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Evaluation of Open Geospatial Consortium Standards for Use in LLNL Geographic Information Systems (GIS)

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SUMMARY

The objective of this project is to evaluate existing and emerging Open Geospatial Consortium (OGC) standards for use in LLNL programs that rely heavily on geographic data. OGC standards are intended to facilitate interoperability between geospatial processing systems to avoid duplication of effort, lower development costs, and encourage competition based on improved capability and performance rather than vendor lock-in. Some of these standards appear to be gaining traction in the geospatial data community, the Federal government, DOE and DHS. A serious evaluation of this technology is appropriate at this time due to increasing interest and mandated compliance in the Federal government in some situations.

A subset of OGC standards is identified and reviewed with a focus on applications to LLNL programs. Each standard or recommendation reviewed was evaluated in general terms. In addition, for specific programs such as Gen&SIS and NARAC, a specific evaluation was made of several of the standards and how they could be used most effectively. It is also important to evaluate the acceptance of these standards in the commercial arena. The implementation of OGC standards by the largest GIS vendor (ESRI) was reviewed.

At present, OGC standards are primary useful in specific situations. More generally, many of the standards are immature and their impact on the government and commercial sectors is unclear. Consequently, OGC and related developments need to be observed. As specific standards or groups of standards mature and establish their relevance, these can also be incorporated in LLNL programs as requirements dictate, especially if open implementations and commercial products are available.

INTRODUCTION

Geographic data are used extensively by many programs at LLNL, particularly in the areas of Energy and Environment and Homeland Security. In addition, a GIS group has been formed in Engineering that focuses on spatial analysis and statistics. As a particular example, NARAC uses more than a dozen types of geographic data in model calculations, effects analysis and visualization. As the atmospheric modeling capabilities associated with NARAC improve and as NARAC's mission grows, the coverage, resolution, accuracy and timeliness requirements for geographic data will increase. Other LLNL programs often do not have the same coverage requirements but often need more types of geographic data and specialized analytic techniques. The range of efforts supported by the E&E GIS Center is evidence of this. Thus, effective means of acquiring, processing and presenting these data are of interest to the Laboratory.

Background

While geographic data are used in a variety of applications, traditional implementations of geospatial processing capabilities that use such data have been associated with substantial expenses. Such expenses can take many forms including:

- production or identification of datasets required for a project or program
- manipulation of data formats, coordinate systems, classification schemes and other details to transform externally generated data into forms that can be used within a project or program
- learning the very complex user interfaces associated with full-function GIS and maintaining that knowledge as the systems evolve
- development of applications that rely on software packages with complex application programming interfaces (APIs)
- development of custom software to meet specific needs

Most significant geospatial processing efforts involve many, if not all, of these expenses. As a consequence, the use of geospatial data has been limited by the expense of acquiring and maintaining the data and technology necessary to incorporate geospatial processing into a program. Also note that the production of datasets can be enormously expensive, particularly if the geographic coverage is extensive. In the past, large government agencies (e.g., USGS) have applied large portions of their workforces for years to generate single datasets.

The issue of inefficiency in the management of geographic data was identified as early as 1982 (see http://fgdc.er.usgs.gov/publications/fgdc_history.html). For example, data sets are often redundant, having been previously produced by multiple organizations. Such redundancies are due to both lack of knowledge of available data sets and the fact that, traditionally, available data sets have been implemented in a variety of incompatible formats that do not allow the data to be used easily in different applications. The plethora of formats contributes to vendor lock-in. In addition, many users of Geographic Information Systems (GIS) are interested in incorporating geographic information into their system in a seamless way. This has been very difficult and expensive due to a wide range of formats, interfaces and licensing issues.

There are many organizations that are playing a role in attempting to improve the efficiency of geospatial data management. The Federal Geographic Data Committee (FGDC) has promoted "the coordinated use, sharing and dissemination of geospatial data on a national basis" since 1990 with the issuance of OMB Circular A-16, which addresses a variety of issues dealing with effectively using geospatial information in the Federal government (see http://fgdc.er.usgs.gov/index.html). The efforts of the FGDC are focused on the evolution of a National Spatial Data Infrastructure (NSDI), which has four components:

1. *Metadata* – an expectation (and, increasingly, a mandated requirement) that all geospatial data created by the Federal government will be described using a metadata standard that will allow potential consumers of a geospatial dataset to evaluate the dataset for applicability to their work. Thus, the metadata standard requires descriptions of the geographic coverage, coordinate system, thematic classification systems, accuracy, timeliness, and generation procedures in one of two formats (an XML format and a legacy text format).
2. *Clearinghouse* – the metadata described above is to be made available in a public clearinghouse that supports browsing and discovery of metadata. This allows potential clients to find datasets that are most applicable to their work and thereby avoid the expense of producing and minimize the cost of acquiring the necessary data.
3. *Standards* – essential components of an effective NDSI are standards that allow consistent interaction between geospatial data producers, consumers and framework components. While there are many standards maintained and being created by FGDC (see http://fgdc.er.usgs.gov/standards/status/textstatus.html), two are mentioned here: the Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998), and the Spatial Data Transfer Standard (FGDC-STD-002). The metadata standard is central to all aspects of the NSDI. The Spatial Data Transfer Standard (SDTS) is a very complete and complex standard that attempts to allow any geospatial information to be encoded and transferred from one installation to another. Note that the FGDC standards efforts are coordinated with other national and international standards organization (e.g., ANSI and ISO).
4. *Framework* – the framework is composed of a number of standard datasets that are maintained by appropriate Federal agencies and made available so that there is no need for other organizations to develop comparable datasets. The framework data layers are:
   - Geodetic control
   - Orthoimagery
   - Elevation
   - Transportation
   - Hydrography
   - Governmental units
   - Cadastral information (land ownership boundaries)

