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Geospatial Standards and Interoperability **

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Geospatial standards and interoperability: a necessary foundation for responding to climate change and managing disasters

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Paper for the Tenth United Nations Regional Cartographic Conference for the Americas (UNRECCA), in New York, 19 - 23 August 2013, to be presented in session 9, Climate Change and Disaster Risk Reduction, on Wednesday 21st August 2013 in the afternoon, from 15:00 to 16:20. This conference session explores the ways in which member states within the region may strengthen their collaborations using existing and new regional institutional mechanisms and resources to spearhead the geospatial initiatives required to manage climate change and effect disaster risk reduction.

Our paper focuses on the value of geospatial standards in responding to climate change and managing emergencies and disasters. We consider how nations in a region can strengthen their collaborations using regional institutional mechanisms and resources to spearhead geospatial initiatives that result in improved use of geospatial information in the management of emergencies and disasters and improved strategies for adapting to climate change.

The premise is that information is power. We show how it is possible to have timely access to relevant information, information that is distributed, that is in multiple formats produced by multiple technologies provided by multiple organizations.

Twenty years of work by information and communications technology (ICT) standards development organizations (SDOs) has yielded a framework of standards for discovery, access, processing, and sharing of geospatial information. We provide examples, showing how these are being piloted in the multination Global Earth Observation System of Systems (GEOSS) context for disaster management.

The standards are international, the community is international, and the problems are global. We need to keep working together to leverage technology standards in ways that maximize our mutual benefit. Our problems (e.g. disasters) are local, regional and global in extent, so we need global coverage and interoperability to facilitate coordinated climate mitigation and emergency and disaster response.

Introduction

As population density increases, infrastructure ages, resources deplete and weather becomes more intense and chaotic, timely access to diverse and distributed geospatial information becomes more critical than ever. Coordination is necessary to make such access possible. Around the world, governments and their private sector and non-governmental organization (NGO) partners have been engaging in regional geospatial initiatives in parallel with their development of regional and institutional mechanisms to deal in a cooperative fashion with these issues. Cross-border emergency response and disaster management are two principal drivers for this collaboration.

In all such efforts, planning for access to relevant information is a critical requirement, but no one knows precisely what information and what actions will be required by the next emergency or disaster. Some disasters will be local impacts of climate change, but these impacts can be foreseen only in general terms.

One thing that is certain about the data required by decision makers is that it will be diverse and distributed. That is, it will be in multiple formats and schemas on multiple servers running different kinds of software, and it will be provided by multiple companies, NGOs, government organizations and research centers. Or, as happens too often, it won't be provided, because it couldn't be found, accessed and integrated in a timely manner, or because gaining access rights proved impossible or excessively difficult.

Fortunately, such access is more possible than ever because we've made great strides in technical interoperability, and technical interoperability has been co-evolving with the information access policies of institutions. Whether or not such timely access is possible depends on organizational preparation and on deployment of software and online services that have implemented the correct standards. Timely access to spatial information is no longer contingent on yet-to-be-developed technologies. Rather, it is contingent on organizational commitment to understanding interoperability and implementing policies that result in widespread public and private sector purchase of software and services that implement open standards.

The OGC has become involved in risk and crisis management standards efforts because this domain needs standards that address a wide-ranging set of critical real world information interoperability demands. Major software vendors, solution providers and government members in the OGC consensus process are working to accelerate the development and adoption of these standards. The OGC has demonstrated its ability to rapidly develop, test and validate standards that meet real world business requirements and that work well with other standards. This saves organizations time and money.

