# FOO 2.0 System Report

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BACKGROUND AND INTRODUCTION

The need for interdisciplinary, internationally integrated ocean observations was a key recommendation of the decadal Ocean Observing 2009 Conference in Venice, Italy. In response the Framework for the Ocean Observing or FOO was developed and describes a structure that allows ocean observing providers and users to more readily plug-in to the observing system at various points. The FOO traces the path from Inputs (requirements) to Processes (observations), to Outputs (data and products). FOO principles and processes are designed to maintain an ocean observing system that is fit-for-purpose, with outputs that properly address the issues that drove the original requirements. Integral to the functioning of the system are the feedback loops that ensure requirements are always science-driven and informed by societal needs. (http://www.oceanobs09.net/foo/FOO_Report.pdf)
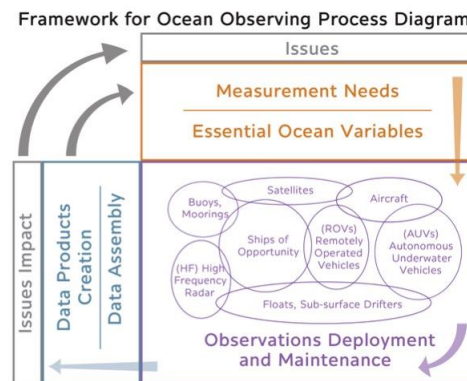
Leading to the Ocean Observing 2019 Conference in Honolulu, USA (September 2019) a community-wide review of the FOO's usefulness was launched in August 2017. Twenty-one extensive one-on-one interviews were conducted with representatives from nine countries and 19 groups, including federal agencies, research institutions, academia, and the private sector. Broader community feedback was also collected at project briefings, community meetings, Town Halls, and conference presentations.

Following an initial round of scoping interviews with leaders that had used the FOO, discussions where then focused on three broad categories of how the FOO can be of greater benefit. These categories are listed below:

- Technology and Implementation,
- Data and Analysis, and
- Management and Governance.

The table below is an outline of the topics discussed during the study.
*In the fall of 2019 detailed reports containing interview comments can be found at the following URL: **frameworkforoceanobserving.org***

Primary Discussion Topics	Sub-topics
Technology and Implementation Since the adoption of the FOO by GOOS in 2012, and given the tremendous focused-work done on the 'input' or requirements setting elements of the observing system, it was no surprise the study found that a good deal of effort for the next 5 – 10 years should seek to improve the downstream aspects of the system as they relate to the system 'processes' or deployment and maintenance. Feedback on the effectiveness of using the FOO spoke to the difficulties related to implementation, especially when it came to activities associated with network design and prioritization.	• Extending FOO Text Beyond Requirements (EOV) Setting • Platform Pro and Con Review and Assessment • Documentation and Socialization of Best-Practices • Defining the Path to Maturity • The Role of Pilot Projects • Design and Implementation of Efficient Networks and Programs
Data and Analysis Much has changed in the data and analysis arena in the past decade. Open data policies, improved communications technology and methodologies, and the adoption of data management techniques that facilitate sharing and integration, now allow data managers and analysts to better serve their community with quality data, improved data products, and services. As the observing system becomes increasingly fit-for-purpose the data community is challenged to allow users to discover and use available data that addresses thematic, local, regional, and global concerns.	• Improving Data Efforts (Legacy and New) • Building Data Analysis Capacity • Supporting Multiple Data Levels
Governance and Management When the FOO document was originally drafted it was unclear if an oversight group would adopt a system-engineering approach as a working model. The FOO suggested that governance should include the ability to provide an interface to external groups and assist with the coordination of internal panels and teams; with the end result of all feeling a part of the system or enterprise. Today there continues to be a need to better address the activities associated with the 'feedback loops' related to ocean science and societal needs.	• Coordination of Global Programs • Assessing a Resource Commit and Review Process • Use of the FOO for Fundraising and Branding

The remainder of this report has taken the results of these discussions and organized them in alignment with the elements and processes of the FOO. Key findings from this endeavor will highlight the desired changes, updates, and additional guidance to the ocean observing community. The express goal is to improve the utility of FOO during the next decade. *Reader Note: This report is not meant to be an exhaustive list of all issues, rather an overview of those articulated during the study discussions, see page 13.*

