DIALOGUES
WITH INDUSTRY

Dialogues with Industry - Draft Synthesis

Maturing the Ocean Enterprise to Deliver Essential Societal, Economic, and Environmental Benefits

17 April 2023

Authors:

Zdenka Willis (Marine Technology Society), Emma Heslop (IOC/UNESCO), Peer Fietzek (Kongsberg Maritime), Liz Tirpak (NOAA), Donna Kocak (L3Harris, MTS), Ralph Rayner (NOAA), Michelle Heupel (Integrated Marine Observing System)

GOOS Report No.: GOOS-282

The Global Ocean Observing System

marine technology SOCIETY

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Table of Contents

Introduction

This document provides a synthesis of the content and outcomes of four *Dialogues with Industry* held from September 2022 to January 2023. The objective of these Dialogues was to explore and define opportunities for maturing public and private sector capability and capacity to support a growing need for actionable ocean data, information, and knowledge in support of the delivery of economic, societal, and environmental benefits.

The Global Ocean Observing System (GOOS) coordinated by the Intergovernmental Oceanographic Commission of the United Nations Education Scientific and Cultural Organization, the Marine Technology Society (MTS), and the National Oceanic and Atmospheric Administration (NOAA) partnered in the delivery of this United Nations Ocean Decade action. The title Dialogues with Industry was intentionally chosen to recognize and emphasize the private sector's evolving role in all parts of the ocean information value chain.

Delivering the ocean data, information, and knowledge needed to address societal and environmental challenges such as climate change and the restoration of ocean health, at the same time as realizing growth in the use of the ocean for economic benefit, will require sustained **critical infrastructure** equivalent in scope and scale to that of the present Weather Enterprise.

Further evolving the relationships between government, academia, and the businesses that provide most of the technological means to observe and measure the ocean, as well as much of the capacity to translate the resulting data into information services, will be fundamental to enabling this future Ocean Enterprise.

The Dialogues comprised curated conversations that brought together 87 invited participants and more than 400 observers from forty countries. They included representation from private (for-profit and nonprofit/NGO) entities, governmental and other public bodies, as well as the academic sector. The Dialogue participants provided insights and identified issues, barriers, and opportunities. These discussions offered actionable recommendations that will help to unlock the potential of the Ocean Enterprise ensuring, its capacity to support meeting increasing requirements for ocean data, information, and knowledge over the coming decade.

This draft synthesis report provides an initial assessment of more than 400 discrete recommendations and next steps for furthering the Dialogue process. It is the intention to hold future Dialogues with a diverse group of Ocean Enterprise stakeholders to prioritize and further detail these recommendations, providing a basis for the development of strategic road maps for their implementation.

The feedback from the participants in this initial round of Dialogues was clear regarding the value of regular, multi-directional, inclusive, and structured dialogues between Ocean Enterprise stakeholders. There was a genuine sentiment that the process should be further pursued to determine concrete actions and clearly defined pathways for their implementation.

Background

Through four curated, moderated discussions among representatives from new and established businesses, nonprofit/non-governmental organizations, academia, and government, the goal of the Dialogues was to develop actionable recommendations concerning how the public and private sectors can work together to meet the future needs of science, society, and the Blue Economy by evolving and expanding the ocean observing systems and ocean information service delivery. Each Dialogue lasted between 2.5-3 hours and included approximately 20 invited panelists and 100-200 observers. Panelists responded to a series of prepared and ad-hoc questions. Observers used the chat function to interact with the moderator and panelists during each Dialogue. Each session ended with an open discussion between the moderator, panelists, and observers.

Appendix 1 provides a demographic analysis of participation in the Dialogues. Full reports and videos of each of the *Dialogues with Industry* are available at the Marine Technology Society (MTS), here, and the Global Ocean Observing System (GOOS), here.

Overall Synthesis

The four Dialogues were structured around the Ocean Information Value Chain, described in Appendix 2. This approach allowed an in-depth discussion around each stage in securing observations and measurements and transforming these data into actionable information (prediction system, assessment) that has value to decision makers and business leaders, as well as society as a whole. The four Dialogues: (1) Instrument Provisioning, (2) Multi-Sectoral Ocean Architecture; (3) User Driven Ocean Information Services; and, (4) Looking Ahead, were chosen to focus on the main components of the Ocean Information Value Chain.

The first synthesis of the outcomes and recommendations of the individual Dialogues was to group them into four focus areas that reflect essential actions needed across the Ocean Enterprise market as reflected in Figure 1, where focus areas two and three inform focus areas one and four. Under each of the focus areas, twelve categories were identified to expose unseen dynamics of the Ocean Observing and Services market to help structure future conversations with stakeholders.

Figure 1: Focus Areas and Categories

Focus Area 1: Improving the market

While the Blue Economy is seeing increased investment from the private sector in Ocean Enterprise, public sector funding still represents a significant portion of this investment. Further, it was noted that funding levels necessary to sustainably observe Essential Ocean Variables (EOV) at the required spatial or temporal scales do not currently exist. While funding for capital expenditures is more readily available, longer-term operational funding is not. These factors impact how the Ocean Enterprise sectors interact.

The market size and profitability of Ocean Observing and Services are directly linked to the value they add to the subsequent industries they support, i.e., tourism, aquaculture, transport, and others. The critical role of Ocean Observing and Services in enabling the realization of value in these subsequent or end-use markets is where real value can be articulated and value assigned.

While it is likely that new markets, such as marine carbon dioxide removal will take years to mature, the Ocean Enterprise needs to be poised to service those markets when they take off. One of the issues that the industry serving this area, both technology providers and intermediaries, has always faced, is that the demand for data and information is not there at the start of the emergence of a new user area. It will be important to communicate the right market signals to create the technologies and information that will be needed. The challenge is that this requires cash upfront to incentivize those markets and make sure that the capacity develops in tandem with the growth of the market.

Market size and aggregation

Understanding and articulating market size helps facilitate and drive investment. Overall today's market for Ocean Observing and Services is perceived as being a fragmented niche (e.g., specialized one-off sensors) and a static market, which makes it difficult for businesses to determine where there is potential for growth and scaling. Two main issues were identified:

- Ocean Observing and Services is not established as an independent industry sector/activity**.** While ocean observing data, products, and services are recognized as underpinning the Blue Economy, Ocean Observing and Services is not recognized as an independent sector/activity. The Ocean Enterprise studies conducted by the United States, Canada, and the United Kingdom have begun quantifying the size of the private sector component of the Ocean Enterprise, which is growing. However, there is no systematic and international approach, based on standard codes, to measure the value of the private sector of the Ocean Enterprise. Consequently, it is not highly visible nor is Ocean Observing and Services independently measured as an activity in OECD's Blueprint for Improved Measurement of the Ocean Economy[1], or the United States Department of Commerce Marine Economy Satellite Accounts. An open question remains as to whether Ocean Observing and Services is or can become strong enough to be recognized as a stand-alone market, or must be viewed as supporting a diverse array of other industry activities (e.g., tourism, aquaculture, transportation).

[1] OECD Science, Technology and Industry Working papers 2021/04; Blueprint for Improved Measurement of the International Ocean Economy; An exploration of Satellite Accounting for Ocean Economic Activity; https://dx.doi.org/10.1787/aff5375b-en

- Blue investments are risky. Blue/ocean investments are not at the same level as green/environmental investments, in part due to the perceived risk in ocean ventures which itself would be reduced by increased market knowledge, information, and ocean observations and services. This is another opportunity as Blue investors are looking to the Ocean Enterprise to provide more certainty around specific use cases, market size, and the profitability of ocean observing technologies, products, and services.

