring analysis reference documents (3102-00026, 3102-00027). Test deployments of the moorings at the MAB location are planned in calendar Q1 2023.

Minor engineering updates to the Coastal Surface Mooring to accommodate the new location/environment or instrument requests includes:

- Updated instrument clamping for Near Surface Instrument Frame (NSIF)
- Updated instrument clamping for the seabed Multi-Function Node (MFN)
- Increased NSIF size to accommodate additional/larger instruments
- No electro-mechanical cable is required since moorings will be located in water depths of 100 m or shallower.

Minor engineering updates to the Coastal Profiler Mooring to accommodate the new location/environment or instrument requests includes:

- Updated instrument clamping for the 64” sphere
- Updated instrument clamping to accommodate instruments on the base of the buoy
- Increased linepack size for Profiler Moorings deployed in 600 m water depth.

Based on the Innovations Lab #2 feedback, CGSN selected two potential shallow mooring designs for review:

- The existing Endurance Inshore Surface Mooring (ISSM) with a surface expression, NSIF, and seabed MFN (Figure 19)
- A new, simpler design for a Shallow Water Mooring, incorporating a ratcheting profiler vehicle and smaller seabed MFN.

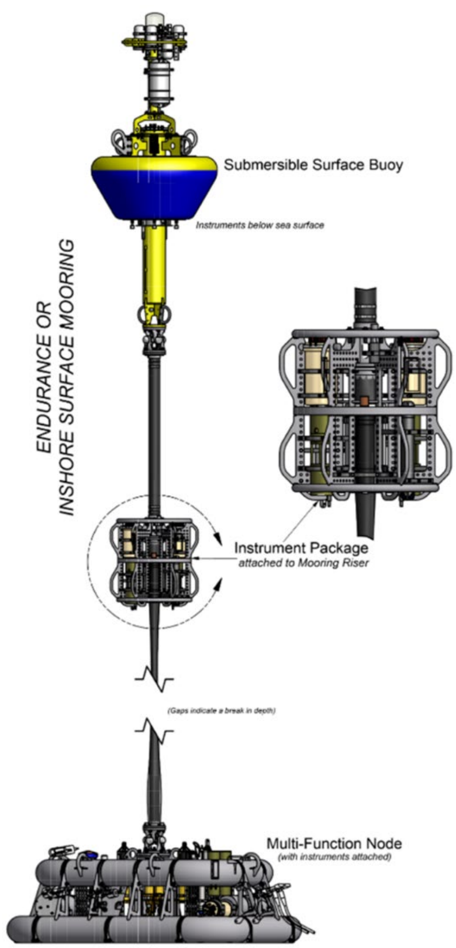

Figure 19: Endurance Inshore Surface Mooring

CGSN has performed a budgetary impact assessment and the Endurance Array ISSM design appears to be more costly than the Shallow Water Mooring. This is due to:

- Greater number of instruments, increasing procurement and refurbishment costs
- Larger, more costly MFN.

In addition, Innovations Lab input clearly indicated the desire for vertically-resolved near-surface measurements that could not be provided by the Endurance Array ISSM design. CGSN believes the Shallow Water Mooring design with a profiling body could measure the upper 80% of the water column, while the multi-function node provides some near seabed instrumentation. Co-locating one of the Surface moorings, as discussed in Section 10.0, with a Shallow Water Mooring would also meet the science measurement recommendations. The Endurance Array ISSM alone would not be able to provide the same water column resolution.

All mooring types were presented to the Focus Group in September 2022. Selection of the final Shallow Water Mooring design is pending a Request For Information (RFI) process currently underway with vendors. Final technical details and budgetary impacts will be assessed in Q1 2023 and a design review process specific to the shallow mooring will be implemented. A test deployment is scheduled for calendar Q3 2023.