FOO 2.0 RECOMMENDATIONS

Within the ocean observing community it is generally recognized that the research funding-base cannot alone meet the growing requirements for ocean information. Today there are two primary challenges facing the community, first is sustaining the necessary long-term observations, the other is providing operational ocean services; both are critical to addressing society's needs. The FOO was adopted to address this by presenting concepts and processes on how to better sustain global ocean observing. In an effort to meet the ongoing needs of the research and operational communities the FOO is designed to be flexible, adapting with new scientific, technological, and societal needs while building on existing infrastructure.

With the expansive goal of assisting in the development of an integrated ocean observing system, serving multiple purposes, it was important to understand where the FOO has had the greatest impact on the most critical elements of the system.

Generally, it was agreed that outcomes from an alignment with the FOO helped with widespread community progress toward multi-disciplinary design, and improved global coordination, however, the processes did not assist fully with negotiation of issues related to implementation. An important next step is to highlight where and why within the system architectural patterns exist and thus where the adoption of enterprise-type practices and decision-making are most important and/or needed.

FROM SYSTEM TO ENTERPRISE
The FOO has proved helpful in socializing a common set of principles and processes that if adhered to, allowed disciplinary disparate and geographically separated groups to better collaborate and coordinate through a shared nomenclature or common language. Today, in order to capitalize on this growth across the community, a new set of interfaces that are supported at all levels, from funding sources to governance bodies, are in need of exploration and development. In general, the ocean observing community, could benefit from a more broadly adopted enterprise approach, or an architecture that serves as the organizing logic for the system's processes and infrastructure.

Once in practice an architecture will assist in the maturity of the enterprise through a common strategy focused on achieving results where all parts of the system work together. More specifically, an architecture will facilitate the practice of attaching data from multiple sources to user solutions through improved interfaces among otherwise disjointed stakeholders and sponsors. Individuals will more commonly think of themselves as belonging to an organization larger than their team or operating unit, and regularly make decisions to support successful outcomes locally, regionally, and globally. Most important users will have the ability to access outputs of the system regardless of their geographic location, and expect results based on a common functions and performance metrics; supported by a shared operational philosophy or set of processes.

In order to further facilitate this shift, it was suggested that there is a need for the observing system to be reviewed by engineering architects for overall system effectiveness. Such a review would distill what elements or practices can best be replicated and which should be updated or eliminated. (It was noted that similar reviews have been conducted at meteorological offices.)

Generally, there needs to be a more formal way to identify major groups collecting ocean data, distributing it, processing it, and developing applications, as it is critical that all data generated from observations can be used; anything less should be deemed a waste of resources. There is also a need to develop cross-function interfaces designed to assess how well the system is responding to the needs of intermediate users, these are required to facilitate the adoption of best practices and mature data management dialog across the system. There is also a need to recognize that the implementation of the entire observation lifecycle process takes a long time, and that it is often difficult to consistently engage the concerted expertise of science volunteers. Long term science achievement often requires a more operational approach to observations and this recognition needs development.

THE FOO ELEMENTS

It was broadly recognized that the identification of EOVs was an important focus for the research community. While it was helpful as a process development tool, more detail is required in order to make it a fully useful tool when the task is to implement elements of the observing system. Just as important, today there is a broadly recognized need to expand on the data and information components of the FOO. There is a strong desire to see a critical assessment on how effective the FOO was in improving the observing system as many found the document helpful but then difficult to implement.