The NSDI has been evolving since the early 1990s and is becoming a practical reality in the form of the Geospatial-One-Stop (GOS; see http://www.geo-one-stop.gov/). These various components are clearly necessary conditions for flexible and effective use of geospatial information.

While the NSDI is central to efforts to promote effective geospatial data use, many have argued that it is insufficient to support effective data sharing and the broader goal of geospatial interoperability. Geospatial interoperability can be viewed as a special case of software interoperability where heterogeneous, independently-managed, distributed systems can interact using requests for services based on mutually understood formats for request and data specification. Considering geospatial interoperability introduces a variety of issues that allow transferred information to be shared (e.g., coordinate system management) along with non-distributed interactions between competing vendors implementations, which is important given the strong commercial component of the geospatial information processing industry. This is a significant step beyond sharing a neutral file format (e.g., SDTS) that requires conversions by both the producer and consumer (SDTS is far too bulky and complex for internal use in practical systems).

The Open Geospatial Consortium (OGC) is a consortium of commercial, government and university organizations with the goal of promoting interoperability involving geospatial information and location (see http://www.opengeospatial.org/). While OGC has multiple efforts that support this goal, the effort of interest here focuses on standards development. OGC standards include conceptual models, data formats and interfaces that facilitate communication, interpretation and integration of data and services. Thus, OGC moves beyond FGDC by standardizing interfaces for communication between systems that exchange geospatial data and processing. OGC also supplements ISO high-level standardization efforts by defining more detailed implementation specifications that allow software developers to build applications in differing technologies on the basis of the specification that in fact interoperate when deployed. The expectation is that vendors will compete on the basis of their implementations of the interfaces, so that users and developers can build to the interfaces and use any vendor's implementation without changing their software. For comments about the OGC role in the geospatial standards community see http://unstats.un.org/unsd/geoinfo/8unrccaIP25.pdf

Scope

In approaching the issue of geospatial data standards and geospatial interoperability, the enormous number and size of many directly relevant standards must be considered. The FGDC, GOS, OGC, ANSI, ISO each have 10 to 100 standards in various states of development and acceptance. These standards are typically built on numerous other standards such as XML. In addition, each of these organizations has many supporting documents intended to explain and facilitate the use of the main standards. OGC standards have been selected here because they are detailed enough to allow developers to build working implementations. This applies to developers at LLNL and one aspect of the problem is to assess the effort required to implement various standards. However, it is often the case that custom developers do not have to write standard implementations but can acquire or buy them from commercial vendors or open software providers. Again, the software available in various forms that addresses OGC standards is a large and growing topic. This topic will be considered briefly by summarizing support for OGC by the largest commercial GIS vendor of systems used in the Federal government, i.e., ESRI.

Considering OGC standards is timely from a number of perspectives. Until recently it was unclear how much impact OGC would have on the geographic data community as the traditional approaches continued to be dominant. However, a number of OGC standards are beginning to be used in a variety of areas and particularly in the Federal government. The President's e-gov initiative (see FY-2003 E-Government Report) includes a GIS component that is focused on avoiding duplication of effort in this technical area. Conformance to standards has been identified as a way to make effective use of existing data collections and processing capabilities. For example, the Geospatial-One-Stop provides a portal to support the discovery and transfer of existing geographic data resources. The Federal government is mandating conformance to OGC and other standards in the implementation of such capabilities. For these reasons, ESRI is integrating OGC standards into all their main products lines. There are efforts in both DOE and DHS that are attempting to facilitate geospatial data interactions by identifying important standards and requiring conformance by supported programs.

APPROACH

Selection of standards

The full range of OGC standards are too much to consider in a project of limited scope (see http://www.opengeospatial.org/specs/?page=baseline for lists of OGC standards and related documents). Fortunately, the industry focus on OGC standards at this time involves a substantially smaller subset. From general observation of the industry, literature, presentations and comments from commercial vendors, and comments from government personnel, it is quite clear that two main OGC standards are getting significant attention and are in fact gaining traction in the commercial and government sectors. These are the Web Mapping Service (WMS) and the Web Feature Service (WFS).

