

# Improving Operational Responsiveness Using Open Geospatial Consortium Web-Enabled Nodes in a Space Environment

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[Abstract] “The Secretary of the Defense Office of Force Transformation (OFT) is currently undertaking an initiative, which seeks to provide operationally responsive access to, and near term tactical exploitation of space. TacSat-1 is the first adaptive experiment in this initiative, which seeks to exploit access to space within the operational contingency planning cycle.”<sup>5</sup>

As this effort becomes successful and scales up to many satellites and other assets, the ground segment quickly becomes the weakest link in that chain as we can foresee thousands of web-enabled space/ground/sea nodes interconnected to provide for a better tactical awareness and more responsive operations.

Operational users need to rapidly access the data products they need. If the products do not exist, the ground system needs to quickly discover how to generate them and what sensors to task. Tactical users will not task satellites or unmanned aerial vehicles (UAV’s) directly as those assets will become part of an invisible infrastructure available on-demand 24 hours per day, 7 days per week.

The Open GeoSpatial Consortium (OGC) is actively working on many specifications that are extremely relevant to this application. The OGC Webservices Testbed Phase-4(OWS-4) experiment which culminated in December 2006, demonstrated more than 40 organizations inter-operating using the OGC standards and tasking sensors including the NASA EO-1 satellite as part of a disaster relief scenario. The EO-1 GeoBliki, a Sensor Web Enabled Data node, was one of the first operational instantiations of a space node in advance of TASCAT-1.

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<sup>5</sup> [http://www.oft.osd.mil/initiatives/ors/tacsat\\_fact\\_sheet.cfm](http://www.oft.osd.mil/initiatives/ors/tacsat_fact_sheet.cfm)

**This effort is actually an offshoot of the OFT/Naval Research Laboratory (NRL) Virtual Mission Operation Center built to support Tacsat-1. Many OGC standards have been integrated, including the Sensor Planning Service, Observation Service, Alert Service, Web Feature Service and an innovative way of distributing data using GeoRSS Feeds. Several other specifications include catalog services, workflow automation and identity/rights management, which are critical to this endeavor.**

**This paper will detail the emergence of new capabilities based on upcoming availability of standard OGC sensor services and service orchestration to shift the paradigm from sensor-centric tasking to user-centric tasking across the enterprise in a seamless manner. From data provided by first-responders on the ground or from spacecraft in space, rapid operational response based on the transparent availability of a wide range of cooperating sensors can become a reality to operational users in the field. The Identity 2.0 solution detailed, in this paper, will provide those operational users access to unprecedented services and data from other trusted organizations in the distributed federation. The transactions are beyond simple authentication and authorization. We will describe how user profiles need to be exchanged and need to contain pre-agreed upon permissions to access those services.**

**This paper will show that with some pre-arranged and simple conventions over a given configuration, an Identity 2 solution can offer a “good enough” solution to start bringing together disparate organizations, from military and civil agencies to non-government and foreign organizations, to solve humanitarian assistance and disaster relief problems in a very effective manner.**

### **Acronym List**

<i>BPEL</i>	= <i>Business Process Execution Language</i>
<i>CSW</i>	= <i>Catalog Services for the WEB</i>
<i>DSS</i>	= <i>Decision Support System</i>
<i>GML</i>	= <i>Geography Markup Language</i>
<i>OGC</i>	= <i>Open GeoSpatial Consortium</i>
<i>OPS-B</i>	= <i>OGC Publish/Subscribe Service - Basic</i>
<i>SAS</i>	= <i>Sensor Alert Service</i>
<i>SPS</i>	= <i>Sensor Planning Service</i>
<i>SOS</i>	= <i>Sensor Observation Service</i>
<i>WCS</i>	= <i>Web Coverage Service</i>
<i>WCTS</i>	= <i>Web Coordinate Transformation Service</i>
<i>WFS</i>	= <i>Web Feature Service</i>
<i>WFS-T</i>	= <i>Web Feature Service with Transactions</i>
<i>WFS-S</i>	= <i>Web Feature Service – Simple</i>
<i>WMS</i>	= <i>Web Map Server</i>
<i>WPS</i>	= <i>Web Processing Service</i>

## I. Introduction

Traditionally, making space sensors more operationally responsive is centered around the technology and deployment speed of a particular space asset. Significant progress has been made in these areas. Deploying new payloads in space in twelve months or less has been achieved many times now. These payloads have become more complex and more sophisticated. A richer data stream can be generated in seconds and beamed to the ground. From Multi- and Hyper-Spectral imagers such as those on Earth Observing 1 (EO-1) to the Copperfield Payload of Tacsat-1 engineered for specific emitter identification, these payloads can certainly generate a lot of data. Although very complex in nature, these payloads can be autonomously controlled by onboard software. We have reached a turning point that allows us to send goals to the satellites rather than specific commands. Goal-oriented commanding has considerably streamlined space operations. From an engineering standpoint, goal-oriented commanding can be considered a technological success.

