Bigelow | Laboratory for Ocean Sciences

Dr. Beth N. Orcutt (she/her)
Senior Research Scientist
Bigelow Laboratory for Ocean Sciences

12 November 2020

RE: Public Comment on Exploration Priorities for the National Strategy - NOMEC

Dear NOMEC Council Co-Chairs Dr. Alan Leonardi (NOAA), RDML Shepard Smith (NOAA), and Dr. John Haines (USGS),

Thank you for inviting public comment on Exploration Priorities for the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone ("NOMEC"). As a marine scientist with over a decade of experience mapping, exploring and characterizing the deep sea, I humbly submit these comments for your consideration, guided by the questions proposed in Federal Register Document 85 FR 64448. These comments build on input I provided as a participant in the recent Workshop to Identify National Ocean Exploration Priorities in the Pacific ("Pacific Priorities Workshop") coordinated by the Consortium for Ocean Leadership in partnership with the NOAA Office of Ocean Exploration and Research. As such, and considering that the Pacific region is the least mapped area of the US EEZ, my comments are geared toward implementation in the Pacific region, and with a focus on deep-water (>200 m) environments where mineral resources are generally found. I am submitting these comments as an individual scientific citizen not representing any particular organization, although I hope that they reflect the missions of scientific networks I am a member of, such as the Deep Submergence Science Committee (DeSSC) of the UNOLS program, the Deep Ocean Stewardship Initiative (DOSI), and the International Scientific Council Scientific Committee on Oceanographic Research Working Group 159 (SCOR-DeepSeaDecade).

1. NOMEC Strategy Goal 3.1 "Identify Strategic Priorities" describes the need for strategic ocean exploration and characterization priorities and lists some examples. What do you feel are the most important strategic national priorities for exploration and characterization efforts in the deep sea (depth >40 m)? These can be specific geographic areas within the U.S. EEZ or thematic/topical issue priorities.

I think that characterization of ecosystems and resources in US EEZ areas predicted to have high critical mineral content should be the priority for NOMEC in the coming decade. There is growing industry interest in this extractive activity, so it is imperative that we understand the potential mineral resource as well as the ecosystems in which they exist. As outlined in the Pacific Priorities Workshop[1], these areas are primarily located in regions of the Central and North Pacific Ocean, surrounding inhabited islands such as Hawai`i and the Northern Hawaiian

[1] https://oceanleadership.org/wp-content/uploads/2020/11/OceanExploration_PacificPriorities_WorkshopReport_NOV2020.pdf

Islands, Guam, American Samoa, the Northern Mariana Islands, and the Marshall Islands, as well as non-inhabited island areas such as Wake and Jarvis Island. These regions are predicted to have critical minerals on as ferromanganese crusts that form on older seamounts and/or on abyss plains with polymetallic nodules. I agree with the sentiment of the Pacific Priorities Workshop that "Given the large extent of the Pacific, exploration will need to focus on more fully characterizing a few representative sites well, and then extrapolating data onto similar features across the broader region using predictive habitat models." These could be considered "flagship" initiatives.

2. What are the most important questions for exploration and characterization to address?

What is the diversity of benthic and pelagic life in the regions with mineral resources, from the microscopic scale to megafauna? What are the services that life provides in these ecosystems? How sensitive and resilient are biodiversity and ecosystem services to potential mining impacts? What is the mineral content of resources in these regions?

3. What are the most important data variables that need to be measured, and what are the most valuable physical samples to collect; to conduct baseline exploration and characterization?

Sensor data for baseline characterization: bathymetry, seafloor backscatter, temperature, dissolved oxygen, current direction and speed, turbidity

Samples: rock and sediment core samples for both biological and geological characterization; representative meio-, macro- and mega-fauna biological specimens; bottom seawater samples for baseline chemical and biological assessment

4. What novel or established tools, platforms, and technologies could advance our capability to explore, and characterize the U.S. EEZ more efficiently and effectively? To the extent innovative capabilities already exist, but are not being effectively used, what are the barriers to adopting them? How can these barriers be overcome?

One of the biggest challenges in understanding deep-sea ecosystems is cataloging the diversity of life. Machine learning and artificial intelligence strategies are beginning to be employed to make identifications of marine species from video footage, although this approach is not widely adopted and still requires significant investment in expertly-curated training sets for making determinations. Accelerating this technological approach could be of great benefit to efficiently catologuing the easily visible diversity of life on the seafloor, and also in the water column. However, considering the novelty of many deep-sea ecosystems, these approaches may only be accurate to the Order, Family, and Genus level, but maybe not to the Species level. Furthermore, physical sampling will still be necessary for categorizing meiofauna and microscopic life in these systems, which can contain more biomass than the easily visible life.

An equally important challenge is measuring rates of ecosystem services in the deep-sea, such as primary production, nutrient recycling, habitat formation processes like precipitation of carbonate, and larval recruitment. There are generally two approaches used: collecting samples and measuring processes shipboard or in a shore-based laboratory, or trying to conduct experiments on the seafloor under in situ conditions (for example, by deploying a benthic lander equipped with experimental devices). The benefit of the former is the possibility to do more measurements with more control, but with the negative impact of removing in situ conditions like high pressure. The benefit of the later is retaining in situ conditions, but being limited in replication and requiring technical expertise to conduct the experiments. Both approaches should be used in "flagship" initiatives to characterize a few sites as well as possible to enable viable extrapolation to uncharacterized sites.

5. Deep waters within the U.S. EEZ host a wide variety of habitats and geomorphological features (*e.g.*, continental shelves, canyons, seamounts, trenches, abyssal plains, and mesopelagic and bathypelagic zones of the water column). Which ones of these do you think are most important to explore to address the priority questions you identified above?

Given the bias of my response towards Pacific deep-sea ecosystems, I think priority areas include seamounts and abyssal plain regions with polymetallic nodules.

6. How can artificial intelligence and machine learning be used to guide planning, execution, and analysis of exploration and characterization activities?

Please see my response to question #4.

7. How should the data generated by implementation of the Strategy be managed so that it is most accessible and useful (file formats, compatibility, etc.) to public and private sectors?

NOAA's NCEI is already a great model for aggregating existing data types such as bathymetric data, the USGS Marine Mineral database, and biological specimen collection information. Not yet included are linkages to ecosystem service process studies. Currently, these mostly exist in other databases like BCO-DMO or Pangaea as bespoke entries that are not necessarily geographically linked in a searchable context.

Sincerely,

Beth Orcutt

Public Comment on Exploration Priorities for the Implementation Plan

IOOS Association
Josie Quintrell, Director

NOMEC Strategy Goal 3.1 "Identify Strategic Priorities" describes the need for strategic ocean exploration and characterization priorities and lists some examples. What do you feel are the most important strategic national priorities for exploration and characterization efforts in the deep sea (depth >40 m)? These can be specific geographic areas within the U.S. EEZ or thematic/topical issue priorities.

1. What are the most important questions for exploration and characterization to address?

In addition to mapping and exploring the EEZ, it will be valuable to characterize and understand the water column and the life it supports. Understanding the dynamic and changing nature of the ocean, how the changes impact the biogeochemical, biology, biodiversity and ecosystems of the oceans and Great Lakes will be critical for understanding and managing ocean resources in the coming decade. Important questions include:

- How can US food security be strengthened by tracking hydrographic conditions in support of commercial and subsistence fisheries, and aquaculture?
- How can protecting public health be improved by tracking conditions that lead to harmful algal blooms and the toxins that pose a threat to human health?
- How can development of offshore energy be conducted safely, efficiently and with minimal damage to the environment?
- How can coastal resiliency be improved by observing and predicting changes to habitats, coastal stability and the protection from extreme weather and sea level rise?

3. What are the most important data variables that need to be measured, and what are the most valuable physical samples to collect; to conduct baseline exploration and characterization?

As noted above, biology, biogeochemistry, and biodiversity will be an essential component of a characterization of the ocean, including the benthos and the water column. The tools and technologies exist, and promising new tools will soon be available for monitoring and detecting these parameters.

5. Deep waters within the U.S. EEZ host a wide variety of habitats and geomorphological features (*e.g.,* continental shelves, canyons, seamounts, trenches, abyssal plains, and

mesopelagic and bathypelagic zones of the water column). Which ones of these do you think are most important to explore to address the priority questions you identified above?

In recent years, scientists have discovered dozens of new deep ocean features and habitats, yet there remain significant gaps in our understanding of deep sea biodiversity and whether and how deep ocean habitats support life. It is critical that we establish routine observations of deep sea conditions and living marine resources to ensure that our ocean activities from the coasts to the abyss are sustainable and do not cause irreparable harm.

6. How can artificial intelligence and machine learning be used to guide planning, execution, and analysis of exploration and characterization activities?

Artificial intelligence (IA) and machine learning will be important to process the large and rich data sets that will be collected. Many of the IOOS Regional Association (RAs) are working with their research and industry partners on emerging technologies such as artificial intelligence, machine learning, sensor miniaturization, autonomous sensors and platforms, and acoustics. This includes developing data management techniques to handle the large data sets. Work is currently underway to apply machine learning tools in an operational setting for harmful algal blooms, which can be applied to non-harmful phytoplankton species as well.

7. How should the data generated by implementation of the Strategy be managed so that it is most accessible and useful (file formats, compatibility, etc.) to public and private sectors?

The implementation plan should include the use of ship surveys, gliders, moorings, and satellite approaches as a priority to advance national habitat delineation, characterization, and mapping efforts in the US EEZ. Further, the NOAA IOOS Program and associated Regional Associations provide an established avenue to advance the marine Science and Technology priorities, particularly those in concert with the private sector. This system is already being leveraged for mapping the Artic and in the Lakebed 2030 Initiative and can be further leveraged to assist with this larger effort.

As a distributed system, IOOS links the interests of 17 federal agencies with 11 regional observing systems into a single, integrated system. The RAs can be viewed as collective impact organizations that bring together consortia of research institutions, management agencies, industry members, non-profit organizations and the general public to identify needs for data and information to support societal needs. IOOS integrates data from a variety of disparate sources, applies standards for quality assurance and makes them available in accessible formats for users. The IOOS process could serve as a model for this effort. The RAs support data portals that integrate data from multiple platforms and providers from around the nation, creating easy access to data for assimilation into models. Each of the 11 IOOS Regional Associations are certified by NOAA as Regional Information Coordination Entities (RICE), meaning they meet strict federal standards for data quality, data accessibility, archiving and data dissemination.

IOOS can bring together the public and private entities needed to successfully implement the goals of mapping, exploring and characterization by leveraging public/private partnerships.

nomec execsec - NOAA Service Account <nomec.execsec@noaa.gov>

Public Comment on Exploration Priorities for the Implementation Plan

1 message

Peter Auster <>
To: "nomec.execsec@noaa.gov" <nomec.execsec@noaa.gov>

Thu, Nov 12, 2020 at 3:32 PM

SUBJECT: Request for Information - Implementation Plan for the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone (FR Doc. 2020–22413).

To Whom It May Concern:

Thank you for the opportunity to respond to your request for information. Here I provide, for your consideration, priority needs for mapping and exploration in response to questions 1-3 in the subject Federal Register Notice. This response is in large part driven by continued policy and management conflicts related to multiple human uses of the waters off the east coast of the United States. Conservation and sustainable use of our natural resources requires policy and management approaches to address the needs of multiple stakeholders (e.g., commercial and recreational fisheries, offshore wind development, exploration for oil and gas, sand and gravel mining, biodiversity conservation, conservation of protected species). There are multiple arenas where these issues are addressed but foundational to any discussion is knowledge of the landscape in which resources are distributed. My experience has been that high-resolution map products (bathymetry, topography, backscatter, habitat classification or related proxies) greatly facilitate the discussion, assessment of the trade-offs, development of alternatives, and evaluating decisions. Use of lower resolution products engender more conflict and uncertainty when stakeholder data (e.g., resource species distributions) are mis-matched in spatial scale.

Here I list priority areas, from north to south along the US Atlantic EEZ, based on the need for map products to aid in diverse management and policy issues:

- northern Gulf of Maine sites in and around deep-sea coral zones (connecting Schoodic Ridge, Mount Desert Rock, western Jordan Basin) and designated habitat management areas (HMAs) designated by the New England Fisheries Management Council and NOAA Fisheries,

- Cashes Ledge Complex in the central Gulf of Maine, inclusive of Sigsbee Ridge, Fippennies Ledge and Cashes Basin,

- area along the US-Canada boundary in the Gulf of Maine to northern Georges Bank including Lidenkohl Knoll,

- the Northeast Peak, Northern Edge, and Cultivator Shoals areas of Georges Bank,

- Nantucket Shoals and Great South Channel region (inclusive of the NOAA Fisheries HMA),

- wind energy areas south of Cape Cod, Block Island, Long Island and Virginia,

- shallow canyon head regions from Nygren Canyon at the US-Canada boundary south (these were not surveyed during earlier continental margin mapping due to depth limitations of survey systems),

- shallow canyon heads of Oceanographer, Gilbert, and Lydonia Canyons and the unmapped areas between seamounts in the Northeast Canyons and Seamounts Marine National Monument,

- live-bottom areas off Maryland, and

- inshore to continental margin regions inclusive of Gray's Reef National Marine Sanctuary.

Map products from these areas would address needs for fisheries policy and management (defining essential fish habitat and habitat areas of particular concern, habitat monitoring); wind area development, research, and monitoring; management and protection of MPAs including those designated by NOAA Fisheries, National Marine Sanctuaries, and Marine National Monuments; environmental evaluations for non-renewable resources, and would facilitate exploration and scientific research (both basic and applied).

Here I have described general areas as priorities but would be interested in future discussions to better delineate survey areas when details of survey technologies, vessels, and effort (budget) are available. Thank you, in advance, for your consideration.

Sincerely,

Appendix A - Federal Register Requests for Information responses

Peter J. Auster

MBARI Response to the NOMEC RFIs - Exploration and Characterization Priorities

This response from the Monterey Bay Aquarium Research Institute (MBARI) included inputs from HA Ruhl, JP Barry, CK Paull and DW Caress.

N.B. Responses to the initial Strategy for Mapping RFI in spring 2020 include relevant feedback and are at the bottom of this document:

- **Geohazards in the Pacfic Northwest: CA Scholin and CK Paull**
- **Biological and Ecosystem Perspectives: HA Ruhl, LA Levin, P Heimbach, KS Van Houtan and JP Barry**

1. NOMEC Strategy Goal 3.1 "Identify Strategic Priorities" describes the need for strategic ocean exploration and characterization priorities and lists some examples. What do you feel are the most important strategic national priorities for exploration and characterization efforts in the deep sea (depth >40 m)? These can be specific geographic areas within the U.S. EEZ or thematic/topical issue priorities.