These two standards are the central focus of this evaluation. However, these standards are not complete in and of themselves. They are built upon and relate to a number of other OGC standards as well as non-OGC standards. Consequently, considering a set of standards that would allow working implementations to be developed requires consideration of the Stylized Layer Descriptor (SLD), Web Map Context Documents (WMC), Catalog Services Specification (CAT), Coordinate Transformation Services (CT), Simple Feature Specification (SFS), and Geographic Markup Language (GML) OGC standards. GML is also related to OGC Sensor Model Language (SML) and Observations and Measurements (O&M) standards, which could have near-term applicability to LLNL programs. These standards are built on and refer to numerous non-OGC standards such as XML, XPath, XLink, XSL/XSLT, GIF, JPEG, PNG, SVG and TIFF, GeoTIFF. These non-OGC standards will only be mentioned in passing although actual implementations would need to consider which of these could be easily supported given a program's current capabilities and experience. Note that while WMS and WFS are Web services in the general sense of being services available on the Web with some use of XML, they are not Web Services in the specific sense of be services advertised and discovered using WSDL and UDDI and with communications based on SOAP/XML. See Figure 1 for a diagrammatic representation of how these various standards interrelate.

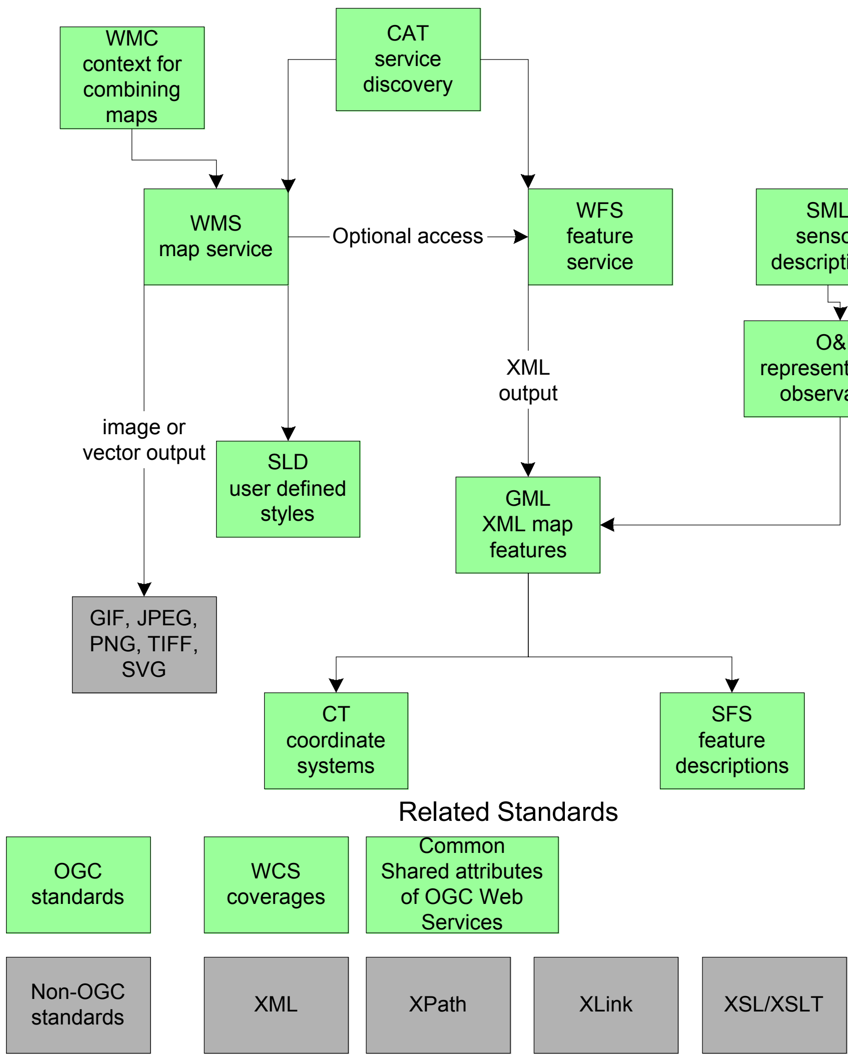

Figure1. Relationships between key OGC standards.

In summary, a central focus on WMS and WFS quickly expands to the ten closely related standards that are examined in this project.

Evaluation of standards
Each standard was read by one or more participants in the project, with a few of the most central standards being reviewed by most or all of the participants. The standards were discussed to clarify the relationships between the standards, how difficult it would be to implement portions or all of a standards. In addition, some evaluation of the availability of software tools that implement the standards was considered with particular attention to integration of OGC capabilities into the ESRI GIS. The applicability of these standards to projects or programs that the participants are or have been involved with was evaluated. The follow discussion summarizes these efforts.

RESULTS

Summary of standards
This summary will begin with the two central standards (WMS and WFS) then consider GML and SML. The remaining standards will be presented in alphabetical order.