System Input Gap: Measurement Effectiveness Assessment

Within the FOO, in order to maintain an ocean observing system that is fit-for-purpose, the outputs of the system must properly address the issues that drove the original requirements. A key aspect of this is to align observations according to community vetted EOVs. This focus requires assessments that cut across platforms and recommend the best, most cost-effective plan to provide an optimal global view for each variable.
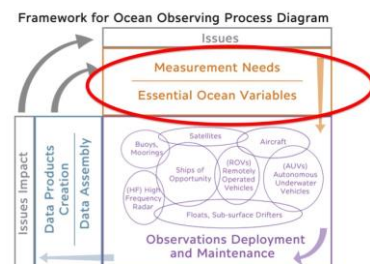

As mentioned earlier an important outcome of the use of the FOO was that it facilitated community agreement related to EOVs. However, there are improvements called for to further improve the functioning of the system. Some implementation issues stemmed from the fact that EOVs did not drive network requirements. This needs to be addressed and a mechanism for assessing the effectiveness of the system requires definition and incorporation into a regular review cycle. More specifically, it may be there is a need to develop interfaces that facilitate a more vertical approach to requirements setting and maturation.

There are several subtle benefits that may arise from a more concerted approach to EOV measurement scheme planning and implementation. For example, in further developing the FOO, it may be helpful to incorporate a systemic consideration of different time scales when assessing the value of observations. In addition, to better meet user needs it may have been more helpful to have first looked at indicators along with EOVs (this is especially true today for the biology and ecosystem community). In both instances it was discussed that certain data sets and streams should be allowed to mature prior to release of the data in order to better assess and/or evolve their value within the system.

To facilitate this evolution, it may be that the governance community needs to better consider a vertical as well as a horizontal structure or set of interfaces. A governance infrastructure should be designed to establish and better drive requirements throughout the system, from EOVs- to networks and technologies- to data management and application needs. As such the role of an EOV in driving network requirements needs to be addressed and a mechanism for system-wide review of requirements defined.

System Process Gap: Effective Use of Best Practices and Improved Design

Observations make up the core of the system, the FOO is designed to better connect observational elements into the broader requirements process and into the assessment of the design and delivery of data products. Within the system, technology and networks are used to collect the data required to address EOV measurement needs. Reviewing requirements according to EOVs, rather than by individual observing assets, allows for innovation in observing technology and encourages technological tradeoffs where possible. This has the added benefit of focusing the observing system on sustaining the quality of the observations regardless of how the underlying observing techniques and programs may change.
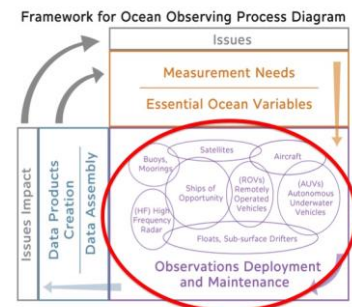
Generally, to move beyond EOVs (system input) and mature all elements of the observing system, additional guidance is needed on best practices for implementation and maintenance. Documentation and socialization of EOV measurement best practices for operations and maintenance is needed, preferably similar to the guidance for EOVs in the original document. Streamlining implementation practices may reduce costs through adoption of standardized sensors, maintenance practices, and data management.

It is well known that various platforms hosting ocean-observing sensors have inherent strengths and weaknesses. Articulation of these can assist in tabulating trade-off assessments. This practice will facilitate the articulation the effectiveness of measuring

ocean variables from different platforms and assist in the evaluation of technology trade-off needed to optimize observing networks.

More specifically, today given that EOVs did not drive the need for many of the networks in place there is a disconnect between the planning process and a path forward to improve upon the linkages among EOV measurement schemes, the networks, and the national efforts which are building them. As such, there is a need to find a governance structure that understands and promotes the importance of the role played by managers of observing networks.

Governments need to recognize that successful observation projects require more than the volunteering of scientific expert time alone; asset development, deployment and maintenance are equally critical. Important to building on this evolution is an ability to report on all manner of contributions to the system. The idea of tracking national commitments to the observing system is deemed desirable and, in some instances, necessary for coordination activities within nations, and thus to fully recognize the value-added of the groups that implement the observing system; this may reduce such a strong emphasis on scientific publication as a measure of success.

On another note, during the early parts of the study there was a good deal of discussion as to whether or not the certification of certain best practices or methodologies would be of benefit to implementation teams. It was agreed that practitioners would benefit more from the development of courses that demonstrate concerted exposure to focused implementation principles and best practices rather than a formalized certification course, or more generalized courses that present exposure broadly across multiple topics or methodologies.

