United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea should focus at its twenty-third meeting, to be held from 5 to 9 June 2023, on the theme "New maritime technologies: challenges and opportunities".

Contribution from the Intergovernmental Oceanographic Commission of UNESCO / Global Ocean Observing System (GOOS) Programme

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New technologies that are shaping the future of the global ocean observing system across the public and private sector

Innovative sensor instrumentation is enabling enhanced observation capacity and efficient data collection, which will support more efficient and streamlined reporting on biodiversity indicators for the Convention on Biological Diversity and for the Convention on Climate Change than has previously been possible.

Biological observation is being transformed by the development of environmental DNA (eDNA) samplers and in-water eDNA sensors, as well as in situ imaging systems that deliver rapid analysis of plankton and marine snow. The unparalleled access to high-resolution data provided by all these sensors is driving an increase in the volume and diversity of data collected and transmitted, and requiring a step-up in high-throughput communications, in both hardware and software.

Autonomy, the innovation in platforms and robots carrying sensors to points of measurement (e.g., floats, gliders, Autonomous Surface Vehicles - ASVs) are providing improved spatial and temporal coverage, and lower carbon solutions. Advanced instrumentation on deep-diving marine animals allows sampling through poorly sampled ocean regions (e.g., under ice).

Miniature and ruggedized lab-on-chip sensors are now capable of 1000's of chemical measurements per deployment, and innovation is allowing high-precision measurements of carbon-linked parameters such as pH and Total Alkalinity (TA).

As the expanding multitude of data types and sources are fused with new Artificial Intelligence and data-analysis methods, it is becoming simpler and cheaper to inform biodiversity and climate indicators and targets.

Enhancing traditional platforms with these new sensors is key, this is however not yet sufficiently realised. With new and developing sensor technology, traditional platforms such as the vessels of many different sizes and shapes, can observe more and more Essential

Ocean Variables, encompassing biogeochemistry, for example surface ocean carbon, and biological variables, such as plankton, and human impact variables, such as marine plastics. These are collected under the coordination of the Global Ocean Observing System (GOOS) Ships Of Opportunity Programme (SOOP) network, which coordinates the collection of observations from commercial vessels, ferries, cruise liners, and other ships of opportunity. To meet the growing need for ocean observations to support our response to urgent societal issues associated with climate change, biodiversity loss, overfishing, and pollution, issues that are often compounded in any given environment, and to build resilient coastal communities, we need to be able to equip more commercial and private vessels with observing capability. At the same time there is increased interest from all parts of the maritime sector, including shipping companies, racing yachts, fishing vessels and wind farms, in contributing to being part of the solution by taking ocean observations. Enabling such observations is becoming increasingly important for the global ocean observing system, but GOOS is challenged in this endeavor by two issues, firstly the need to develop infrastructure to support data streams from these sectors, and secondly by the Marine Scientific Research (MSR) application process. Under the United Nations Law of the Sea (UNCLOS), such MSR clearance should be requested 6 months in advance, which is not possible considering the flexible operation of commercial vessels and yachts. Under the UN Decade of Ocean Science for Sustainable Development the team at OceanOPS (IOC-WMO Operational Centre and part of GOOS that works with global networks, tracks, and reports on ocean observing status) has launched a programme to help develop new observing capability across all types of vessels, potentially even including divers and other marine professionals. Called Odyssey, this project is aimed squarely at developing new observation streams from across maritime operations, and the infrastructure to support this as a part of GOOS. However, if we are to make full and cost effective use of commercial and private vessels to undertake ocean observation for climate, safety of life and property, and other societal issues, there will be a need to find some practical solutions within UNCLOS to support the development of these new public-private networks.

In September 2022, GOOS and the Marine Technology Society (MTS) initiated the Dialogues with Industry - a forum for compact and meaningful dialogue with new and established companies, academia and government. The dialogues aim to highlight opportunities for the public and private sectors to work in partnership towards achieving a mature, vibrant ocean observing enterprise that will help accelerate the development of a thriving blue economy, and were highlighted as an upcoming initiative of interest at the June 2022 ICP meeting. Dialogues with Industry is a joint activity between MTS, GOOS and the National Oceanic and Atmospheric Administration (NOAA), and is a recognised Ocean Decade Action.