12.0 Instrument Selection

Over 40 different instruments, measurements, or measurement concepts were identified from the input of the Innovations Lab #2 participants. Seven measurement concepts were mentioned by all four of the breakout groups:

1. CTD measurements near the surface, focusing on the upper 25 m that is unresolved by the Coastal Profiler Moorings and only sparsely sampled by the Coastal Surface Moorings,
2. Phytoplankton imaging near the surface, in the upper 10 m,
3. Passive acoustics, from a combination of marine mammal listening hydrophones and fish/mammal tag receivers,
4. Turbidity measurements in the water column,
5. Turbidity measurements in the Bottom Boundary Layer,
6. Turbulent velocity and/or velocity profiles in the Bottom Boundary Layer,
7. Methane measurements near the shelfbreak.

An additional five measurement concepts were endorsed by three of the four groups:

1. Velocity profiles near the surface,
2. Nitrate measurements on gliders,
3. Additional CTD measurements in the water column, particularly on Shallow Water Moorings,
4. Multibeam bathymetry and/or sub-bottom profiling from AUVs,
5. Particulate measurements in the Bottom Boundary Layer.

Thirty other concepts were mentioned by just one or two groups, and had features that would make them difficult to implement (e.g. not commercially available, complex and/or expensive) or difficult to justify (e.g. not well aligned with the MAB regional science themes). CGSN reviewed all of the instrument and measurement concepts, consolidating where possible, and focusing on the twelve that had multi-group consensus and relevance to the MAB science themes. Feasibility (e.g. cost, complexity, technical readiness) was also considered. The result was a tiered priority list (Table 4):

- Tier 1: Recommend for implementation as a new OOI core measurement
- Tier 2: Evaluate for potential implementation and/or accommodation when requested by an outside PI
- Tier 3: Eliminate, not a commercial-off-the-shelf instrument, low technical readiness, low relevance to science themes, or recommended by single group.

Table 4: Tiered Priority: Science Measurements

Tier 1	Tier 2	Tier 3
Phytoplankton imagery, species identification and particle counts **Turbidity (Tu)**, optical scattering **Near surface velocity (profile)**, near surface and near bottom mean current **Suspended particulates,** laser diffraction particle size & concentration	**Turbulent velocity**, high-freq 3D point velocity for turbulence **Methane,** detect methane seeps **Marine animal tags,** acoustic receiver for tagged animals (fish, sharks, turtles) **Passive acoustics,** detection/classification for marine mammals (whales) **Environmental Sampling**, in-situ sample analysis for microbes, algae, DNA **Turbidity and particulates on gliders** **POC/DOC/PIC/DIC**, particulate and dissolved organic carbon, inorganic carbon **Zooplankton imagery**, in-situ digital imagery of zooplankton **Phytoplankton primary productivity**, fluorescence-based sensor for ADP detection **Environmental DNA** (eDNA), DNA extraction from water samples	• Multibeam bathymetry/sub-bottom profiling • Sediment trap • Seismometer/OBS • Microstructure on gliders • Wet chemistry for nutrients (beyond nitrate) and other constituents • Surface met and flux on profiler moorings • Carbonate chemistry from DIC • Multibeam bathymetry in canyons • HF radar transmitter on buoys • Change all point velocity measurements to Aquadopp HR • LISST on WFP • Nitrate on WFP • pH on WFP • Radon for groundwater • LIDAR on surface buoy • FoSI (shadowgraph imaging) • bird tracking antenna on buoy • thermal imaging (whale blows) on buoy • methane on WFP

CGSN then performed a budgetary assessment of the procurement and refurbishment of the Tier 1 instruments. Based on the type and priority of measurement, the location of the measurement requested by the Innovations Lab #2 groups, and the cost impact assessment, CGSN recommended the instrument updates shown in Figure 20 through Figure 22. The phytoplankton imagery is proposed on a single surface mooring. This would be the Surface Mooring located in 30 m water depth co-located with a Shallow Water Mooring. All other instrumentation is planned for all moorings as noted in the figures.