Most important, the technology and data implementation teams may benefit to the same degree of definition and emphasis that the Expert Teams received since their creation within GOOS during the past five years. A redraft of the Implementation and Data sections of the Framework document is needed to reflect the same level of emphasis and guidance given to identifying multi-disciplinary measurement requirements (EOVs) in the initial document.

System Output Gap: From Data Availability to Discoverability and Utility
The outputs of the system are the data and information products that also constitute the interface to the system for most users. Increasingly, ocean information products are required to support both research and decision-making in diverse arenas. Use of the FOO is designed to promote widespread stakeholder input into the best approaches for data management and dissemination, as well as to facilitate the collaborative work being done to coordinate across disparate systems and foster widespread awareness of available data among an expanding user base.

Framework for Ocean Observing Process Diagram
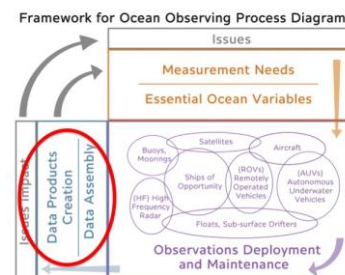
Today the global ocean observing system is under tremendous pressure to reconcile the requirements generated by the growing and inhomogeneous amount of data that are available from the observing system, and yet to provide these data and data products with increased consistency and interoperability. The more traditional practice of embedding unique data solutions within specific technologies leads to a larger issue of data archeology that unless modified, or even abandoned will persist into the future. There is a need to build on the growing practice of sharing data by developing software data product management best practices and maturing de facto standards.

More generally the global sustained observing system (facilitated by the FOO) needs to more fully consider data needs as user driven. Robust use of data in user applications falls short, as often observing system funding involves planning for a common environment, designed to facilitate the integration of data, yet lacks required national funding to develop applications or services, and to assist with the long-term use of the data. Within the current governance structure there is little-to-no dialog among data providers, application developers, and the rest of the observing system to help bridge this gap.

For data managers and application developers the persistent issue exists that when projects are funded there is just enough funding to apply the data, but little else to demonstrate ongoing progression of its use and resolution of known problems. Important to the resolution of this issues is that an improved understanding of data management and implementation teams is needed; it was noted that even when successful these groups rarely seem to be more than an idea or concept rather than organizations with long-term sustained funding and Terms of Reference. Further it was emphasized that data centers and data management entities need to develop as separate from the development of data products/models.

At the same time, improved coordination is needed such that all relevant information resources (data, metadata, services) appear to the user like a constellation of data and services; and include data streams from satellites to those from small *in situ* observations in remote regions. It was suggested that there may be a need to fundamentally change the IT infrastructure from the present Virtual Private Network (VPN) system to a cloud-based environment. Beyond this it may also be important to develop the infrastructure required to support a federated data architecture allowing for a system better able to address local, national, regional, and global needs.

Adding to the complexity of data management issues, are the many legacy ocean data systems in existence. While the ultimate goal of many of these systems is to have all ocean observations quickly stored in standard formats, there remains a critical need to more rapidly provide access to user-friendly data and products. There is an expanding and urgent challenge presented across the observing community to overcome the difficulties in data discovery, delivery, and stewardship.

There also remains the more traditional concerns related to data use. Despite the advances made during the last decade related to open data practices, it remains that

pushing data out openly is sometimes frowned upon because the benefit is not yet seen. Making the community aware of the importance of regularly citing the open data that they use remains critical.

Also, in this arena, in order to encourage the publication and sharing of more ocean observing data, it may be desirable to define multiple levels of data standards. As some data sources are reluctant to release their data because it is not perceived by its owners as being of sufficient quality for use by other groups. A well-defined raw, unprocessed data level might encourage more sharing from such data sources. Data providers can then release data and products at these standardized levels without concern for the need to fully clean or refine their data.

During the next decade further consideration is required related to the development of a more effective data policy. A global data policy needs to find a balance of resisting the need for too much top-down administration, but also facilitate progress when adhered to; resulting in funding, and/or enhanced national support, along with greater data uptake.

