Maximizing the Value of Ocean Sensors

Standards Enable Web-Based Sensor Publishing, Discovery, Access, Tasking and Fusion

by Mark Reichardt

Introduction - The Interoperability Challenge

Digital ocean observation systems serve many purposes, such as ocean research, engineering, resource exploitation and management, transportation, recreation, weather forecasting and disaster management. In all these domains, the transition from analog to digital ocean observation systems was motivated largely by two benefits: digital devices offer the potential to be efficiently connected with other digital devices, and digital communication enables flexible one-way, two-way, one-to-many and many-to-one exchanges of information.

Satellites, monitoring buoys, research vessels, and autonomous underwater vehicles carry a wide range of sensors. Though some sensors are application-specific, in many cases sensors measure phenomena that are useful to a wide variety of research and user communities. Some parameters of general interest include surface water temperature, atmospheric pressure, cloud cover, salinity, wind speed, wave height, plankton count, and ocean current speed and direction. There is great value in sharing ocean sensor data, because ocean sensors are expensive. The sensors themselves are sometimes inexpensive, but because the oceans are huge and inhospitable to electronics, the cost of fielding, maintaining and communicating with sensors makes sharing ocean observation data an attractive proposition.

Due to the diversity of sensor types and the phenomena they measure, developing standards has required considerable thought and effort. There are multiple schemes for controlling sensors, and the universe of legacy systems for collecting, storing and using atmospheric, ocean and biological data is very broad.

“Sharing” in the context of the modern Internet computing environment is not a matter of sharing data files, but instead using Web Services, consistent interfaces, and community content models. Even scientists, who in many cases are comfortable managing bits and bytes, are beginning to expect tools and data sharing policies that do not require file management tasks. No files are managed directly by users of MapQuest or Google Earth; users instead use mouse clicks to invoke Web Services that automatically query remote Web-resident databases and deliver results. The standards described in this paper are specifications for software interfaces (application programming interfaces, or APIs), XML encodings and best practices that work with the Web's underlying Web Services infrastructure to provide scientists with similar economy of effort.

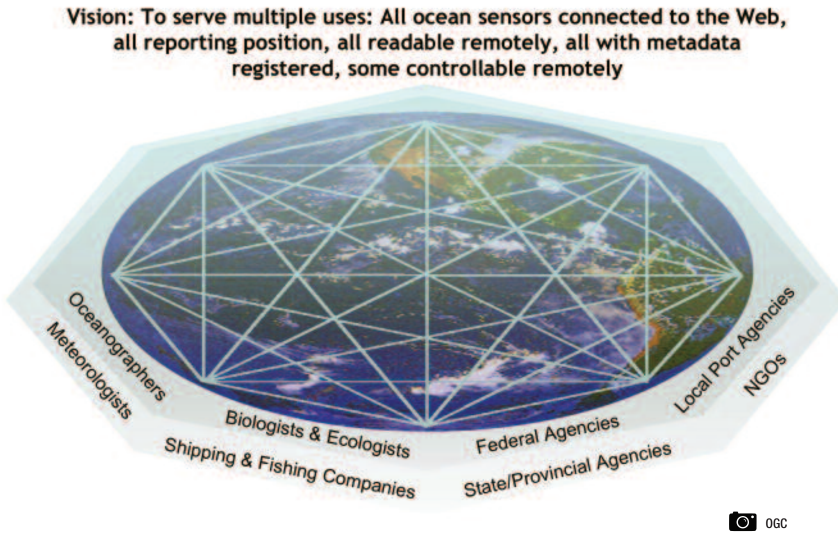


Figure 1: Standards make it possible for ocean sensors to become part of the World Wide Web.

Open Standards for Ocean Sensors

Since 2000, the Open Geospatial Consortium (OGC) membership has had a domain community, the Sensor Web Enablement Working Group (SWE WG), focused on standards for sensor description and Web access. The SWE WG Charter states: "OGC members are specifying interoperability interfaces and metadata encodings that enable real time integration of heterogeneous sensor webs into the information infrastructure. Developers will use these specifications in creating applications, platforms, and products involving Web-connected devices such as flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, Webcams, and robots as well as space and airborne earth imaging devices."