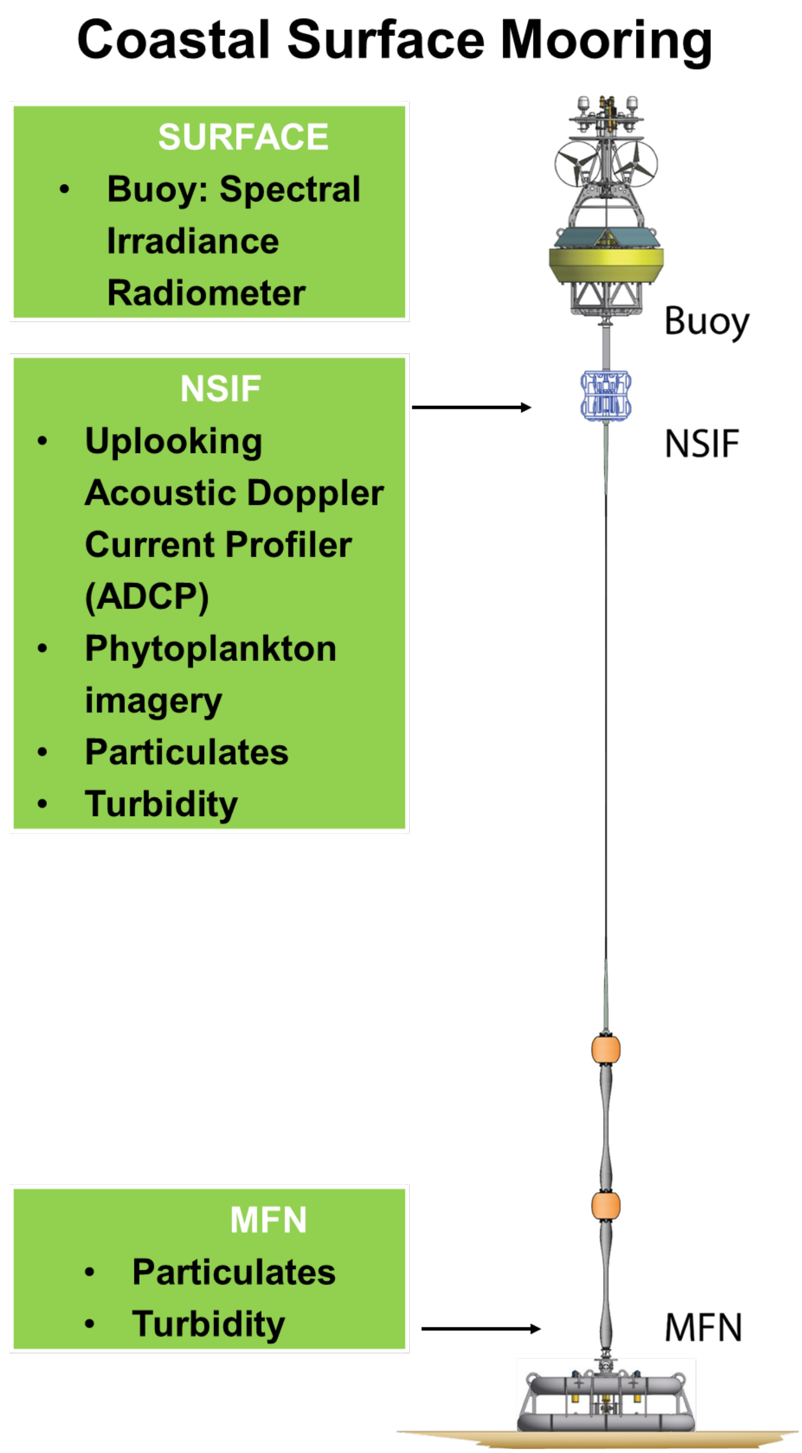

Figure 20: Additional Planned Instruments on Coastal Surface Mooring

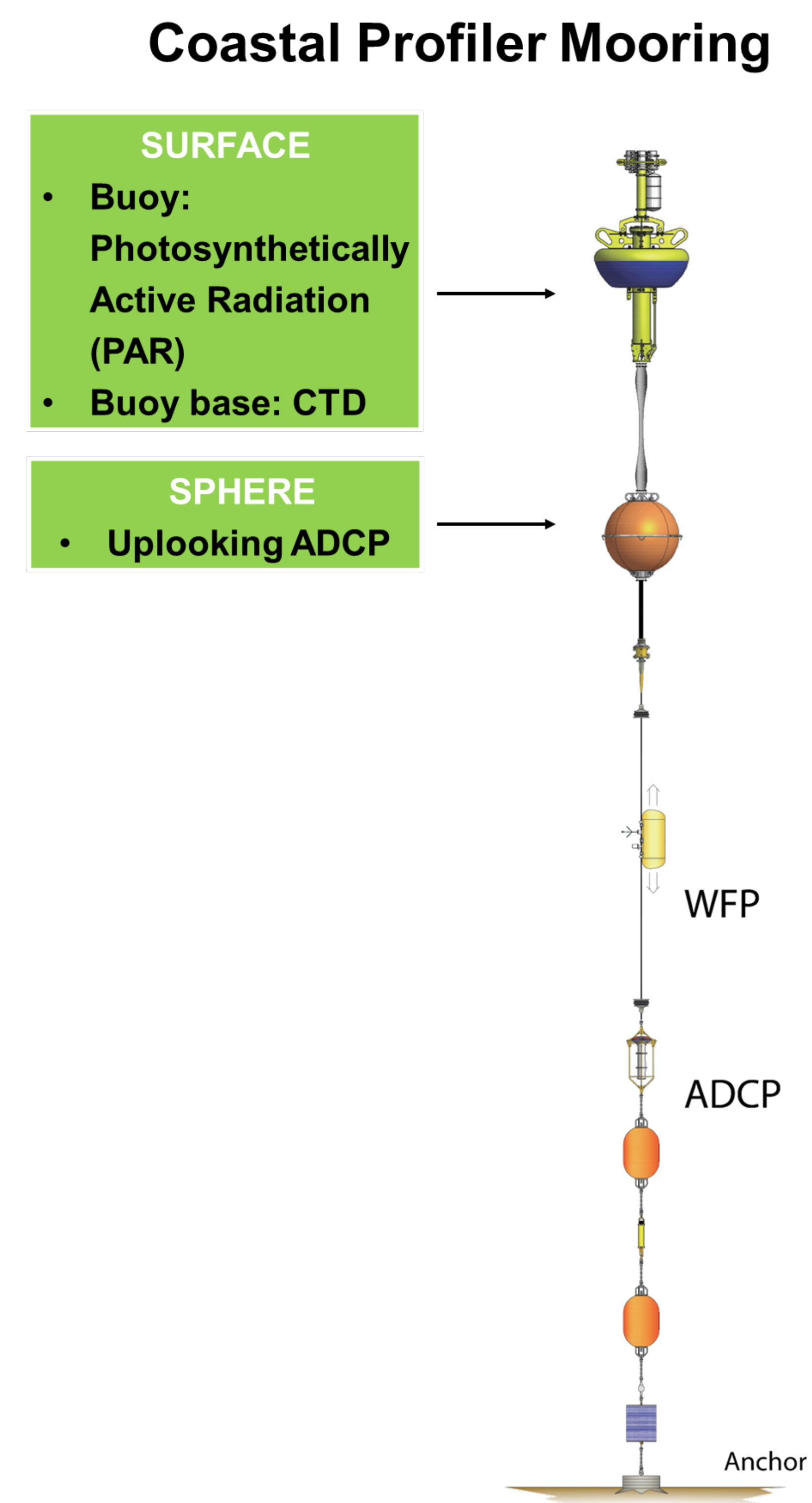

Figure 21: Additional Planned Instruments on Coastal Profiler Mooring

Shallow Water Mooring

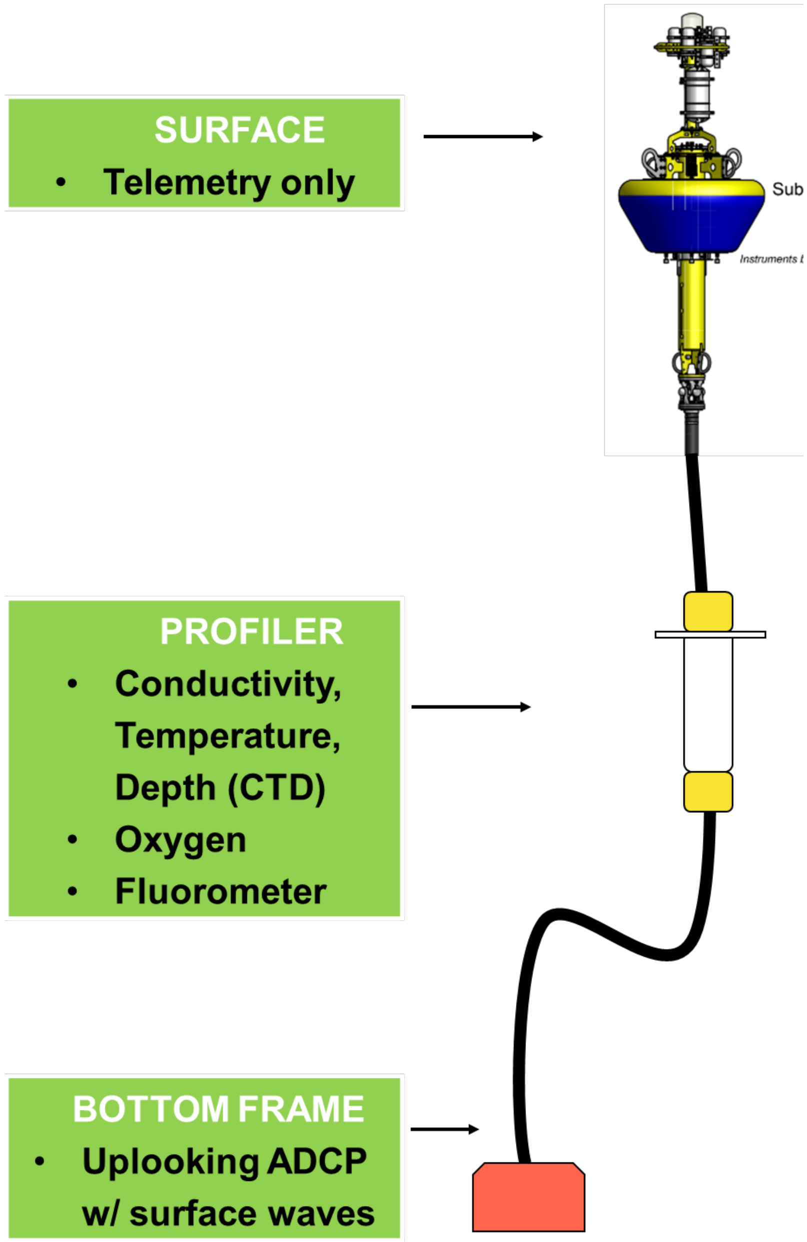

Figure 22: Instruments under Assessment for Shallow Mooring

Tier 1 measurements and instrument location plans were provided to the Focus Group for review in September 2022, no comments indicating significant alteration to the plan were received. Minor comments were incorporated into the planning process.

CGSN has implemented a RFI process to review instruments from multiple vendors, as well a comparison of existing instruments in OOI inventory for applicability. The RFI process will be completed and an assessment be undertaken in calendar Q1 of 2023. Test deployments of instruments will also be undertaken in Q1 2023 as part of the mooring test deployments at MAB.

13.0 Mobile Assets

During Innovations Lab #2, the groups were requested to review potential operating areas for mobile assets, as well as potential payloads. This applied to both gliders and autonomous undersea vehicles (AUVs).