A final consideration is that today technology transfer and international science issues are deeply related to capacity building and data management. In many instances, 80% of data required by developing nations, to address their scientific or societal needs, already exists. Researchers trained in data analysis are needed to facilitate better use of existing resources. There is a need for data analysis capacity development that includes data discovery/analysis, as well as technology training. A concerted training effort is needed to demonstrate the transformation from raw data to a data product as part of user capacity building. The necessary additional observational resources can then be brought to address subsequently known gaps.

Feedback Loop Gap: Development of User Engagement
At the edge of the system there exists a broad range of activities resulting in greater use of ocean observing data. The maturity of these activities needs to be promoted as their

feedback related to the setting of observing requirements is critical. This is an important part of the continued cycle of assessing and updating requirements, measurement approaches, and the data and information products addressed by the FOO. As a result of these user-based activities proponents of emerging requirements are better able to engage in discussions with stakeholders and to create the case for new observations to be conducted at the global level.

Framework for Ocean Observing Process Diagram
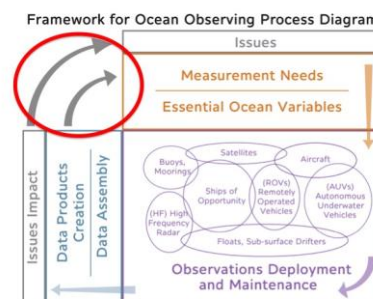
During discussions, in addition to the EOV assessment, implementation, and data concerns mentioned earlier, it was found that the feedback loops are also in need of development, or at a minimum given some measure of concerted consideration. Specifically, it is recognized that there is an urgent need to better understand 'the who'

of those most relevant when analyzing the system's fit-for-purpose; ranging from internal and external data integrators, to all stakeholders engaged in the oversight of national concerns, and all manner of sponsors.

Fundamental to an effective assessment of the observing system is an iterative and adaptive process involving regular evaluation of infrastructure based on new methodologies, knowledge, technologies, issues, and priorities. As an example, there now is a more developed or mature community working on hybrid- or coupled data assimilation models. It would be advantageous to get these groups to come together; though it is not clear what this might look like. In addition, by refining observational data for use within models, system designers can then use them as tools to both refine the models and gain a better understanding of where observations should be made.

In order to effectively create requirements across the system there is a need to look at incoming as well as outgoing needs of users including both internal and external uses. During discussions a targeted effort was called for to generate a heightened focus on the traceability of measurements to societal issues as well as the information services and products addressed via observation platforms and technologies.

This traceability is also important when addressing sponsor concerns at all levels, as there is a need for guidance on how to build an effective business case to demonstrate return-on-investment from ocean observing. The processes of the FOO can provide an important tool in demonstrating assurances to potential funders that resource requests are well vetted among scientific experts, implementation teams, and users.

Enhanced Readiness Levels

In alignment with FOO processes, the proposed approach for evaluating new components for inclusion in the system is informed by their readiness level.   The FOO describes three broad categories: concept, pilot, and mature roughly aligned with technology readiness levels as adopted in large engineering projects. Use of the FOO encourages increased partnerships to assess and improve the readiness levels of requirements, observation elements, and data systems to measure EOVs. Requirements are matured such that they demonstrate an ability to address scientific and societal needs.
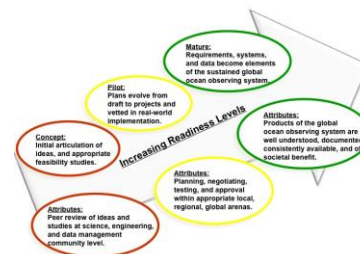
It was broadly acknowledged that Readiness Level assessment was a very positive outcome of adopting FOO processes; and has been one of the great benefits of using the FOO. It was suggested that an application of 'Science Readiness Levels' to observations may be of similar benefit. As it has been made clear that if the science community is not ready to use the data produced by the system, this leads to integration gaps as the requirements, technologies, and data are not sufficiently matured.

As a related issue, within the community today an understanding of what constitutes an official Pilot Project (GOOS or otherwise) is far too ad hoc for there to be much concerted benefit from what they contribute to the maturation of the system. There exists a need for a sound description of what is meant by a pilot project (and its desired scope), as this may be helpful toward understanding their value. In order to assess a pilot project's contribution to the system or enterprise it is important to understand what it is they are trying to accomplish. The FOO could be used to articulate and socialize this nomenclature (some of this can be found in the TPOS 2020 First Report released in 2016). There is a need for the governance structure to identify and socialize language of what pilots are and what they are designed to accomplish.