Market demand for ocean observing technology, data, and information, must be aggregated to illustrate the critical mass of opportunity that is needed to create markets of sufficient size for ongoing investment. Using a meteorological analogy, significant demand is driven by the high priority needs of both the private (e.g., airlines and shipping) and the public (e.g., defense and emergency management) sectors. For ocean information, there is not yet a diverse ecosystem of paying customers to foster and sustainably support new venture investment and business creation. **New markets and innovation will be driven by specific applications** such as marine carbon renewal sequestration and wind farming, e.g., rather than generalized concepts such as enhancing data collection. Venture-funded startups require evidence of large, rapidly scalable existing and potential new markets. Mechanisms for aggregating market demand include:

- International conventions. Currently, these conventions do not provide mandates to collect the ocean information needed to underpin indicators and assessments. The Ocean Enterprise needs to be more proactive in being part of the writing of international conventions to ensure that nationally-defined contributions associated with undertaking observations are required to evaluate the effectiveness of actions, such as the Convention on Biological Diversity, the Task Force on Nature Related Financial Disclosures (TFND), the United Nations Sustainable Development Goals, etc.
- Regulation. Mandated actions associated with Ocean Enterprise activities, such as permit compliance and regulations guiding operating procedures, define business opportunities and markets. For example, the Norwegian government has set regulations to minimize the risks associated with mariculture pests/infestations and their spread. This required and resulted in a robust observing system, which in turn was supported and funded by private-sector mariculture operators who must report through government-organized frameworks. Siting, permitting, and operating offshore wind farms is an analogous situation where defining and sustaining ocean observations is required, along with associated measurement, reporting, and validation standards.
- Policy. There is a lack of recognition of ocean information informing policy decisions. The Ocean Enterprise would benefit from a better understanding of the benchmarks, drivers, and frameworks that either exist currently or that could be developed to constrain, incentivize, and drive the Blue Economy.
- Environmentalism. There is an opportunity with the increase in public awareness of the importance of the ocean and the seriousness of climate disruption to drive demand; however, these markets will largely be driven by specific applications (e.g., push for net zero, marine carbon sequestration, carbon credits, reporting and verification of carbon removal, and infrastructure changes for adaptation to climate change).
- Publicizing. Communicating the value of public data can also aggregate and increase sustained demand. Everyone, regardless of where they live, has a connection to the ocean. That connection and its relevance in sustaining human civilization are not widely understood.

Next steps:

1. **Market reports.** Conduct and distribute authoritative, targeted market studies that provide the vital information needed to convince investors and corporate board members that Ocean Observing and Services, as an independent industry sector, is of sufficient magnitude to warrant investment.
2. **Repository.** Foster a centralized repository for Blue technology and Blue Economy literature (e.g., market reports, impact studies, emerging technology assessments) to provide investors with a single source of reliable information on the current market as well as market opportunities.
3. **Protocols.** Establish mechanisms where the Ocean Enterprise actively participates and influences the use of ocean information in the determination of indices to measure the effectiveness of regulatory measures and international conventions.
4. **Metrics.** While creating metrics for the economic benefit of ocean observations is challenging, such measures are crucial for justifying investments. "Social license"—tying governmental performance to societal impacts rather than observational metrics—should be the next key performance indicator (KPI) adopted by both public and private entities.

Risk

Risk is a cost driver and a limiting factor for market growth. For example, while the Ocean Enterprise public sector sees a strong need for low-cost, easy to use sensors to expand the global ocean observing capacity, and while governments may require an overall guarantee on sensor performance, the private sector must assume the financial risk for developing ocean observing platforms and sensors. There is a real need for low cost and easy-to-use sensors, but it is important to note that the public sector often conflates low cost, easy-to-use, as meaning low cost to develop. The private sector participants strongly made the point that **low cost, easy to use sensors have higher development costs** and longer development cycles, which significantly increases the risk to a company. For the private sector to pursue these sensors, they need to see a commitment from the public sector that there will be a large enough market to justify the development costs. Further, the goal is to grow the Ocean Enterprise where there is an opportunity for both complex sensors that are likely to be more costly and as the market matures the development of more low-cost, easy-to-use sensors. Likewise, when the public sector requests a guarantee of the overall performance of ocean observing systems, this increases the risk to platform providers who are often integrating a variety of third-party devices and must absorb that risk as well.

To escape from what appears to be a chicken and egg position, the public sector could consider ways to lower risk in the short term to achieve societal goals. As the Ocean Observing and Services market develops and reaches greater maturity, this need may reduce, but for now, several methods to reduce risk were identified through the Dialogues.

Industry also needs to have an enabling environment to move toward economies of scale and away from high-cost, high risk customized, one-off, short-term projects. The current market size makes the ability to quickly scale manufacturing difficult, the reasons for which span from low and fragmented purchase volumes, to overdesign due to unknown/not articulated user needs, which also differ from organization to organization. Options to mitigate this risk include:

- Modularization. Modular configurations that are interoperable with standardized sensor configurations that support multiple missions. This will require upfront investments.
- Harmonized procurement. Greater harmonization at the institutional, national, and intergovernmental levels can increase the efficiency of procurement, economy of scale, and create a less administrative burden on industry and institutions.

Risk on all sides includes the sustainability of the observing system supply chain. While public sector funding represents a significant portion of the overall investment in ocean observing systems, that funding is variable and not in general sustained beyond short-term science funding horizons, with longer term operations and maintenance funding sometimes hard to justify under existing science funding models. The instability of funding for the ocean observing systems impacts how industry can interact with and support the public sector. Sometimes this results in an operationally-critical sensor being discontinued, with negative impacts on the systems. One option is to develop multiple and more sustained funding streams that can support both innovative and sustained observations. For example, United States federal investment grants like Defense Research Projects Agency (DARPA), the Advanced Research Projects Agency-Energy (ARPA-E), or the Small Business Innovation Research Program (SBIR) provide non-dilutive funding (agencies do not take an equity stake in the companies they fund) and are vehicles for addressing the higher risk and innovation timelines.

A longer-term public-sector commitment to funding the sustained components of GOOS would provide the private sector with a significantly greater level of stability and is a major factor to consider in creating an environment that is favorable to making blue investments.

Next steps:

1. **Trade-offs.** Continue dialogs between the public sector and industry on user needs and risks to understand the perspectives of each group and the trade-offs required (e.g., between easy to use, affordable, and high quality/precision in product development and/or between what data to collect and what to leave out).
2. **Re-thinking Funding.** Identify potential funding streams that support and help speed new technology to market at volume. At the same time, the public sector needs to consider the impact of the non-sustained, short term, funding horizons on maintaining higher costs in ocean observing, the loss of investment from the private sector, and the slowing of growth in the Ocean Enterprise and Blue Economy.
3. **Economies of scale.** Support the transition of existing private sector sensors as well as research and development prototypes to large scale observing systems by developing road maps that include information related to the protection of intellectual property, specified use cases, the understanding of commercial viability, the ability to scale up manufacturing, and the benefits of running programs in parallel using established technologies to validate the new technologies.