SensorML (Sensor Markup Language), a specification initially developed under a NASA Advanced Information Systems Technology (AIST) Program, was brought into the OGC in 2000 as candidate OGC standard. SensorML is used to describe sensor models and collection processes using XML schema. SensorML became the first focus of the SWE WG. Member-approved OGC OpenGIS® standards (http://www.opengeospatial.org/standards) and OGC Best Practices (http://www.opengeospatial.org/standards/bp) that relate specifically to sensors now include:

- Sensor Model Language (SensorML) Encoding Standard – Used to define the general models and XML encodings for sensors.
- Observations & Measurements (O&M) Encoding Standard – Used to define the general models and XML encodings for sensor observations and measurements.
- Sensor Observation Service (SOS) Interface Standard – Provides an open application programming interface (API) for managing deployed sensors and retrieving sensor data and specifically "observation" data.
- OpenGIS Sensor Planning Service (SPS) Interface Standard – Provides an open API for a service by which a client can 1) determine the feasibility of collecting data from one or more mobile sensors/platforms and 2) submit collection requests to these sensors/platforms.
- Web Notification Service (WNS) (OGC Best Practice) – Provides an open API for a service by which a client may conduct asynchronous dialogues

(message interchanges) with one or more other services.

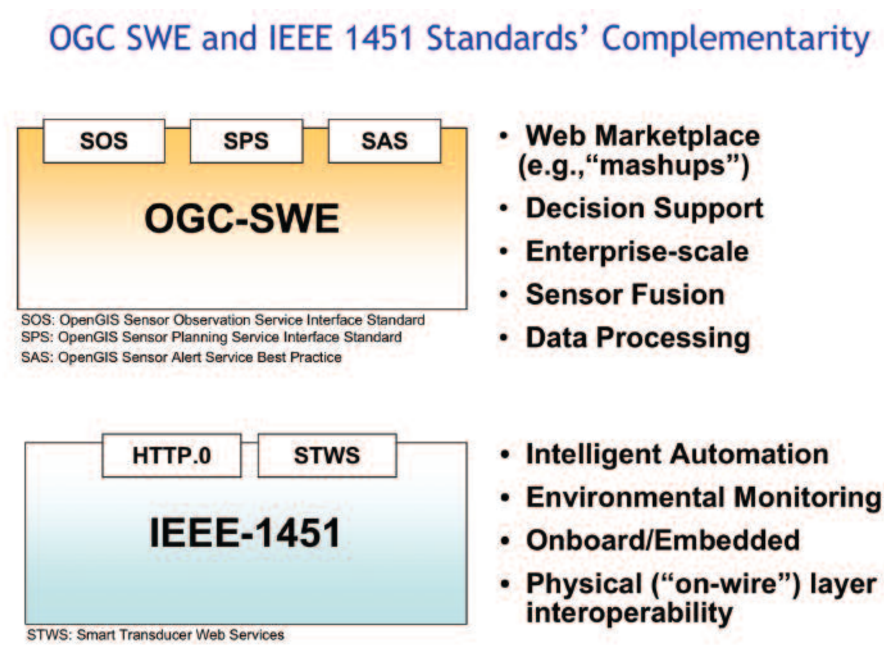
- Sensor Alert Service (SAS) (OGC Best Practice) can be compared with an event notification system. The sensor node is the object of interest.
- Transducer Markup Language (TML) Encoding Standard – Used to define an application and presentation layer communication protocol for exchanging live streaming or archived data (including control data) to and/or from any sensor system.

All of these except WNS and SAS have now been formally adopted by the membership as OGC standards. Together with the other OGC standards, they comprise an open framework for exploiting Web-connected sensors and sensor systems of all types. The SWE standards also support improved management and discovery of stored sensor data and improved use of Web services for processing data.