Natural resource management requires a broad array of information, for both living and non-living resources. Examples come from the CA Marine Protected Area program, the California Current - Integrated Ecosystem Assessments (IEAs), Condition Reports (CRs) of the Office of National Marine Sanctuaries (ONMS). Similarly from the Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS, https://on.doi.gov/2w5BDLg) is achieving the linkage of many threads of partnership and data gathering to address the growth of wind energy in deep water offshore. Baseline and impact assessment in relation to industrial activities will almost always rely both on water column and seafloor information. Integrative and modelling approaches now regularly facilitate producing such information as maps. And many regulations apply to attributes of physical, biogeochemical, biological and ecosystem related variables where maps are very effective towards policy and decision making. Examples in the central and northern California region include:

Federal legislation:

- Integrated Coastal Ocean Observing System Act
- Magnuson-Stevens Act
- Marine Mammal Protection Act
- National Ocean Policy
- Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)
- National Environmental Policy Act (NEPA)
- Endangered Species Act (ESA)

State legislation:

- California Ocean Protection Act
- California Coastal Act
- Marine Life Protection Act and the Marine Life Management Act

- California Environmental Quality Act (CEQA)

An example of where these concepts are rapidly evolving is with the recognition that deep seafloor mining activities, which include seafloor modification and release of some form of produced water and suspended materials at one or more depths, will require both seafloor and water column (Clark et al. 2020, Drazen et al. 2020, Jones et al. 2020).

2. What are the most important questions for exploration and characterization to address?

A fundamental question linked to establishing a baseline and impact assessment from industrial activity is; *What is the abundance, function and distribution of seafloor and water column life*? Key ancillary questions focus on the response of ecological communities to human (e.g., industrial, extractive, climate change) and natural drivers , over short to long time scales This information is beneficial for both industry and management actors towards creating a transparent framework where values can be assessed from commercial to societal (e.g. Ardron et al. 2018). Additional integrative questions/concepts can be found in the DOOS Science and Implementation Plan (Levin et al. 2019a) and related research paper (Levin et al. 2019b).

3. What are the most important data variables that need to be measured, and what are the most valuable physical samples to collect; to conduct baseline exploration and characterization?

Ruhl et al. are working in the GOOS BioEco Panel context to document and share best practices towards integrating biology observations from multiple sources to produce gridded model outputs, some of which is detailed in the previous RFI response re: biology and ecosystem perspectives. Elemental to this is identifying the size(biomass) and identity(type) of organisms, where the parts of the size spectra that are well quantified can be determined, which then enables integrating and jointly analyzing data.

4. What novel or established tools, platforms, and technologies could advance our capability to explore, and characterize the U.S. EEZ more efficiently and effectively? To the extent innovative capabilities already exist, but are not being effectively used, what are the barriers to adopting them? How can these barriers be overcome?

5. Deep waters within the U.S. EEZ host a wide variety of habitats and geomorphological features (*e.g.,* continental shelves, canyons, seamounts, trenches, abyssal plains, and

mesopelagic and bathypelagic zones of the water column). Which ones of these do you think are most important to explore to address the priority questions you identified above?

One of the challenges with producing high quality integrated biology and ecosystem maps is having sufficient information across a wide variety of seafloor habitat gradients. Therefore, a systematic approach and gap analysis can inform where to focus surveying and sampling to produce maps with reliable and consistent information across these habitat types.

Key environments that are perhaps the least known in the U.S. EEZ include canyons, seamounts, abyssal plains, and particularly the epi- to mesopelagic zones that encompass the majority of the diel vertical migration assemblage.

6. How can artificial intelligence and machine learning be used to guide planning, execution, and analysis of exploration and characterization activities?

As noted previously in the Biology and Ecosystems perspectives response, AI and machine learning will be very valuable in processing acoustic, optical and genomic data. MBARI is working with MITs Media Lab and others on *FathomNet*, a publicly available database that makes use of existing (and future), expertly curated data from a number of sources, including MBARI's Video Annotation and Reference System (VARS). IOOS and others are now transitioning machine learning tools from research to operations, including processing plankton images in real time to identify species abundance and community composition, in cooperation with UCSD, WHOI, MBARI, and Axiom Data Science. This involves clarifying ways to create, share, evolve, version control and run machine learning tools.

7. How should the data generated by implementation of the Strategy be managed so that it is most accessible and useful (file formats, compatibility, etc.) to public and private sectors?

A system that can accomodate inputs from a variety of sources has proved valuable in IOOS. This requires communicating whatever standards are being applied to the providers. And some resource on integration and assisting data providers in such processes is inevitably needed. However, the benefit outweighs the cost when the overall pool of data is much larger. IOOS, MBON and OBIS can provide inputs for biology and ecosystem observing (e.g. Muller-Karger et al. 2018, e.g. OBIS-ENV-DATA standards)

References

Ardron, JA, HA Ruhl, DOB Jones, 2018. Incorporating transparency into the governance of deep-seabed mining in the Area beyond national jurisdiction. Marine Policy 89: 58-66. https://doi.org/10.1016/j.marpol.2017.11.021

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Drazen JC, et al. 2020. Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining. Proceedings of the National Academy of Sciences, USA 117 (30) 17455-17460, https://doi.org/10.1073/pnas.2011914117.

Jones, Daniel O.B.; Ardron, Jeff A.; Colaço, Ana; Durden, Jennifer M. 2020 Environmental considerations for impact and preservation reference zones for deep-sea polymetallic nodule mining. Marine Policy, 118, 103312. https://doi.org/10.1016/j.marpol.2018.10.025.

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Levin, LA, et al. 2019b. Global Observing Needs in the Deep Ocean. Frontiers in Marine Science 6:241. doi: 10.3389/fmars.2019.00241.

Muller-Karger, F.E. et al. 2018. Advancing Marine Biological Observations and Data Requirements of the Complementary Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) Frameworks. Front. Mar. Sci., 27, https://doi.org/10.3389/fmars.2018.00211.

Geohazards in the Pacfic Northwest: Chris Scholin and Charlie Paull

MBARI is a non-profit research institute dedicated to developing new tools, platforms, and techniques to study the ocean. MBARI operates Autonomous Underwater Vehicles (AUV) and Remotely Operated Vehicles (ROV) to investigate deep-water areas of special significance. MBARI's assets are commonly used in applications focused on addressing societally relevant issues and these applications are frequently conducted in collaboration with other research institutions and governmental agencies (i.e., NOAA, USGS, & BOEM), which have limited access to such deep-water survey tools.

As strategies for future mapping efforts are developed, priority should be given to areas of high economic importance and geohazard potential. Large areas of the EEZ in the Pacific remain unmapped by multibeam survey systems. However, within the areas for which multibeam mapping datasets exist, the resolution and inherent data quality vary widely. Some existing maps in areas of high interest are of very low quality and are of marginal utility for the evaluation of natural resources or geohazard risk. Consequently, it would be extremely important to consider remapping some of these areas to optimize map resolution which is necessary to characterize the economic or geohazard potential.

For waters depths below 1500 meters, the resolution and quality of the existing datasets, especially along the U.S. west coast margin, from California to Washington, are highly variable. Some old datasets were collected with the best resolution available at the time, but there have been considerable improvements in the resolution of multibeam sonar technology over the last few decades. Moreover, early multibeam systems did not collect backscatter and water column data which are now viewed as essential for many applications. These improvements render selected maps obsolete for modern research involving habitat mapping, resource evaluation, and geohazard assessment. Currently, the utility of these old datasets is restricted to providing a very general background of a region but fall short of providing the detail necessary to serving as roadmaps for follow-on surveys. In addition, a lack of consistency in the manner in which old datasets were collected makes use of these old datasets problematic. Existing deep-water grids have been assembled over decades from individual swaths collected from various ships while transiting using different generations of sonars. Transit data are characteristically collected at sub-optimal speeds and commonly lack adequate sound velocity calibration data for accurate bathymetry determinations. The result is that the quality of the mapping data covering some areas of special scientific and societal interest is low by present standards and thus of limited utility.

An example of a deep-water area where there is an urgent need to obtain the highest quality data, but where the existing bathymetric data are of problematically poor quality, is along the Cascadia Subduction Zone between 1.5 and 4 km water depths. This area contains the junction between the North American and Juan de Fuca tectonic plates. Here, the deformation associated with plate boundary thrust faults approach the seafloor. Ruptures along this front are a mechanism to produce earthquakes and tsunamis like the one associated with the Mw 9.0 2011 Tohoku-Oki earthquake in Japan, which devastated the surrounding coastal areas, and even caused damage along the western coast of the US. Research over the last two decades shows that earthquakes and associated tsunamis of a similar magnitude have occurred multiple times along the entire Cascadia coast. The last such event occurred on January 1700 when a Cascadia earthquake caused a tsunami which both inundated the Northwest Pacific coast and also propagated across the Pacific to cause considerable loss of life in Japan.

Lessons learned from the Tohoku-Oki event show that the most important data for determining earthquake deformation come from systematically collected multibeam data prior to and after the event. Currently, mapping data of adequate quality to precisely define the bathymetry along the frontal thrust of the Cascadia subduction zone in the area most likely to rupture does not exist. Moreover, the low quality of the existing bathymetric maps along this tectonic interface is also a significant impediment for the effective use of robotic high-resolution surface and sub-surface mapping tools. Such tools play key roles for determining the frequency of fault deformation, as well as earthquake triggered submarine sediment flows and landslides. A detailed understanding of these frequencies is critical for determining the probability of when the next mega earthquake event will occur. The tools needed to acquire that knowledge (autonomous underwater vehicles optimized for seafloor mapping) are wholly reliant on base maps with a resolution higher than what exists today.

High-resolution base maps are required for guiding mission planning to undertake detailed, targeted seafloor surveys to promote understanding of geohazards and deep-water natural resources in the EEZ. Systematic remapping of this area with the state-of-the-art deep-water sonar systems NOAA has in place today should be a national priority, so that conditions before the next great earthquake occurs are appropriately documented.

Biological and Ecosystem Perspectives: Henry Ruhl, James Barry et al.

Ocean biology and ecosystem data are critical to support a Blue Economy that is sustainable into the future (e.g. Bax et al. 2019, Levin et al. 2019). Needs for mapping data include navigation, understanding and mitigating geo-hazards, characterizing habitats, managing and stewardship of natural resources and supporting the fishery, energy and mineral resource industries. Here we focus on issues of characterizing habitats and managing and stewardship of natural resources.

Biology and ecosystem variables encompass key information related to a sustainable Blue Economy, but such data are also still challenging to measure and use. Many initiatives have recognized this and are working to overcome these issues including the Organisation for Economic Co-operation and Development (OECD, https://www.oecd.org/ocean/), the Global Ocean Observing System (GOOS, https://www.goosocean.org/eov), and its related initiative the Deep Ocean Observing Strategy (DOOS, https://deepoceanobserving.org/), as well as the Group on Earth Observations – Biodiversity Observation Network (GEO – BON, https://geobon.org/) and its US affiliate, the Marine Biodiversity Observing Network (MBON, https://ioos.noaa.gov/project/bio-data/). Indeed, advanced approaches in bioacoustics, photography, genetics and artificial intelligence have started to scale into relatively operational settings such as the Integrated Ocean Observing System (IOOS, the US Regional Alliance of GOOS, https://ioos.noaa.gov), and figure prominently in NOAA's strategies for applying emerging science and technology (https://bit.ly/38IhVTb) to advance agency priorities.

We suggest that the developing EEZ mapping Strategy include consideration of biology and ecosystem variables through a structure that allows existing, and newly collected observations to bridge understanding from relatively small areas of the EEZ where we have direct data/samples, to management scales of the EEZ, National Marine Sanctuaries, energy lease areas and similar management spaces. This necessarily includes field observations that can then form and parameterize model tools that can take information from limited survey areas to broader management zones and the overall EEZ. All the pieces to build dynamic seafloor macro-ecological indicator maps exist now and can be refined with new observations and information over time. Coordinating base map refinements as noted here will create a framework for stimulating partnerships among academic, non-profit, industry and government entities, precisely in-line with the priorities drawn from November 2019 White House Summit on ocean science and technology (https://bit.ly/38IhVTb).

1. Given the tools, platforms, and technologies of which you are aware, what is the most effective approach for mapping the remaining unmapped portions of the U.S. EEZ? How should areas be prioritized for mapping?

Mapping in the ocean is often equated to acoustically measured bathymetric variables. However, just as with mapping on land, there is a large number of important variables to consider as has become evident with high-resolution color satellite imagery and multitudes of land-based georeferenced data on society and the natural environment. Multibeam acoustic systems are naturally the best, highest priority tool for wide coverage on bathymetric mapping and others will be commenting on the best sensors and platforms for this. Side-scan sonar also forms the key tool for understanding the approximate composition and hardness of the seafloor substrate.

High-resolution photographic mapping has undergone a revolution in the last decade where continuous areas of 50 ha or more can be mapped in 3D in a single day (https://bbc.in/38NXhkw, Thornton et al. 2016). Advances in navigation, photogrammetry, camera sensor sensitivity and platform endurance have enabled this, in part (e.g. Durden et al. 2016, Morris et al. 2016). Data processing rates now mean that a survey of >100,000 seafloor pictures can be readily stitched together, on the scale of days, to form photographic image maps similar to what is visible in Google Earth on land. Moreover, machine learning and computer vision tools are now able to discern and classify seafloor life in an automated way such that we can process large volumes of information much more efficiently than even a year ago with known error rates. This can lead to streamlined estimates of the size, type and biodiversity of observed individuals on the seafloor over landscape scales. Photography can also validate habitat mapping from acoustics, visualize sub-sea infrastructure such as cables and pipelines, marine litter, and naturally occurring leakage of methane or oil. Such wide-area camera systems are in the commercialization process making the technology more accessible and scalable. Advances in digital hydrophones and acoustic data stream processing have similarly advanced with soundscapes revealing wide variations in space and time from marine mammals, to plankton migrations and anthropogenic noise.

2. What innovative tools, platforms, and technologies could advance our capability to map, explore, and characterize the U.S. EEZ more efficiently and effectively? To the extent innovative capabilities already exist, but are not being effectively used, what are the barriers to adopting them? How can these barriers be overcome?