Bringing in new actors

While it is necessary to continue to build the connections between the private sector, public sector, and academia, new actors also need to be brought into the community to build collective solutions that quickly and creatively respond to gaps in the market. The introduction of new technologies in the ocean observing systems is a difficult process often met with reluctance due to the complexity and longevity of the existing infrastructure. Further, industry has sometimes found that agencies and observing systems are a closed club and hard to break into, which can be a distinct disadvantage to small and medium businesses that are often agile and have the potential to provide disruptive technologies.

The high-tech industry and ocean exploration can benefit from a stronger relationship, as it provides financial support and STEM education opportunities, inspires employees, and creates platforms and supply chains. Establishing public/private partnerships to undertake co-design activities, such as that occurring between the ocean observing community and the undersea cable industry to create smart underwater cables, offers similar benefits. Future opportunities could include partnering with the pharmaceutical or fashion sectors, which have begun discussing and applying sustainable practices, including ideas such as recycling recovered material from the ocean.

Next steps:

1. **Inviting.** Inviting traditional and non-traditional actors into the community and working together to: (1) learn and understand respective missions, drivers, and needs; (2) add different perspectives, resources, and skill sets.

Focus Area 2: Societal/Governmental change

Understanding the differences between the motivations, timelines, and expectations across the Ocean Enterprise sectors is fundamental to realizing a high-functioning multi-sectoral ocean observing systems. At a high level, the public component's focus is on the public good for broad societal needs. The focus of the private component centers on shareholders' and stakeholders' specific interests, solution offerings, and profit. While academia's focus is on the basic and applied research needed to continually improve our knowledge of ocean processes through observations and models. Throughout the Dialogues, there was recognition of these differences, a genuine interest to understand the various perspectives, and an overwhelming desire for open communication amongst the community on current and emerging needs.

The Ocean Enterprise private sector recognizes the public sector's role and influence in shaping the overall Ocean Observing and Services market and encourages the public sector to structure the growth of this sector going forward.

Data and missions as a service

The typical business model around ocean observing has been either the public sector developing the platforms and sensors in-house, or procuring and operating these systems independently (e.g., government-owned, government-operated). Within the Ocean Enterprise, that model is undergoing a paradigm shift to one that recognizes data and meeting mission needs as a service, where the product purchased by the customer is the data produced by an independent operator of the system or contracts to the private sector to conduct the mission. Under this model, company-owned, company-operated missions have the potential to help government agencies avoid acquisition, operation, and maintenance costs. Further, there are potential human resource savings; instead of government agencies using personnel to deploy and maintain equipment, the focus can be on translating the data into applications and decision-support tools.

In the private sector, data is categorized as an asset. Considerations when shifting the primary provider of data, mission, and technology solutions to the commercial sector, include:

- Defining the requirements of both the public and private sectors, while acknowledging that some commercial solutions may only partially meet the requirements and/or are not cost effective for the market;
- Ensuring transparency in calibration, validation, and data quality assurance;
- Understanding the commercial viability of new technology and the underlying stability of the private sector markets; and
- Requiring a license to protect intellectual property that could limit use when data were previously available at no cost to users.

For commercial entities, sharing data in an open and unrestricted way is at odds with the realities of how business works, where data are viewed as an asset, with an associated value that must be paid. However, revenue is not the only motivating factor for industry. The social value of data and working with the academic sector to advance science by providing the data at little to no cost can be highly beneficial to these companies and has resulted in the development of new data markets.

Moving to a hybrid public-private ocean observing architecture business model, one akin to the Weather Enterprise where the meteorological community works together to create services and products that align across many needs would help address the trade-offs listed above. For instance, participation could require the private sector to provide: (1) documentation on protocols; (2) a tiered licensing schema that is transparent and universally adopted; and (3) the generation of "test data sets" that measure effectiveness of privately provided observations. Using this type of model, more opportunities would be available for commercial entities to create products and services that could then be scaled for the market.

Data is an asset and understanding the licensing of these assets is complex. As we increase the number of private sector businesses that are offering data, missions, and services, there is not yet a consensus on a data licensing schema for commercially procured data. Although licensing is complex, the Ocean Enterprise can look to the Space Enterprise and Weather Enterprise for examples. Alignment of interest and partnership were identified as important components of successful licensing agreements. In that regard, defining ownership of the data and the terms of how it can or cannot be shared is critically important.

Next steps:

1. **Hubs.** Develop hubs or focal points to work together on the issues raised in the Dialogues with Industry. Organizations like the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO) could also help by setting a common framework to meet user needs, thereby creating a common platform across which commercial entities could create products and services that meet a range of user needs.
2. **Licensing Schema**: Develop End User License Agreements (EULA) applicable to the Ocean Enterprise.

Ocean information perception

Ocean Observing and Services are not yet considered to be essential elements required for making national and international strategic, safety, operational, and environmental management decisions. Changing the perception of ocean data will require strengthening government and international commitment to a necessary ocean observing system. **Ocean Observing and Services must be considered critical infrastructure,** which would drive funding and mitigate risk in this market area.

Additionally, the Ocean Enterprise uses a great deal of jargon and their communications can be fragmented and difficult to understand for the uninitiated. If the essential need for ocean information could be more fully recognized, ocean information would move from the periphery to the mainstream. In turn, the private sector would have more assurance that governments are committed to sustained funding for the ocean observing systems, which would lower the risk of investment and corporate participation.

Ocean Literacy remains low overall. Addressing this gap is an important need that should be addressed from early childhood education to higher education/professional development.

Next steps:

1. **Ocean Decade.** Invite GOOS and individual observing systems to co-create a U.N. Ocean Decade Program focused on strengthening the commitment of governments and international organizations to a vital and necessary ocean observing system, as a part of national infrastructure rather than being funded as short-term, regionally transient research projects.
2. **Impact studies.** Generate additional curated impact studies to raise awareness globally of the importance of sustained Ocean Observing and Services.
3. **Addressing Ocean Literacy at the Undergraduate/Graduate level.** Use real-world problems of societal/national/international concern that are grounded in ocean science to expose individuals outside of the Ocean Enterprise to the importance of the ocean.
4. **Improve branding.** Increase public awareness of the need to protect our oceans and their resources through science and innovation by creating and promoting a unified brand focused on ocean technologies and their associated benefits.

Focus Area 3: Collaborating to grow

Establishing a hybrid public-private ocean observing architecture business model will require ongoing collaboration across the Ocean Enterprise. Such a model requires developing deep relationships to better understand an ever-evolving set of prioritized end user needs as well as the best path taken to respond to those needs. This model also accounts for understanding where the public/private/academic sector contributions start and end, and the efficiency gains that may be realized from better defining participants' roles and responsibilities.

Standards

The lack of standards in both hardware and data protocols (e.g., common languages, controlled vocabularies, taxonomies) is a **significant barrier** to the growth of the Ocean Observing and Services market. Standards are driven by the fundamental need of both providers and consumers that the product and data outcomes will achieve a known minimal level of quality from which insights and services can more easily be developed. The discussion concerning the acceptance and adherence to standards was such an important point that it was raised in each of the four Dialogues sessions.

When standards are not identified, set, and communicated, private sector companies have no target point, leading to higher risk as developing economies of scale are less certain in these circumstances. Conversely, when evolving standards and requirements for measurements and data sharing are actively communicated across the Ocean Enterprise and are not overly burdensome, the resulting outcomes will be more fit-for-purpose technologies that stimulate market demand. As discussed previously, the Weather Enterprise sets a helpful example. In the weather prediction community, set standards and conventions are followed by all meteorological agencies around the world, and data, regardless of the brand of instrument, are integrated and made available around the clock and in near-real-time.