The complexity we face

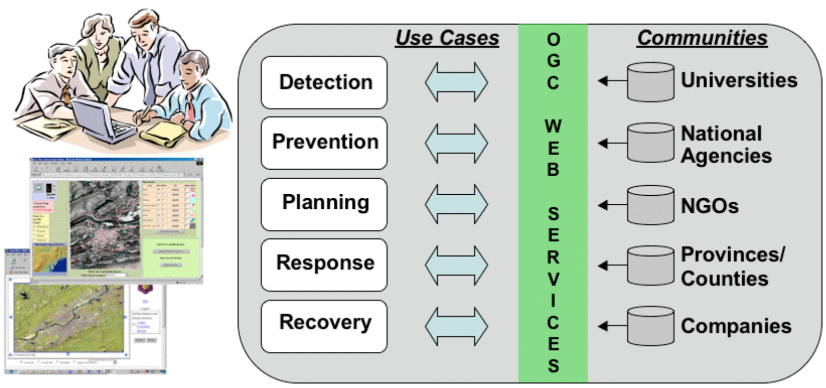
Few kinds of information are more complex than information about the location, shape of, and relationships among geographic features and phenomenon. One reason is that there are many fundamentally different kinds of *geoprocessing systems*, that is, systems for creating, storing, retrieving, processing, and displaying geospatial data. These include vector and raster geographic information systems (GIS) and systems for Earth imaging (imaging devices on satellites and airplanes), computer-aided design (CAD) (for roads, sewers, bridges, etc.), navigation, surveying, cartography, and location based services (delivered, for example, via cell phones that can give directions and report about what's nearby), facilities management, etc. Numerous vendors work within each of these technology domains who did not, until they joined OGC, consult with their competitors to form agreements on how the data should be structured and how the systems might communicate. This lack of communication coupled with the many different ways of measuring and mathematically representing the Earth produced a complex and non-interoperable geoinformation environment. Added to that chaos are the user-side semantic issues: Without coordination, no two highway departments, for example, will use the same attribute schemas, measurement types, and data types in describing a road. Their "metadata" (data describing their data sets) will also use different schemas, making automated data discovery and data sharing difficult.

Chaos in a hypothetical emergency/disaster

Suppose a gasoline truck hits a utility pole where a major highway intersects a local road. Gasoline spills and burns, some of it running into a storm drain that empties into a stream. The utility pole, owned by the electric utility and used also by a cable company and a phone company, falls amid a tangle of wires. Traffic backs up in all directions. People are injured, communication is disrupted, and the fire is spreading to nearby properties.

In considering the information sharing one would like to see in this scenario, we begin by merely listing the government and private entities that might have and/or urgently need spatial information: the state (or provincial) and local police, the ambulance company, the local fire department, the company that employs the truck driver, the company that does the hazardous material (HAZMAT) transportation monitoring, the state (or provincial) and local highway departments, the local sewer department, field engineering and customer service groups at each of the "wires" companies, the traffic reporters at the local news broadcasting stations, the departments of environmental protection (various jurisdictions from federal to local), the owner of the burning property, and others, including federal authorities responsible for emergency management, environmental protection and transportation safety.

Currently, some of these information flows, particularly those that require only a phone call or that work through proprietary interfaces in tightly coupled systems, work smoothly. But most of the information sharing that involves digital spatial data cannot happen in real time. Emergency managers need to see the big picture quickly and clearly in what's described as "Situational Awareness" or a "Common Operational Picture." In these days of changing technology, rapid response and varied forms of information delivery, emergency managers, and their teams, must depend on standards.



"On demand map creation" means that no information layer combinations need to be created "ahead of time"; all queries can be done when needed, across many heterogeneous information stores, servers and hardware platforms. This vision means that no responder will have to juggle an incident at the corners of four map sheets with missing information layers.

Now imagine a much broader disaster such as a major flood, an earthquake, an explosion, a building collapse in a downtown area, a natural gas pipeline explosion, or a sudden national epidemic. A disaster consists of perhaps 10, 100 or 1000 simultaneous emergencies like the scenario above. Consider the impact of non-interoperable data on services such as power, water, electricity, sewage, and transportation, and consider the impact on safety and on repair costs. Suffice it to say that all spatial data infrastructure (SDI) stakeholder groups along with the vendors who serve them have a responsibility to work together to establish interoperable geoprocessing that will help agencies plan for, mitigate, and respond to such real world chaos. As the HAZMAT carriers say, "Information is safety."

Alan Leidner, who headed the New York City geospatial response for 9/11 said that, "9/11 taught us that the rapid integration of combinations of data often were necessary to satisfy responder needs, and you never knew from one moment to the next what data would be required." Developing confidence in this sort of system requires using it every day in routine activities, not just in emergencies. That way, just as longtime users of mobile phones, the Internet and banks gain confidence in their offerings built on standards, so too will emergency response personnel.

What are open standards?

As a Delphi report[1] titled "The Value of Standards" states, "There is a clear and sudden shift in attitudes towards software standards." Both intra-enterprise interoperability and inter-enterprise interoperability are now seen to be much more important than just a few years ago. There is a simple logic behind this:

1. Computing means to store, retrieve, and process data.
2. To enjoy many positive benefits, our computer systems need to be able to communicate.
3. Communication means transmitting or exchanging through a common system of symbols, signs, or behavior.
4. Standardization means agreeing on a common system.
5. Therefore, we should promote standardization and employ standards in our computer systems.