The anticipated growth of the ocean or blue economy has been well documented: the OECD's report predicted the ocean economy will reach 3 trillion $ by 2030, and in June of 2022 the United States Department of Commerce found that the American 'blue economy' contributed about $361 billion of the nation's gross domestic product across 10 sectors representing businesses dependent on the nation's oceans, coasts and Great Lakes. In addition

NOAA, GOOS and MTS are seeing a growth in businesses that are either producing ocean observing platforms and sensors, providing ocean observations as a service and/or using ocean information to provide a product for sale, these businesses are termed the Ocean Enterprise in the USA report. The United States, Canada and the United Kingdom have developed a consistent survey to determine the value and trends of the Ocean Enterprise. In all three countries the trend is positive, for example, within the United States, since the first study in 2015, the number of businesses grew by almost 60% and annual revenue grew by 1B$.

The Dialogues with Industry were created to lower barriers and increase opportunity for the maritime sector and technologies to be a part of a thriving and fit for purpose global ocean observing system (GOOS). The blue economy will not reach its potential without the data from ocean observations and the vision underlying the Dialogues is that the ocean observing system in the future will be multi-sectoral, with private and public organizations as well as public-private partnerships on a local, national, regional, and global level contributing to ocean observing through networks, sensors, platforms, data delivery and services.

Taking a value chain approach (from observations to end users) allows us to illustrate how ocean observations are converted through a wide range of interactions, transformations and service delivery mechanisms to produce information products and services that have value to decision makers and business leaders, and thus the importance of the ocean information and related services, and the ocean observations and predictions on which they are based. The private sector can play a role in any part or multiple parts of this value chain. A background paper is available here, which details the concepts.

To date there is perhaps most private sector activity in the technology around sensors and platforms, however there is great scope for advanced technology and services across the range of the ocean observing value chain, from observing, through data management, modeling and assessment, to applications and services. We also need partnership in the value chain to interconnect to deliver information to end-users, who in turn derive socioeconomic and economic benefits from these information products.

GOOS and MTS have just completed the final of four Dialogues with Industry sessions in January 2023 and already they offer a wealth of insight into the issues from different perspectives across government, industry, academia, and international ocean observing coordination. The results will be compiled into a final summary paper, however below is a preview of some of the initial findings - which are relevant to technology developers and operators in the maritime sector.

- To support investments and development the “ocean” market sector needs further articulation. Studies such as the NOAA/IOOS Ocean Enterprise report, are vital to convincing investors that start ups are addressing a real need/marketplace. There is a need for independent and credible market evaluations that address both the international scale of the ocean observing enterprise as well as the niche and smaller

scale markets (i.e., uncrewed systems market). The ocean observing market is often framed in the context/in support of other market sectors (i.e., Blue Economy).

- Investments in sustainable 'blue' business models trail behind those in 'green' (land), because many investors perceive such investments as too risky, and further, these investors are looking for observations/data to reduce or de-risk these investments. This can be seen in new areas such as carbon credits and marine carbon storage, which need data on the carbon cycle, particularly in the ocean. The business community is looking to the ocean observation and ocean knowledge communities to help them de-risk these opportunities.
- The need for standards were a consistent theme across the Dialogues and are vital to efficient market function. Standards play an important role in leveling the playing field, providing stability, and opening the market for technology and data. There is a more transparent market when the same standard is required regardless of whether the provider is a public, private or academic component of the Ocean Enterprise.
- Aggregation of demand would also lead to more efficient market development, because a critical mass of opportunity is ultimately important to strengthen growth. This is something that governmental and intergovernmental agencies would need to spearhead. Aggregated demand could also be created when countries sign up to international conventions, for example for biodiversity or climate, where there are associated nationally defined contributions to undertaking observations to evaluate the effectiveness of actions, in the future this might also create institutionalized frameworks for demand.
- The government sector often requests low cost, easy to use sensors, for example as a solution to expand capacity. Easy to use and affordable is often conflated with low development costs, but industry experience shows that in fact the reverse is true. Easy to use technology requires longer development times, and significant effort and testing to build-in the operational intelligence required to make it easy to use. This means higher development costs and higher risk. If the ocean observing community is interested in easy-to-use instrumentation, then industry needs some guarantee of market size or other methods to reduce investment risk. This also implies that low cost easy to use sensors will be available for applications that are sufficiently frequent/numerous and would not be expected for niche applications.
- There is a new paradigm of data/mission as a service. There is a long history of this in the space remote sensing sector and more recently in the meteorological sector with the purchase of commercial radio occultation data. This business model can alleviate some acquisition, operation and maintenance costs, however norms for licensing and data validation/quality assurance need to be resolved. The Ocean Enterprise can apply the lessons learned from the space sector to speed up this paradigm shift.
- The shift from government-owned and distributed data to a commercially procured model also raises several questions and concerns. From a legal standpoint data is an asset, and how a company maximizes value and minimizes risk for this asset is how legal systems view the issue. The move to open data and sharing in an unrestricted way is at odds with the realities of how businesses work. For example, entering into a software license we do not require that this software is free to everyone. In addition,

different types of data and different types of data use, have different legal regulatory risks associated with them. If these are not reflected in the license agreements, then it will be difficult to share data, even under an open license.