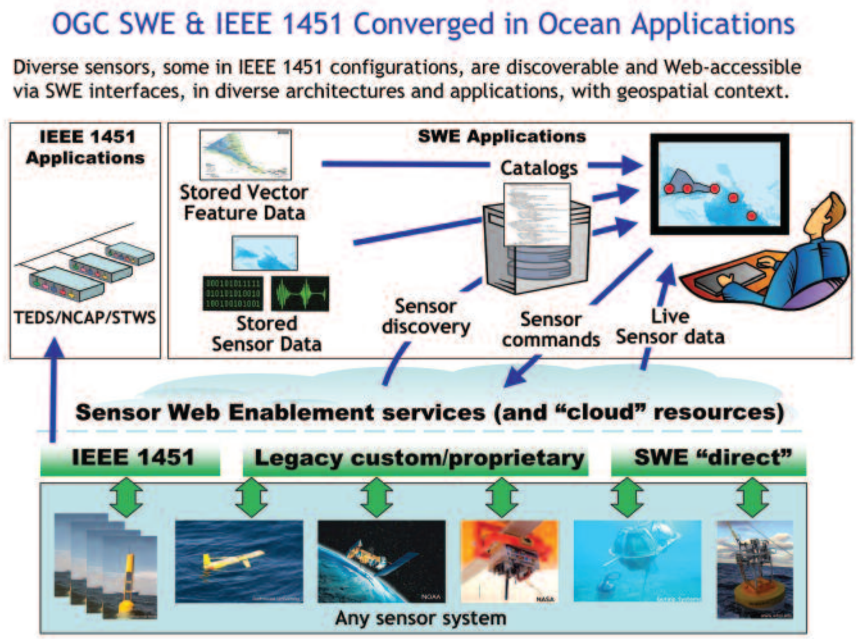
SWE standards have been and continue to be developed in cooperation with other standards organizations such as IEEE Technical Committee 9 (Smart Sensor 1451 standard), the World Wide Web Consortium (W3C), OASIS, and the Internet Engineering Task Force (IETF).

IEEE 1451 is "A Standard for Smart Transducer Interface for Sensors and Actuators." "Smart sensors" are sensors that handle their own acquisition and conversion of data into a calibrated result in the units of the physical attribute being measured. The OGC-IEEE collaboration focused on finding a universal way of connecting two basic interface types – transducer interfaces and application interfaces. Specifications for transducer interfaces typically mirror hardware specifications, while specifications for service interfaces mirror application requirements. The sensor interfaces and application services may need to interoperate and may need to be bridged at any of many locations in the deployment hierarchy. As a result of the OGC's collaboration with the IEEE 1451 standards working group, many legacy sensor networks and sensor control systems can now be integrated with other Web-based sensor networks that use OGC standards to interface to the Web and, in particular, the "geospatial Web" enabled by the OGC's other standards. The standards can be used together to increase the utility, reuse and mobilization of new sensors into programs, systems and enterprises.

Figure 2: OGC SWE and IEEE 1451 sensor standards are complementary.