WMS

Title (shorthand reference)	Web Map Service Implementation Specification (WMS)
OGC Reference	04-024
OGC Description	Provides three operations (GetCapabilities, GetMap, and GetFeatureInfo) in support of the creation and display of registered and superimposed map-like views of information that come simultaneously from multiple sources that are both remote and heterogeneous.
Description	The WMS service allows clients to receive descriptions of layers, coordinate reference systems (CRS), output formats and display styles supported by the service (GetCapabilities). The capabilities are described in an XML format. Clients can request available layers in supported CRS, display styles and output formats using CGI-style parameter specifications (GetMap). Conforming WMS implementation may optionally allow the client to request feature information for a specified location (GetFeatureInfo). The interaction is based on HTTP GET and POST requests. While vector representations of the resulting map are allowed, WMS implementations usually provide image data (e.g., GIF, JPEG, PNG) to the client, which can be displayed on the clients system in combination with other map data.
Related Standards	Stylized Layer Descriptors allow clients to control display styles Web Map Context Documents allow grouping of maps into composite products Catalogue Service allows WMS to be registered for discovery CRS are specified using the conventions of the Coordinate Transformation Service.
Comments	WMS appears to be gaining significant traction in the commercial and government sectors. OGC has fostered this by supported various test beds where a variety of client and server implementations can interact. This mechanism of distributing map images can be useful in many situations that require convenient access to base map information without needs for users to interact closely with the maps. High levels of interactivity are generally better supported by WFS, which returns the fully attributed vector geospatial features.

WFS

Title (shorthand reference)	Web Feature Service Implementation Specification (WFS)
OGC Reference	02-058
OGC Description	The OGC Web Map Service allows a client to overlay map images for display served from multiple Web Map Services on the Internet. In a similar fashion, the OGC Web Feature Service allows a client to retrieve and update geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services. The requirements for a Web Feature Service are: 1. The interfaces must be defined in XML. 2. GML must be used to express features within the interface. 3. At a minimum a WFS must be able to present features using GML. 4. The predicate or filter language will be defined in XML and be derived from CQL as defined in the OpenGIS Catalogue Interface Implementation Specification. 5. The datastore used to store geographic features should be opaque to client applications and their only view of the data should be through the WFS interface. 6. The use of a subset of XPath expressions for referencing properties.
Description	The WFS service allows clients to receive descriptions of layers, coordinate reference systems (CRS), output formats and display styles supported by the service (GetCapabilities). The capabilities are described in an XML format. Each supported feature type is also described in similar way. Clients can request available features in supported CRS, display styles and output formats using CGI-style parameter specifications (GetFeature). The output of a GetFeature request is normally GML. WFS with the above capabilities are considered basic. A conforming WFS implementation may optionally allow clients to edit features using a set of transaction-oriented commands. The interaction is based on HTTP GET and POST requests.
Related Standards	Geography Markup Language (GML) supports an XML-based description of geographic features. Catalogue Service allows WMS to be registered for discovery CRS are specified using the conventions of the Coordinate Transformation Service.
Comments	WFS appears to be gaining significant traction in the commercial and government sectors although not to the same degree as WMS. OGC has fostered this by supported various test beds where a variety of client and server implementations can interact. This mechanism of distributing geospatial features is important when clients may want to interact closely with or locally cache the geospatial features.

GML

Title (shorthand reference)	Geography Markup Language Encoding Specification (GML)
OGC Reference	03-105r1
OGC Description	The Geography Markup Language (GML) is an XML encoding for the transport and storage of geographic information, including both the geometry and properties of geographic features.
Description	GML supports a rich means of describing geographic features. It covers both 2- and 3-dimensional features. It also supports the description of CRS, observations, units, temporal coordinate systems and is coordinated with the O&M standard. The CRS are described by Well-Known Text (WKT) strings or by XML equivalents.
Related Standards	CRS are specified using the conventions of the Coordinate Transformation Service.
Comments	The current version, GML-3, which supports 3-dimensional features is complex enough that a simpler version of the standard focusing on 2-dimensional, i.e., geographic features, is under development. The standard provides an easy format for sharing data without having to install a full GIS system (although, obviously, some GIS expertise and programming capabilities are required). Because GML is self-documenting and lends itself to metadata inclusion, using XPath and Xlink, it is an excellent, simple approach to sharing data.

SML

Title (shorthand reference)	Sensor Modeling Language for In-situ and Remove Sensors (SML)
OGC Reference	04-019r2
OGC Description	The Sensor Model Language work proposes an XML schema for describing the geometric, dynamic, and observational characteristics of sensor types and instances.
Description	Sensor Model Language (SensorML) is a generalized model for describing sensors, devices for the measurement of physical quantities. The purpose of SensorML is to: • provide general sensor information in support of data discovery • support the processing and analysis of the sensor measurements • support the geolocation of observed values (measured data) • provide performance characteristics (e.g. accuracy, threshold, etc.) • archive fundamental properties and assumptions regarding sensor. SensorML is a part of the OGC's Sensor Web Enablement (SWE) activity, which establishes interfaces and protocols to enable applications to access sensors of all types over the Web. SensorML works with the Observations and Measurements (O&M) standard to encode sensor observations and measurements. SensorML is used to encode O&M metadata and sensor characteristics; O&M is used to encode data produced by the sensor.
Related Standards	Observations and Measurements (O&M) supports the expressions of measurement data. It is coordinated with and shares common definitions with GML, which can also express measurement data. Sensor Collection Service (SCS) allows a client to obtain observations from one or more sensors/platforms. Sensor Planning Service (SPS) allows a client to determine collection feasibility for a desired set of collection requests for one or more mobile sensor/platforms and to submit collection requests to such platforms. Web Notification Service (WNS) allows a client to conduct asynchronous dialogues with other services.
Comments	SensorML enables diverse projects to share sensor information with significantly less development effort. It also provides a long-term storage format for sensor characteristics that can be retrieved after a project has ended.