If we have achieved, or if we are on the verge of making space sensors operationally responsive, then the question is whether that view shared by the end-users? Or in other words, are end-users receiving responsive data products from space? The Office of Force Transformation announced this as “A New Business Model”. They want to change the World. This is a grand plan. But, in this new “Business” or “New World”, who are the end-users and the real customers? Our observations have led us to the conclusion that high performance space assets are providing data to high-end customers: scientists and engineers tightly coupled with their specific programs. Those high-end users may know what to do with that specific space asset and know how to transform the data to relevant information. This capability has not reached the masses. The targeted user for responsive space sensors might be the deployed Marines or a US Coast Guard cutter looking for a ship. They are probably asking themselves a common question: “Where is that ship?” As the intent to make relevant data available in a responsive manner to a broader audience increases, so does the mismatch. More and more complex payloads will become available faster but to whom?

We have increased raw data availability to a potentially wider audience to the point of surrounding users with noise. New organizations with unexpected needs cannot find the relevant data they need when they need it. We do know that the data is there after the fact (a week or two after the event). Humanitarian assistance or disaster relief crews are as valid users as Marines in the field. Neither of them have engineers or scientists available to custom process a specific data set for a specific situation from asbestos contamination in the air above New York City after September 11 to an oil spill disaster in the Chesapeake Bay or wide spread fires in California.

Custom portals are emerging to provide better data to a targeted audience. But those are merely stovepipes that do not scale and cannot serve a greater community. A distributed approach, user-centric, standards-based is currently being deployed for several programs. This paper will focus on the “RapidFire workstation” at the MODIS instrument center and the use of its Sensor Web Enabled Data nodes to provide end-users relevant data products just-in-time through seamless access to various space assets and UAV’s.

## II. The Sensor-Web Enablement Approach

Based on previous work of data aggregators, it became very obvious that we needed to decouple the data providers from the aggregator to provide some scalability in the architecture. Data nodes could become commodities, easy to clone with a standard interface. The aggregator can then easily accept new data from many different sources and even discover new sources as they come online. This, in effect, decouples the users from the data. Although aware of the data sources if necessary, the user can now focus on his need. The aggregator can focus on providing a seamless service to that user rather than focusing on data acquisition. The next logical step is to provide that same seamless interface to the user and respond to specific high-level requests.

In the case of a supervisor working at the Forest Service Remote Sensing Application Center (RSAC), the focus is to keep some situational awareness of wild fires in a given region. New fire events can be generated from multiple sources such as firefighters on the ground or satellites in space. MODIS satellites can provide hot pixel detections that are downlinked directly to Salt Lake City.

Moving responsibilities to the data nodes is critical. Standard interfaces between data nodes and aggregator are required. Figure 1 depicts such an architecture. Our current list of target capabilities is as follows:

- Formation of a data node which encapsulates a given asset and collects data on command. The data node needs to provide an interface for tasking that asset rather than allow an external user to make tasking requests. This is achieved by the OGC Sensor Planning System (SPS). Many operations are available such as GetCapabilities, GetFeasibilities, and SubmitTask.
- Creation of a Sensor Alert Service is normally used to notify the user that the task has completed (or was rejected). In our implementation, we have developed a more generic (and more basic) OGC Publish/Subscribe service (OPS-B) that can deliver the same service to the users.
- Creation of a service to distribute raw data, called a Sensor Observation Service (SOS). The user has the option to split Gigabyte-size files into more manageable chunks. In the case of EO-1, the user could subset the data and request two or three bands out of the two hundred forty two bands available from the hyperspectral imager.
- Creation of a service to process raw data called a Web Processing Service (WPS). The output of the WPS can be GeoTiff files or jpeg/gif images that can be delivered immediately to the user. GeoTiff Files have to be served in a Web Coverage Service (WCS) or Web Map Service (WMS)
- Creation of a service to store the data product meta-data via a Web Feature Service (WFS-T). Users can choose the filter specification to query the database and display the items on a map. In our GeoBliki implementation, a more basic version of the WFS has been implemented. The output of our WFS-Simple is a GeoRSS feed in Atom 1.0 format. This is the same format used by the OPS-B. A major advantage of the output is the availability of readers. A user can make a query and retrieve the results directly in the browser. There is no need to write any code to parse the results.