OGC



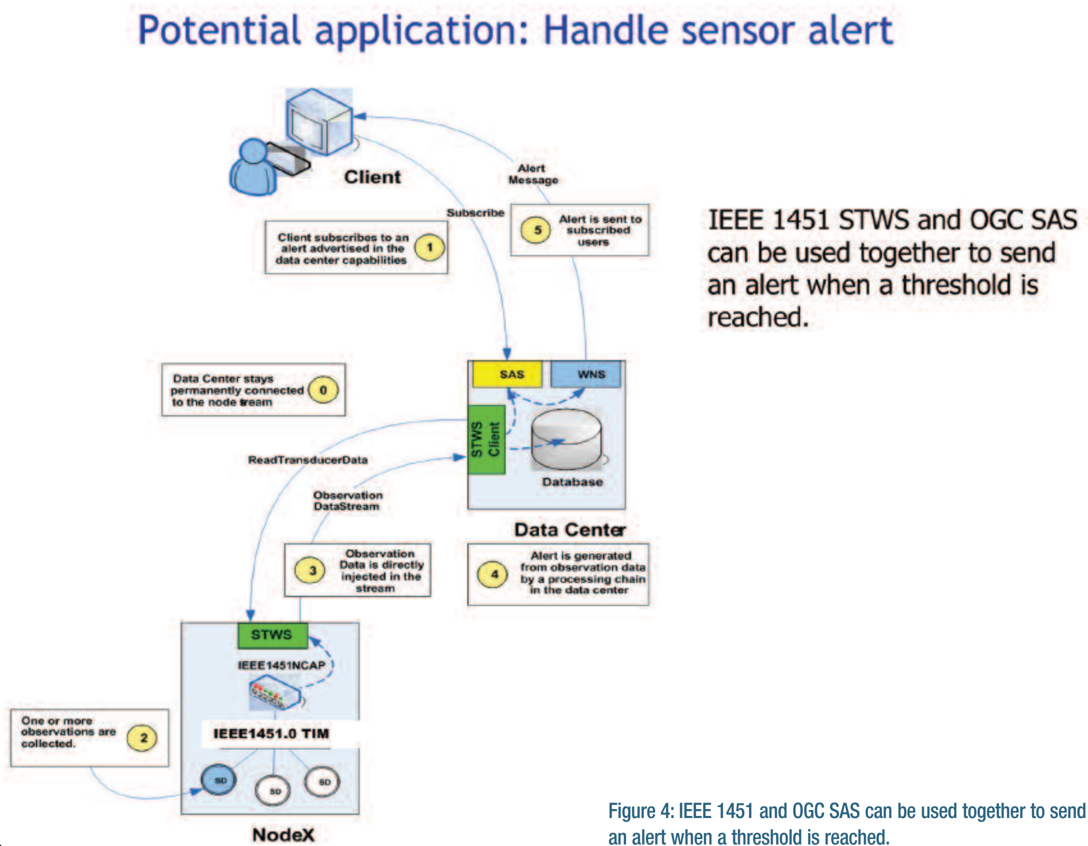
OGC

Figure 3: This figure depicts OGC SWE and IEEE 1451 standards used in ocean applications. Various kinds of sensors, some in IEEE 1451 configurations, are discoverable and Web-accessible via SWE interfaces, in diverse architectures and applications, with geospatial context.

At the application level, developers of Web-based ocean sensor systems can use OGC standards to make sensors discoverable, accessible, and controllable. They can spend less time custom coding and focus instead on user requirements and deploying operation applications that meet community needs. Further, standards-based approaches ensure that systems can be easily expanded and integrated with other current and future systems (future proofing). Standards-based software components are more reusable and can more easily be integrated with tools and components from different technology providers. Standards-based products have greater market reach.

Users of ocean standards-based sensor systems can exploit new or extended application capabilities. For example, using the OGC SPS and SOS interface standards, water temperature sensors in an ocean region can be sampled at frequent intervals and those readings can then be aggregated as a map layer in any number of client applications, fed into a modeling workflow, or provided as RSS feeds into a news aggregator – all with no changes to the sensor description or the interface used to access the sensors.

The OpenGIS Catalogue Service (Web) Interface Standard (CS-W) provides a standard mechanism for interfacing and accessing metadata on resources and services. CS-W enabled repositories can provide online access to sensor descriptions, sensor observation archives and/or Web accessible sensor assets. For example, SensorML can be used to describe a sensor and the processes associated with that sensor. The SensorML descriptions can be stored in a registry of sensor descriptions. A CS-W enabled application can then be used to ask the question, "Find all sensors that measure surface temperature in the Indian Ocean and return the sensor descriptions." Another example is the ability to describe a collection of archived sensor observations using the ISO 19115 metadata standard. Again, such metadata can be made discoverable and accessible using an OGC Catalogue interface. The ability to describe sensor assets and resources in a standard way as XML schemas, using standard metadata tools, enables communities of practice to more easily derive and use pared-down common "application schemas" that meet community needs.



OGC

Figure 4: IEEE 1451 and OGC SAS can be used together to send an alert when a threshold is reached.