Standards for ocean observation hardware and data protocols can lead to de-risking blue investments by (1) increasing the confidence that product development will be readily accepted and useable; (2) leveling the playing field; (3) providing stability (or reduced uncertainty) of the sector; (4) increasing transparency; and (5) creating the opportunity for scalability, co-design, and public-private partnerships.

Next steps:

1. **Standards.** Identify a small number of standards (that go beyond existing agreements/understandings) that would significantly advance the community and the pathway to developing them through public-private interaction, and overseen by a recognized international body.
2. **Incentives.** Identify community motivation and incentives for incorporating standards (e.g., economic, regulatory, societal) to reduce risk by ensuring that everyone across the Ocean Enterprise is adhering to the same standards.
3. **Authority.** Determine the facilitator (e.g., Group on Earth Observations, GOOS) that will work with member governments and industry to establish these standards.
4. **Repository.** Publicize the IOC/UNESCO Oceans Best Practices System as a starting point for a repository for the standards.

Intermediaries

Today the largest component of the Ocean Enterprise industries are the producers of observing platforms and sensors. For example, producers make up 82% of the companies in United States Ocean Enterprise and this component is expected to continue to grow. Intermediaries are entities that leverage producer outputs to derive new products and services that are of greater value than what consumers could realize from the primary producer alone. Intermediaries are currently an emergent factor in the Blue Economy, but their participation and role are expected to increase sharply to meet end-user needs as the provision of ocean observation products and services grows. As intermediary participation increases, there will inevitably be an overlap between public and private efforts, with the public sector fulfilling its duty to provide actionable products and services and the private sector seeking market opportunities. This blurring can be a challenge, however, the societal need (and therefore market) for solutions that improve the access to and utility of ocean data is very real, and public and private sectors can both exist and thrive while delivering ocean information services.

National/government agencies should consider whether there is a viable commercial solution that exists or can be developed more economically by an intermediary provider before undertaking the development and delivery of those services themselves. Moving in this direction would mean that ocean observing services would be available from a variety of actors – public and private - each offering different cost/benefit tradeoffs, levels of utility, and end-user service needs.

Much of the data collected in the ocean takes a degree of sophistication and knowledge to interpret and then derive the operational insight that decision makers need. It is the role of all in the Blue Economy to make every effort, wherever possible, to share ocean data with others. Intermediaries are in the sweet spot to reinforce this necessity, which is most successfully accomplished when they can access public and private data efficiently and then create a value-added derivative product. While there is still a lot of market development needed to promote the development of derived products that are fit for purpose and suitable for industries, both the public and private sectors strongly agree that creating public-private partnerships to facilitate "co-designed services" would be beneficial. It should be recognized that such coordination and collaboration is labor intensive, and requires deep trust and understanding.

Next steps:

1. **Translate.** Determine how to best translate user needs to create opportunities for future public-private partnerships.
2. **Engagement.** Create systematic engagement among the community to ensure success. For example, the public sector should share plans for new product development (which may impact private service providers), and the private sector should specify the public data that are most needed/useful for their services. Such a dialogue will provide intermediaries with a sense of the opportunities, threats, and sustainability of their offerings, including the timescales for product evolution.

Data access

There are national, international, and intergovernmental programs that are making data accessible through portals; however, participants stated that accessing public data is cumbersome and is a detriment to building the Blue Economy. Further, there are still examples where data are not being shared. This issue can be technical (e.g., software bugs) and/or cultural (e.g., different industry tolerances for sharing data, and sensitivity to proprietary information) and will require a persistent effort to resolve.

Taken together, public, and private sector data are complementary, with private sector data often providing high density, limited spatial coverage, and the public sector providing lower resolution, global spatial coverage. Having access to both sets can lead to more partnership opportunities. Further, there is a growing recognition within companies that making their data interoperable to facilitate external sharing is an important aspect of their mission.

Private sector data acquired for private sector clients are often dense and more limited in scale, whereas public sector data are often broader scale; this makes the data sets complementary. The private sector can accelerate the use of their data both internally as well as externally to a public/private venture by adopting the Findable, Accessible, Interoperable, Reusable (FAIR) data principles.

Despite the desire for a hybrid public-private ocean observing architecture business model, it is likely that some data streams, such as those critical to human safety, may need to remain as public data whether it is provided by publicly funded infrastructure or privately (through contracts to the public entities). **There may also be classes of data that can never be profitably generated and are thus never delivered by commercial entities**.

Next steps:

1. **Data portals.** Understand the issues with the current national, international, and intergovernmental data portals that impair access and use by different stakeholders.
2. **Private data.** Connect with the Ocean Decade Corporate Data Group to understand their efforts to create frameworks and mechanisms to make privately owned ocean science data publicly available.
3. **Data marketplace.** Create data marketplaces that can lead to the desired data flows, with (1) the public sector creating such exchanges and the associated standards for data comparability and interoperability; (2) intermediaries enhancing access to ocean data that adds value to the data; and (3) the private sector that creates a commercially viable product or service.
4. **Data access.** Ensure data access across public and private datasets to provide opportunities for intermediaries to create products and services based on ocean data and information. This would include: (1) funding data infrastructure to ensure that data portals are accessible and dependable; and (2) optimizing conditions to allow for machine-to-machine data protocols through the preparation of adequate APIs that allow users and businesses to find, enhance, and add value to public data, and develop regulations that mitigate impediments to accessing data.

Blue tech clusters, incubators, and accelerators

Blue tech clusters, incubators, and accelerators allow early-stage ocean-related technology companies to work on innovative solutions to current challenges by expediting access to information resources, mentorship, and funding opportunities, the latter of which may not be accessible without explicit notices of funding.

Blue tech clusters, incubators, and accelerators also facilitate market growth through networking, workforce development, attracting software engineers and system architects from adjacent industries, developing solutions with other companies, and keeping abreast of advancements in technologies. Small companies need to take advantage of these resources to help ramp up some of their ideas. Since a cluster's value may be limited to its local network, a comprehensive list of these clusters, incubators, and accelerators would be useful.

Next steps:

1. **Promote.** The public and private sectors can spur rapid market growth by promoting blue tech clusters/incubators/accelerators across the globe and encouraging the establishment of cluster organizations in areas where capacity is limited or in communities most vulnerable to ocean hazards.

2. **Measure.** Support Ocean Decade actions that promote tech clusters/incubators/ accelerators, such as 1000 Ocean Startups, the objective of which is to scale at least 1000 transformative startups by the end of the Ocean Decade, and the associated Ocean Impact Navigator that seeks to capture the impacts innovators are driving across ocean health, climate change, and human wellbeing and equity.
3. **Collaborate.** Embrace the "coffeehouse" idea, where researchers discuss collaborations and partnerships about how technology can be accelerated through commercialization and investment.
4. **Pilot Projects:** Identify and sponsor a pilot project that would highlight new technologies that represent a multi-sectoral ocean observing architecture to solve a problem/ocean observing gap. The project could serve as a blueprint for achieving a multi-sectoral observing architecture and mixed public, private, and academic investment, development, and testing.