It will be generally worthwhile to quantify scenarios involving novel approaches such as renewable powered unmanned surface vehicles (USVs), possibly even carrying small acoustic tow bodies. For biology and ecosystem applications, it will be constructive to also evaluate how underwater gliders and long-range and long-endurance autonomous underwater vehicles (AUVs) can contribute to this effort. This can come in the form of both water column and seafloor focused surveying. Remotely operated vehicles also offer a platform that can cover terrain that is more challenging for autonomous systems to navigate, such as canyons.

Advances in metagenomics, metabolomics, proteomics, etc. (“omics”), offer opportunities to map the microbial (and small animal) realms with a goal of understanding ecosystem function and services as well as biodiversity. Genetic sensing *in situ* is now possible through systems such as the Environmental Sample Processor (https://bit.ly/2TYIoHP, Yamahara et al. 2019). This system has been integrated into a long-range, long-endurance platform and can process samples *in situ* for eDNA, specific compounds and report data back to shore. eDNA technologies and interpretability are advancing rapidly while costs are decreasing. Stable isotopes can be used to produce isoscapes that imply changes in processes and trophic food web structure. Mapping would be facilitated by development of proxies and/or indicators of key ecosystem functions or of ecosystem vulnerability. Omic surveys will also form a foundation for bio-prospecting -- the search for natural compound**s of biological origin that offer novel biomedical research and therapeutic applications.**

3. Given the tools, platforms, and technologies of which you are aware, what is the most effective approach for exploring and characterizing priority areas of the U.S. EEZ?

We clearly cannot currently map large areas of the EEZ for biology and ecosystem variables directly, but a modest set of existing and new surveys can feed artificial intelligence tools (i.e. computer vision and automated object classification) and models that can bridge to larger management scales. For example, macro-ecological models now exist that can estimate seafloor biomass for seafloor life at a global scale (e.g. Yool et al. 2017). These models use *in situ* observations to set relationships between the amounts of food resources arriving to the seafloor over time and the abundance of life in well-described body size bins. Satellite observations can then estimate the available food supplies over time in the area(s) in question and in turn estimate time/space variant and body size-specific biomass.

Acoustic tools that detect bubble plumes can infer the existence of thousands of potential methane seeps on the US west and east coasts (*sensu* Thornes et al. 2019). Seafloor exploration of these sites usually yields chemosynthetic communities. Hotspots of biological activity in the water column, or in association with geomorphic features such as seamounts or canyons can also be mapped acoustically.

In the frame of genetics, a rapid assessment program could be undertaken that included eDNA surveys throughout the water column and with seafloor samples combined with metabarcoding. From these data one could generate a diversity index or classifications that could be related to known physical and bathymetric features and classes, as well as with oceanography (e.g. Seascapes, https://bit.ly/39IBg8d, Yamahara et al. 2019).

4. What selection criteria should inform the determination of priority areas of the U.S. EEZ for exploration and characterization?

The selection criteria for prioritizing surveying can come from first using acoustic mapping data to define habitat classes and seafloor features. Then biology and ecosystem surveying can be targeted to cover an achievable range of habitat areas with enough effort to create statistically robust relationships between habitats and the macro-ecological features found there. However, there are many other factors to consider that depend in part on the desired policy and management outcomes. For example, the occurrence of specific minerals, habitats, living resources or industries will have varied estimated spatial footprints that would drive survey targeting. Records on bottom-contact fishing and other industry activity can inform prioritization. A set of standardized rankings across a variety of thematic priority variables can then be accumulated to create a priority index. The thematic priority variables can also be weighted to understand or imply the importance of one factor or another on what areas are higher priority.

The Scientific Committee on Ocean Research (SCOR) has a working group that is developing survey and monitoring design criteria for global study site selection based on stratification of key environmental drivers of species distributions and processes. This will use classifications based on temperature, oxygen saturation, food availability, water mass structure, depth, distance from land and anthropogenic stressors. This could be applied within the US EEZ.

5. How can public-private partnerships be utilized to effectively implement the Strategy?

There are at least four partnership types that can catalyze effective implementation of the Strategy overall:

1. Linking individuals and organizations with existing data to data integrating experts and facilities that connect to leading national and international data accumulation centers;

2. Linking technology developers and mapping and exploration practitioners to advance the maturity of tools that will make transformative leaps for capability;

3. Enabling the shipping, energy, fishing, mineral, biomedical, aquaculture and other Blue Economy industry actors to partner more effectively in the effort to contribute data in the areas where they operate;

4. Linking research and operational scientists (including academic non-governmental bodies) to tribal, Federal, State and local government agencies responsible for management and policy influencing the EEZ.

5. Facilitating links between research and operational scientists with outreach experts (e.g., teaching, public communications) to broaden the dissemination of emerging NOMEC results to the public. This may require effort to facilitate the creation of ‘teaching-ready’ products easily implemented by educators.

These types of partnerships will increase the efficacy and value of investment (see also Weller et al. 2019). Such relationships are often complex and have unstructured features. Building upon strong examples and illustrating how various groups and individuals play a role to realize an ‘all hands on deck’ approach would be fruitful. For example, energy industry actors now regularly supply weather data from their platforms to the Global Telecommunication System (GTS) that ultimately improves weather forecasts at the platform locations. Ocean mapping and other observation data can similarly be shared more comprehensively and contribute to efforts of GOOS and this Strategy. For example, the Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS, https://on.doi.gov/2w5BDLg) is achieving the linkage of many threads of partnership and data gathering to address the growth of wind energy in deep water offshore.

6. Which Federal programs are best positioned to support public-private partnerships to advance ocean exploration, mapping, and characterization? What changes are needed, if any, to these programs to improve their effectiveness?

The importance of the Strategy themes have been long recognized, including with the start of the US National Geodetic Survey in 1807 by Thomas Jefferson (now, of course, part of NOAA). Several other NOAA affiliated efforts can inform this effort. IOOS, Regional Ocean Partnerships (ROPs), Sea Grant, the NOAA Office of Exploration and Research (OER), Bureau of Ocean Energy Management (BOEM) and similar efforts are delivering partnerships with outstanding value. For example, there are 11 IOOS Regional Associations (RAs) whose domain covers the head of tide to EEZ. Each of these RAs have dozens of established partnerships that cover most or all of the types mentioned above, which can help framing understanding of stakeholder needs and priorities. The Intergovernmental Ocean Observation Committee (IOOC) also aids in coordination. Mapping has not been a large part of the portfolio of most of these efforts to date. Including additional mapping into any of these would need care not to disrupt the many strengths that they are now able to deliver. Nonetheless, the wider availability of biology and ecosystem data mapped into major EEZ areas will benefit their respective visions and missions in many ways (e.g. with EXPRESS).

DOOS is another effort that is currently building partnerships that will bring value to the developing Strategy. DOOS is a project of the Global Ocean Observing System and covers the area below 200 m with focus below 2000 m. DOOS is driven by several objectives including:

- Build an understanding of observation priorities;
- Develop deep observing requirements;
- Provide a hub for integration opportunities;
- Coordinate observations to improve efficiency, standards, and best practices;
- Improve readiness in observing technology and techniques;
- Foster availability, discoverability, and (re)usability of deep ocean data;
- Facilitate community science implementation planning.

7. How should the data generated by the Strategy be managed so that it is most useful to public and private sectors?

The agreement of data categories, observation variable vocabularies, recognition of national and international data standards will be critical, as will adhering to, and working toward implementing open data policies and the principles of findability, accessibility, interoperability and reusability (FAIR). Using tools developed through the Ocean Biogeographic Information System (OBIS), the Environmental Research Divisions Data Access Program, (widely used by IOOS and others, ERDDAP, https://coastwatch.pfeg.noaa.gov/erddap/index.html), EMODNet and related efforts will insure that metadata standards are meeting globally agreed standards and practices for handling biology data (e.g. the Darwin Core metadata standard). Two ends of a strategic spectrum include setting up a Strategy-specific data accumulation center and portal, and the other being to put data in many different places with machine-readable tags so that it can be discovered and accessed in many places and data portals. The latter is more complex to implement, but is more akin to how just about all consumer products are distributed and used.

8. Is there any additional information related to mapping, exploring, and characterizing the U.S. EEZ, not requested above, that you believe the Ocean Policy Committee should consider?

If not already planned, it might be useful to consider engaging Google (Google Earth) and other service providers that can support integration, synthesis, presentation and access to mapped data. Accessing scalable cloud computing services provided by companies such as Amazon and Microsoft (etc.) can greatly speed up and lower the cost of data processing.

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Appendix A - Federal Register Requests for Information responses

November 12, 2020

Subject: ***Request for Information: Public Comment on Exploration Priorities for the Implementation Plan***

To the National Ocean Mapping, Exploration, and Characterization (NOMEC) Council,

On behalf of the Consortium for Ocean Leadership (COL), which represents our nation's leading ocean science, research, and technology organizations from academia, industry, and the larger nonprofit sector (to include philanthropy, associations, and aquariums), we appreciate the opportunity to provide input in response to the *Request for Information: Public Comment on Exploration Priorities for the Implementation Plan.*

As the NOMEC Council develops its implementation plan for the national strategy for ocean mapping, exploration, and characterization, we recommend that it include an independent organization to convene the ocean exploration community and to facilitate communication and collaboration among stakeholders across government, academia, industry, and private and philanthropic organizations to implement the strategy. The facilitation of a true national ocean exploration program would serve both the interests of the exploration community and Congress, enabling stakeholders to communicate common priorities and needs, hopefully securing resources necessary to accomplish objectives critical to national security, conservation, and the economy.

The recently concluded *Workshop to Identify National Ocean Exploration Priorities in the Pacific,* hosted by COL as part of a cooperative agreement with NOAA OER, is an example of cross-sector, cross-agency convening of the ocean exploration community to establish common priorities, capabilities, resources, and potential partnerships. The workshop summary report, released in November 2020, includes input from nearly 60 prominent individuals in the ocean exploration community, and outlines key priorities in the U.S. Pacific EEZ for characterization of the seafloor, benthic biology, water column, marine resources, and cultural heritage sites. This event was planned before the release of the Presidential Memorandum and announcement of the Office of Science and Technology Policy strategy, as NOAA OER and COL recognized the necessity of formalizing regular convenings of the community. This kind of partnership, though on a larger scale and beyond just NOAA, is what is needed to effectively manage this role and to best implement the strategy.

The full workshop summary report is available on the COL website. We have also attached the Executive Summary of the report to this submission. It describes overarching priorities across many disciplines, as well as the specific priorities of the five thematic areas listed above. Although this workshop and report are focused on the U.S. Pacific EEZ, we believe that the community feedback presented will be substantially helpful in answering Questions 1-7 of this *Request for Information.*

Thank you again for the opportunity to provide input for this implementation plan. We applaud the NOMEC Council, NOAA, the Office of Science and Technology Policy, the Council on Environmental Quality, the Ocean Policy Committee, the Ocean Science and Technology Subcommittee, and the Ocean Resource Management Subcommittee for your efforts to build this strategy and implementation plan to advance ocean exploration and research.

Respectfully,

Jonathan W. White, RADM (Ret.), USN
President and CEO
Consortium for Ocean Leadership

Consortium for Ocean Leadership Member Institutions

Alaska Ocean Observing System • Alaska SeaLife Center • Aquarium of the Pacific • ARCUS • ASV Global, LLC • Bermuda Institute of Ocean Sciences • Bigelow Laboratory for Ocean Sciences • Chevron USA • College of William & Mary • Consumer Energy Alliance • Cooperative Institute for Research in Environmental Sciences • Dauphin Island Sea Lab • Duke University • Earth2Ocean • East Carolina University • Esri • Estuary & Ocean Science Center, San Francisco State University • Exocetus • FAU Harbor Branch Oceanographic Institute • Florida Institute of Oceanography • Harte Research Institute • Hubbs-SeaWorld Research Institute • IEEE Oceanic Engineering Society • Institute for Global Environmental Strategies • JASCO • Johns Hopkins University APL • L-3 MariPro, Inc. • Lamont-Doherty Earth Observatory • Liquid Robotics, Inc. • Louisiana State University • Louisiana Universities Marine Consortium • MARACOOS • Marine Technology Society • Massachusetts Institute of Technology • MBARI • MIST Cluster program • Monmouth University Urban Coast Institute • Moore Foundation • Moss Landing Marine Laboratories • Mystic Aquarium • NERACOOS • New England Aquarium • NOIA • North Carolina State University • North Pacific Research Board • Nova Southeastern University • Old Dominion University • Oregon State University • Pennsylvania State University • Rutgers University • Saildrone • Savannah State University • Sea-Bird Scientific • Severn Marine Technologies, LLC • Shell • Skidaway Institute of Oceanography of UGA • Sonardyne, Inc. • South Carolina Sea Grant Consortium • Stanford University • Stony Brook University • SURA • Teledyne CARIS • Texas A&M University • The IOOS Association • U.S. Arctic Research Commission • U.S. Naval Postgraduate School • UCSD Scripps Institution of Oceanography • University of Alaska Fairbanks • University of California, Davis • University of California, Santa Barbara • University of California, Santa Cruz • University of Delaware • University of Florida • University of Hawaii • University of Maine • University of Maryland Center for Environmental Science • University of Massachusetts, Dartmouth • University of Miami • University of New Hampshire • University of North Carolina, Chapel Hill • University of North Carolina, Wilmington • University of Rhode Island • University of South Carolina • University of South Florida • University of Southern California • University of Southern Mississippi • University of Texas at Austin • University of Washington • University of Wisconsin, Milwaukee • Vulcan, Inc. • Woods Hole Oceanographic Institution