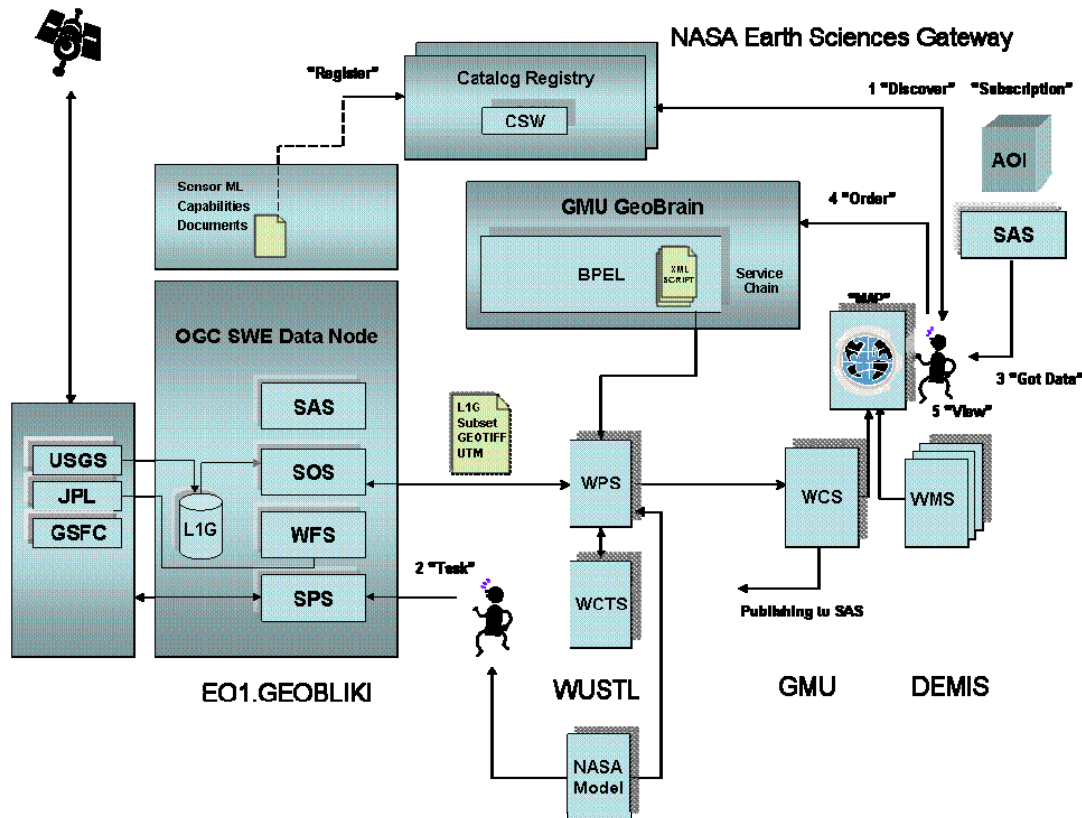


Figure 1 OGC compliant architecture with various services. Note that everything is an information feed

### III From Mass Production to Mass Customization

Automated processing of the data is not new. The U.S. Geological Survey (USGS) in Sioux Falls, SD, offers many data products processed routinely from their web site and charges a fee ranging from eighty to several thousand dollars. Some specific products can be acquired on-demand. The list is however very short. USGS manages production lines capable of generating fairly standardized data products at a reasonable price. This assumes a very homogenous customer base interested in that limited product offering. This is a standard mass production process flow.

Today's availability of standard web processing services is now opening the door to custom output or mass customization targeting a specific user's need to be addressed in a timely manner. This is highly critical for emergency response.

Hyperspectral raw data can be processed many different ways using specific classifiers. Combining specific bands and algorithms, imagery can be produced to detect specific phenomena such as fire, water, oil spills, and contaminants. This processing opportunity can be next to infinite and new classifiers can come online very quickly.