Focus Area 4: Market elements shaping the future

To unlock the economic potential and meet the increasing demands of ocean information to support the Blue Economy, marine ecosystems, living marine resource management, and navigation, the Ocean Enterprise must work to identify and map the workforce and technology needs of the future that have the potential to foster market growth.

Workforce

One of the most significant obstacles to market growth is the availability of a skilled workforce. As the Blue Economy develops, there is an opportunity to build a more diverse workforce. The challenge is working together to communicate and generate excitement about having an ocean-based career regardless of the discipline (e.g., engineering, software programming, or robotics) or program (e.g., fieldwork, program management, policy management, data and information services, engineering). Further, there is currently a major lack of visibility for potentially exciting and fulfilling ocean-related careers.

The workforce opportunities in the Ocean Enterprise are interdisciplinary and are open for new entrants from (1) along the spectrum of education levels, and (2) among experts from adjacent industries. This recruitment should emphasize that the ocean presents a variety of business opportunities where the results can have a significant impact on profit, people, and the planet. Additionally, there is a negative perception by academia of pursuing a career in ocean industry. There needs to be a partnership between industry and academia where careers in industry are viewed on par with careers in basic and applied research.

Next steps:

1. **Promote.** Develop promotional campaigns around careers that are linked to major global topics such as climate and biodiversity, and linked to sustainability.
2. **Engagement.** Working with existing ocean literacy efforts: (1) develop a needs assessment and communications plan for expanding the talent pool for Ocean Enterprise workforce; (2) conduct an evaluation of current internship, fellowship, post-doc programs, and technical programs/certification to determine if there are opportunities for having Ocean Observing and Services specific foci; (3) develop industry-university partnerships to create opportunities for students to create majors and step into careers in the Ocean Enterprise;

and (4) identify opportunities for increasing the communication of job opportunities and/or for raising awareness of the career potential.

3. **Remote learning.** Train local scientists in areas with limited resources by providing efficient and cost-effective access to educational resources (e.g., remote lectures, online tutorials, and other educational materials from experts in the field, enabling scientists to learn from the best minds in the world without the need to travel or invest in expensive equipment).

Technology transfer

The transfer of ocean-related technology from the lab to the market is vitally important because it is a key step in the development of technological solutions to the world's most pressing environmental issues. Factors in this transition include: identifying the potential market for the technology, developing a business plan, developing, and testing prototypes, securing capital for production and marketing, and bringing the technology to the marketplace. Early engagement between the public, academia, and private sector partners is critical. This process is complex and involves an across-the-board understanding of aspired unit numbers, time horizons for production, intellectual property protection, manufacturing considerations, and technology integration challenges.

New technology ventures often face a funding gap between initial product development and mainstream use (known as the 'valley of death'). While there are some funding mechanisms (e.g., in the United States there is an SBIR fund that provides seed funding while other schemes look at access or sharing facilities for testing new technology), ensuring that standards and user needs are defined and well-known would help the private sector determine how to scale technology production in the early planning stages and avoid the 'valley of death'. In the United States federal investment grant programs such as DARPA/ARPA-E provide a means for addressing longer-term research and development lead times typical of basic research and development projects that lead to innovative startup companies.

Next steps:

1. Facilitate the transfer of ocean sensor technology by: (1) including lab-to-market and science-industry-linkage criteria as standard elements within publicly funded project evaluations to spur market development; and (2) developing standards and quality assurance processes for new technologies (e.g., running programs in parallel using older technologies to validate the new technologies) to ensure trust and successful adoption.

Emerging technology

The public sector must stay abreast of the new technologies under development that could improve the delivery of public services. However, the public sector struggles to (1) understand the pace of technology development; and (2) fund new technology innovation at the same time as investing in mature technologies.

To meet the challenges of net zero, new policy demands, a lack of resources for marine monitoring, and a growing Blue Economy in sectors such as ecotourism, offshore energy, and carbon sequestration, there is an urgent need to integrate new technologies. Those highlighted below were identified in the Dialogues as being particularly important in shaping the future:

- Artificial intelligence**.** The use and adoption of artificial intelligence (AI) will be critical for automating the analysis of vast amounts of data, especially for large underwater images and acoustic data sets. AI will also be critical for understanding complex relationships of ocean variables as they relate to local and global ocean challenges (i.e., climate change, ocean acidification, plastic pollution, harmful algal blooms, etc.) and making informed decisions to improve and solve these challenges.
- Communications. The internet has been a disruptive force in terms of facilitating ocean observation data gathering and transmission, but challenges remain since ocean data are not as readily available/accessible relative to terrestrial-based data. Low Earth Orbit (LEO) satellites make it possible to have improved access to broadband communications in the ocean space, allowing for global, reliable, and faster communications than ever before. However, this does not apply to the deep sea.
- New Sensors. A major transformation in ocean observing will come from the next generation of sensors that provides insights into biogeochemistry, ocean health, and marine life. This will be enabled by: (1) Advances in material science are enabling low size, weight, power, and cost (SWaP-C) sensors that can be housed on autonomous surface and underwater vehicles, leading to the reduced use of research vessels and the increased ability to fill gaps in underserved communities; (2) inclusion of biogenic or anthropogenic activity-based ocean variables that can be derived from scalar (environmental) measures; and (3) hybrid sensor systems that detect and record multiple disparate events simultaneously, which are expected to become more common in the future. It is unlikely that in the near future low-cost sensors will be able to accommodate these complex observations, but low-cost sensors can contribute to understanding aspects of complex environments, especially when large numbers are distributed in an area and their individual detections are combined; or when used in cooperation with more exquisite, higher cost sensors. This is the concept of the "Oceans of Things" where very low-cost sensors (integrated circuit sensors in some cases) are widely distributed in an area on the surface of the ocean and their real-time (scalar) measurements can be "fused together" to reveal a larger picture of what is happening in an area (e.g., a ship passing by, whale coming to the surface, etc.) in real-time.
- Molecular technology. The molecular technology revolution is making its way into oceanography with technologies to detect specific genetic signatures and gene products, DNA sequencing for understanding whole organism and ecosystem function and diversity, and biosensors that enable new measurements and discoveries in situ as well as onshore. Moving to more specialized measurement campaigns, augmented with sensors for new EOV measurements, can help with improving the modeling and forecasting of submeso-scale ocean features (< 100 km in size).
- Autonomy. Perhaps the most impactful, nascent, or emerging technological transformation for the next decade of ocean observations are autonomous floats and vehicles including those that cruise on the surface (ASVs), underwater (AUVs), and their hybrids (AxVs). Autonomous vehicles are becoming increasingly capable and cost-effective, and are increasingly being equipped with chemical, biological, and physical sensors/samplers to generate data sets that can replicate ship capabilities.
- Multi-purpose. Taking advantage of existing infrastructure can help overcome observing limitations; (1). Subsea cables could host sensors and by that would make continuous measurements in the deep sea accessible; (2) Continuous measurements at active or

inactive offshore structures, e.g., in offshore wind parks or platforms; and (3) Enhancing the use of Voluntary Observing Ships / Ships of Opportunity.
- Crowdsourcing. Crowdsourcing ocean observation data is an increasingly popular way for oceanographers to collect data. Examples include measurements on surfboards, air quality measurements on land, and measurements on sailing yachts.

