Implementing a Small Satellite Information Enterprise Using a Modular Open Architecture Approach Based on International Standards

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ABSTRACT

Today each Small Satellite system has a "stove pipe" approach to exposing their requests for tasking and sensor observations / products to the end user. This approach is cost effective from the satellite operator perspective but from an end user perspective the costs can get very expensive when integrating multiple satellite systems, airborne and in-situ sensors. The Group on Earth Observations (GEO) disaster management mission space is an example where multiple sensor systems are needed and integrating the data is critical piece for mission success.

GEO and the Small Satellite community can utilize an existing Open Geospatial Consortium (OGC®) Sensor Web Enablement (SWE) international standard, started in 1999, to address and reduce integration costs with new and legacy end-user systems. The OGC® mission is "To serve as a global forum for the collaboration of developers and users of spatial data products and services, and to advance the development of international standards for geospatial interoperability."

This paper makes recommendations for moving forward and provides details on how to reduce costs of implementing the OGC® SWE though government and commercial open software efforts. For additional interoperability improvements we also seek to advance the OGC® SWE standards to meet mission requirements. Encourage the use of OGC® SWE standards over proprietary solutions throughout the Small Satellite Community to expose their sensor observations, request collection, provide feasibility analysis, and collection request tracking to new and legacy systems, thus enabling a federated Small Satellite information enterprise.

INTRODUCTION

Every day we are inundated with the next new sensor object. Sensor providers race to get their offerings to the market place using proprietary "stove-piped" solutions. When the next humanitarian event occurs, the humanitarian mission team must write custom software to interface with each proprietary sensor system available in the operational area. Based on time or funding, this integration may never happen. The value of that new sensor object is not realized and revenue is lost by the sensor provider.

The sensor provider may not have anticipated the possible value of their system to provide value to other missions such as environmental monitoring, border protection, logistics support, etc. What if the sensor provider implemented a "plug and play" solution that would reduce the integration cost for new and legacy missions?

THE SEARCH FOR A SOLUTION

A sensor provider would ideally like to build to a standard. But what capabilities would be needed to support integration of a sensor?

- Description of the sensor capabilities
- Sensor observation – data fields and units
- Query archive sensor observations
- Subscribe to real time or near real time sensor observations
- Submit collection request
- Feasibility analysis of collection request
- Collection request tracking / status
- Federated data storage
- Support "plug/play" of sensors

Need to Think International

Sensor providers typically think in terms of the customers within their country. Satellite sensors traverse the entire world, thus we need to think in terms of an international standard(s).

Sensor Observation Customers Want Open "Non-Proprietary" Solutions

The United States Department of Defense published the Better Buying Power 3.0. They want to "Use Modular Open Systems Architecture to stimulate innovation".

Modular Open Systems Architecture will increase competition and allow the government to swap out new modules to extend the life expectancy of their mission system. This will also reduce the integration cost.

Proprietary solutions lock a customer into a system integrator, thus the trend is to specify open systems architecture approaches.

Standard Not Invented Here Syndrome

"The nice thing about standards is that there are so many of them to choose from" – Andrew S. Tanenbaum. In addition, the US government continues to create new standards.

The US Army at Aberdeen Proving Ground is working a new standard called "The Integrated Sensor Architecture". "You have this fundamental architecture enabling sensors to not only recognize the systems they want to interact with, but to also broker the information exchanges," said Joe Durek, deputy director for the Modeling and Simulation Division of the Communications-Electronics Research, Development and Engineering Center´s Night Vision and Electronic Sensors Directorate".[i]

I emailed the US Army and asked why they were creating a new standard rather than using or building upon an existing standard. I received no response.

The US Defense Intelligence Agency (DIA) was developing their Terra Harvest standard – "an open, integrated battlefield unattended ground sensors (UGS) architecture that will employ multiple, flexible sensors via standards-based integration.[ii]

I came across the DIA standard in 2013. On April 7, 2015, I visited their collaboration site and noticed that the last time the site was updated was February 2013.

Need to Filter Out the Standards Chaff

Standards can be expensive for a company to implement. You need to pick the right one. Below are some questions to ask.

The US Army is creating a standard for their organization. Will the organizations within the US Army adopt this standard? Is this standard to be used outside the Army? Who is going to maintain this standard? Is there a plan to turn this standard over to an international standard's developing organization (SDO)? Will the SDO be willing to adopt and promote the standard?