This approach enables information fusion: the ability not only to discover, access and task sensors, but to merge query results with other information to establish meaning in a place and time context. “Sensor fusion” is critical in addressing a range of social needs, such as tsunami warning, algal blooms, climate monitoring, and marine ecosystem research. Information fusion and the integration of sensor observations into decision workflows is critical for researchers and policy makers working together on environmental challenges. At the core of many environmental strategies is the recognition that complex systems involve many features and phenomena in relationships that change together in response to stresses. Modeling such systems requires many inputs, and sensor fusion can be an important element in such efforts.

The core OGC Web Services standards enable detailed “situational awareness” of coastal and other ocean environments, and the SWE framework improves our ability to mobilize and benefit from an increasingly sensed environment. The OGC standards can be used with powerful standards-based workflow and processing tools, including Grid processing, that enable complex Web Services to be invoked and applied. The OpenGIS Web Processing Service Interface Standard (WPS) enables processing of raw sensor data along the service chain to render sensor information readable by humans and applications.

Progress

Many organizations are taking action to advance policy positions that encourage consistent use of standards as best practice.

- In January 2007, OGC members launched the Ocean Science OGC Interoperability Experiment (http://www.opengeospatial.org/projects/initiatives/oceansie) to study implementations of OGC Web

Service (OWS) standards being used by the ocean-observing community and to recommend best practices.

- One of these OGC members, the Gulf of Maine Ocean Observing System (GoMOOS) (www.gomoos.org/), aims to predict coastal events, promote understanding of natural systems, and solve problems that affect commerce and public safety in the coastal waters of the Northeastern US
- GoMOOS is also an active partner in the Integrated Ocean Observing System (OpenIOSS) project (http://www.openioos.org/). OpenIOSS is a demonstration portal application for visualizing provisional information products produced by the Southeastern Universities Research Association (SURA) Coastal Ocean Observing and Prediction (SCOOP) system (http://scoop.sura.org/). SCOOP partners include federal agencies and US research universities.
- Another active partner in such activities is the Marine Metadata Interoperability (MMI) project (http://marinemetadata.org/), which seeks to promote collaborative research in the marine sciences by simplifying the complex world of metadata.
- The OOSTethys (http://www.oostethys.org/) program is developing cookbooks, reference materials, and software to enable a "system-of-systems" of linked data providers in the marine domain based on OGC standards, with a focus on sensors. Participants from this effort are involved in and are sharing their knowledge with participants of the OGC Ocean Interoperability Experiment. Their website is the community portal for the OGC Oceans Science Interoperability Experiment.
- GMES is the EU Global Monitoring for Environment and Security program (http://www.gmes.info). The EU's InterRisk project (Interoperable GMES Services for Environmental Risk Management in Marine and Coastal Areas of Europe) (http://interrisk.nersc.no/) is developing a pilot system for environmental management. Also, the European Sea Floor Observatory Network (ESONET) (http://www.oceanlab.abdn.ac.uk/research/esonet.php) is a proposed 10-region sub-sea GMES project to provide strategic long term monitoring capability in multiple sciences. InterRisk and ESONET will utilize SWE and IEEE standards.
- SeaDataNet, a Pan-European project to provide Infrastructure for Ocean and Marine Data Management (http://www.seadatanet.org/) and the UK Met (Meteorology) Office's DEWS (Delivering Environmental Web Services) project (http://www.dews.org.uk) are using OGC standards. The EUCC (EU Coastal Union) (http://www.eucc.nl/) promotes standards-based interoperability and facilitates stakeholder involvement in MOTIIVE (the EU Marine Overlays on Topography for Annex II Valuation and Exploitation) (http://www.motiive.net).
- MOTIIVE and the Australian Oceans Portal project (http://www.aodc.gov.au/index.php?id=34) are collaborating on a registry to deliver OGC standards-driven query models, presentation resources and processing chains.
- A global effort that touches these programs is the Global Earth Observing System of Systems (GEOSS). Development of GEOSS interoperability is led by the GEO Architecture and Data Committee of the Group on Earth Observations (GEO). Several of the GEOSS demonstrations that OGC has supported with ISPRS and IEEE have had an oceans focus. OGC is leading the GEOSS Architecture Implementation Pilot, which involves over 120 organizations.
- In the US, the NOAA IOOS program made a recent decision to leverage SWE as the basis for interoperability of sensors. Also the US Department of Defense and coalition partners have adopted OGC and ISO standards for interoperability across military operations, including naval operations.