Widespread acceptance of this reasoning is reinforced by widespread awareness that open standards (HTTP, TCP/IP, XML, etc.) are responsible for the extraordinary success of the Internet and the Web.

Open Standards in the Geospatial World

OGC defines an open standard as one that:

1. Is created in an inclusive, international, participatory industry process.
2. Is owned in common.
3. Has free rights of distribution. That is, anyone can share it with anyone, free of charge.
4. Is free and openly available to the public, in all its details.
5. Does not discriminate, in the license or the standard, against persons or groups.
6. Is technology neutral--no provision of the license may be predicated on any individual technology or style of interface.

By this definition, a de facto standard established by one company, an exclusive group of companies, or a government is not an open standard, even if it is published and available for use by anyone at no charge.

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[1] A Delphi Survey, "The Value of Standards", ©2003 Delphi Group, Ten Post Office Square, Boston, MA 02109

Open standards are developed by non-exclusive industry consortia and task forces (like the OGC, the World Wide Web Consortium (W3C), the Open Mobile Alliance (OMA), the Internet Engineering Task Force (IETF), and others) as interlocking parts of interoperability frameworks and reference models. These organizations' framework and reference model documents guide developers and integrators in designing customer-specific open architectures, which specify the open data models (information schemas) and open interfaces, protocols, etc. that will meet the needs of particular enterprises based on their user needs, including business models and work flows.

Open standards address user needs that can only be met by cooperation among system vendors. Overall, users want to maximize the value of past and future investments in systems and data.[i] [ii] In the geospatial world, that general statement points to the following user needs:

1. The need to share and reuse data in order to decrease costs (avoid redundant data collection), obtain additional or better information, and increase the value of data holdings
2. The need to choose the best tool for the job and the related need to reduce technology and procurement risks (i.e., the need to avoid being locked in to one vendor)
3. The need to leverage investments in software and data, such as enabling more people to benefit from using geospatial data across applications without the need for additional training

It happens that the open framework that addresses these basic needs (documented in more detail in any open geoprocessing architecture) makes it possible for vendors to address a whole new array of user needs that require a standards foundation. These additional user needs include:

1. The need to organize geographic data stored in text and on video, audio, and other media
2. The need to access and process on-line sensor data (a sensor is always someplace) from multiple sources
3. The need for Location Based Services that are portable across devices, networks, and providers
4. The need to apply different symbology to data for different applications
5. The need to take advantage of grid computing for geoprocessing applications

The solutions that vendors will offer to fill these needs have a standards platform that enables them to establish new markets and new opportunities for growth.

OGC Web Services (OWS)

Distributed computing, cloud computing, apps and many other elements of this century's information environment depend on programs and devices being able to request "services" that are provided by remote services. This represents a radical departure from the world in which the Internet was used mainly for file transfers.

The difference between file based computing and service based computing is evident in map browsers such as Google Maps. To get a map on your desktop or smart phone, you don't download, convert and process a data file. Instead, a client process on your device links to a service through a service interface, in this case KML (an OGC standard which the average user doesn't see or need to know about). You don't get data; you get an answer to a query. Services can invoke services in "service chains." Financial transactions on the web usually involve chains of services that invoke and respond via open service interfaces and encodings (known mainly to programmers to set up the transaction applications.)

Most OGC standards[iii] are standard service interfaces the provide communication between servers and client processes that invoke geospatial services on servers. Some OGC standards, such as the Geography Markup Language (GML) and Sensor Model Language (SensorML), are encoding standards. Such data encoding standards are a requirement when services need to exchange data.

As of July 2013, 39 OGC Standards have been adopted as official OGC standards by the OGC membership. A few of the OGC Web Services standards that have been widely implemented in vendors' products are listed below. These enable client processes to dynamically query, access, and combine different types of spatial data over the Web, information that is made available on servers with the same interfaces or protocols. Such interfaces and protocols can be implemented by any software provider.