- There is a lack of understanding of how to fully engage stakeholders to develop a hybrid architecture. Alignment can accelerate a hybrid architecture through incentives such as purchases, regulations, and sharing in discoveries.
- In general, countries consider data needed for weather forecasting, most of which is collected from terrestrial stations or from space, as an essential element of operating a country. Ocean data is not yet considered to be similarly essential. Many nations still do not understand that ocean data is key for managing a country. We need to work together to fully recognize the criticality of ocean data to move this data from the peripheral to the mainstream. Changing the perception of ocean data will require strengthening government and international commitment to a necessary ocean observing system.

The final Dialogue with Industry focused on new technology and early insight to the issues discussed is provided below:

- The biggest transformation soon will come from the new generation of sensors in terms of biochemistry, ocean health, and life in the ocean. This will revolutionize scientific understanding, monitoring, and enable new capabilities for ocean predictions and assessments.
- Low-cost, small, easy-to-deploy platforms and sensors have the potential to help disadvantaged communities globally by providing them with the necessary ocean information to participate in the Blue Economy - however we should bare in mind the experience from manufacturers that low cost and easy to use sensors are a more risky investment (see above) and thus there will need to be some aggregation of demand and lowering of investment risk to precipitate this change. The development cost of creating affordable disposable sensors is high, so for many applications it is perhaps more realistic to focus on creating slightly larger, more expensive sensors.
- Another big change could be seen in the locus around 'Ocean of Things' a concept related to utilizing sensors, such as cameras, accelerometers, GPS, temperature, and barometric pressure, in order to obtain high density measurements on a commercial scale. These sensors are driven by the cell phone industry which provides a cost-effective solution. However it is unlikely that in the next couple of decades all essential ocean variables (EOVs) will be addressed by small and cheap sensors, as some of the key technologies being observed are difficult to measure and require more advanced and expensive sensors. The outcome is likely to be a mix of small, cheap, and robust products, especially in the coastal environment, alongside a larger number of more complex products that require larger systems for measurement.
- AI and machine learning can be used for the characterization of big data sets such as imaging and acoustics data, and taxonomy, however other areas will not benefit, e.g, seawater chemistry. However the use of machine learning to analyze data and the idea

of the internet staying at sea are two key changes that will more broadly shape the future.

- The molecular technology revolution is driving change, with technologies such as EDNA, DNA sequencing, biosensors and antibodies, enabling new measurements and discoveries.
- Observations from ships were broadly viewed diminishing with the push towards low carbon. There have been increasing chemical, biological, and physical sensors on autonomous vehicles to generate data sets that replicate some of what a ship can do. The trends in maritime shipping point towards more efficient, autonomous systems that use energy harvesting, battery technology, and autonomy to reduce the need for carbon-producing ships. Autonomous systems such as drones, robots, and underwater vehicles can be used to collect data at higher frequency and resolution than traditional methods. Furthermore, the sensors that these vehicles carry can detect data on a much finer scale, allowing for more accurate data collection. Ultimately, such systems could revolutionize ocean observation and provide more and more detailed data.
- Integrating new technologies into long-term datasets that inform policy decisions requires validation to ensure the accuracy and precision of the new sensors and to trust the new data sources, this challenge should be recognised and addressed.
- Ocean observing has the potential to be greatly enriched through co-design and a focus on the local needs for ocean observations. This presents a challenge in terms of connecting with communities to get feedback and inform investments, but it is a necessary step. This has to be an iterative process in order to prioritize data collection and technology development, while taking into account the perspectives of industry on what the needs are for ocean observing data.
- Using other existing marine industry platforms, for example the challenge of providing power and communication to the deep sea is a major cost inhibitor and subsea cable technology can help address this issue by providing a cost-effective and sustainable means of access and sustained observations over long periods of time.
- A fundamental need is the development of human capacity through better organization of learning strategies and training of scientists to meet the needs of industry and government. We need to improve the connection between oceanography and technology, so that multiple career pathways are visible. Many students are motivated by the potential to contribute to improved environmental or ocean outcomes and this is as possible in industry as it is in science.