Additionally, there was general agreement that a concerted suite of pilot activities may have a very positive impact on the system overall. It is recognized that pilot projects are a powerful tool in testing and assessing new technologies for ocean observing. If done properly a pilot project can be a mechanism used to bring new technologies and best practices into the mainstream such that all stakeholders seem smarter rather than appearing to know less. An improved understanding of the various types and levels of pilots can help the community improve their role in establishing best-practices and maturing system elements, processes, and technologies.

Further, it was agreed that a mature pilot and/or assessment program would help facilitate the FOO becoming a more robust fund-raising tool. The FOO (or systems approach) could then more naturally be used to fund raise as a brand; similar to the way some Projects/Programs create a brand, as it could also be used to help facilitate the creation of a better business case for observations. This is important as today there exists several ocean-observing processes that are used to assess technologies for inclusion in global sustained observations, the ability to declare new observing technologies "mature" or "fit-for-purpose" assists funders and implementation teams in their decision-making efforts. Clarifying processes to assess the readiness of ocean observing technologies will help transition and mature technology into operational and sustained use.

Expanded Feasibility and Impact

One of the benefits of aligning with the FOO was that a focus on measuring EOVs provided a way for stakeholders to speak a common language; fostering collaboration, developing observing requirements, and promoting the development and use of best practices. This was in-part a function of the fact that EOVs are identified based on how feasible they are to observe and their level of scientific or societal impact. Targeting ocean observing investments based on feasibility and impact, in conjunction with the evaluation and encouragement of improved readiness levels for sustained observations, ensures a path for research and innovation to shape the evolution of the system.
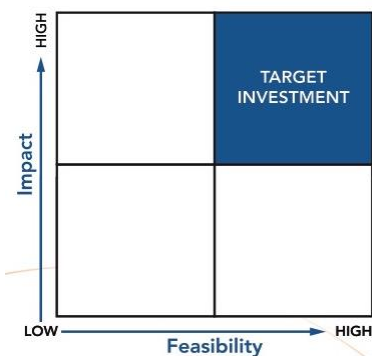
Effective measurement of an EOV often requires a blend of technologies, such that the determination of which sensors on which platforms becomes quite complex. The analysis and negotiations required to determine a cost effective, technologically feasible solution often requires expertise from a broad spectrum of geographically distributed individuals and implementation groups.

Added to this, it was also agreed that the FOO does not do a good job of assisting in the process of reconciling local, regional, global needs. Much planning, design, and implementation is still done in a compartmentalized or regionalized way. There are Task Teams and Working Groups that may work thematically or are platform focused; however true integration thinking across geographies, disciplines, and platforms is limited.

During a consideration of the desired level of integrated planning and design, it was noted that some successes have been achieved once a project or program and its measurements have become mature. It has been demonstrated that there is benefit in the creation of theme driven working groups (depending on the scale, a coordinating project office may be useful). These thematic groups (science, engineering, data management) can be organized to feed into larger or more regionalized working groups that then become a more effective way to keep the science moving forward through more efficient engagement, understanding, and management of evolving requirements and shifting priorities.

This process is made even more difficult as when some local, regional, and national projects and programs mature they may adopt additional requirements beyond the original scientific or societal drivers that generated the need for the initial observations. As the focus becomes more on sustainability and maturation, the shift away from a specific EOV or science focus creates a need for a greater reliance on standardized technologies and best practices to assess the efficiency of the system.

So, just as the underpinning of the assessment as to whether an observation was in the beginning fit-for-purpose based on its feasibility and impact, this analysis maintains its value at various levels of the system or enterprise as expert teams of all types and at all levels validate the ongoing value of an observation. This practice creates flexibility throughout the enterprise enabling the philosophy of measure once- use many times. Successes may be made more obvious through the articulation of case studies and proven return-on-investment scenario showing successful results from previous requests for funding and project and program outcomes.