- **OGC Web Map Service Interface Standard (WMS)**: This standard specifies a set of protocols that provide access by Web clients to maps rendered by diverse map servers on the Internet. The WMS interface allows the client to query the capabilities of a given map server that serves maps derived from vector or raster data. Based on the capabilities, the WMS interface enables a server to return a GIF, PNG, or JPEG image for a given area of interest and a specified coordinate reference system. An associated technology, the "Cascading Map Service," serves as a gateway for multiple map servers and enables the user to overlay multiple views. A WMS client can request different map layers from independent distributed map servers. If each map has the same geographic area and physical dimensions, and if their backgrounds are transparent, then they can be overlaid in a single window to produce a combined map. Another associated standard, the OGC Styled Layer Descriptor (SLD) profile of WMS provides control of the display characteristics – color, line thickness, etc. – of displayed features. (Note that only a map "picture," not the spatial data itself, is returned.)
- **OGC Web Feature Service Interface Standard (WFS)**: WFS supports the query and discovery of geographic features and attributes (vector data). WFS-enabled services are capable of supporting web-based data collection and maintenance. Clients (service requestors) access geographic feature data through a WFS by submitting a request for just those features that are needed for an application. The client generates a request and posts it to a WFS server on the Web. The server executes the request. It returns to the client results that encoded in the OGC Geography Markup Language (GML) Encoding Standard. GML, developed in OGC, has become the global standard XML encoding for spatial data.
- **OGC Web Coverage Service Interface Standard (WCS): WCS** was designed to promote interoperability between software implementations that provide coverage analysis and processing capabilities. "Coverage" refers to digital geospatial

information representing space/time-varying phenomena, such as grids, triangular irregular networks (TINs), Earth images and digital elevation models. Software with conformant interfaces provides for requesting and viewing a grid coverage and performing certain kinds of analysis such as histogram calculation, image covariance and other statistical measurements.

- **OGC Catalog Services – Web Interface Standard (CS-W):** Catalog services maintain, publish and access information *about* resources that are available on a network. Some CS-W catalogs catalog metadata about data sets containing geographic features (vector data) or coverages (raster data, TINs, etc.). Other CS-W catalogs catalog metadata about services (online geoprocessing services based on OWS.) A Discovery Client enables the user to: build queries to find data or services; issue those queries to the appropriate catalog(s); and display the returned result set. A Publisher Client enables the user to insert new data source (or service source) entries into the Registry so that it can be searched by discovery clients.

All of these are "adopted" or "approved" OGC Standards, as opposed to candidate standards that have not yet worked their way through OGC's rigorous (but relatively fast) consensus process. All are implemented in products from various vendors. Almost all are the only standards of their kind, except for the corresponding ISO standards, which ISO and OGC work to make identical.

All of the OGC standards and other standards-related documents can be viewed and downloaded at no cost from http://www.opengeospatial.org/standards.

The reason there are many OGC standards instead of only few is that geospatial information and geospatial processing are inherently complex:

- Some OGC standards, such as CS-W and Sensor Model Language (SensorML), primarily enable publishing, discovery and assessment of geospatial resources (including sensors and sensor data).
- Others, such as WMS, WFS and WCS, serve mainly to provide access to and communication between geospatial resources.
- Others, such as the Web Coverage Processing Service (WCPS), provide standard ways of encoding instructions for geospatial processing.
- Others, such as Web Map Context (WMC), Web Service Common, Symbology Encoding (SE), (and the candidate GeoPackage standard), support sharing of geospatial information.
- Others, such as WaterML, CityGML and cf-NetCDF (fluid Earth systems), are domain-specific.

About ten new candidate standards are being developed and/or evaluated by OGC Technical Committee Standards Working Groups (SWGs) and a number of existing standards are being revised or enhanced. Some new standards address geospatial applications of new technologies and applications, such as virtual reality and indoor location/navigation. Others address new domains. A recently proposed standard called CarbonML, for example, would provide consistent and transparent communication of data associated with carbon credits and carbon offsets. If a CarbonML Standards Working Group is chartered, nations with a commitment to climate management may soon have an opportunity to help shape a key foundational element of the international carbon market.