Next steps:

1. **"Library" of ocean technology.** Establish repositories that provide a centralized, defined, credible source of reliable information for all users, including congressional staff and investment analysts.
2. **Testbed.** Establish testbeds or demonstration platforms on national and international levels to conduct experiments for developing/evaluating new ocean sensors and technology. Testbeds help to reduce the risk of unexpected outcomes, as developers can see how their technology performs in a simulated or controlled environment before deploying it in real-world scenarios. Additionally, testbeds can be used to measure the performance of the technology and identify areas of improvement, allowing for an iterative development process. Finally, testbeds can be used to educate others about technology, helping to spread knowledge and build confidence in the technology.
3. **Leveraging industries not in the ocean arena.** Target other external businesses to establish partnerships for the extension of ocean observing, e.g., measurements on offshore structures or merchant vessels. The high-tech industry and ocean exploration can benefit from a stronger relationship, as it provides financial support, inspires employees, and creates platforms and supply chains. This connection can also accelerate the work being done in the ocean, such as the USD 12 billion electronic sensor sector which is resulting in low-cost sensors and platforms. Seek out and leverage Tech clusters, Incubators, and Accelerators outside of the ocean domain.
4. **Expose AI experts to the ocean**. Exposing AI tech experts to ocean science problems is important because they can help develop innovative new solutions to some of the most pressing issues facing the ocean. Work with funded AI projects to enable the use of ocean data as the training data. Foster existing programs that are working with university computer science programs to introduce ocean scenarios in their projects.

Summary of Key Findings and Potential Pathways Forward

FOCUS AREAS	TOP-LEVEL POTENTIAL PATHWAYS
1 Improving the market • Market size and aggregation • Risk • Bringing in new actors	**Conduct regular, bi-directional, and structured dialogues across the Ocean Enterprise to** (1) identify existing areas for revisions and improvements (2) identify market gaps and opportunities (3) accelerate and aggregate market demand; and (4) support risk reduction for market growth.

2	Societal/Governmental change • Data and mission as a service • Ocean information perception	**Co-develop multi-sectoral ocean observing systems, products, and services to** (1) understand the emergence and inclusion of the private sector in providing data and services; (2) recognize the value of ocean observations/public good; (3) adopt licensing schema that provides mission efficiencies for the public sector, profit for businesses and maintains scientific access for the academic sector.
3	Collaboration to grow • Standards • Intermediaries • Data access • Blue tech clusters, incubators, and accelerators	**Develop action plans to** (1) lower a significant barrier by adopting standards; (2) provide an agile structure for co-development and creating space for the private sector's growth in service delivery; (3) develop marketplaces to foster data exchange and the landscape for data services.
4	Market elements shaping the future • Workforce • Technology transfer • Emerging technology	**Underpin the Blue Economy by** (1) building a robust inclusive workforce for the Ocean Enterprise; (2) speeding the development of technologies through combining collaboration and investment models; (3) leading the identification of emerging technologies.

Next Steps

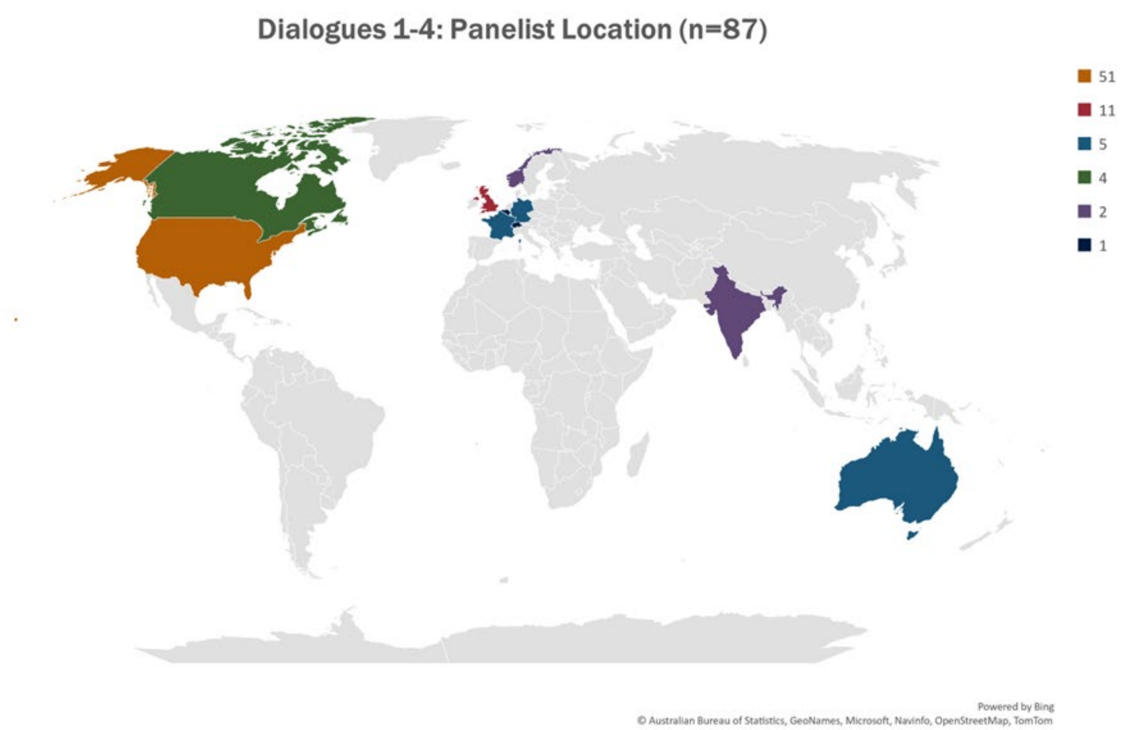
This report represents an interim synthesis of the findings and recommendations from the *Dialogues with Industry* sessions. The next step is to assess the interest of the Ocean Enterprise in advancing the potential pathways that have been identified. The goal is to seek feedback from the community on the viability, scale, and impact of these potential paths, to develop implementable road maps to grow the Ocean Enterprise. Facilitated discussions by and among the public, private and academic sectors at a variety of events in Q2 and Q3 2023 will be used to collect feedback on these pathways, identify others, and check for bias in the findings. A final report with implementation recommendations will be completed for Q4 2023.