LIST OF ACRONYMS

ADCP . . . . . Acoustic Doppler Current Profiler
AI . . . . Artificial Intelligence
AUV . . . . . . Autonomous Underwater Vehicle
BOEM . . . . . Bureau of Ocean Energy Management
CAPSTONE . . Campaign to Address Pacific Monument Science, Technology, and Ocean Needs
CCZ . . . . . . Clarion-Clipperton [Fracture] Zone
CHIRP . . . . . Compressed High Intensity Radiated Pulse (Sonar)
COL . . . . . . Consortium for Ocean Leadership
ConOps . . . . Concept of Operations
CRADA . . . . Cooperative Research and Development Agreement
CTD . . . . . . Conductivity, Temperature, and Depth (Sensor)
DE&I. . . . . . Diversity, Equity, and Inclusion
DPAA . . . . . Defense POW/MIA Accounting Agency
DTM . . . . . . Digital Terrain Model
eDNA . . . . . Environmental DNA
EEZ . . . . . . Exclusive Economic Zone
EXPRESS . . . Expanding Pacific Research and Exploration of Submerged Systems (Campaign)
FAO . . . . . . Food and Agriculture Organization
FEMA . . . . . Federal Emergency Management Agency
HOV . . . . . . Human Occupied Vehicle
IHO . . . . . . International Hydrographic Organization
IMO . . . . . . International Maritime Organization
IOC . . . . . . Intergovernmental Oceanographic Commission (UNESCO)
ISA. . . . . . . International Seabed Authority
IUCN. . . . . . International Union for Conservation of Nature
MBARI. . . . . Monterey Bay Aquarium Research Institute
MBES . . . . . Multibeam Echosounder
ML . . . . Machine Learning
MPA . . . . . . Marine Protected Area
MSR . . . . . . Marine Scientific Research
NASA . . . . . National Aeronautics and Space Administration
NDPTC . . . . National Disaster Preparedness Training Center
NEPA . . . . . National Environmental Policy Act
NGO . . . . . . Nongovernmental Organization
NHPA . . . . . National Historic Preservation Act
NOAA . . . . . National Oceanic and Atmospheric Administration
NOMEC . . . . National Ocean Mapping, Exploration, and Characterization (Strategy)
NOPP . . . . . National Oceanographic Partnership Program
NSF . . . . . . National Science Foundation
OEAB . . . . . Ocean Exploration Advisory Board
OER . . . . . . Office of Ocean Exploration and Research
OET . . . . . . Ocean Exploration Trust
PCZ . . . . . . Prime Crust Zone
PMEL . . . . . Pacific Marine Environmental Laboratory
ROM . . . . . . Rough Order of Magnitude
ROV . . . . . . Remotely Operated Vehicle
SCOR . . . . . Scientific Committee on Oceanic Research
SSS . . . . . . Sidescan Sonar
SUBSEA. . . . Systematic Underwater Biogeochemical Science and Exploration Analog (Mission)
UNESCO . . . United Nations Educational, Scientific, and Cultural Organization
UNOLS . . . . University-National Oceanographic Laboratory System
USGS . . . . . United States Geological Survey
USM . . . . . . University of Southern Mississippi
USN . . . . . . United States Navy
USS . . . . . . United States Ship
UUV . . . . . . Uncrewed Underwater Vehicle
WHOI . . . . . Woods Hole Oceanographic Institution
WWI . . . . . . World War I
WWII. . . . . . World War II

EXECUTIVE SUMMARY

WORKSHOP OUTCOMES AND NEXT STEPS

The *Workshop to Identify National Ocean Exploration Priorities in the Pacific* takes advantage of an opportunity and a challenge. There is increased general interest and a new national imperative for ocean exploration, which includes ongoing initiatives related to a sustainable Blue Economy. NOAA OER's efforts are but one piece of an increasingly complex national and multi-national initiative to explore, map, and characterize the ocean. Such an exploration effort, in the Pacific and beyond, is so vast that it will take a full community of stakeholders to achieve, certainly over multiple decades.

This workshop, and likely others to come, helps to set the stage for the work that NOAA OER and others, both in partnership with NOAA and independently, are going to conduct in the Pacific. These workshops will also be helpful in informing the broader planning and implementation effort in support of the NOMEC Strategy and potentially other ocean-focused U.S. national strategies. Additionally, such work must involve from the outset relationship building and sustained interactions with Indigenous communities and partners in this region. While discussions at this workshop focused on U.S. ocean exploration, collaboration with multiple partner nations will be needed to meet some of the priorities identified in this report. The imminent United Nations Decade of Ocean Science for Sustainable Development (2021-2030) offers one potential and significant opportunity for broad-scale strategic international collaboration and public engagement.

This workshop, conducted virtually by way of an extended timeline involving two plenaries and separate breakout discussions in five subject areas – seafloor characterization, biology characterization, marine resources, water column characterization, and cultural heritage – generated significant and productive interactions among 59 participants representing 46 different organizations (government agencies, academic institutions, industry, and various private and philanthropic organizations). In addition, there were ~30 observers who attended from various government and private organizations. The closing plenary also included an important panel discussion with cultural practitioners from around the Pacific. Each group generated an executive summary and report from which a number of important take-away messages can be derived. They are summarized below (in no defined order):

Exploration is *human* exploration. All discovery is *human* discovery.

- The importance of storytelling and multiple lines of direct communication with the public (e.g., telepresence, social media, etc.) cannot be overemphasized.

DE&I in the Pacific:

- The *DE&I in the Pacific* panel discussion during the closing plenary was impactful; the cultural practitioners on the panel emphasized that ocean exploration in this region must include local communities, from the outset of planning through execution, data analyses, and application.
- Further, these relationships must be continuously “relational” rather than “transactional.” Partnerships are often pursued because of requirements for funding – that is transactional. Focus on building the relationships by talking about the environment and the communities themselves.
- The imperative of developing and sustaining productive relationships among ocean exploration and Indigenous communities across the Pacific led the panelists to suggest a mechanism for promoting such relationships, before, during, and after ocean exploration expeditions, “…where we might inspire the cultural reboot that resets, realigns, and converges the software of modern science and native ways of knowing…” (Kahu Ramsay Taum, Life Enhancement Institute of the Pacific).
- Consultation is important, but collaboration should be the goal. Involvement of Indigenous communities offers unique opportunities for broad engagement and deeper understanding of the value and human history of the Pacific.
- Traditional Knowledge systems are equivalent to other knowledge systems in a holistic understanding of the Pacific; such inclusivity enhances the ocean exploration enterprise.

Data – Increase Availability, Achieve Standards and Protocols:

- Standards and protocols need to be established so that all stakeholders, across all sectors, can have a clear idea of the requirements for acceptable data. Input from entities outside the federal government will be critical in establishing broadly acceptable standards. Better control and calibration of, as well as sharing of and access to, backscatter seafloor data are also critical.
- Presenting data resources curated at distributed data centers is critical, and the development of an integrated data portal that provides visibility and easy access to all existing ground truth and sample data within the U.S. EEZ would be a useful asset to inform new data acquisition and to ensure that previous investments in data acquisition can be leveraged.
- Data extraction via AI and ML are critical to improve rapid decision making and allow researchers to synthesize quickly the large volumes of data needed to characterize large areas.

Coordinate Existing and Integrate Emerging Technologies:

- Ocean exploration in the Pacific will require the coordinated use of the full spectrum of deep-sea technologies that are available. Emerging technologies will need to be progressively integrated with traditional characterization approaches that have endured the test of time.
- For biological characterization at or near the seafloor (benthic species) and in the water column (pelagic species), *in situ* sample collection and linked training of taxonomists will continue to be essential, to complement and increase the usefulness of emerging technologies. In addition, support of long-term archival collections to maintain the collected specimens is important.

Conduct a “Concepts of Operation” Workshop:

- ConOps in ocean exploration are complex and dependent on vessel and crew capabilities, specific goals/objectives and regions, and overarching mission constraints (e.g., available technologies and partnerships). Specific expedition planning requires knowledge of Pacific operations as a whole and careful consideration of tradeoffs (e.g., sampling vs. mapping and related spatial characterization). Workshop participants acknowledged this complexity and suggest a follow-on workshop to consider such details, first for the Pacific, and then generally in the context of planning and implementation of the NOMEC Strategy and potentially other ocean-focused U.S. strategies.

Plan and Execute "Flagship" Initiatives:

- Dedicated ocean exploration expeditions to target water column characterization priorities, like an oxygen-minimum zone and/or the bathypelagic-mesopelagic transition, should be considered. One possible location to pursue is offshore Hawaiʻi, as this region lies near an accessible port in the Pacific basin suitable for a sustained effort.
- Panelists also suggest undertaking dedicated cultural heritage expeditions associated with the WWII Battle of Midway (e.g., to investigate both ship and aircraft wrecks) and/or the lost Pan American *Samoan Clipper* off the coast of American Samoa.
- Prioritizing and promoting marine resources field efforts that purposefully – but not exclusively – inform resource characterization are important. This can be achieved by engaging in resource-specific discussions with key personnel in federal agencies and/or other scientific partners to determine how federal and public-private efforts can supplement resource characterization needs. Public input must also inform these discussions.

Optimize and Facilitate Stakeholder Communication:

- Successful Pacific exploration hinges on the ability to engage, through effective and continuous communication, needs, plans, and outcomes, with the wide diversity of stakeholders that have worked previously and/or are currently working in this region.

Partnerships are Essential for Success:

- Beyond stakeholder communication, incentivizing collaboration amongst partners to assure participation is critical. Traditional mechanisms (e.g., CRADAs and NOPP) that have been effective on a project scale or between a limited number of organizations will not be sufficient for the national-scale collaboration needed to meet ocean exploration, mapping, and characterization goals; a more robust and reimagined NOPP could serve as a such a vehicle. However, barriers still exist with respect to technology transfer and data handling, particularly with industry.
- A nimble and adaptive public-private partnership model is now being implemented off the U.S. West Coast (see the Marine Resources Breakout Report, *p.33*). Early successes like this demonstrate great promise for broader applications through the NOMEC Strategy and potentially other national ocean exploration strategies.

A Potential National Ocean Exploration Program:

- A successful national program for seafloor characterization requires a combination of nationwide management and robust coordination with and among scientists and managers implementing regional field efforts. This is also true for other ocean exploration initiatives.

Geographic Priorities:

- Beyond the areas already highlighted for dedicated ocean exploration campaigns, the breakout groups note many geographic areas as particularly high priorities. Some examples include deep-water areas around Hawai‘i and off California, the northern Mariana arc, various Pacific MPAs, the Cascadia margin, and the Aleutian Islands. The white papers submitted for this workshop are a valuable resource in this regard.

The *Workshop to Identify National Ocean Exploration Priorities in the Pacific* has focused on the potential and the promise of ongoing and future ocean exploration activities in the Pacific. This report should give expedition strategists an effective blueprint for those detailed planning activities. Workshop outcomes should also benefit the development of relevant national strategies and implementation plans for ocean exploration, in the Pacific and beyond, for years to come.

For additional details, please see the following executive summaries for each of the five thematic breakout reports.

SEAFLOOR CHARACTERIZATION EXECUTIVE SUMMARY

The seafloor characterization breakout discussion focused on strategies and tools needed to identify and prioritize areas that are appropriate for more detailed characterization, as identified in the other breakout groups; however, the continuum of these strategies and tools represents a multi-scale approach that must be considered from the outset.

- For large-area underway mapping, foundational systems include low frequency (12-30 kHz) acoustic systems, with primary data including multibeam sonar bathymetry, backscatter (seafloor and water column), quantitative fisheries echo sounders, and sub-bottom profiling; requirements for magnetics/gravity data at this scale should be established by cultural heritage experts.
- Standards and protocols need to be established, so that all stakeholders, across all sectors, can have a clear idea of the requirements for acceptable data. Input from those outside the government will be critical in establishing broadly acceptable standards. Better control and calibration of, as well as sharing of and access to, backscatter seafloor data, are critical.
- A national database (or similar) that provides visibility and easy access to all existing ground truth and sample data within the U.S. EEZ would be a useful asset.
- Numerous software tools and approaches are being developed for the quantification and remote characterization of seafloor properties; however, these techniques will require more effort in the calibration of MBES backscatter and the ability to share processed backscatter data widely.
- ConOps are complex and dependent on vessel and crew capabilities, on specific goals and regions, and on overarching mission constraints. These decisions need to be made by those with the broad picture of all these issues and careful consideration of the tradeoffs. However, the general consensus of the seafloor characterization breakout group is that, where possible, sampling should be part of mapping, exploration, and characterization surveys.
- New technologies and capabilities that can enhance seafloor characterization include: long-range, uncrewed platforms that can support large acoustic arrays and launch and recover other vehicles; calibrated backscatter systems; sparse array technology; enhanced data telemetry capabilities; edge-based processing tools, including AI and ML techniques; and better tools for data management and data sharing.
- Partnerships are essential for the success of U.S. national strategies for ocean mapping, exploration, and characterization. Communication of needs amongst partners is critical, as are mechanisms to incentivize partner participation. CRADAs and NOPP are mechanisms that have worked in the past, but barriers still exist with respect to technology transfer and data handling. Involvement of local communities offers unique opportunities for broad engagement and buy-in.
- Seafloor characterization can benefit a sustainable Blue Economy in many ways, including identification of critical fisheries habitat, aquaculture sites, gas seeps, geohazards, and potential mineral deposits. Identification and characterization of potentially polluting wrecks may also lead to job-generating mitigation efforts and the prevention of pollution that may be a significant threat to existing sustainable Blue Economy jobs in fishing and eco-cultural tourism.
- A successful national program for seafloor characterization requires a combination of nationwide management and robust coordination with and among scientists and managers implementing regional field efforts. The U.S. Department of State should continue its efforts to obtain data from foreign scientists who conduct MSR under diplomatic consent.

BIOLOGY CHARACTERIZATION EXECUTIVE SUMMARY

The biology characterization breakout group aimed to prioritize strategies, tools, data, and partnerships that are needed to conduct baseline biological characterizations of deep-sea (>200-meter depths) benthic habitats across the U.S. EEZ in the Pacific Ocean basin. The group included representatives from a variety of stakeholders that are actively working in the region, including researchers and managers from government agencies, academic institutions, nongovernmental institutions, and the private sector. Participants highlighted that exploration needs to link directly to resource management, protection, and stewardship, since the region includes many Pacific Island communities that are highly dependent on their ocean resources. This work will inevitably include passage through international waters; thus, deep-sea exploration in the Pacific will not only inform U.S. management actions, but also those of other countries, as well as international policies. Given the captivating nature of many deep-sea benthic species and habitats, exploration will provide a gateway to engage the broader community, including scientists, resource managers, policymakers, educators, cultural practitioners, and the public.