OGC programs supporting disaster management information infrastructure

The OGC Interoperability Program[iv] is a series of hands-on engineering initiatives to accelerate the development and acceptance of OGC standards. A number of different initiatives[v] are currently under way. OGC Interoperability Initiatives often feature disaster scenarios. In the 2005 OGC Web Services (OWS-3) test bed, a team of experts from OGC member companies demonstrated geospatial information system interoperability in a fictional scenario involving a forest fire approaching a warehouse full of toxic chemicals in a heavily populated area. Live aerial imaging, first responders with cell phones, GPS and video cameras, and multiple decision support systems were involved in giving all parties improved awareness and information for planning and coordination. The scenario for the 2006 OWS-4 testbed also addressed a disaster. Activities in the scenario were supported by interoperability between a building information model (BIM), an indoor navigation system, IEEE 1451 sensors, wireless communications, live imaging from an unmanned aerial vehicle, maps and modeling and simulation tools. Each of the major yearly testbeds since then has included scenarios related to disasters. As of July 2013, sponsors of OGC Testbed 10 are developing use cases and scenarios that pose interoperability problems which will be addressed in the coming months by teams of technology providers. Their efforts will produce OGC Engineering Reports that will provide a basis for new standards development, standards revisions and enhancements, and best practices involving appropriate use of OGC standards.

In the OGC Standards Program[vi] the Technical Committee and Planning Committee work in a formal consensus process to arrive at approved (or "adopted") OGC standards. OGC holds three or four Technical Committee meetings each year at which working groups meet and adoption votes are held in plenary sessions. The Standards Program provides a forum members from government, research and industry worldwide can use to do this work together in a collaborative and collegial environment. The OGC and its members promote worldwide use of these standards.

The OGC Technical Committee's Emergency and Disaster Management Domain Working Group (DWG) works closely with other Working Groups in the OGC, such as the Decision Support DWG, the Earth Systems Science DWG and the Workflow DWG. In addition, the OGC works closely with ISO, OASIS, IETF, W3C and other standards groups to ensure that their location related encodings use or are harmonized with OGC standards.

The activities of the Sensor Web Enablement DWG, the Sensors and networks, both wired and wireless, are key components in building distributed sensor networks for monitoring and protecting critical infrastructure such as buildings, airports, railways, bridges, utilities, and water supplies. Such networks also play a role in tsunami and earthquake warning systems, severe weather forecasting and tracking, flood warnings, and environmental health.

Deployment of interoperable information systems and related information system policies for disaster management depends on proofs of systems' interoperability. The testbeds, pilot projects and interoperability experiments of the Interoperability Program are important for developing such knowledge, but compliance testing and compliance certification are key resources for routine purchasing of interoperable products and online services. The OGC Compliance Program provides an online free testing facility, a process for certification and branding of compliant products, and coordination of a vibrant community that develops and supports test scripts. The Compliance Program also runs plugfests, which are short term events for proving and increasing interoperability among vendors' products.

In addition, the OGC and its members support publications, conferences to help technology developers, integrators and procurement managers introduce OGC plug and play capabilities into their architectures. OGC GovFuture membership provides special programs and materials to help subnational and local governments build and maintain Spatial Data Infrastructures that maximize the capabilities available through use of products that implement OGC standards.

GEOSS as an exemplar and resource

For eleven years, the Group on Earth Observations (GEO) has been coordinating efforts to build a Global Earth Observation System of Systems (GEOSS). GEOSS provides a model for what can be accomplished by UN members in a region, and it also provides tools, best practices, and a network of experts and technology providers that can be tapped to achieve the aims of UNRECCA.

GEO was launched in response to calls for action by the 2002 World Summit on Sustainable Development and by the G8 (Group of Eight) leading industrialized countries. These high-level meetings recognized that international collaboration is essential for exploiting the growing potential of Earth observations to support decision making in an increasingly complex and environmentally stressed world. GEO is a voluntary partnership of governments and international organizations. It provides a framework within which these partners can develop new projects and coordinate their strategies and investments. GEO’s Members include 88 Governments and the European Commission. In addition, 67 intergovernmental, international, and regional organizations with a mandate in Earth observation or related issues have been recognized as Participating Organizations.

OGC is a Participating Organization in GEO. The OGC leads the GEOSS Architecture Implementation Pilot (AIP)[vii], now in its 6th year. The OGC is co-leader of the GEO Standards and Interoperability Forum (SIF) and led the organization of a series of GEOSS Workshops. The OGC was also a member of the European Commission's GIGAS (GEOSS, INSPIRE and GMES – an Action in Support) Consortium[viii].

GEO is constructing GEOSS on the basis of a 10-Year Implementation Plan for the period 2005 to 2015. The Plan defines a vision statement for GEOSS, its purpose and scope, expected benefits, and the nine “Societal Benefit Areas” of disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity.