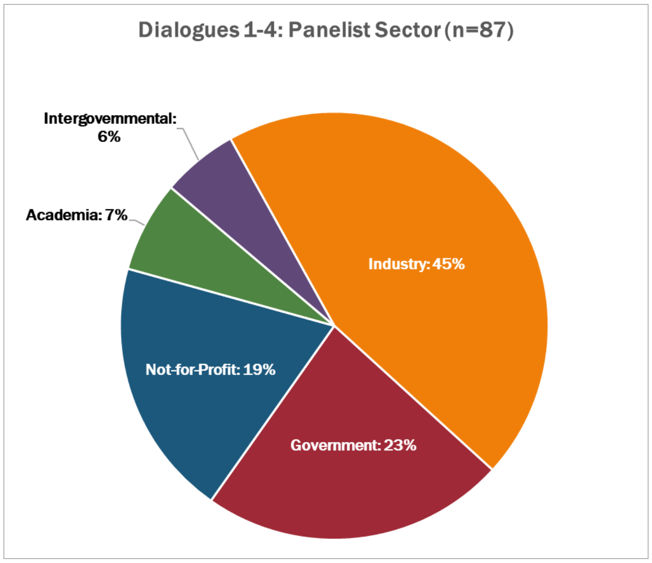
Appendix 1: Participants

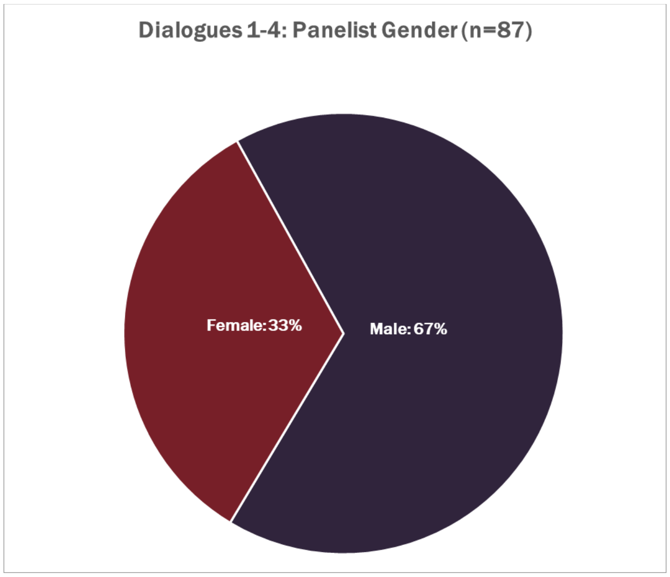
The four *Dialogues with Industry* virtual sessions brought together a total of 87 panelists representing key stakeholders from industry, government, and academia. In addition, there were approximately 492 observers (see charts below for additional information on each set of participants).

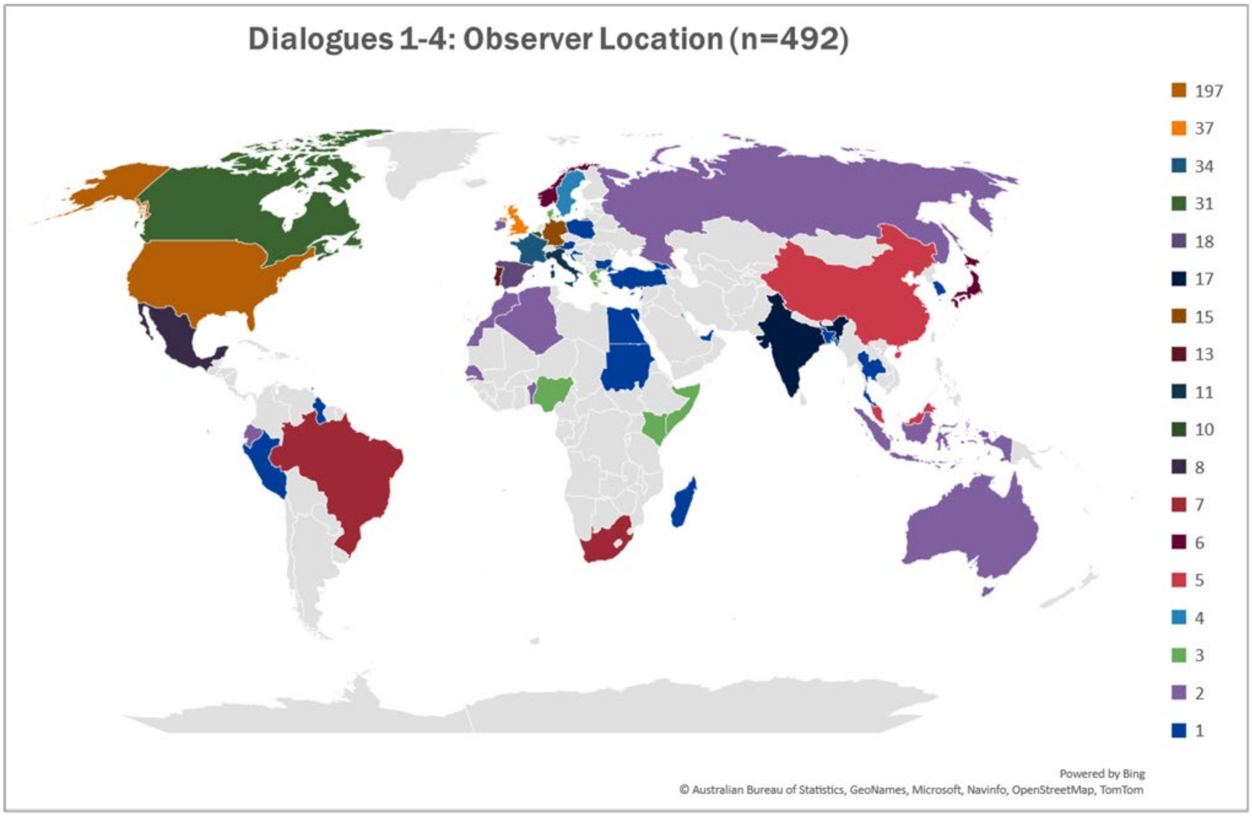
The panelists were invited to participate. The observers self-registered based on social media engagement. The focus of the panelists was on representatives from the industry and not-for-profit sectors. Across the four Dialogues with Industry sessions, 69% of the participants were from that sector. While a global distribution of panelists is the goal, the heavy participation by North America, Europe, and Australia follows the current market trend of companies within the marine sector. The timing of the dialogues contributed to the lack of participation in the Asian region. While the core planning team, composed of five women and two men, recognized the importance of gender diversity on the panels and made a conscious effort to have better gender balance it was still difficult to identify women panelists representing the Ocean Enterprise private sector. Additional demographics were not collected.

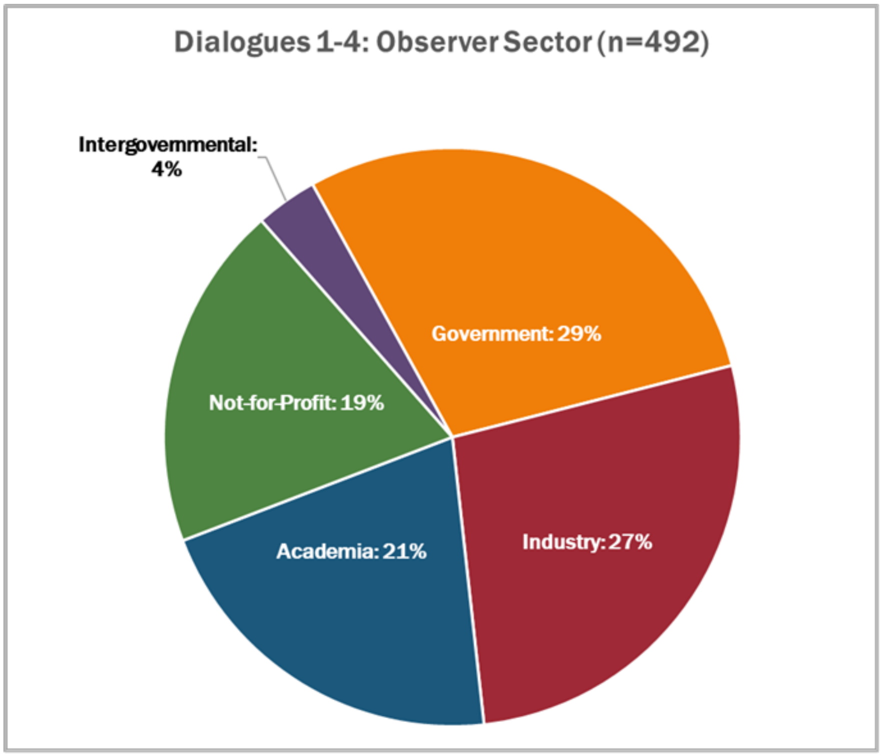
Note on the location graphics the numbers within the legend do not match the total number because a color is assigned to a number; therefore, if there is more than one country that has the same number of participants the color will be the same for all those countries. For example, in the graphic for the panelist, Australia, Germany, and France all had five participants so they are all assigned blue.