We can attain mass customization by assembling those web service components in custom workflows. OWS-4 has demonstrated this possibility using the George Mason University (GMU) Business Process Execution Language (BPEL)<sup>6</sup> engine on the GMU GeoBrain website. BPEL workflows can execute web services running across the country in many different government organizations and/or universities. A Simple Object Access Protocol (SOAP) interface defined using Web Service Definition Language (WSDL)<sup>7</sup> is usually necessary to make this happen seamlessly. This may or may not be a problem for some depending on your position in the SOAP<sup>8</sup> versus Representational State Transfer (REST)<sup>9</sup> debate. This battle of the Titans is fracturing the web service world. Although proponents of a message-based mechanism across services have found that the SOAP route is unfortunately paved with many complexities that limit its utility to high-end systems that can afford it.

As high-level workflows can call lower-level workflows, there is no doubt in our minds that SensorWeb Enabled data nodes need to support a workflow capability. We are currently using a visual approach to building workflow using Business Process Modeling Notation Standard (BPMN) sponsored by the Object Management Group (OMG). Serialization of BPMN can be achieved using XML Process Definition Language (XPDL) 2.0, another recent standard from the Workflow Management Coalition<sup>10</sup>. Although BPMN-XPDL should not be viewed as a direct competitor to the BPEL execution language according to Keith Swenson<sup>11</sup>, newer workflow engines can process XPDL directly bypassing the BPEL step<sup>12</sup>. Using Ruby-on-Rails, an open source ruby-based workflow engine is currently being integrated within the GeoBliki code base. As a result, an end-user, leveraging standardized visualization techniques of process modeling, can get one step closer to an operationally responsive space by creating custom workflows just-in-time.

### IV Service Discovery

As many data nodes come online to offer their services to the end-users, it quickly becomes a management nightmare to maintain that information up-to-date. OGC has recommended using catalog services (CSW) such as ebRIM (e-Business Registry Information Model) using a tailored profile. This work is currently on going. Unfortunately, this has proven to be quite a burden on the data node side for several reasons. While it is undeniable that there is a need to agree on a geospatial ontology, the Common Observation Model is turning out to be extremely

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<sup>6</sup> Business Process Execution Language

<sup>7</sup> Web Service Definition Language

<sup>8</sup> Small Object Access Protocol

<sup>9</sup> Representational State Transfer

<sup>10</sup> <http://www.wfmc.org/standards/xpdl.htm>

<sup>11</sup> <http://kswenson.wordpress.com/2006/05/26/bpmn-xpdl-and-bpel/>

<sup>12</sup> <http://www.wfmc.org/standards/xpdl.htm>

complex for integrators. SensorML has also been introduced as a way to describe sensor, observations and processes. The idea was to create a SensorML file for each service and then get the data node to publish the various files to the proper catalog service. This presents a new challenge for the data node and forces tight coupling to a catalog service. As new catalog services become operational, the data nodes are required to perform those same operations to properly register the supported web services and respective capabilities. This is an obstacle to scalability. Our approach is to publish the data nodes supported services using OPML (Outline Processor Markup Language). A simple outline document of describing the supported services and their end-point is all that might be required. Similar to a play list, this document can easily be exchanged among organizations and discovered in the browser if you have installed the proper plug-in to auto-discover it from the header in the top page of the site.

## **V Identity Management**

Identity is a hard problem to tackle. Security cannot be bolted on as an after thought; it has to be designed in from the beginning. So you want to allow a user to task a satellite, however the question is how to accomplish this when you are typically five or six steps removed from the user? Not just anybody should be able to task a satellite. From the user's perspective they only want to pass along the minimal amount of personal identifying information required. For example it is reasonable to expect that their email address be passed along, whereas perhaps their phone number and mailing address might be too much. What happens if you need to charge the user? You then would need a credit card number and mailing address. To further complicate the situation there are times when users are allowed free access, say during a natural disaster. Quickly, Role Based Access Control (RBAC) becomes a requirement. The business logic for all of these cases and anything else you can come up are wired in how the various roles have access to the system.