Work Remains

Even with the great strides made in the last few years, there is still work to be done in developing technical standards and there is even more work to be done at the institutional policy level.

Though this framework of sensor standards is fully capable of addressing a wide range of requirements in communities such as the oceans community, further standards work is ongoing in a number of areas:

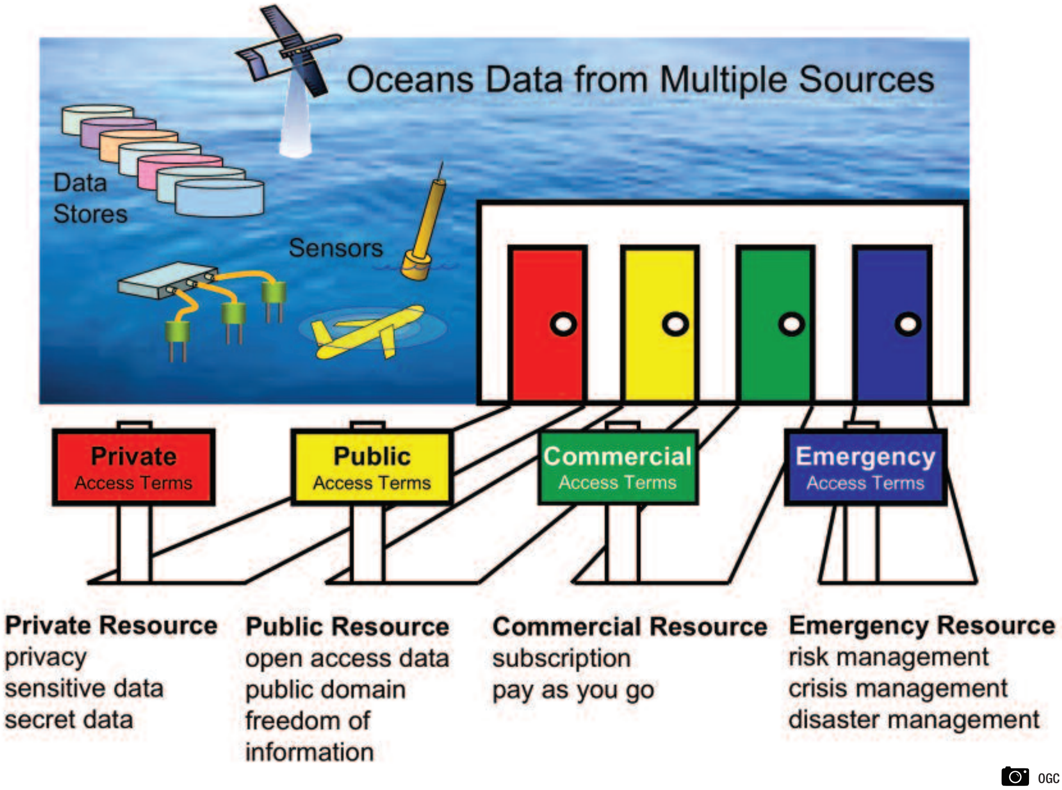


Figure 5: Geospatial Rights Management (GeoRM) standards will make it easier for organizations to establish data access policies.