Creation of More Responsive Governance and Coordination
Adequate measurement of the ocean requires the coordination of technology deployment and the integration of data. In a global system made up of local, regional, and national players, almost by definition, the level of buy-in among sponsors and stakeholders varies. Currently there is a need to assess the known levels of 'buy-in' desired from participants and sponsors. For large global networks and technology solutions, long-term and wide-scale buy-in is needed in order to develop, mature, and

sustain observations. In order to evaluate the resources and coordination needs of the ocean observing system a review of requirements needs to include a review of each EOV measurement scheme, technologies required for observation, as well as desired data and information services.

Global ocean observing processes, roles, and services require improved understanding as well as visibility to others in the coordination and management community. This issue is often made worse as many community members are missing coordination and management at a national level. While some international coordination exists and has proven helpful, it often lacks an associated national-level contact point that has access to a structure focused on concerted coordination and implementation within the nation.

Today there are several global groups that govern and/or coordinate various aspects of the observing system. It was agreed that these groups are in need of better defined and delineated roles, along with a supporting structure consisting of well-understood interfaces accompanied by collaborative or demonstration activities. Discussion often focused on the need to better define the roles between GOOS, BluePlanet, POGO, and the evolving GODAE or OceanPredict (among others). A series of activities that consider and explore a 'cross-walk' of items of mutual concern to these groups is a desired next step.

FOO Value Chain and Coordination & Oversight Groups (2019)
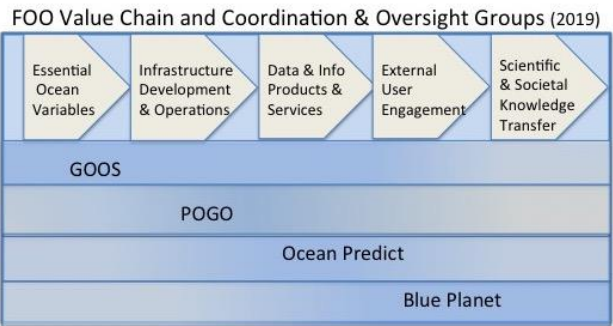
Global ocean observing system activities are the function of a voluntary system of partners that agree to participate in the system given the benefit provided to all through coordination and cooperation. These loosely coupled activities can easily lead to significant gaps. To help address this ongoing deficit it was discussed that the stakeholders may want to consider the incorporation of basin-scale governance structures. The use of a cross-national yet geographically focused governance structure, or set of interfaces, may more readily ensure that the activities within a basin-scale system are better fit-for-purpose. This may then facilitate the ability to establish a method of tracking commitments made by nations and groups regarding their observing goals and plans. Regardless of the structure, it is important to track commitments made related to the system; as successes and failures often have consequences that may impact seemingly unrelated arenas.

Generally, within the observing community there is a requirement for a governance structure with the ability to organize and coordinate integration and standardization needs that socialize and mature best practices in accordance with the architectural logic, or strategic goals and objectives of the enterprise it supports.

FOO 2.0 Project Interviewees and Contributors	
Andrew Constable	Southern Ocean Observing System
Brad deYoung	AtlantOS
Paul DiGiacomo	NOAA NESDIS, GEO BluePlanet
Albert Fischer	GOOS Director
Carl Gouldman	NOAA IOOS
Katherine Hill	WMO
Pierre-Yves Le Traon	Mercator
David Legler	NOAA GOMO
Patricia Miloslavich	GOOS BioEco Panel
Tim Moltmann	IMOS
Glenn Nolan	GOOS GRA
Sylvie Pouliquen	Ifremer
Eric Lindstrom	NASA (Co-Chair, GOOS SC)
Neville R. Smith	Retired (Co-Chair, TPOS 2020 SC)
Derrick Snowden	NOAA IOOS
Krisa Arzayus	NOAA IOOS
Emily Smail	NOAA NESDIS, GEO BluePlanet
Toste Tanhua	GOOS (Co-Chair, GOOS SC)
Maciej Telszewski	GOOS BGC Panel
Martin Visbeck	GEOMAR
Dawn Wright	ESRI
Robert Weller	WHOI