In the DIA Terra Harvest case, if you committed to that standard you would have lost your investment.

The point is to look for standards that support your requirements. Make sure that they are maintained by a SDO and not an individual organization within the US government.

What Are Other Integrators Using?

The Group on Earth Observations (GEO) consists of 97 member countries and 87 Participating Organizations whose goal is to "To realize a future wherein decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive and sustained Earth observations and information. They are building the Global Earth Observation System of Systems (GEOSS).

GEOSS goal is to integrate in-situ, ground, airborne and remote (satellite) sensors to monitor the health of the entire world.

CleanSeaNet

European Maritime Safety Agency (EMSA) – detects possible oil spill in European sea areas using radar satellite images within 30 minutes of collection.[iii]

CITI-SENSE Project

The CITI-SENSE Consortium consists of 29 European Union partner institutions.[iv] It supports a community based environmental sensing initiative using mobile phones and sensors.[v]

Earth Observation to Heaven

Earth Observation to Heaven is funded by the European Commission as part of the 7th Framework Programme (FP7) Environmental theme to link health and environmental data to decision makers and scientists.[vi]

Heterogeneous Mission Accessibility (HMA)

European Space Agency's Heterogeneous Mission Accessibility (HMA) – a project involving satellite or mission owners and operators to harmonize the ground segment services and related interfaces.[vii]

German Indonesia Tsunami Early Warning System (GITEWS)

GITEWS is a tsunami early warning system for the Indian Ocean. It uses ocean bottom pressure sensors, and tsunami buoys. [viii]

GeoCENS

University of Calgary in Alberta integrated agricultural and water level sensors across Canada.

All of these projects are using the Open Geospatial Consortium (OGC®) Sensor Web Enablement (SWE) set of standards.

OPEN GEOSPATIAL CONSORTIUM (OGC®) SENSOR WEB ENABLEMENT (SWE)

The Open Geospatial Consortium (OGC®) is the "…global forum for the collaboration of developers and users of spatial data products and services, and to advance the development of international standards for geospatial interoperability". The consortium consists of 508 companies, government agencies and universities. OGC® was founded in 1994.[ix]

Figure 1: OGC(R) International Membership

OGC® Sensor Web Enablement (SWE)

Within the OGC® standards, there is a set of standards call the Sensor Web Enablement (SWE). These standards have been under development since 2000. These standards have been implemented in the annual OGC® test beds.

OGC® SWE support in-situ, airborne, and satellite sensor systems. Human reporting maybe viewed as an observation. Open Source analysis, image change detection, and automatic target recognition can also generate observations.

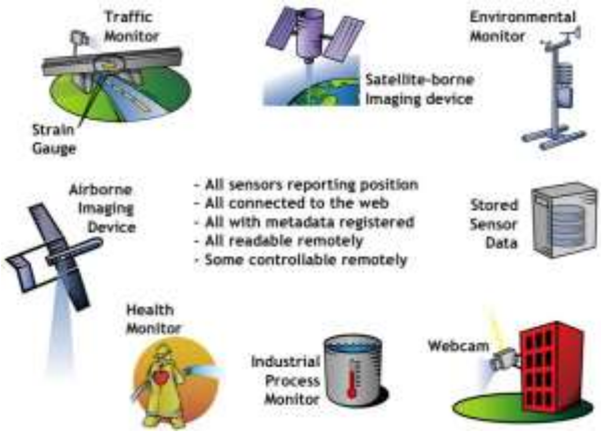

Figure 2: OGC(R) Sensor Web Enablement (SWE)[x]

The set of standards include:

- **Senor Planning Service (SPS)** – web services that allow a client create, modify and/or delete a collection request. Each request is given a unique tracking identifier and status. Feasibility analysis (can the sensor/platform do what your requested) is supported. The sensor/platform manager maintains ownership and determines which collection requests that they will fulfill. SPS tells the client where to go to find the related product. SPS can also be used for controlling a sensor. SPS supports simple to complex collection requests which accommodates casual to sophisticated users.

- **Sensor Observation Service (SOS)** – web services that may reside on a cloud environment. A sensor system announces itself to SOS, and then inserts sensor observations to the SOS. Typically sensor systems have a gateway that talks to the internet. The gateway interfaces with the SOS and determines which observations to forward to SOS. Consumers of sensor observations, ask one or more SOS what sensors that they have. Consumers can query those sensor observations and display them in their system.