Dialogues 1-4: Panelist Sector (n=87)
Intergovernmental: 6%
Academia: 7%
Industry: 45%
Not-for-Profit: 19%
Government: 23%


Dialogues 1-4: Panelist Gender (n=87)
Female: 33%
Male: 67%


Dialogues 1-4: Observer Location (n=492)
197
37
34
31
18
17
15
13
11
10
8
7
6
5
4
3
2
1
Powered by Bing
© Australian Bureau of Statistics, GeoNames, Microsoft, Navinfo, OpenStreetMap, TomTom


Dialogues 1-4: Observer Sector (n=492)
Intergovernmental: 4%
Government: 29%
Not-for-Profit: 19%
Academia: 21%
Industry: 27%

Appendix 2: Ocean Information Value Chain

The Ocean Information Value Chain is used as a simplified conceptual illustration of how ocean observations are converted through a wide range of interactions, transformations and service delivery mechanisms into services that have value to decision-makers and Blue Economy activities, delivering societal and economic benefits. **Figure 1** combines and provides an overview of the Ocean Information Value Chain and the Ocean Enterprise. It shows the different elements of the value chain and provides the content that they cover in more detail. It also shows the Ocean Enterprise sectors and components in the value chain that interconnect to deliver information to end-users, who in turn derive socioeconomic and economic benefits from these information products. Private and public organizations as well as public-private partnerships on a local, national, regional, and global level can contribute to any number of these elements according to the nature of their organization, i.e., through commercial products, public services, data collection and provision, and philanthropy. There is a requirement for innovation as well as business opportunities within all these elements. A return can be gained from investments both within and across components, as indicated by the estimated relative potential growth of each component.

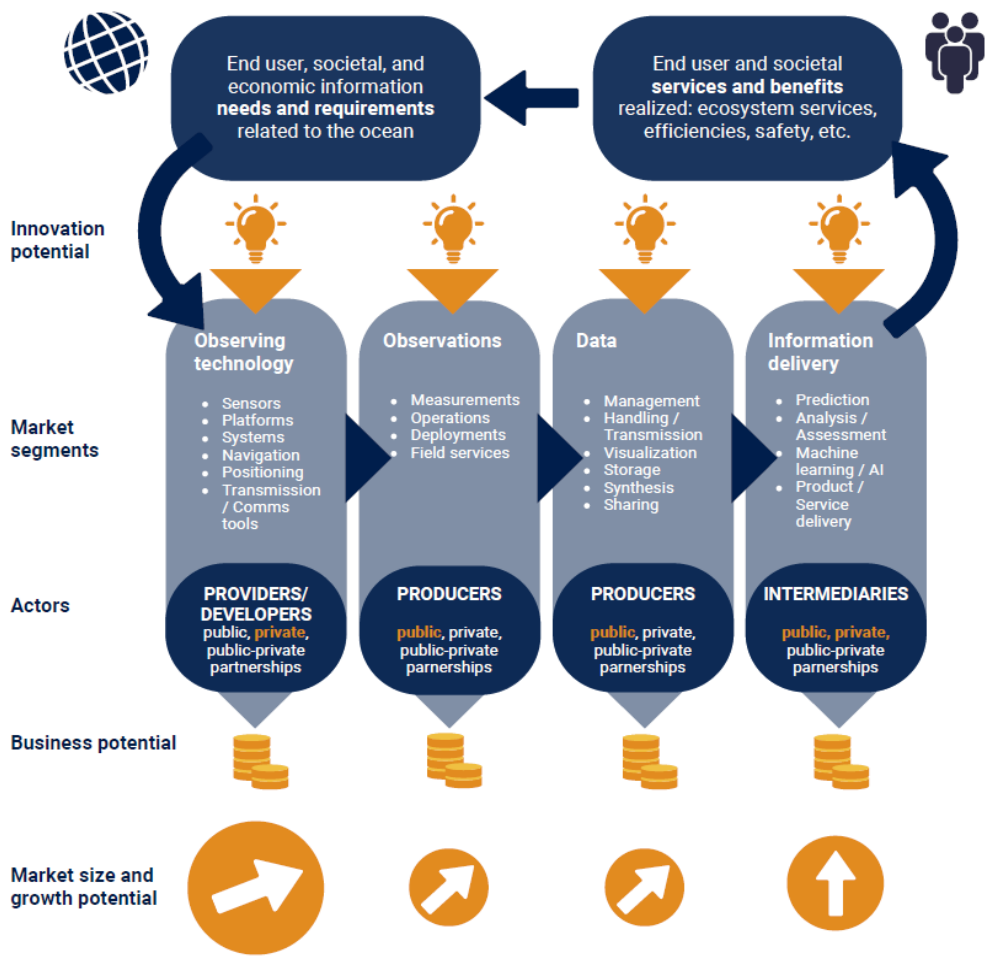


Figure 2: Ocean Information Value Chain and the Ocean Enterprise

Appendix 3: Definition of Key Terms

The term '**Ocean**' is generally taken to refer to the whole body of saltwater that covers nearly three-fourths of the surface of the earth. In some instances, and especially in the United States, it is also taken to include large bodies of freshwater, and especially the Great Lakes.

The United States National Academies of Science defines the '**Weather Enterprise**' as including all entities in the public, private, nonprofit, research, and academic sectors that provide information, services, and infrastructure in the areas of weather, water, and climate.

A corresponding definition is generally applied to the term '**Ocean Enterprise**', which similarly is taken to include all entities in the public, private, nonprofit/NGO, research, and academic sectors that provide infrastructure and capacity for ocean observation, measurement, and forecasting, or who deliver operational ocean information services. The public sector includes governmental entities such as the national, local, and tribal governments, and other public entities.

The term '**Ocean Economy**' is generally taken to refer to economic activity on, in, and around the ocean as distinct from the '**Blue Economy**' which encompasses both economic activity and the non-market benefits of the ocean such as ecosystem services and natural capital.

Appendix 4: Planning Team

Sector	Affiliation	Name
Public - Australia	Bureau of Meteorology	Boris Kelly-Gerreyn
Public - United States	NOAA	Brittany Croll
Public - United States	NOAA	Matt Hodanbosi
Public – United States	NOAA	Ralph Rayner
Public - United States	NOAA	Kelly Spalding
Public – United States	NOAA	Liz Tirpak
Intergovernmental	GOOS IOC/UNESCO	Emma Heslop
Intergovernmental	GOOS IOC/UNESCO	Laura Stukonyte
Industry	Kongsberg Maritime	Peer Fietzek
Industry/Not-For-Profit	L3 Harris/MTS	Donna Kocak
Industry	South Seas Science Consulting	Sebastien Boulay
Nonprofit/NGO	IMOS	Michelle Heupel
Nonprofit/NGO	MTS – India	R. Venkatasen
Nonprofit/NGO	MTS	Chris Ostrander
Nonprofit/NGO	MTS	Monica Ostrander
Nonprofit/NGO	MTS	Zdenka Willis