- Despite recent initiatives that focused on the deep waters of the Pacific, the vast majority of deep-sea benthic habitats in this region are still virtually unknown, so exploration will continue to focus on some of the most basic questions, such as identifying the species and habitats. This will require collecting physical samples, as well as working closely with taxonomic experts to identify them. Given the large extent of the Pacific, exploration will need to focus on more fully characterizing a few representative sites well, and then extrapolating data onto similar features across the broader region using predictive habitat models. These models will require high-quality data sets that should be collected in priority exploration areas such as MPAs, which besides being largely unexplored, also provide places to test new management measures.
- Essential data variables to capture include information on species identities, sizes, conditions, abundances, and distributions, as well as environmental data on temperature, salinity, dissolved oxygen, fluorescence, turbidity, currents, total alkalinity, pH, and carbonate chemistry. Sound is a data variable that is largely unexplored in the deep sea and therefore represents another opportunity for future exploration. Understanding the scales of variability and connectivity is particularly important for deep-sea benthic characterization and needs to be linked to efforts to characterize the overlying water column. Exploration will require the coordinated use of the great wealth of deep-sea technologies that are available. Emerging technologies will need to be progressively integrated with traditional characterization approaches that have endured the test of time. *In situ* sample collections will continue to be essential, and funding should be set aside so that taxonomists can rapidly identify collected specimens, as well as to help train the next generation of explorers with this knowledge. Additionally, it is important to support long-term archival collections to maintain the collected specimens.
- Priority geographic areas for exploration include Central Pacific seamounts, particularly those found within the PCZ and the CCZ, Pacific MPAs, and areas along the Aleutian Islands and the Cascadia margin. The biology characterization breakout group suggests possible approaches for prioritizing specific areas for exploration, such as focusing on key areas that may be imminently impacted by human activities (i.e., seabed mining and bottom fisheries), areas that may be vulnerable to disturbance due to underlying hazards (i.e., seafloor instability or landslide-prone areas), and/or regions that might be particularly susceptible to climate change impacts.
- Successful Pacific exploration hinges on the ability to engage the wide diversity of stakeholders that work within this region, who should be engaged early and often to ensure data are collected and disseminated in a culturally appropriate way, that local knowledge is strategically incorporated into expedition planning, and that information from exploration is disseminated to local stakeholders in a timely manner. Given the vast area that needs to be explored and the diversity of systems within it, no one organization will be able to do it alone.

MARINE RESOURCES EXECUTIVE SUMMARY

Despite economic and national security issues that increase national attention on the importance of energy and mineral resources, there remains a very limited understanding of these resources within U.S. Pacific waters. Ocean exploration can serve an important role in addressing this need.

Appropriate sustainable management of energy and mineral resources requires an understanding of the resources and the surrounding environment. While the traditional NOAA OER energy- and mineral-related efforts focus on locating and characterizing sensitive biological communities in areas that could be impacted by future extraction, the questions of how ocean exploration efforts can enhance the understanding of the actual resources has only rarely been discussed.

The marine resources breakout group focused its discussions on how ocean exploration can have a greater impact on this understanding. Although the baseline information about the surrounding environment is also a critical contribution of exploration for stewardship and management, it was not the focus of this breakout group. Such baseline information about biological diversity would inform stakeholders about the potential genetic resources that could lead to natural product discoveries and support a sustainable Blue Economy, but this was also not a focus of this discussion.

This breakout group's assessment is that ocean exploration efforts can likely make greater progress on understanding U.S. Pacific EEZ mineral resources than energy resources. This is largely because understanding energy resources requires substantial subsurface work beyond the scope of historical exploration and NOAA OER activities. However, NOAA OER and others can help advance understanding of critical mineral resources – as well as associated biological communities – if adjustments are made to where exploration is conducted and how samples are collected.

The following suggestions are provided for high level consideration on how ocean exploration efforts could better advance understanding of energy and mineral resources in U.S. EEZ waters in the Pacific:

- Prioritize and promote future ocean exploration field efforts that purposefully – but not exclusively – inform resource characterization. Engage in resource-specific discussions with key federal personnel, Indigenous leaders, and scientific partners to determine how federal and public-private efforts can supplement resource characterization needs. Allow public input.
- Areas of significant economic potential, and industry interest, within the U.S. EEZ should be the highest exploration priorities for resource characterization. For minerals, this is primarily in the Central and Western Pacific.
- Strengthen public-private partnerships to advance marine mineral mapping and characterization.
- Establish a venue or platform for parties to communicate and discuss needs, plans, and outcomes. This will help connect the needs of the marine resource community with the capabilities of the more traditional ocean exploration community and vice versa.
- Explicitly state the need and importance for geological and habitat characterization efforts that other organizations can and should conduct following initial exploration efforts to characterize resources. Without these statements, stakeholders are likely to assume inaccurately that the exploratory efforts alone are enough.
- Help facilitate systematically ground-truthing USGS offshore mineral maps.
- Identify standard location(s) to gather exploration and characterization data appropriate for synthesis and discovery efforts, including from industry partners, and define necessary data collection standards.
- Work with appropriate parties to define a baseline habitat characterization for areas of potential mineral and/or energy interest. This information is critical to subsequent monitoring efforts if extraction is pursued.

WATER COLUMN CHARACTERIZATION EXECUTIVE SUMMARY

Water column characterization has long been recognized as an important component of a national ocean exploration program, including in the initial advice from the scientific community in 2007 for NOAA Ship *Okeanos Explorer*. Following that report, development of methods using a two-body ROV system for direct observation of water column biology began in 2012. Additionally, subsequent planning workshops for regional ocean exploration campaigns have received recommendations for midwater exploration. In 2016, the National Academies Keck Futures Initiative convened an interdisciplinary workshop to brainstorm ideas and to develop proposals for improved methods to understand the mesopelagic (National Research Council, 2018). Shortly thereafter, in 2017, NOAA OER also sponsored a workshop, *From Surface to Seafloor*, focusing on the development of a more comprehensive framework for multi-disciplinary midwater exploration. Despite these calls for action, little systematic progress has been made. A few dedicated midwater dives, in addition to limited time at the end of some benthic dives, have occurred on some NOAA OER-sponsored expeditions. A national ocean exploration program that includes dedicated characterization of the water column as a primary component would significantly improve our knowledge and understanding of the largest and least-explored ecosystem on Earth (Webb et al., 2010), by providing the resources and partnerships necessary to build a community of scientists, technologists, and stakeholders to develop and test informed strategies.

The following should be included as tenets of a potential ocean exploration program for water column characterization:

- Devote ship time to dedicated expeditions for addressing large data gaps in the water column.
- Build partnerships with groups to aid in rapid image- and data-analysis tools and leverage the strength and resources of commercial, governmental, academic, and nonprofit institutions.
- Support the development and testing of water column-specific technologies to improve our ability to collect, analyze, and visualize appropriate data within this four-dimensional environment.
- Develop efficient and effective characterization protocols by utilizing multiple complementary techniques and approaches (e.g., nets, acoustics, imaging, and *in situ* sensing) to execute multi-disciplinary programs.
- In addition to standardized characterization, determine how best to target specific pelagic phenomena, such as oxygen-minimum zones and the bathypelagic-mesopelagic transition (particularly in areas targeted for uses such as mining), to support informed decision making regarding a sustainable Blue Economy.

CULTURAL HERITAGE EXECUTIVE SUMMARY

- Exploration is human exploration. All discovery is human discovery. What lessons can our discoveries teach us for humankind's future? Our exploration must engage with living cultures, societies, and groups for whom the past, as well as the oceans today, have relevance and meaning. This can be achieved through collaboration, transparency, and public outreach.
- Exploration, mapping, and characterization must be inclusive regarding participation from scientists and non-scientists across a variety of disciplines, and by individuals who reflect human diversity.
- We should consider characterization that offers an opportunity to find less visible or tangible traces of the past, such as largely or completely consumed wooden wrecks, but also features of cultural significance, such as the Bowie Seamount, known to the Haida Tribe as SGaan Kinghlas and considered spiritually important to members of that living culture.
- Initial seafloor mapping is an invaluable guide to enable identification of human interaction with the ocean environment. For cultural heritage, we should identify key ocean routes where evidence may be found on the seabed, such as patterns for Polynesian navigation, European and American sailing trade routes, established routes for regular trans-Pacific steam voyages, sites of major sea battles, and the routes of significant seabed cables of the past.
- A primary focus of identifying cultural heritage as part of the overall strategy for ocean exploration is to locate and characterize shipwrecks, aircraft, and other human-made artifacts in the Pacific. Another is to search for and identify the location of potentially polluting shipwrecks that may also be historic. A third is to examine existing finds and data that build towards a cultural heritage strategy for the Pacific and sharing of lessons learned. Our exploration must also contemplate unintentional or surprise discoveries, perhaps evidence of early transmigration or trade routes; these searches can be aided by available knowledge of human history.
- Cultural heritage can and should be used to excite larger public interest in the oceans, ocean exploration, and support of ocean issues. High-value targets of opportunity should be considered. Cultural heritage is found at times when it is least expected; therefore, planning for cultural heritage encounters should be included on any exploration mission through a known strategy to activate cultural heritage scientists and specialists as needed.
- The cultural heritage breakout group identified six potential signature missions: a) the full span of the Battle of Midway, including downed aircraft; b) the pioneer Pacific aircraft *Samoan Clipper*; c) the iconic battleship USS *Pennsylvania* off Kwajalein; d) the waters off the Northern Mariana Islands, an ancient maritime highway and the setting of modern losses of ships and aircraft; e) the "Kelp Highway," seeking evidence of early human migrations into the Americas following the now-drowned coastline at the 100-meter depth level and shallower in the U.S. EEZ, from Beringia (Alaska) to Baja California; and f) the veteran destroyer USS *Stewart*, scuttled in Bodega Canyon (off California) as part of a larger mission to explore that canyon in Greater Farallones National Marine Sanctuary.

FUGRO
Fugro USA, Inc.

RFI Response: Strategic priorities for mapping, exploring, and characterizing the U.S. EEZ

Fugro USA is pleased to provide the National Ocean Mapping, Exploration and Characterization Council (NOMEC Council) with information, comments and perspective on exploration and characterization priorities to be included in the Implementation Plan for the National Strategy for Ocean Mapping, Exploring and Characterizing the United States Exclusive Economic Zone (National Strategy). We strongly support the goals and objectives outlined in the November 2019 Presidential Memorandum on Ocean Mapping of the United States Exclusive Economic Zone and the Shoreline and Nearshore of Alaska, as well as the June 2020 National Strategy and look forward to a robust implementation of these initiatives that includes a meaningful and substantial role for the private sector, which can bring appreciable expertise, experience, resources, capacity and support to the program.

Background

Fugro is the world's leading Geo-data specialist, collecting and analyzing comprehensive information about the Earth and the structures built upon it. Our US and regional (Americas) headquarters are located in Houston, Texas, and we employ approximately 1,100 employees in the US across 20 offices in 9 states. Working predominantly in the energy and infrastructure markets, we serve both public- and private-sector clients on land and at sea.

For more than three decades, Fugro has been active in all U.S. coastal states, including Alaska and those on the Great Lakes. This work has supported resource development initiatives and coastal infrastructure development, as well as surveying and mapping programs for federal, state, and local governments. Fugro's federal government experience includes contracts with NOAA's Office of Coast Survey, National Geodetic Survey and Office for Coastal Management; the U.S. Army Corps of Engineers; the U.S. Geological Survey; the Federal Emergency Management Agency; the Bureau of Reclamation, and the U.S. Navy.

Responses to Inform Development of the Implementation

1. ***NOMEC Strategy Goal 3.1 "Identify Strategic Priorities" describes the need for strategic ocean exploration and characterization priorities and lists some examples. What do you feel are the most important strategic national priorities for exploration and characterization efforts in the deep sea (depth >40 m)? These can be specific geographic areas within the U.S. EEZ or thematic/topical issue priorities.***

It is Fugro's belief that the prioritization of exploration and characterization efforts requires a priori information that needs to come from mapping activities, covered by NOMEC Strategy Goal 2.2 "Coordinate and Execute Campaigns to Map the United States EEZ". Given that 54% of the U.S. EEZ has yet to be mapped (NOAA January 2020), it is not possible to rigorously and comprehensively develop priorities for exploration and characterization. To do so in a complete and exhaustive way requires systematic mapping of the U.S. EEZ.

Having said that, prioritization of exploration and characterization efforts can be developed based on existing and yet to be acquired mapping data and informed by statutory requirements, federal agency missions, strategic national issues, Administration policy priorities, and stakeholder perspectives. Prioritization should heavily consider the benefits (environmental, socio-economic / blue economy, risk mitigation and knowledge economy) that exploration and characterization will provide. Areas that offer strong benefits and/or multiple benefits should be prioritized more highly than areas that offer weak benefits and/or a single benefit only for example. This weighting should be an important aspect of exploration and characterization prioritization. Without mapping, it will be very difficult to assess the benefits and strength of benefits required to rigorously and comprehensively develop priorities for exploration and characterization.

In order to foster and motivate public-private partnership opportunities and leverage exploration and characterization activities that are already occurring or could occur in the private sector, prioritization should also consider where this private sector work is already occurring or where it is likely to occur in the future. Private sector exploration and characterization activities boost the blue economy and are driven by business opportunities where policy supports economic potential. Historically, this private sector work has occurred within the offshore oil and gas and methane hydrate sectors. Private sector work in this sector has reduced appreciably recently, while activity in the offshore wind sector is now surging. Bolstering the blue economy, there is also the potential for significant future private sector activity in the aquaculture, marine minerals and other marine renewable energy sectors, depending on national policy and the development of a regulatory framework to support that policy. There is also potential for private sector activity in the mapping, exploration and characterization of Essential Fish Habitat (EFH) and the population dynamics of those species supported by those habitats that contribute significantly to the nation's food security and economic health. In all cases, this work must be conducted in an environmentally responsible manner that helps protect critically endangered (North Atlantic Right Whale), threatened and protected species. The point being that the private sector can and should be a partner in NOMEC, including the development of priorities for exploration and characterization.

With the above background and growth of the blue economy in mind, it would be prudent to prioritize exploration and characterization in areas where private sector exploration and characterization in support of the offshore wind sector is already occurring (U.S. northeast and mid-Atlantic coast) and where it is expected to occur (US mid-Atlantic and southeast coast, U.S. west coast and Hawaii).

2. What are the most important questions for exploration and characterization to address?

In general, exploration and characterization should qualify hypotheses derived from regional mapping. As described above, the first step is to perform baseline mapping of the U.S. EEZ. Through this process, it will be possible to assess conditions and state hypothesis, which exploration and characterization can subsequently qualify. Exploration and characterization should confirm the presence or absence and the extent, severity, density and/or quality of the various environmental, socio-economic / blue economy, marine hazard and knowledge economy attributes referenced above. These include, but are not limited to the following:

- Ocean circulation
- Sensitive habitats and ecosystems
- Protected species
- Pelagic and benthic fishery resources
- Energy resources
- Mineral resources
- Biopharmaceutical resources
- Marine geo-hazards
- Tsunami risks
- Flood inundation risks
- Scientific research
- Cultural heritage

It is the answers to these questions, as they relate to these attributes that exploration and characterization must address.