- **Observations and Measurements (O&M)** – XML encodings for sensor observations and units of measurements.

- **Sensor Model Language (SensorML)** – describes processes and processing components associated with the measurement and post processing of sensor observations.

Joint Enterprise Standards Committee (JESC)

The US Joint Enterprise Standards Committee (JESC) recommends standards for the US Department of Defense (DoD) Joint Information Environment (JIE) and the Intelligence Community (IC) Information Technology Environment (IC ITE). Emerging status means a contract can use the standard if there are no existing mandated standards. Mandated means the standard is required for new acquisitions.

Table 1: JESC OGC(R) SWE Status[xi]

Title	DoD Status	IC Status
OGC SensorML: Model and XML Encoding Standard v.2.0.0	Mandated	Mandated
OGC Sensor Planning Service v2.0	Mandated	Mandated
OGC SWE Service Model 2.0	Mandated	Mandated
OGC Sensor Observation Service v2.0	Mandated	Mandated

OGC® SWE USE CASES

This section covers three levels of OGC® SWE sophistication in increasing order.

Heterogeneous Mission Accessibility (HMA) – Harmonizing Access to Earth Observation Data

ESA implemented Heterogeneous Mission Accessibility (HMA) for multiple EU satellites. Users from a single web portal, can request existing products or submit collection requests. OGC® SWE is providing the "harmonization" layer in the HMA architecture. As new sensor/platforms become available, they are "plugged into" the existing ground structure. This reduces integration cost and allows existing users to start leveraging the new capability.

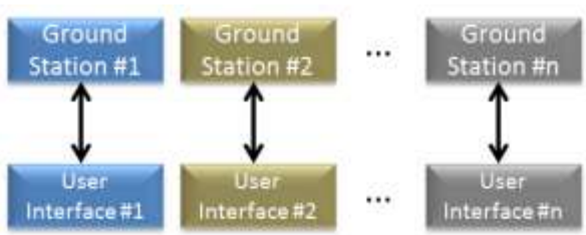

Figure 3: Before HMA - Multiple Proprietary Ground Station Systems[xii]

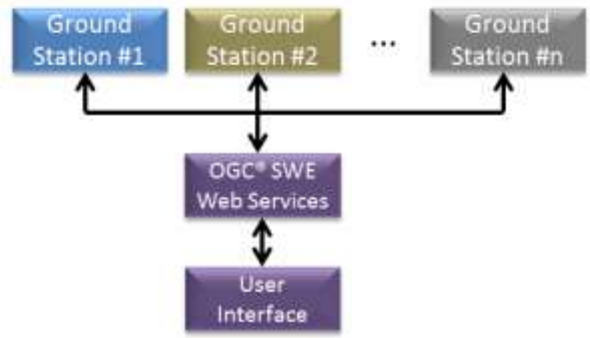

Figure 4: After HMA - Single Web Portal to Multiple Ground Stations

User benefits

- **Quick Response** -- Ability to get EO observations within 24 hours
- **Saves Time** - Submit single query and access multiple catalogs rather than submitting a query to each catalog
- **Ability and Flexibility** – Ability to rapidly integrate new sensors and platforms
- **Data Security and Policy** – addresses these issues for the user

The following is a partial list of satellites that have been integrated:

- ENISAT
- ERS
- Sentinels
- Spot
- Pleiades
- TerraSAR-X
- RADARSAT
- Cosmo-Skymed
- Metop

NASA/JPL Volcano Sensor Web

The US National Aeronautics and Space Administration (NASA) and Jet Propulsion Laboratory (JPL) have utilized OGC® SWE to implement an Autonomy-based

Science Experiment (ASE) for monitoring fifty volcanos world-wide.

The Tera and Aqua satellites observe the volcanos four times in a 24 hour period. The observations are sent to the Goddard Space Flight Center where the Distributed Active Archive Center (DAAC) automatically determines if a significant event is occurring. If an event is occurring, it tips the Earth Observing One Ground System to task the EO-1 satellite to take a high-resolution hyperspectral image of the volcano. Ground based till meters, gas sensors and seismic instruments can also detect an event can automatically request EO-1 Ground System to task the satellite.

The value to NASA/JPL is this autonomy can reduce the operations cost over one million per year.