- Collaboration with the Open Grid Forum (OGF) (www.ogf.org/) to address improved standards harmonization, tools and best practices for grid-based processing that could be used with live and stored sensor data.
- The standards that govern how geospatial digital rights management will operate in a Web services environment are working their way forward in the OGC's Geospatial Rights Management (GeoRM) Working Group (http://www.opengeospatial.org/projects/groups/geormwg). GeoRM standards must address a wide range of inescapable real world requirements that are not addressed by simple permissive/restrictive, open/closed approaches. The standards must make it possible to provide data — including oceans data — under different terms for different circumstances. GeoRM will help institutions resolve many of the non-technical issues that impede wider use of SWE standards.
- Concerted effort is needed to apply metadata standards, frameworks and associated applications to processes involving information semantics. The OGC's Geosemantics Working Group (http://www.opengeospatial.org/projects/groups/semantics) is playing a role in this as they elaborate the concepts of the Semantic Web (http://www.w3.org/2001/sw) and of spatial data infrastructures into the Geosemantic Web (http://colab.cim3.net/file/work/Expedition_Workshop/2006-02-21_GeoSpatialandDRMCoPs/JLieberman02212006.ppt).

The ocean community of researchers, scientists, decision makers, sensor manufacturers and software technology vendors need to work toward a common set of best practices regarding the use of standards. Also, institutions and communities that are dissatisfied with the existing standards need to get involved in the standards process. Only through such collaborative efforts can the ocean community accelerate their ability to:

- Rapidly mobilize new Web services as needed
- Reduce integration and systems operational costs
- Improve the competitive market environment for vendors offering relevant technologies
- Enhance the ability to share information rapidly, and apply this information for enhanced decision making.

Next Steps

Science today is much more focused than before on studying relationships in systems — ecosystems, social systems, complex adaptive systems, and the environmental and social "externalities" of economic activities. The need for oceans data increases with the complexity of such analysis and also with the urgency of the problems that ocean research seeks to address. The efforts described above are creating a web accessible, shared information environment that enables researchers, scientists, and policy makers to better address the critical ecological and political issues involving humans and the world's oceans. The next important milestones involve leveraging the significant standards work in the sensor area by evolving a set of standards-related best practices and policy guidance that can be readily adopted by the vendor and user communities to accelerate the pace toward greater plug and play interoperability of sensors and sensor networks.

Mark Reichardt is President and CEO of the Open Geospatial Consortium (OGC), a consensus standards organization founded in 1994 to make geospatial information resources, including sensors, an integral part of the world's information and communications technology infrastructure.

Publishing and Subscribing

Publishing

The Journal of Ocean Technology is designed to cater to all segments of the global ocean technology community. Its mission is to expand global knowledge and understanding of ocean technologies, to serve as the medium for publishing world-leading research and to promote innovation that contributes to responsible ocean exploitation and management. To do this we seek out and publish (1) essays by acknowledged leaders that highlight selected themes and (2) peer reviewed technical papers that describe cutting edge research in ocean engineering, science and technology.

Essays on a Theme

The JOT publishes essays that describe key issues for the oceans community in a concise manner, using easily understandable language. Submitted essays should be both educational and thought provoking. Essay topics should align with a theme that has been identified in the publication schedule. Essays should be 3,000 words or less in length.

Reviews and Papers

Each issue of the JOT features approximately three peer review papers. While the JOT prefers papers based on the theme for a particular issue, unsolicited themes and papers are also welcome. Abstracts should be 500 words or less in length. Papers for review should be 7,500 words or less in length. The lead-time from initial expression of interest through to publication can be as short as three months.

How to Submit

Authors interested in publishing reviews or papers in the JOT should send their enquiries to papers@journalofoceantechnology.com. Essays should be sent to meditor@journalofoceantechnology.com.

What to Submit

Papers must be submitted in MS Word format. Please do not embed photos or illustrations in the Word document. Photos and illustrations must be submitted separately in JPEG format with a minimum resolution of 300 dpi in the final dimension.

When to Submit

Abstracts for peer review papers must be submitted for consideration at least three months prior to the publication date. Essays must be submitted no later than one month prior to the publication date.

Subscribing

Issues of the JOT are only available by prepaid subscription. The JOT is published quarterly in January, April, July and October. For further information and to subscribe, visit our website at www.journalofoceantechnology.com/subscribe.asp.