The groups recommended the operational focus should be:

- Glider track lines and AUV missions designed to fill the spatial gaps between moorings
- Repeat glider and AUV transects oriented along-and across shelf
- Glider and AUV transects crossing the likely position of the shelf break front, ideally connecting the shelf and slope with a combination of shallow and deep gliders
- Glider and AUV sampling at Norfolk Canyon.

The groups also recommended that the measurements for mobile assets:

- Maintain current glider payloads
- Add nutrients to glider sampling
- Add methane, multibeam, sidescan, and sub-bottom to AUV payload.

CGSN reviewed the Innovations Lab #2 input and developed a preliminary Mobile Assets Plan (Table 5) which was presented to the Focus Group and subject matter experts in September and October 2022. This plan prioritized use of the existing gliders and AUV payloads to address the Innovations Lab priorities. Budgetary and operating constraints meant that no additional instrumentation would be included at this time.

Table 5: Mobile Assets Plan

Glider Plan	AUV Plan
• Retain current fleet level of 12 gliders • Deploy 4 gliders on 90-day intervals • Re-purpose existing profiling gliders on specific tracklines to provide nutrient measurements • Occupy 4 primary tracklines within the moored array providing across- and along-shelf measurements • Supplemental glider line from Norfolk Canyon to MAB could be occupied twice per year	• Maintain campaign mode operations with 2 x REMUS 600 AUVs • 4-6 missions per year • 1 x across-shelf box • 1 x along-shelf box • Boxes provide synoptic transects of the moored array and resolve the shelfbreak front

Table 6 and Table 7 lists the proposed glider and AUV lines as well as planned instruments and operational depths. Figure 23 and Figure 24 depict the geographical layout of the four proposed glider lines, and two proposed AUV lines.

Table 6: Glider Line Descriptions

Glider Line	Instruments	Operational Depths
Slope Sea Mesoscale	Conductivity, Temperature, Depth (CTD) Dissolved oxygen (DOSTA) Photosynthetically active radiation (PAR) Fluorometer (FLORT) Acoustic doppler current profile (ADCP)	100-1000 m
Slope Sea N-S	CTD, DOSTA, PAR, FLORT Nutrients (NUTNR)	1000 m isobath
Moored Array	CTD, DOSTA, PAR, FLORT, ADCP	30-100 m
Cross Shelf	CTD, DOSTA, PAR, FLORT, ADCP	30-100 m

The operational environment of the MAB is different from NES. CGSN is planning multiple test vehicle deployments in 2023 to assess:

1. Buoyancy engine and glider model effectiveness (shallower depths and sharper transition to deep areas, density changes due to freshwater outflow)
2. AUV operability, and
3. The impact of bio-fouling (warmer and shallower water).

Following field testing, the tracklines and glider payloads will be reviewed. Final trackline layout will be subject to review by the Focus Groups and a design review should design updates be required.