CAT2

Title (shorthand reference)	Catalogue Services (CAT2)
OGC Reference	04-017r1
OGC Description	The OGC Catalogue Services 2.0 specification (OGC 04-021) establishes a framework for implementing catalogue services that can meet the needs of stakeholders in a wide variety of application domains. This application profile is based on the CSW schemas for web-based catalogues and it complies with the requirements of clause 11 in OGC 04-021.
Description	CAT2 provides OGC Web service registration, description and discovery mechanisms.
Related Standards	
Comments	The long-term outlook for this standard is unclear given the focus of most of the Web community on UDDI and WSDL. OGC has exploratory efforts that are looking into mapping OGC capabilities into the SOAP/WSDL/UDDI mainstream that could supercede standards such as CAT2.

CT

Title (shorthand reference)	Coordinate Transformation Service Implementation Specification (CT)
OGC Reference	2001-01-12
OGC Description	Provides interfaces for general positioning, coordinate systems, and coordinate transformations.
Description	CT allows locations, coordinate references systems (CRS) and coordinate transformations to be described, implemented and combined. It extends the Spatial Reference System (SRS) portion of the Simple Feature Specification to support a wider range of transformations and the ability to combine transformation flexibly. Coordinate systems of any dimension can be described. In addition, it provides placeholders for other coordinate reference system authorities besides the European Petroleum Survey Group (EPSG). This group has been replaced by the International Association of Oil and Gas Producers (OGP) Surveying and Positioning Committee. The CRS are described by Well-Known Text (WKT) strings or by XML equivalents.
Related Standards	The EPSG conventions constitute the normal specifications for coordinate systems in this standard.
Comments	CT underpins many, if not most, of the OGC standards and so some support for CT will be necessary for most implementations of OGC standards.

O&M

Title (shorthand reference)	Observations and Measurements (O&M)
OGC Reference	03-022r3
OGC Description	This document describes a framework and encoding for measurements and observations.
Description	Observations and Measurements (O&M) is a generalized model for recording sensor observations and measurements. The purpose of O&M is to: • capture data about some phenomenon. • bind observation, spatial, and temporal data together. • provide a common data format to record any type of data. O&M is a part of the OGC's Sensor Web Enablement (SWE) activity, which establishes interfaces and protocols to enable applications to access sensors of all types over the Web. O&M works with the SensorML standard to encode sensor observations and measurements. SensorML is used to encode O&M metadata and sensor characteristics; O&M is used to encode data produced by the sensor. O&M is primarily a data format standard for recording sensor data output; it describes a high level data structure to categorize data and defines data types for storing individual data fields. O&M is similar to other data formats (such as HDF, Net CDF, AVI, PDF, etc) in that it provides a consistent, well documented model to describe and encode application specific data. It differs from other formats in that it uses a transparent encoding scheme (XML) and is structured to incorporate spatial and temporal data.
Related Standards	Sensor Collection Service (SCS) allows a client to obtain observations from one or more sensors/platforms. Sensor Planning Service (SPS) allows a client to determine collection feasibility for a desired set of collection requests for one or more mobile sensor/platforms and to submit collection requests to such platforms. Web Notification Service (WNS) allows a client to conduct asynchronous dialogues with other services.
Comments	Most data-gathering efforts could benefit from using O&M for data storage and transfer formats. Tabular data (including relational data) and complex data types can be represented in the O&M model. Complex spatial relationships, including 3D relationships, can be described using the Geographic Markup Language. Some sensors or projects that could benefit from O&M include: • Meteorological data • Radiation data for surveys or baseline measurements. • Earth-observation data such as meteorological and seismic sensors. • Biological data, such as air sampling or automated test

	results. • Processed output such as motion detectors, alarm conditions, or state information. • Location tracking from GPS-tagged assets. • Earth-modeling simulations including atmospheric, physics, fluid, land-use models.

SFS

Title (shorthand reference)	Simple Features Specification (SFS)
OGC Reference	99-049/99-050/99-054
OGC Description	The Simple Feature Specification application programming interfaces (APIs) provide for publishing, storage, access, and simple operations on Simple Features (point, line, polygon, multi-point, etc).
Description	SFS provides interfaces and structures that allow geographic features to be expressed in SQL, COM and CORBA.
Comments	This standard map be more important for operationally defining a set of useful geospatial constructs that the various implementations. None of the specific implementations are likely to serve as protocols for wide-area distribution of geographic capabilities because they require both the client and server to support the same protocol, which is too expensive a constraint to place on potential collaborators. Web Services can run on top of HTTP or HTTPS to which essentially all participants in the Internet are already committed as so this approach is increasingly superceding the other protocols considered in this standard.