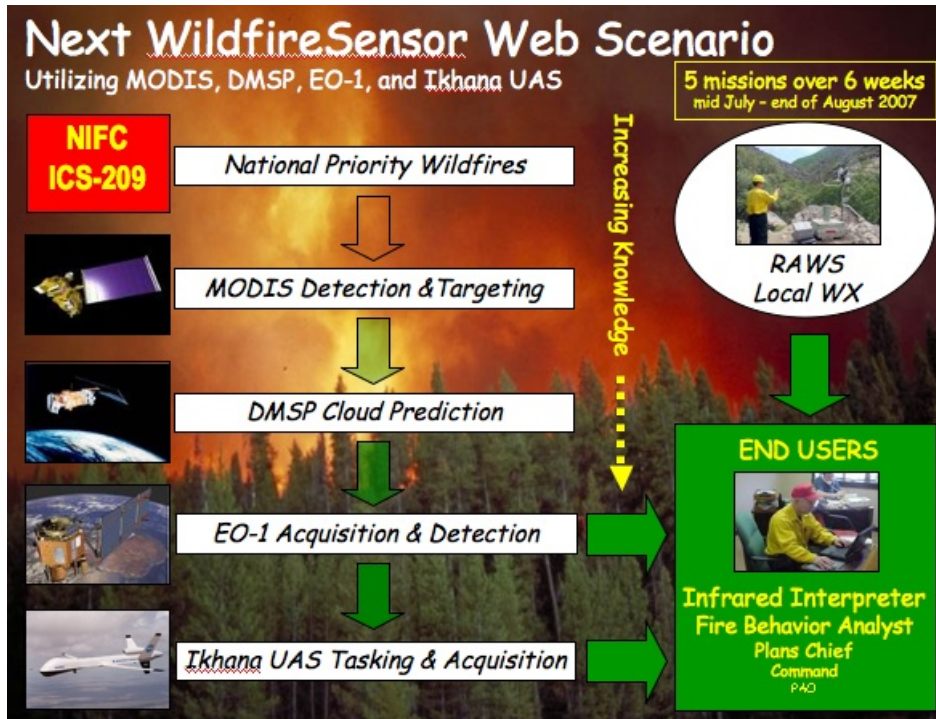
We implemented basic authentication for our local users. We were the authenticating authority. We verified their identity either by personally knowing them, or finding someone we knew who would vouch for them. The maintenance of the 1-degree of separation as well as forcing all users to create a login to our site is not a scalable solution. So the next thing was to try to get groups of people to be "trusted". It's easy enough for us to trust another NASA agency, but very quickly we run into scalability issues having to create the trust relationships with each and every group requiring access. We looked into using Security Assertion Markup Language (SAML) and the various WS-\* specifications, layered on top of SOAP. We found the approach too complicated and expensive to implement and contrary to our design philosophy to keep it simple. Our current architecture is firmly rooted in REST and GeoRSS for the Mass-Market. This is well understood and widely accepted as a current best practice. OpenID 2.0 is the protocol of choice in this realm since it allows for an optional attribute exchange for permissions. Using this protocol, our approach to permission exchange is, again, based on simplifying assumptions and pre-agreed upon arrangements between organizations. We have to agree on a naming convention to be used among trusted servers or authoritative sites. We are assuming that controlling organizations follow the rules and assign the proper permissions to their users. This seems to be acceptable and a small price to pay to be granted access to the desired data or space asset.

## **VI Conclusion**

Making space sensors more operationally responsive can only happen if the relevant data can be distributed in a timely manner to the user in need. A system is only as good as its weakest link. The weakest link today is in data publishing. Humanitarian assistance and disaster relief and recovery efforts bring together many organizations that need access to all the data they can get from many sources. Although available, space-based data is not readily accessible for a larger audience beyond the restricted science or engineering community of that program. This paper demonstrates that utilization of standardized interfaces, simplifying assumptions and pre-agreed upon conventions can simplify the architecture of data nodes to meet the challenging new requirements of higher decision support systems. These data nodes, such as [eo1.geobliki.com](http://eo1.geobliki.com), can be operational quickly and effectively. An open-source approach using available components and standards would lower the cost and provide more responsive access for the space sensor user community.

## Appendix

This viewgraph below highlights one of our current projects to demonstrate Making Space Operationally Responsive using cooperating satellites and Unmanned Aerial Vehicles (UAV's) to distribute relevant information in real-time to end-users from other organizations such as the USDA Forest Service Remote Sensing Applications Center, in Salt Lake City. This application is targeted to the monitoring and management of wild land fires. Multiple data nodes will be used to disseminate data to a Decision Support System.



## Acknowledgments

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