Table 2: Volcano Sensor Web Technical Readiness Levels

Sensor Web Toolkit	OGC® Standard	Years in Operation	TRL
EO-1 SOS 0.3	SPS	5	9
EO-1 SOS	SOS	5	7
Basic Publish Subscribe	WNS	5	9
WCPS	WCPS	3	9
EO-1 SPS 2.0 (JPL)	SPS	5+	9

Proposed Mars Sensor Web

The following is a notional example of what a Mars Sensor Web would look like. Ground and satellite sensors would detect events and trigger other sensors to investigate the event further. Each sensor platform would have total control over their operations, however they would be allowed to response to another tasking request. This would require more processing of the observations on the platform, event determination, compute a response based on sensors currently on the web. Tasked sensors would need to determine feasibility, weigh mission priorities, and determine the appropriate response to the collection request.

An autonomous Mars Sensor Web would be very responsive since processing would be performed on the sensor/platforms and Mars/Earth communication delays would be eliminated.

Mission planning and scheduling on EO-1 is currently being performed on the ground and onboard the satellite. The ground scheduling does a rough calculation and the EO-1 does the detailed scheduling. The ability for a sensor/platform to perform autonomous scheduling will be an enabler for a Mars Sensor Web.

BARRIERS TO ADOPTION OF OGC® SWE

Now that the international community has invested in the OGC® SWE standards, the next great challenge is adoption by more than ESA, NASA and JPL. The following paragraphs discuss the barriers to adoption and possible solutions.

Sensor / Platform Investment Priorities

Challenge: Platform/sensor owners have limited funds and choose to invest in operations, maintenance or the next generation. Funding an interface that may benefit unknown customer(s) is a tough internal sale.

Possible Solution: Educate your customers as to the benefits. Show your customer how moving to this open architecture can help their mission.

Chicken and the Egg Syndrome

Challenge: No platform/sensor provider wants to be first to implement the standard. They prefer to wait till other providers do the same thing and consumers start asking for the capability.

Possible Solution: Talk to ESA, NASA or JPL to see if they would be receptive to adding an additional sensor/platform to their portfolio.

OGC® SWE Learning Curve

Challenge: There are a number of OGC® SWE standards. The standards are very robust and as a result it takes a long time for your technical staff can come up to speed.

Possible Solution: Contract out implementing the standards with a company or organization that is knowledgeable.

Cost of Implementing the Standard

Challenge: The OGC® SWE standards are very robust and detailed. Implementing the standards and certifying the implementations can be an expensive proposition.

Possible Solution: Ask NASA or ESA if they would be willing to share their software. Form a consortium such as the Europeans did with 52North.org.

Loosing Proprietary Information (Myth)

Challenge: By moving to an open standard, I will lose my proprietary information.

Possible Solution: In open systems, only the interface is required to be open. Proprietary algorithms and information do not need to be released. In fact, that software will typically reside on the sensor gateway.

We Need a Champion

Challenge: Heterogeneous Mission Accessibility (HMA) and the Volcano Sensor Web are successful initiatives. ESA and NASA/JPL were the respective champions.

Possible Solution: Contact OGC® to see if they have any recommendations. Educate your existing customers to see if they would be will to support.

We Can't Make Money on Open Systems

Challenge: Some companies make their money by implementing proprietary interfaces with each customer.

Possible Solution: Customers are demanding open solutions. Companies that continue providing proprietary solutions may be disqualifying themselves.

SUMMARY: THE VISION – BUILD ONCE AND SUPPORT MANY MISSIONS

For whatever reason, natural and man-made disasters are appearing world-wide. These disasters lack predictability and can occur any place on the earth. The capability to predict, assess and support relief efforts can help communities to become more resilient.

The orchestration of water, ground, air and satellite sensors and platforms is critical to the emergency / disaster management mission. The OGC® Sensor Web Enablement can provide this orchestration at the international level. Satellites can respond to any location around the world. A satellite provider can expose their products and provide a collection request capability one time using OGC® SWE. Then any country's new or legacy system can easily leverage that satellite capability. In other words, build once, use in many different ways.

International piracy and humanitarian relief missions can utilize the satellite systems in different ways. The international piracy can orchestrate ORBCOMM's Automatic Identification System (AIS) ship tracking capability to provide a location to Skybox Imaging that can take a still image or 90 second video of the ship. The Humanitarian Relief mission could leverage Planet Lab's change detection capability to identify a possible natural disaster, and Skybox Imaging could take still images or video of the location. Additional missions can be supported without satellite providers having to build new custom interfaces.

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