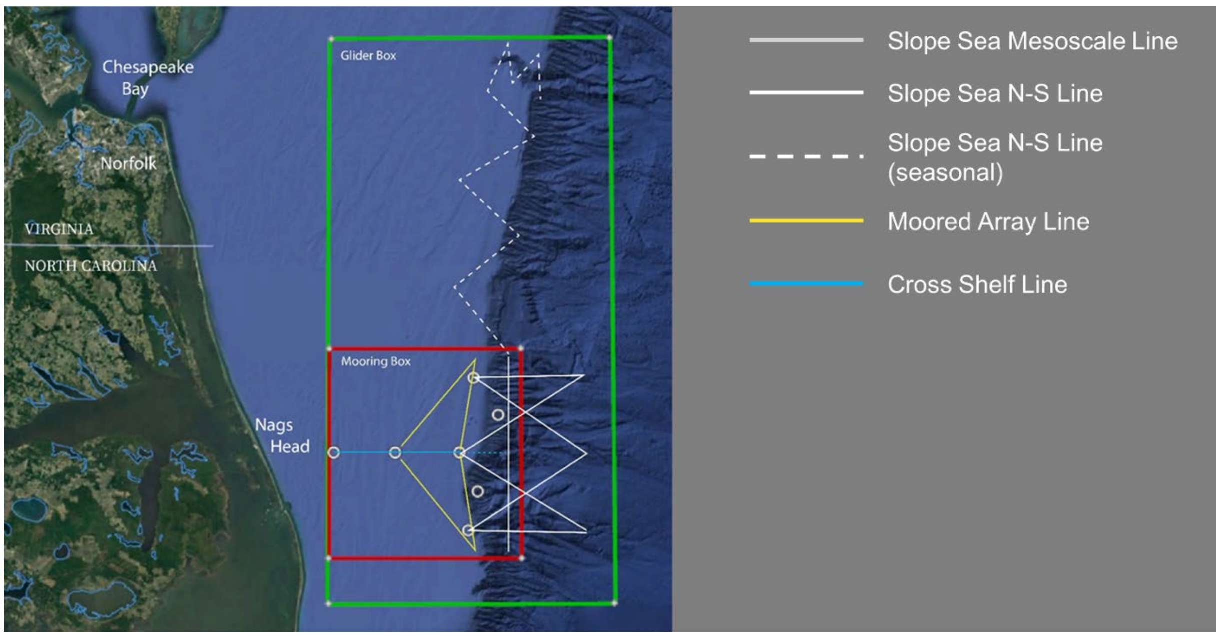

Figure 23: Proposed Glider Line Layout

Table 7: AUV Line Descriptions

AUV Line	Instruments	Operational Depths
AC-1 (across-shelf)	CTD, DOSTA, PAR, FLORT, NUTNR, ADCP	30-1000m
AL-1 (along-shelf)	CTD, DOSTA, PAR, FLORT, NUTNR, ADCP	30-100m