SLD

Title (shorthand reference)	Stylized Layer Descriptor Implementation Specification (SLD)
OGC Reference	02-070
OGC Description	The SLD is an encoding for how the Web Map Server (WMS 1.0 & 1.1) specification can be extended to allow user-defined symbolization of feature data.
Description	WMS are implemented with a set of style descriptors that control how various features are symbolized. These sets can be selected by a client. SLD allows a client to generate additional layer descriptors that control the symbolization of the features, which can allow the layer to be used effectively in combination with other layers in the clients applications.
Comments	This can be quite important if combining multiple map layers with client-generated data. There is no guarantee that the supported list of layer descriptors will by usable at all with other data.

WMC

Title (shorthand reference)	Web Map Context Implementation Specification (WMC)
OGC Reference	05-005
OGC Description	This document is a companion specification to the OGC Web Map Service Interface Implementation Specification version 1.1.1 [4], hereinafter "WMS 1.1.1." WMS 1.1.1 specifies how individual map servers describe and provide their map content. The present Context specification states how a specific grouping of one or more maps from one or more map servers can be described in a portable, platform-independent format for storage in a repository or for transmission between clients. This description is known as a "Web Map Context Document," or simply a "Context." Presently, context documents are primarily designed for WMS bindings. However, extensibility is envisioned for binding to other services. A Context document includes information about the server(s) providing layer(s) in the overall map, the bounding box and map projection shared by all the maps, sufficient operational metadata for Client software to reproduce the map, and ancillary metadata used to annotate or describe the maps and their provenance for the benefit of human viewers. A Context document is structured using eXtensible Markup Language (XML).

Commercial Support for OGC Standards

One way to evaluate the acceptance and thus the practical value of geospatial data and processing standards is to examine the support they receive from commercial GIS vendors. This is particularly true for OGC standards given the strong commercial presence in the consortium itself. While a full evaluation of the commercial sector as a whole would be a significant project in itself, a far narrower, but useful, perspective can be gained by evaluating the support ESRI is providing. While a single vendor certainly limits the scope of any conclusions, the fact that ESRI provides 80-90% of the Federal government GIS implementations indicates that any conclusions are of practical value. Consequently, the following will review current and near-term OGC support in ESRI on the basis of information presented at the ESRI International Users Conference in San Diego in July.

ESRI support of OGC builds on GML. ESRI currently supports GML 2.1.2 but is working on moving to GML 3. Current GML support is summarized in Table 1.

Product	*Support*
ArcIMS 9.0	Data Delivery Extension supports GML 2.x
ArcGIS 9.0	Reads GML 2.x Data Interoperability Extension writes GML 2.x, GML 3.x
ArcIMS 9.1	WFS connector GML 2.x

Table 1. Current ESRI GML support

ESRI is also taking a lead role in evolving the GML standard. In particular, they are pushing the development of a less complex GML standard for 2-dimensional, geographic work. The Simple Features Geography Markup Language (SF-GML) that will have a simple fixed schema (no connectors) and will support simple geometry (point, line, polygons, features and collections) very similar to the SFS (which is an almost verbatim acceptance of the initial ESRI proposal). Topology will not be supported in SF-GML. ESRI expects to make support for SF-GML free of charge but will charge for full GML-3 support.

ESRI is also providing increased support for WMS and SLD. Table 2 summarizes ESRI's current and near-term support for WMS.

Standard	*Support*
WMS Server	ArcIMS, Portal Toolkit
WMS Client	ArcGIS, Portal Toolkit, ArcExplorer
SLD	will be in ArcIMS 9.2, Portal Toolkit

Table 2. Current and near-term ESRI WMS support

ESRI is planning support for WFS but considers the standard to be in flux and is not proceeding rapidly. They expect to provide ArcIMS support for the WFS Server interface and WFS Client support in ArcGIS/Data Interoperability Extension and Portal Toolkit products. ESRI expects to have support for WMC Server capabilities in ArcServer 9.2 and WMC Client capabilities in ArcGIS 9.2. ESRI is also working on the Web Coverage and Open Location Services but provided no specifics regarding deliveries.

Overall, ESRI is showing a significant commitment to the support of the key OGC standards considered here. ESRI has the stated goal of having relatively full support of these core standards by the release of ArcGIS 9.2. They also appear to be considering the incorporation of other OGC standards as they mature and gain support. While they are not considered in any detail here, other GIS vendors are implementing OGC standards (e.g., see http://www.mapinfo.com/ogc/)

CONCLUSIONS

Evaluation of OGC Standards for the GEn&SIS Project

The Nuclear Regulatory Commission (NRC) Geographical, Environmental, & Siting Information System (GEn&SIS) project is a web-based GIS that was developed to enable data reconnaissance in support of nuclear reactor site licensing and license renewal using publicly available data. Specifically, the graphics and supporting data are used to support decisions in the Environmental Impact Statements and are also used to justify those decisions in public hearings.

The original implementation used X-Windows with a web interface for specifying input parameters. As it became increasingly cumbersome and cost prohibitive to maintain a homegrown GIS for such a small project, the project was moved to an ArcIMS implementation when it was deemed that ArcIMS had matured enough to be stable. The decision to use ArcIMS in particular was driven by two factors:

1. the E&E GIS Center's partiality to ESRI products
2. the growing use of ESRI products throughout the government complex.