GEOSS will yield a broad range of societal benefits, notably:

- Reducing loss of life and property from natural and human-induced disasters;
- Understanding environmental factors affecting human health and well-being;
- Improving the management of energy resources;

- Understanding, assessing, predicting, mitigating, and adapting to climate variability and change;
- Improving water resource management through better understanding of the water cycle;
- Improving weather information, forecasting and warning;
- Improving the management and protection of terrestrial, coastal and marine ecosystems;
- Supporting sustainable agriculture and combating desertification; and
- Understanding, monitoring and conserving biodiversity.

These intended benefits of GEOSS are well aligned with the aims of the August 2013 UNRECCA Conference and Conference Session 9, Climate Change and Disaster Risk Reduction.

Development of the AIP follows a process[ix] whereby the architecture, the delivered systems and stakeholders co-evolve. This general GEOSS AIP process itself exemplifies the process to be followed by nations and their partner nations in developing more robust spatial communication capabilities for disaster management.

Each of the Societal Benefit Areas (SBAs) described above has an associated AIP Working Group. Responses[x] provided by 17 organizations have responded to the 2013 AIP-6 Call for Participation can be accessed on the OGC Network website. Many of them involve disaster management, climate studies and climate change adaptation strategies. For example:

- INCOSE will develop requirements for selection of components that enable assessment, selection and exploitation of Earth Observation resources.
- The COBWEB project will address user registration, authentication and Single Sign On.
- FCU will establish means to maintain the availability of a near real-time satellite information web service which has been registered with GEOSS portal (ETA4Satellite service) and the Web-Based Near Real-Time Satellite Information Query System which can be used to get the latest satellite images effectively and efficiently. FCU will also develop a service that can query certain historical satellite images (Formosat 2) provided by the National Space Organization (NSPO).
- Compusult will provide components and services to support the Disaster SBA, including an app for Android and iOS devices that will display OGC services and use the built-in sensors (GPS, camera, microphone, etc.) of mobile devices to provide improved real-time situational awareness for disaster management and mitigation.
- NASA[xi] will develop an architecture for mobile device end-users that is easily discoverable and can generate information products on-demand, including flood maps, flood predictions, precipitation and weather forecasts.

Conclusion

The disaster management and climate forecast communities are international and the problems they confront are global. Most of the information system standards that UN Member Nations need for responding to climate change and managing emergencies and disasters are international. Our problems (e.g. disasters) are local, regional and global in extent, so having global coverage and interoperability to facilitate a broad coordinated response for any type of disaster is the key. So we need to keep working together to leverage Information Technology (IT) properly for all of our benefit. Working together helps us solve the technical issues and develop best practices for using the technology. Working together also helps us solve the institutional issues that invariably arise as new technologies disrupt old business processes, workflows and institutional arrangements.

IT's exponential advance precipitates concerns about IT's impacts on security, privacy, employment, physical and mental health, education, crime, governance, poverty etc. Beyond their narrowly focused technical standards work, consensus standards organizations can provide a good forum for addressing these broader issues, because such a forum requires expert participants who can discern ways that standards might serve to address such concerns. The OGC, for example, has a Government SIG and a Business Value SIG, and the OGC Board of Directors has a Global Advisory Council (composed of many industry leaders who are not members of the OGC or its Board) and Spatial Law & Policy Committee. These bodies are effective, but only to the extent that governments and NGOs participate to raise issues and elaborate possible solutions.

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[i] "The Importance of Going 'Open,'" an Open GIS Consortium (OGC) White Paper, September, 2003

[ii] Chuck Heazel, "An Architecture Approach for Web-Enabled Systems," an unpublished article written for OGC, August, 2003

[iii] http://www.opengeospatial.org/specs/?page=specs

[iv] http://www.opengeospatial.org/ogc/programs/ip

[v] http://www.opengeospatial.org/projects/initiatives

[vi] http://www.opengeospatial.org/ogc/programs/spec

[vii] http://www.ogcnetwork.net/AIpilot

[viii] http://www.thegigasforum.eu/project/project.html

[ix] http://www.earthobservations.org/documents/cfp/201302_geoss_cfp_aip6_development_process.pdf

[x] http://www.ogcnetwork.net/node/1887

[xi] http://www.ogcnetwork.net/system/files/NASAAIP-6Response20130415.doc