3. What are the most important data variables that need to be measured, and what are the most valuable physical samples to collect; to conduct baseline exploration and characterization?

The importance and relevance of data variables and physical samples to be collected will depend on the type of exploration and characterization being performed. Exploration and characterization of marine biology / ecology may be different and involve different data variables and physical samples than exploration and characterization of seabed minerals, for example. Fugro would suggest a standard or baseline exploration and characterization, that, to the extent possible, provides information that is common and beneficial to all types and applications of exploration and characterization.

There are some standard data variables and physical samples that are relatively application agnostic, which, given the above, makes them the most important in our opinion. Having said that, there can be subtle variations in data variables and physical samples that depend on resolution and approach. For example, the most important data variables and physical samples to conduct baseline exploration and characterization from surface vehicles (crewed, uncrewed or autonmous) are slightly different that those to conduct baseline exploration and characterization from subsea vehicles (AUVs or ROVs). For this reason, the most important data variables and physical samples to conduct baseline exploration and characterization from surface vehicles (crewed, uncrewed or autonomous), AUVs and ROVs are all presented below.

- Surface vessel-based exploration and characterization:
    i. Multibeam bathymetry, seafloor backscatter and water column backscatter
    ii. Subbottom reflectivity
    iii. Electromagnetic field direction, strength and relative change
    iv. Earths gravitational field
    v. Near-surface water properties such as T, S, pH, CO_2, Methane, eDNA etc.
    vi. Physical specimens of rocks, sediments, flora and fauna acquired by coring, drilling or grab samples
    vii. Water column properties, such as temperature, conductivity, density, acquired by CTD

- AUV-based exploration and characterization:
    i. Multibeam bathymetry, seafloor backscatter and water column backscatter
    ii. Sidescan sonar seafloor backscatter
    iii. Subbottom reflectivity
    iv. Electromagnetic field direction, strength and relative change
    v. Laser Line Scan near photo quality imagery and point cloud
    vi. Still and video imagery
    vii. Physical, chemical and biological properties of water masses traversed, such as T, S, pH, CO_2, Methane, eDNA etc.

- ROV-based exploration and characterization:
    i. Multibeam bathymetry, seafloor backscatter and water column backscatter
    ii. Sidescan sonar seafloor backscatter
    iii. Subbottom reflectivity
    iv. Electromagnetic field direction, strength and relative change
    v. Laser Line Scan near photo quality imagery and point cloud
    vi. Still and video imagery
    vii. Physical, chemical and biological properties of water masses traversed, such as T, S, pH, CO_2, Methane, eDNA etc.
    viii. Physical specimens of rocks, sediments, flora and fauna acquired by coring, drilling or grab samples

4. ***What novel or established tools, platforms, and technologies could advance our capability to explore, and characterize the U.S. EEZ more efficiently and effectively? To the extent innovative***

capabilities already exist, but are not being effectively used, what are the barriers to adopting them? How can these barriers be overcome?

What novel or established tools, platforms, and technologies could advance our capability to explore, and characterize the U.S. EEZ more efficiently and effectively?

As referenced above, there is already a lot of mapping, exploration and characterization work occurring in the U.S. EEZ and around the world on private sector projects that grow the blue economy. There are established, maturing and novel tools, platforms and technologies that already are and have the potential to substantially advance our capability to explore and characterize the U.S. EEZ more efficiently and effectively. Many of these are driven by a combination of private sector market influences and the advancement of core and enabling technology. Regardless, Fugro has already developed or is in the process of developing the numerous tools, platforms and technologies that have direct relevance to mapping, exploring and characterizing the U.S. EEZ. A summary of Fugro and other relevant tools, platforms and technologies is presented below:

- Technology that provides the remote monitoring and management of assets (vessels, USVs, UAVs, AUVs, ROVs, etc.) from shore-based control centers. Fugro is already monitoring and managing its assets from seven remote operations centers around the world and the same approach could be adopted by NOAA for NOMEC.
- Technology that provide the remote operation of shipboard systems, sensors and ROVs from shore-based control centers. Accelerated by the COVID-19 pandemic, Fugro is already controlling shipboard systems, sensors and ROVs from seven remote operations centers around the world and the same approach could be adopted by NOAA for NOMEC.
- ASVs capable of performing mapping work, including the collection of multibeam bathymetry, seafloor backscatter and water column backscatter data, as well as CTD data. Fugro is already operating a fleet of ASVs and one of the vehicles in that fleet was recently used to perform hydrographic survey work for NOAA. The fleet is rapidly expanding.
- ASVs capable of performing mapping work, such as that described above, as well as hosting eROVs and/or AUVs for high-resolution site-specific exploration and characterization. Through a strategic partnership with SEA-KIT, Fugro now has this capability and can make it available to NOMEC. The fleet is rapidly expanding.
- Still and video imagery acquired during coring, drilling and grab sample collections. Fugro has developed imagery systems that can be mounted onto coring, drilling and grab sample equipment, so that high resolution still and video imagery of the seafloor can be obtained while collecting physical specimens of rocks, sediments, flora and fauna.

- Real-time geochemical detection and analysis from AUVs and ROVs. Fugro has developed underwater mass spectrometers that can be deployed from AUVs and ROVs to detect geochemical properties of water masses traversed.
- Cobalt coring systems capable of acquiring multiple, high speed cores of cobalt crusts in deep water. The system is the first of its kind and can dramatically accelerate the efficiency and effectiveness of coring in seafloor massive sulfides. Fugro has a beta version of this system now ready for testing.
- Next generation airborne LIDAR technology that can acquire high-resolution / high-point density data at depth in optically clear waters. The technology is light, low power, has no moving parts and is capable of being deployed from fixed or rotary wing aircraft, including unmanned aircraft systems (UAS).
- Electromagnetic sensors deployed on eROV and AUVs. These encompass magnetometers, self-potential and controlled source electromagnetic (CSEM) systems and all are useful for mineral exploration and characterization. The latter can also map gas hydrate deposits. These sensors are in various stages of development and except for magnetometers, further development is required. Software to interpret the data are all in stages of development that need advancement and improvement as well.
- There is great potential in repurposing existing sensor suites and metocean models to monitor sediment plumes and predict behavior and settlement areas. This will be made possible by utilizing additional data from fixed sensors on bottom mounted nodes / landers and from transient sensors on eROVs / AUVs for example.
- An extension of the above, is the use of gliders and expanded observational networks of bottom mounted nodes/landers that can be integrated and would work cooperatively to characterize both the spatial and temporal conditions of the maritime domain.
- An area that is still relatively novel and immature, but which holds great potential is the application of low-cost swarms of surface and subsurface autonomous sensor platforms. These can either be drifting or powered but have the potential to support the characterization of the ocean surface, the water column and seafloor.
- Another area that is still relatively early in its development, but which holds great potential is the leveraging of hydrokinetic/ocean power generation investments such that charging station networks for AUVs become ubiquitous in the ocean environment. This obviously means network of AUVs could remain productive in the water column and near the seafloor for days or weeks at a time, without the need to return to surface platforms for recharge.

To the extent innovative capabilities already exist, but are not being effectively used, what are the barriers to adopting them?

As presented above, there are numerous innovative capabilities that already exist. Many of these are not yet being effectively used in a mapping, exploring and characterizing context, however. There are various reasons why this is the case, ranging from regulatory frameworks, real-world testing opportunities and funding. Some of the barriers to adopting these existing capabilities are summarized below:

- The complex and outdated regulatory framework around the use of uncrewed and autonomous platforms is a significant barrier. While these regulations are admittedly very complicated and need to be focused on maritime safety, the pace of technology development is greatly exceeding the pace of regulatory reform. This means that highly productive and efficient solutions may not be adopted simply because regulations have failed to keep up with technology.
- The relative lack of opportunities to finalize development of technology and revised scopes of work utilizing autonomous platforms and technologies is another barrier. While there are clearly many new autonomous systems being developed, generally speaking, their maturity is not at Technical Readiness Level (TRL) 9 and will not reach TRL 9 until opportunities are provided to mature these systems in real-world trial scenarios. Willing clients and partners are required to support these operational trials, as they will help ensure the maturation of fit-for-purpose technology / solutions, while helping frame suitable scopes of work that maximize the benefit of the new technology / solutions.
- The level of funding is generally weak and inadequate to support the introduction of new and emerging technology. In many cases and as described above, it is often not possible to simply introduce new technology, without operational trials that facilitate the maturation of fit for purpose solutions and the development of revised and appropriate scopes of work that fir the new technology. Funding is also weak and inadequate to support the redesign of and/or adaptation of existing technology for deep water (>3000m) applications. Because most exploration and characterization activity has historically supported oil and gas applications in hydrocarbon provinces with water depths less than 3000m water, investment is required to adapt these solutions to even deeper water applications.

How can these barriers be overcome?

For each of the barriers identified above, potential solutions for overcoming those barriers are presented below:

- Related to regulatory barriers, it is critically important that technology developers from industry and academia work side-by-side with marine registry organizations and government regulators to accelerate the adaptation of regulations to support the available technology and solutions related to uncrewed and autonomous platforms. Technology is changing rapidly, and marine registration organizations and government regulators need to be kept appraised of these changes and expected future changes, so that the incorporation of highly productive and efficient solutions is not constrained by an outdated regulatory framework.

- Related to opportunities to finalize development of technology and revised scopes of work that utilize autonomous platforms and technologies, it is important that a flexible contracting environment is available, which encourages and promotes operational trials. Having flexible contracting mechanisms that support multiple objectives, such that technology can be matured, capabilities / limitations recognized, systems / processes established, and operational objectives achieved are necessary.
- With respect to funding, in many cases, additional funds are required to adapt or mature existing technology, such that it is optimized for the government's mapping, exploration and characterization mission. Technology and solutions may have been developed for other related sectors or markets and additional funding may be required to support operational trials and demonstration projects that would not only finalize technical developments, but would also produce revised scopes of work that reflect the incorporation of these new developments. This concept of funded public-private demonstration projects with commercialization potential is already being used successfully in the marine hydrokinetic research and development space and could be applied to new technology developments, as well as the adaptation of existing technologies. The use of innovation incubators and technology accelerators, such a XPRIZE and other similar programs could also be used here.

5. ***Deep waters within the U.S. EEZ host a wide variety of habitats and geomorphological features (*****e.g.*****, continental shelves, canyons, seamounts, trenches, abyssal plains, and mesopelagic and bathypelagic zones of the water column). Which ones of these do you think are most important to explore to address the priority questions you identified above?***

Notwithstanding the extensive information and comments provided above regarding the prioritization of ocean mapping, exploration and characterization activities, Fugro can offer the following additional comments with respect to the types of habitats and geomorphological features that are also important from a mapping, exploration and characterization perspective. While the types of habitats and geomorphological features referenced here are important, in our opinion, they do not necessarily trump or have higher weighting than the other prioritization considerations and factors mentioned earlier in this document.

A summary of the types of habitats and geomorphological features that we believe are most important are presented below. Most of these directly support expansion of the blue economy:

- Canyons, especially along the east coast, are significant contributors to, and conduits for the overall coastal shelf and abyssal plain ecology of the U.S. EEZ. Additional mapping and study of these features will increase our understanding of their functions, benefits and services.

- Expanded understanding and mapping of Essential Fish Habitat (EFH) and the population dynamics of those species supported by those habitats contribute significantly to the nation's food security and economic health. Most habitat studies are conducted at project development scales and would benefit from larger scale efforts.
- Spreading centers and seamounts, such as those associated with Gorda Ridge, offshore Oregon, are not yet adequately mapped, explored or characterized. The area was discovered in the late 1980's, but the extents of habitat, mesopelagic, and bathypelagic biodiversity, and marine mineral distribution should be mapped, explored and characterized.
- Areas that are known or suspected to be rich in terms of ecology, habitat, and marine minerals, such as the Taney seamounts off California would be important for mapping, exploration and characterization. Such activity would be able to assess and document the biodiversity and cobalt-rich ferromanganese crusts in this area.
- Habitat and mineral resource mapping, exploration and characterization on the seamounts and abyssal plains in the U.S. EEZ, such as Kingman Reef, Palmyra Atoll, Jarvis Island, Wake Island, and Howland and Baker Islands is also important. Portions of the seamounts may be covered with cobalt-rich crusts and the abyssal plains in this part of the Pacific are known to have rich polymetallic nodule deposits on the seabed.

6. ***How can artificial intelligence and machine learning be used to guide planning, execution, and analysis of exploration and characterization activities?***

Artificial intelligence (AI) and machine learning (ML) can be used to guide planning, execution and analysis of exploration and characterization activities in activities in several ways. Fugro is already using AI and ML on Geo-data in the planning, execution and analysis of our site characterization and asset integrity activities both on land and at sea. Some applications are directly applicable to exploration and characterization, while others would have to be adapted for exploration and characterization.

The following provides a summary of how artificial intelligence and machine learning can be used to guide planning, execution and analysis of exploration and characterization activities:

- Artificial intelligence and machine learning can be used to help prioritize exploration and characterization activities. Existing data combined with business rules and training would allow AI / ML to be used to provide this prioritization function.
- Artificial intelligence and machine learning can be used to operate ASVs, AUVs and ROVs in a fully autonomous mode without human supervision. This application applies not only to collision avoidance, but also to operational optimization. In both instances, the operational environment and in-situ observations are used by AI / ML to meet mission goals.

- A combination of artificial intelligence and machine learning can be combined with simulation to provide just in time information to control the operation of autonomous platforms, such as ASVs, AUVs and ROVs. With this approach. simulation of ASV, AUV, and/or ROV operations are performed against real world data models, supported by in-situ observations, and where those simulations run just ahead of the physical operation. The just in time simulation provides quantitative assurance that the next micro operations about to be taken are safe and positively aiding in the mission objectives.
- Artificial intelligence and machine learning can be used to automatically identify features and items of interest while performing exploration and characterization. It can also be used to automatically conduct interpretation and characterization. As an example, Fugro developed ML algorithms to automatically detect in excess of a million boulders in support of marine site characterization activities for offshore wind farm developments on the U.S. East Coast.
- Significant progress has occurred on the use of AI and Machine learning to detect and identify species of interest. This work should continue and would also allow large-scale regional studies of Essential Fish Habitat to be efficiently conducted
- Protected species identification (from a multitude of observational platforms) can help protect critically endangered (North Atlantic Right Whale), threatened and protected species. There should be a swift uptake of AI-assisted detection technologies by fishing and commercial maritime operators to reduce strikes and entanglements.