The scope of the project specifies the datasets and the functionality required of each but does not necessarily specify the implementation. However, the main goal of the project is to take the raw data and present it in a final format, with all of the intermediate steps transparent to the end user. These intermediate steps include substantial post processing and statistical calculations on the data. Although the client base (mostly National Lab scientists from varying environmental and socioeconomic backgrounds) includes a number of users very familiar with GIS, their sole interest is in the generated maps and underlying processed data.

Originally, the system was to be made available to the public. However, in the post-9/11 era, NRC does not want to be a "supplier" of the aggregated data even though the data are all publicly available.

Given the project's current state and its near-term plans, the implementation of a data distribution format such as GML would probably not provide any benefit as far as distribution of the data itself. However, if and when it is ever decided that these data sets are a valuable public commodity, the most effective way to make the data (as opposed to an image of the data displayed through ArcIMS) available would be to create a standards-based (GML) generator. Because of limitations in the WFS, specifically, the lack of a method for performing complex spatial queries against the feature sets, WFS in it's current form would not be applicable to the project. The WMS would lend itself well to this application, allowing end-users the freedom to chose their viewer. But because WMS is currently quite lean, we would not have the facility for distribution of the metadata, or any of the underlying, processed data. GML could be used for metadata distribution, and potentially for the processed data, but the latter would require extensive customization of the current system.

As of this writing, ESRI does provide (mostly at an extra cost) extensions and add-ons to conform to most OGC standards, but only 2 of 8 have passed compliance testing, and neither of these is the GML data export module. This would indicate that ESRI is heading in the right direction but is nowhere close to full implementation.

From a broad perspective, it is problematic for any GIS project to become so heavily dependant on a particular software package that its data cannot be generally available to the masses, even if those "masses" are the restricted user base within LLNL. However, implementing the OGC standard (in part or in whole) on the Gen&SIS project is currently cost-, time-, and scope-prohibitive. Unfortunately because there is no application of standards, the project continues to become more and more deeply rooted into ESRI technology. And while this isn't necessarily a bad thing for this project, until ESRI fully implements the OGC standard, there is not a good alternative path if the ultimate goal is data accessibility and universal-usability.

Evaluation of OGC Standards for the NARAC Program

The National Atmospheric Release Advisory Center (NARAC) provides tools and services that map the spread of hazardous material released into the atmosphere. NARAC is a national support and resource center for planning, preparedness, real-time emergency response, and detailed assessments of threats or incidents involving a wide variety of hazards, including nuclear, radiological, chemical, biological or natural emissions. NARAC products provide information on affected areas, potential casualties, health effects, and recommended protective actions. NARAC is a distributed system providing modeling tools for deployment to an end user's computer system as well as real-time access to advanced model predictions from the national center.

There are three key roles for geospatial data in NARAC:

1) Geospatial data of several types is an integral part of the model calculations used to estimate the transport and diffusion of hazardous material. Examples are elevation, land characteristics and 3-d building data.
2) Dispersion model results are analyzed to estimate health effects. Population data has a central role in this process.
3) Base maps are necessary for geographic orientation in NARAC map products.

In addition, NARAC dispersion patterns can be transferred to commercial GIS to be displayed and analyzed with a variety of other data. NARAC has national and global responsibilities and responds at a wide range of domain sizes, which necessitates a large requirement for multi-scale geospatial information.

The NARAC distributed system is implemented as three tiers:

1. The *User Tier* includes:
   - the *iClient*, a deployed application that is installed on a user's computer
   - the NARAC Web, a Web browser-based capability
   - a Web Service interface, for integration of NARAC with other systems

   Each of these capabilities allows clients to submit modeling requests to NARAC and to display and manage the resulting products.
2. The *Enterprise System* provides the support for all User tier access including forwarding advanced data and modeling requests to the Central System, as well as security and product sharing.
3. The *Central System* provides the platform for advanced model calculations along with global meteorological and geographical data archives and expert user interfaces that allow NARAC operational scientists to refine calculations in great detail to create quality assured products.

There are numerous ways in which NARAC could take advantage of OGC standards with varying degrees of short-term practicality. These will be evaluated in rough order of decreasing short-term viability.

- Generation of GML products – NARAC currently integrates with GIS by creating ESRI shape file representations of dispersion patterns along with limited metadata describing the product. While shape files are an ESRI specification, they have become an *ad hoc* standard and most GIS have some ability to ingest them. The shape file mechanism has a number of weaknesses and non-ESRI GIS would likely be better served by a GML representation of NARAC products. Note that ESRI supports GML and is moving away from shape files, so GML might play a role in interacting with ESRI as well as non-ESRI systems. While a full implementation of a GML processing capability is a substantial undertaking, producing a valid representation of a NARAC product would only require very limited portions of GML and related standards such as CTS, hence, a basic capability could be implemented cost-effectively. Since both GML and NARAC products are XML-based, some parts of the metadata associated with a NARAC products could be integrated into a GML representation although this would require additional effort.