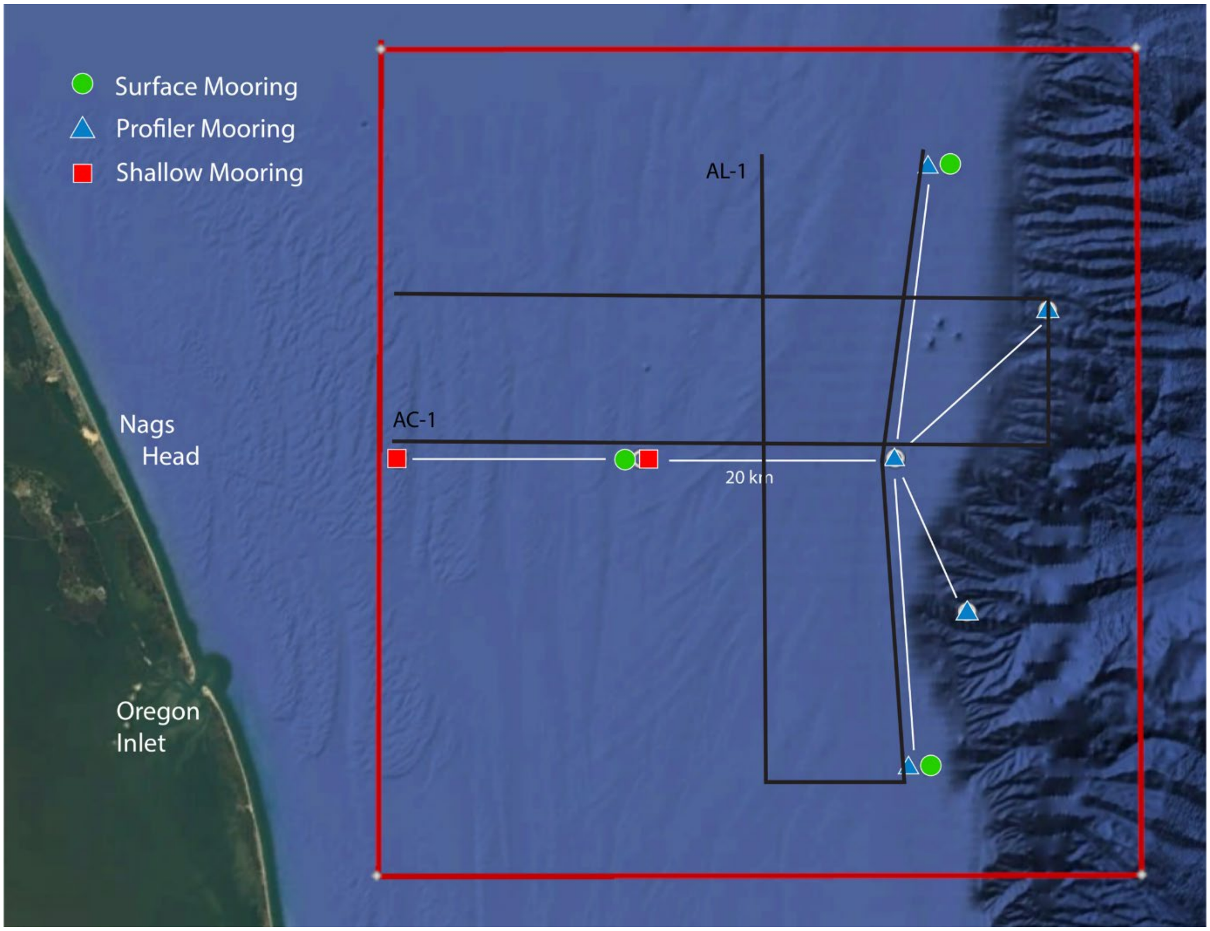

Figure 24: Proposed AUV Line Layout

14.0 Compliance with Themes

The Innovations Lab process resulted in a set of regionally-specific science themes that fit well within four of the six overarching OOI science themes (see Section 9.0). The consensus array design and mobile asset plan using existing Pioneer Array infrastructure is capable of addressing those themes.

However, the community input from the Innovations Lab, when overlaying the themes, indicated some measurement gaps within the CGSN infrastructure. Table 8 provides how CGSN plans to address these gaps based on a tiered prioritization of Innovations Lab input.

Table 8: Addressing Measurement Gaps

Measurement Gap	CGSN Infrastructure Update
Surface Radiation	• SPIKR on Surface Mooring towers • PAR on Profiler Mooring towers
Near surface water column gaps (temperature, salinity, velocity)	• Upward-looking ADCP on Surface Mooring NSIFs • CTD on Profiler Mooring buoy base • Upward-looking ADCP on Profiler Mooring 64" sphere
Turbidity	• Turbidity sensor on Surface Mooring NSIFs and MFNs
Suspended particulates	• Particulates sensor on Surface Mooring NSIFs and MFNs
Phytoplankton Imaging	• Phytoplankton imaging at shallow Surface Mooring location
Glider Nitrates	• Re-purpose profiling glilders to trackline duty (profiling glider payload includes NUTNR)

The Pioneer MAB location has specific features of interest addressed by the array layout and mobile asset plan. Table 9 shows the linkages between the MAB regional science themes and the CGSN infrastructure.

Table 9: Addressing MAB Specifics

MAB Regional Science Theme	CGSN Infrastructure Plan
Dynamics of shelf-slope exchange	Moorings are laid out as T-shape along and across shelf. Surface moorings are located at 30-100 m water depths and co-located with profiler or shallow moorings, further profiler moorings are located at 600 m water depth on shelf break, mobile assets fill gaps between moorings and provide repeat across- and along-shelf transects. Mooring spacing is ~20 km.
Biogeochemical cycling and transport	Existing instruments, some deployed at additional locations, and new instrumentation, increases ability of infrastructure to measure BGC properties.
Extreme events	Moorings are laid out to capture episodic events such as shelf intrusions, freshwater outflows, and hurricane events. New and relocated instruments improve the near-surface measurement capability. Modeling supports the proposed layout of the array to capture events.