7. ***How should the data generated by implementation of the Strategy be managed so that it is most accessible and useful (file formats, compatibility, etc.) to public and private sectors?***

Fugro participated in the Standard Ocean Mapping Protocol Symposium that was organized and facilitated by the Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM) on October 6-7. We provided several lighting talks during the symposium and submitted several sets of written comments in advance of the symposium. These talks and comments covered the various data types addressed during the symposium. They were both extensive and detailed, and amongst other things, covered file formats and compatibility issues. That input and those comments will not be repeated here. Instead our comments focus on more general approaches to data management to ensure that it is most accessible and useful to public and private sectors.

Data visualization and centralized repositories of mapping, exploration and characterization data should be the goal of any robust and large-scale mapping program. Preference should be given to making data intuitive to use, display, and download in useful products, as identified by stakeholders. The strategy would benefit by engaging User Experience or User Interface professionals from the technology industries to design and develop effective visualizations, and effective data synthesis products for stakeholder use.

All data should be accessible in both spatial and temporal formats, meaning that emphasis should be placed on sliding timelines of observations at a specific spatial point or area.

And lastly, data should be populated in standard GIS models, such as Seabed Survey Data Model (SSDM) and made available to the public via secure GIS portal. Web map services should also be served and available.

November 12, 2020

Dr. Alan Leonardi
Co-Chair
National Ocean Mapping, Exploration, and Characterization Council
1315 East West Highway
Silver Spring, MD 20910

RDML Shepard Smith
Co-Chair
National Ocean Mapping, Exploration, and Characterization Council
1315 East West Highway
Silver Spring, MD 20910

Dr. John Haines
Co-Chair
National Ocean Mapping, Exploration, and Characterization Council
U.S. Geological Survey
12201 Sunrise Valley Dr.
Reston, VA 20192

Submitted electronically via nomec.execsec@noaa.gov

RE: Exploration Priorities for the Implementation Plan for the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone

Dear Dr. Leonardi, Admiral Smith, and Dr. Haines:

The National Ocean Policy Coalition ("Coalition") is pleased to offer feedback in reply to the National Ocean Mapping, Exploration, and Characterization Council's ("Council") request for input on the development of an Implementation Plan for the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone ("Implementation Plan"), including exploration and characterization priorities to be included in the Implementation Plan.

The Coalition is an organization of diverse interests representing sectors and entities that support the development and implementation of sound, balanced ocean policies that recognize and enhance the critical role that our oceans, coastal areas, and marine and terrestrial ecosystems play in our nation's economy, national security, culture, health, and well-being while conserving the natural resources and marine habitat of our ocean and coastal regions for current and future generations. Coalition members include interests ranging from fishing and energy to waterborne transportation that depend on ocean access to provide the nation with economic and societal benefits.

NATIONAL OCEAN POLICY COALITION

Strategic National Priorities

Strategic national priorities for exploration and characterization efforts should be determined based on criteria that reflect the role that the ocean can and does play in providing significant economic and societal benefits for the American people.

To ensure that priority areas adequately account for such contributions, **the Coalition recommends that selection criteria include actual and potential economic value as measured by current and potential future human use activities and natural and living resources in the applicable area**. Given their importance to national interests and societal well-being, strategic priorities should include energy, recreational and commercial fishing, and waterborne transportation.

Overcoming Barriers to Adoption of Ocean Exploration Capabilities

Although innovative tools, platforms, and technologies currently exist that can advance more effective and efficient ocean mapping, exploration, and characterization, the application of such capabilities is often constrained by regulatory burdens, uncertainty, inconsistencies, and delays. However, as outlined below, important opportunities for administrative actions exist to streamline and improve decision-making and facilitate more effective and efficient ocean exploration activities. The Coalition urges the Council to help ensure coordination of the National Strategy with the ongoing interagency effort to increase the efficiency of permitting for ocean exploration, mapping, and research activities, including by providing support for implementation of the opportunities to overcome barriers outlined below.

Entities seeking to obtain Marine Mammal Protection Act ("MMPA") authorizations necessary to conduct ocean exploration activities oftentimes must submit multiple applications to various federal agencies when the proposed underlying activity spans the jurisdiction of multiple entities. In the case of 5-year Incidental Take Regulations, authorization holders must again initiate and navigate the same application and review process when seeking a renewal, even when the underlying activity has not substantially changed.

In such instances, existing protocols require entities seeking to engage in commercial or academic research activities that require MMPA authorizations to expend additional time and resources that could otherwise be allocated toward ocean mapping, exploration, and characterization activities that support the Blue Economy and greater understanding of the ocean. **To help alleviate these unnecessary burdens, the Coalition recommends that the MMPA application and renewal process be reformed by**:

- Allowing applicants to submit a common application to multiple federal agencies including the National Marine Fisheries Service ("NMFS") when seeking an authorization for MMPA-regulated activities that also require approvals under a separate regulatory authority; and
- Developing and implementing a simple, straightforward process for renewing 5-year Incidental Take Regulations for activities that are not substantially changing

As to MMPA application reviews, the process has often been mired in lengthy delays, not consistently applied to user groups conducting similar survey types, and presented questions about whether the purposes of the MMPA and its "best scientific evidence available" standard are being adhered to throughout the course of decision-making. **To ensure that requests for MMPA authorizations are being processed in a timely and scientifically-sound manner that is consistent with the MMPA and existing federal policy, the Coalition recommends that the review process be reformed by**:

- Establishing an efficient, consistent, and predictable framework for NMFS and other relevant agencies to ensure that MMPA application reviews proceed in a timely manner, are grounded in sound scientific reasoning, consistently applied across survey types, feature the intra/inter-governmental coordination necessary to support an efficient process, and afford applicants the certainty needed to plan and conduct their operations;
- Setting specific, matching timelines for decisions involving multiple agencies for all activities (e.g. MMPA authorizations at NMFS and related permits at the Bureau of Ocean Energy Management ("BOEM"));
- Developing criteria for categorical "no take" determination for certain clearly delineated activities; and
- Clarifying that there is no overriding policy in the MMPA that requires implementing agencies to err on the side of conservation when making MMPA decisions based upon uncertain or incomplete data, that the best available science standard should be implemented in a manner that avoids overzealous regulation and unintentional economic impacts, and that decisions be based on most likely, not worst-case, outcomes

To help facilitate ocean mapping, exploration, and characterization activities, **the Coalition also recommends that in developing an Implementation Plan for the National Strategy, the Council include a pathway to ensure an efficient and effective permitting process, including through a potential U.S. acoustics and technology standardization subcommittee** that could be organized by an appropriate ocean convening entity capable of accelerating actions and bringing together public and private experts who can drive needed consistency for how mapping and exploration surveys are permitted (including monitoring and mitigation across survey types), and data quality, control, and management (e.g. standardization of reporting sound metrics, consensus-based field methodologies for data collection, and verification of sources).

The Coalition further recommends that the National Strategy's pathway address the need to ensure data-based approaches to permitting rather than reliance on often precautionary and overly conservative modeling, as well as the need for sufficient agency resources and funding to support the storage and application of ocean exploration-related data, the collection of which oftentimes is required of the permit holder under the conditions of the permit. Data-based approaches will only continue to become more critical as technology and platforms to deploy technology advance.

Regrettably, entities seeking MMPA authorizations necessary to conduct ocean exploration have been subjected to differing mitigation requirements even in instances where the underlying activities utilize the same type of technologies, to the detriment of ocean exploration. Furthermore, MMPA reviews to date have raised concerns that analysis of potential impacts from proposed activities have extended beyond the bounds of impacts on marine mammals. Additionally, through representation by both individual companies and trade associations, regulated industries have been denied access to significant deliberations and documents in cases where a federal agency was deemed the "applicant" for purposes of the MMPA authorization request.

Therefore, the Coalition recommends that the following actions be taken to ensure a more equitable and transparent MMPA process that supports ocean exploration:

- Achieve consistency in MMPA authorizations, particularly in required mitigation measures, where permitted activities use similar technology;
- Clarify that an MMPA authorization only addresses incidental take, not other effects of the underlying activity; and
- Clarify that an applicant for an MMPA authorization, or the industry regulated under an incidental take regulation, are "applicants" for purposes of Endangered Species Act Section 7 consultations

Data Management

Data generated by the National Strategy, and ocean mapping, exploration, and characterization efforts generally, can bring tremendous value to the public and private sectors. Ensuring that data is well-managed -- including data gathered through these strategies on ocean mapping and exploration that may then be hosted on federal platforms such as the Marine Cadastre and OceanReports -- is essential to securing such value and public confidence in its availability and potential use by decision-makers. Unbiased depiction of the ocean's diverse existing and potential future uses and resources (and, when addressed, their economic contributions), and assurance that underlying data is subjected to sufficient quality assurance/quality control processes, are fundamental to sound ocean exploration-related data management.

Therefore, **the Coalition recommends that the federal government manage data generated by the National Strategy as well as other ocean mapping, exploration, and characterization efforts, including through but not limited to federal platforms such as the Marine Cadastre and OceanReports, in a manner that (1) accurately accounts for existing and potential future uses of ocean resources; (2) does not render or imply judgment or favor of certain uses over others or non-use; and (3) ensures compliance with federal data integrity laws and standards**.

In closing, the Coalition welcomes the Council's efforts to develop and implement the National Strategy to facilitate mapping, exploration, and characterization of the nation's oceans and appreciates your consideration of the comments herein.

Sincerely,

Brent D. Greenfield

Brent Greenfield
Executive Director

November 12, 2020

Response of The MITRE Corporation to the NOMEC Request for Information on the development of an Implementation Plan for the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone

For additional information about this response, please contact:
Duane Blackburn
Center for Data-Driven Policy
The MITRE Corporation
7596 Colshire Drive
McLean, VA 22102-7539

dblackburn@mitre.org
(434) 964-5023

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Introduction

The MITRE Corporation is a not-for-profit company that works across government to tackle difficult problems that challenge the safety, stability, security, and well-being of our nation through its operation of multiple federally funded research and development centers (FFRDCs), as well as public-private partnerships. Working across federal, state, and local governments, as well as industry and academia, gives MITRE a unique vantage point. MITRE works in the public interest to discover new possibilities, create unexpected opportunities, and lead by pioneering together for public good to bring innovative ideas into existence in areas such as artificial intelligence, intuitive data science, quantum information science, health informatics, policy and economic expertise, trustworthy autonomy, cyber threat sharing, and cyber resilience.

MITRE has significant experience working in the undersea domain, forging partnerships across government (Navy, Coast Guard, Joint Commands, and others), academia, for-profit industry, and non-profits such as UARCs and other FFRDCs. We welcome the opportunity to respond to this National Ocean Mapping, Exploration, and Characterization (NOMEC) Council Request for Information. Please let us know if you have any questions on this submission, or if we can help you succeed in any other way.

Response to RFI Questions

RFI Question #1: NOMEC Strategy Goal 3.1 "Identify Strategic Priorities" describes the need for strategic ocean exploration and characterization priorities and lists some examples. What do you feel are the most important strategic national priorities for exploration and characterization efforts in the deep sea (depth >40 m)? These can be specific geographic areas within the U.S. EEZ or thematic/topical issue priorities.

Many of the resources which we need for our modern society to exist and thrive can be found in the oceans, including food, energy, oil, precious metals, rare-earth elements, and many other natural resources. It is vital that we continue our mapping, exploration and characterization efforts of the oceans to both understand how the ecosystem fits together and also identify available resources which can be used for the sustainment and protection of our way of life into the foreseeable future. The major areas which should be national priorities include:

- Bathymetric maps of the entire EEZ at sufficient resolution that key features can be identified and unique areas can be more fully explored. Surface optical measurement prediction of bathymetry presents a passive approach to "best guess" at depth, which may be sufficient for wide area mapping reserving higher fidelity, in situ resources for additional collection.
- Cataloging of resources, including fish stocks, minerals, oil and natural gas deposits, etc. which can be used when international forces or economic realities require that these be used.
- Identification of unique or fragile ecosystems which cannot be recovered if destroyed and ensuring that these areas are protected.
- Surveillance of near-shore activities to reduce the availability of the ocean environment for illicit activities or threats to national security such as drug smuggling or exploitation of resources by competitors.
- Monitoring of environmental indicators for climate change such as the release of methane hydrates which could indicate shifts in weather, sea levels, or other threats to coastal

communities. This includes monitoring of undersea “weather” such as current behavior and seasonal upwelling that govern the ability of the oceans to sustain life and moderate atmospheric weather world-wide.

For all these priorities, we recommend dividing geographic regions into economic and impact categories. South pacific territories are the largest contributor to the US EEZ, however these areas also have the fewest residents. Excluding Hawaii, they also currently have limited economic value to the US (little shipping, little fishing, etc.), but provide significant strategic impact to US national security posture. They are also more vulnerable to geological effects, such as ocean level rising, undersea earthquakes and volcanic activity, causing accelerated sinking. Alaska and the Alaskan Arctic are critical to national security and undersea resources. The Great Lakes host our most critical ports for trade. These different areas require different types of ocean mapping information at different scales, and at different revisit rates to be useful in guiding decision making.

RFI Question #2: What are the most important questions for exploration and characterization to address?

The process of exploration and characterization of the ocean have traditionally been incredibly expensive and time-consuming efforts, which have relegated much of the exploration to be done through commercial interests, such as the oil and gas industry, who have motivation to seek out deposits for their own financial gain. However, unmanned vessels and the availability of inexpensive global communication have provided opportunities to increase the areas which can be explored and characterized while reducing costs. The most pressing questions for these efforts include:

- What are the current fish stocks and where are those fish stocks located? What environmental and industrial factors influence the stocks and how can these be best managed so that there is availability of food from the oceans into the foreseeable future? How can incentives for the fishing industry be aligned with the future and ongoing needs of the American population?
- What indicators will there be that climate change will be affecting coastal areas and will be exaggerating weather patterns in the future? How can other natural disasters which affect coastlines be detected and the coastal areas protected?
- Where are the most unique or fragile ecosystems within the EEZ? What factors are affecting these areas and how can we protect them for future generations to ensure the health of the entire ocean ecosystem?
- Where are the most valuable natural resources located? How can this information be conveyed to allow for free and open competition for the resources while maintaining enough of a strategic reserve to protect the US from international market pressures?
- How can we protect the most strategically important areas? How can we ensure that the ocean is not being used for illicit activities or by our competitors to gain an advantage in future conflicts?

RFI Question #3: What are the most important data variables that need to be measured, and what are the most valuable physical samples to collect; to conduct baseline exploration and characterization?

The most important data to collect include:

- Edible stock counts, migration patterns, food source monitoring, and ecosystem maintenance.
- Chemical, biological, current, and temperature characterization of the water column to identify additional indicators of climate change ahead of global reactions, such as increased weather activity.
- Bathymetry, bottom identification, coring, and sub-seafloor assessments for identification of valuable mineral and energy resources.
- Fine-scale bathymetric mapping and change identification of areas of strategic importance or likely landing areas for illicit activities.

RFI Question #4: What novel or established tools, platforms, and technologies could advance our capability to explore, and characterize the U.S. EEZ more efficiently and effectively? To the extent innovative capabilities already exist, but are not being effectively used, what are the barriers to adopting them? How can these barriers be overcome?

Traditionally, sonar and sounding measurements are used to remotely collect bathymetric data due to the penetration depth of the energy. Optical-based bathymetric measurements have been demonstrated in lakes and present an alternative to acoustic sensing. Deploying these systems at scale requires advances in unmanned platforms, reliable communication, and data analytical technology, and are thus three areas which could have the biggest impact on mapping, characterizing, and exploring the EEZ. These technologies together provide a cost-effective method for deploying, collecting, and managing data throughout the EEZ.

Autonomy is currently under development and still requires heavy interaction with a human operator to ensure that it is safe. A large barrier to widescale employment of this technology is the cost to deploy autonomous systems and the cost of each of these systems. There have been steps toward reducing these costs, especially of undersea vehicles, using inexpensive unmanned surface craft to enable the deployment of the undersea vehicles remotely. However, this is still a relatively new field and most efforts are still centered around in-person investigations, partially because there is a strong culture and enjoyment of going to sea from the research community. Collaboration between the ocean research communities (including ONR, NRL, and NOAA) such that all academic and commercial activities were coordinated and there was a benefit for reduced cost of deployment would help to enable more autonomous capabilities. In addition, cross-pollination with defense technologies, including methods of controlling the devices remotely, would help to enhance the efforts to deploy unmanned vehicles more quickly.

Data management is another technology which could greatly enhance the ability to map, explore, and characterize the undersea environment in the EEZ. Too often, data is provided exclusively to a small group of people and no effort is ever made to have the data be widely digestible. Providing a nationally-managed archive of data (similar to the World Oceanographic Database) which could also include data collected from sensitive sources, such as Navy submarines or from the Naval Oceanographic Command, while not risking national security would enhance the content of the database dramatically. Providing standards for data packetization would also enable more data to be used and ingested both commercial and national interests.

Lastly, the use of existing national assets, such as submarines and the Naval Oceanographic Command sensors, to provide information to the academic and commercial interests would dramatically increase the amount and quality of the data collected, without increasing budgets.

RFI Question 5: Deep waters within the U.S. EEZ host a wide variety of habitats and geomorphological features (e.g., continental shelves, canyons, seamounts, trenches, abyssal plains, and mesopelagic and bathypelagic zones of the water column). Which ones of these do you think are most important to explore to address the priority questions you identified above?

The most important areas to assess are those where there are fragile or unique ecosystems, areas with resources which could be reached with currently available technology, and areas near shore, especially in strategically important areas.

RFI Question #6: How can artificial intelligence and machine learning be used to guide planning, execution, and analysis of exploration and characterization activities?

MITRE's overall recommendation is to establish an explicit program for the Test, Evaluation, Verification, and Validation (TEV&V) and Instrumentation and Monitoring (I&M) of artificial intelligence (AI) as an enabler and accelerant for AI use in EEZ exploration and characterization. This recommendation is also consistent with objectives from 2.4 and 3.3 from NOAA's AI strategy[1]:

> Objective 2.4. Evaluate and execute various testbed and proving grounds approaches across NOAA to expand AI research, develop best practices and training data, improve algorithms, and evaluate model performance in support of advancing the NOAA mission. NOAA testbeds and proving grounds play an important role in pre-operational evaluation of new developments performed by NOAA and university scientists.
>
> Objective 3.3. Develop NOAA technical guidelines that are updated annually on the best practices and standards for the training data, training practices, and evaluation of model performance to ensure the integrity, reliability, and credibility of scientific products generated with AI applications.

AI presents opportunities for EEZ exploration and analysis in many ways. Autonomous inexpensive sensor platforms, image (and other sensor modalities) classification to sort through substantial volumes of collected data, predictive maintenance for various air, surface, and underwater vehicles to increase

[1] *NOAA Artificial Intelligence Strategy: Analytics for Next-Generation Earth Science.* 2020. National Oceanic and Atmospheric Administration, https://nrc.noaa.gov/LinkClick.aspx?fileticket=0I2p2-Gu3rA%3D.

availability and utilization, machine learning to identify subtle correlations that indicate various resources, are just a few examples. However, AI presents well-understood challenges to establishing justified confidence that it is sufficiently robust to be used in operation under conditions of uncertainty and varying operational environments, which are certainly attributes of exploring and analyzing the EEZ. These challenges to justified confidence have been the focus of extensive study and investment in multiple sectors and Federal agencies including the DoD, FAA, FDA, and the Intelligence Community. MITRE is supporting many of these efforts to address the challenges of justified confidence and has seen common themes and approaches evolve. This Committee has an opportunity to leverage the growing body of research, tools, techniques, and practices to enhance the confidence that can be established about the operational performance of AI.

Challenges and Opportunities

Fielding AI systems in consequential roles includes establishing confidence that the technology will perform as intended, especially in high-stakes scenarios. An AI system's performance must be assessed, including assessing its capabilities and blind spots with data representative of real-world scenarios or with simulations of realistic contexts, and its reliability and robustness during development and in deployment. For example, a system's performance on recognition tasks can be characterized by its false positives and false negatives on a test set representative of the environment in which a system will be deployed, and test sets can be varied in realistic ways to estimate robustness. Testing protocols and requirements are essential for measuring and reporting on system performance, including reliability, during the test phase (pre-deployment) and in operational settings. AI systems present new challenges to established testing protocols and requirements as they increase in complexity, particularly for operational testing. The importance of the insights gained from comprehensive analysis of data on the EEZ, and the potential risk to expensive or scarce platforms (e.g., autonomously tasked sensor platforms), will require attention on the confidence in AI adoption for EEZ exploration from the start.

Various kinds of AI systems often demonstrate impressive performance on average but can fail in ways that are unexpected in any specific instance. AI can have blinds spots and unknown fragilities. Across multiple MITRE sponsors and stakeholders, there is a current focus on tools and techniques to carefully bound assumptions of robustness of the AI component in the larger system architecture, and to provide sustained attention to characterizing the actual performance envelope for nominal and off-nominal conditions throughout development and deployment.

Traceability, critical for high-stakes systems, captures key information about the system development and deployment process for relevant personnel to adequately understand the technology. It includes selecting, designing, and implementing measurement tools, logging, and monitoring and applies to (1) development and testing of AI systems and components, (2) operation of AI systems, (3) users and their behaviors in engaging with AI systems or components, and (4) auditing. Audits should support analyses of specific actions as well as characterizations of longer-term performance. Audits help assure that performance on tests of the system and on real-world workloads meet requirements by stakeholders.

When evaluating system performance, it is especially important to take into account holistic, end-to-end system behavior. Emergence is the principle that entities exhibit properties which are meaningful only when attributed to the whole, not to its parts. Emergent system behavior can be viewed as a consequence of the interactions and relationships among system elements rather than the independent behavior of individual elements. It emerges from a combination of the behavior and properties of the system elements and the systems structure or allowable interactions between the elements and may be triggered or influenced by a stimulus from the systems environment. As a recent study of the software engineering challenges introduced by developing and deploying AI systems at scale notes, "AI components are more difficult to handle as distinct modules than traditional software components — models may be 'entangled' in complex ways."[2] These challenges are pronounced when the entanglement is the result of system composition and integration.

These use cases clearly can't be adequately addressed at development time; some aspects of confidence in the composition must be shifted to monitoring the actual performance of the composed system and its components. For emergent performance concerns when AI systems are composed, there are advances in runtime assurance/verification and feature interaction management that can be adapted.

As the Committee moves to adopt and integrate rapidly advancing AI capabilities into the exploration of the EEZ, attention to establishing and preserving justified confidence in the use of AI in high consequence systems will be essential. There are many relevant investments and developments in support of TEV&V and I&M of consequential AI systems across the Federal Government and in industry. MITRE is engaged with a broad range of these efforts and has identified some common challenges along with some opportunities for NOAA to accelerate the responsible adoption of AI into EEZ exploration.

RFI Question #7: How should the data generated by implementation of the Strategy be managed so that it is most accessible and useful (file formats, compatibility, etc.) to public and private sectors?

Data should be handled in a modern database, such as a graph-based database, so that it is easily searchable and ingestible by both humans and machine algorithms. The data formatting should be as platform agnostic as possible with complete documentation provided for how the data is structured and complete metadata records, such as time collected, instruments used, etc. For example, pdf file-format thumbnails for all imagery, with tiff files where indexing into individual image elements, enables easy access by a broad set of users. Data packetization standards should be created, adopted, and enforced through requirements for all government-funded research and activities. Data access could be provided to people who are willing to provide their own data, with carefully worded contracts created so that the data is useful to the entire community and to avoid intentional or unintentional flawed data to be inserted into the database.

The United Nations declared 2021-2030 as the "decade of ocean science for sustainable development." This effort[3] has created a multi-national coalition aiming to mobilize scientists worldwide to collectively address gaps in current technology, accelerate research, and develop standards used by the global ocean community. The US should participate actively in this effort and leverage the technology developments and standards adopted across the UN coalition. Underway in the US, there are already several efforts aiming to create data standards for bathymetric and other ocean data. NOAA, NGDC, USGS and other organizations have partnered with and sponsored interest groups, aiming to adapt existing formats and compatibility to new standards. For example, the Great Lakes Bottom Mapping

[2] Amershi, S., et al. Software Engineering for Machine Learning: A Case Study. 2019. Institute of Electrical and Electronics Engineers, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8804457.

[3] https://www.oceandecade.org/

working group is a joint government and academic venture developing data standards for geospatial data around the Great Lakes maritime environment, including bathymetric data. Lessons learned from groups like these can be applied across the entire US EEZ.

nomec execsec - NOAA Service Account <nomec.execsec@noaa.gov>

No. 2 A. Fresco "Public Comment on Exploration Priorities for the Implementation Plan"

Fresco Anthony <>
To: Nomec Execsec - NOAA Service Account <nomec.execsec@noaa.gov>
Cc: Hagen Ruff <>, Thorsten LudwigSPESIF2012 <>

Tue, Nov 10, 2020 at 8:21 PM

To NOMEC Executive Secretary:

1. **Implementing a National Strategy for Mapping, Exploring, and Characterizing the U.S. EEZ** The National Oceanic and Atmospheric Administration (NOAA) issued a notice stating that the NOMEC Council requests input from all interested parties on the development of an Implementation Plan for the National Strategy for Mapping, Exploring, and Characterizing the U.S. EEZ ("National Strategy"). Input should be provided by **12 November**. 85 Fed. Reg. 64446 (10/13/20) [https://www.federalregister.gov/documents/2020/10/13/2020-22411/request-for-comment-implementation-plan-for-the-national-strategy-for-ocean-mapping-exploring-and].
2. **Strategic priorities for mapping, exploring, and characterizing the U.S. EEZ** NOAA issued a second notice stating that the NOMEC Council requests input from all interested parties on the strategic priorities to be included in the Implementation Plan for the National Strategy. Input should be provided by **12 November**. 85 Fed. Reg. 64448 (10/13/20) [https://www.federalregister.gov/documents/2020/10/13/2020-22413/request-for-information-implementation-plan-for-the-national-strategy-for-mapping-exploring-and].

All responses and questions can be addressed to nomec.execsec@noaa.gov. Please reach out for additional information or questions regarding NOMEC.

With respect to Item 1 "Implementing a National Strategy for Mapping, Exploring and Characterizing the U.S. EEZ", the following comments were presented and are reproduced here since the instant comments further below with respect to Item 2 "Strategic Priorities for Mapping, Exploring, and Characterizing the U.S. EEZ" are directly related.

Item 1: As indicated in Goal 2: The United States EEZ is larger than the combined land area of all 50 states, spanning over 13,000 miles of coastline and containing 3.4 million square nautical miles (SQNM) of ocean.

In studying Goals 2, 3 and 4, it appears that there is a very important factor that is being overlooked. The 13,000 miles of coastline provide ready and immediate access to what are probably the most abundant and economically advantageous resources of all: the ocean water and its salt contents.

The following is a very comprehensive publication by the American Chemical Society in 2015:

Mining Critical Metals and Elements from Seawater: Opportunities and Challenges

Mining Critical Metals and Elements from Seawater: Opportunities and Cha...

The availability and sustainable supply of technology metals and valuable elements is critical to the global eco...

1. Should there not be an emphasis on utilizing seawater that is readily available for mining critical elements?

Also there are proposed technologies such as solute ion linear alignment ion beams which could in combination with magnetic fields enable separation of the metals and elements from seawater.

In addition, using the same process, the salt in seawater could become both an extremely powerful energy source and a method of desalination and a method of both endothermic nuclear fusion and exothermic nuclear fusion. In the latter known process, the lighter elements on the periodic table can be combined to form heavier elements such as rare earths and also new alloys, many of which are required for electronic components such as phones, computers, semiconductors, etc.

2. Should there not then be a high priority on research involving such objectives which could also include enabling the pumping of sea water inland for both agricultural purposes and to mitigate sea level rise?

Item 2: Since Item 2 "Strategic Priorities for Mapping, Exploring, and Characterizing the U.S. EEZ" relates to the mapping, exploring and characterizing portions of the ocean that have a depth of 200 meters or more, it should be noted that the very same proposed technology of solute ion linear alignment and a related motor identified above with respect to Item 1 could be applied uniquely to construction of drones that could very effectively navigate both the deep ocean and also the air and sky above the ocean so that such drones could be made to travel long distances airborne to areas of other interest at greater speed and not be forced to remain submerged at slower speeds.

This would be possible since propulsion power would be supplied from the electrostatic fields of the salt in salt water and thus, except for factors such as material fatigue and maintenance requirements and the like, since such drones could theoretically travel indefinitely and at greater speeds, the time required to map, explore and characterize the U.S. EEZ should be significantly reduced.

- Particularly in view of the fact that generally the same technology as identified with respect to Item 1 could be applied also to the development of such drones, should not the development of drones with such capabilities be identified as a priority among, and made a high priority within, the Strategic Priorities?