- WMS/WFS client – Extending NARAC mapping and visualization capabilities to allow the selection and import of map layers from WMS available on the Internet appears to be a viable option to consider. The basic mechanism of requesting an image and displaying it in a NARAC-controlled window does not appear to raise significant difficulties. However, the identification of WMS with sets of data for NARAC base mapping needs would require some effort. A WFS capability would require more complete GML support than producing NARAC GML products, which might make the effort too expensive if appropriate cost-effective open or commercial GML implementations could not be found.
- NARAC WMS/WFS – Exposing NARAC products as a WMS is straightforward from some perspectives but awkward from others. NARAC already produces dispersion pattern images in supported formats as part of the NARAC Web and processing the request/response protocol does not raise difficulties. By limiting the advertised capabilities of a WMS (e.g., supporting only WGS84 geographic coordinates), the core WMS capability would not be terribly difficult to implement. However, creating a product discovery mechanism that would apply to NARAC products from some mix of WMS, WMC and CAT2 appears to be difficult in that these standards do not appear to address same discovery problems as required by a NARAC service. In addition, NARAC is not a public capability, it is only available to clients with proper credentials and so that absence of a secure access mechanism in any OGC standards creates a difficulty. Given a GML expression of a NARAC product, the mechanism for basic WFS would be a comparable effort to that for a WMS. Note that a transactional WFS is not applicable, i.e., it is not a client's role to edit NARAC products via NARAC services. In summary, a NARAC WMS or WFS could be created but would require a significant design effort that will likely require explicit sponsor support to pursue.
- Internal use of OGC services – Most OGC services do not map cleanly into the current geoprocessing that is done in NARAC with the exception of the CTS. Implementing a CTS is well beyond the scope of appropriate NARAC geoprocessing development, however, an appropriate commercial or open implementation of CTS could form a new basis for NARAC coordinate system management.

In summary, OGC standards would provide useful extension of the NARAC system in certain specific situations. In particular, delivering GML products and developing a WMS client capability appear to be valuable and inexpensive enough to give serious near-term consideration. Other applications of OGC services appear to involve substantial efforts at this time and will likely need to wait until specific sponsor-driven requirements arise or until the OGC standards and implementations mature sufficiently to make these tasks more straightforward.

Evaluation of OGC SensorML for the LLNL Programs
Eventually, many lab projects may be able to benefit from the use of SensorML and O&M for data interoperability. At present, however, few projects, if any, have an immediate need to implement SensorML, O&M, or the other SWE standards. Over the long term, all projects producing or archiving sensor data should consider implementing these models to facilitate data interoperability. Areas that could potentially benefit from SensorML and O&M include:

- NARAC - meterological and sampler data.
- Radiation detection - long-term or baseline measurements; configuration data.
- Geology - seismic data for natural and artificial events.
- Biology - time-based air samples, automated test results.
- Processed output - motion detection, “alarm” conditions (ARGUS)

Future projects should consider implementing SensorML for sharing and storing sensor metadata. SensorML would increase interoperability between projects and decrease the effort for projects to share sensor data. SensorML still can be used to describe only sensor metadata if its output cannot be expressed using the O&M specification.

SensorML is a flexible model for describing sensors; as such, it does not enforce or recommend structures for organization sensor metadata. A project may have difficulty consuming other data from similar projects due to differences in sensor metadata and data. For example, two projects can describe a digital thermometer in significantly different manners, e.g., using units of measurement, which can cause problems if they attempt to share data. SensorML would provide a standardized method of expressing these differences and allow consumers to understand how to consume this data.

Evaluation of OGC O&M for the LLNL Programs
Future projects should consider using O&M as a data format for storing and transferring data. For some projects, O&M could be used to replace existing data formats (CSV, proprietary binary formats) to facilitate long-term storage of the data. Other projects may benefit from using O&M as a data-interoperability format. The use of binary data or text-based formats often causes problems when used cross-platform or obfuscates the meaning of data.

O&M is currently in a proposed specification stage and may not be finalized for several months. O&M is currently unsupported by any commercial products and future support is unknown. The lack of a mature API for manipulating O&M software is also a major barrier to adoption. In summary, O&M and SWE are standards that bear watching but are not mature enough to drive current efforts at LLNL.

SUMMMARY

OGC standards are having increasing impact on the GIS community and it is important to be aware of developments in this area. On the hand, many of the standards and standard groupings, e.g., SWE, are immature and evolving rapidly. Consequently, system developers should generally take a measured approach by identifying specific applications where focused use of certain OGC standards and interfaces can provide cost-effective extension of existing capabilities. More general application of OGC standards should wait for the standards as well as the open and commercial implementations of these standards to mature. Thus, the OGC program bears watching both to get a sense of when various standards become viable and which fail to mature or are overtaken by new technologies and approaches. It is also important to note that, by their nature as *de jure* standards, OGC standards reflect common denominator capabilities with the result that performance may suffer. For some high performance applications, proprietary solutions may support optimizations that may be necessary. Consequently, even in areas successfully addressed by OGC standards, vendor-specific implementations may still have a role.

The overriding issues of geospatial data sharing and interoperability are being addressed on several fronts and important progress is being made. However, the promise of a true National Spatial Data Infrastructure with convenient access to geospatial information for all who require it is well short of fruition. Continued evolution of standards and implementation is required. As enabling technologies that support such an infrastructure mature, it is also important that institutional and political barriers to data sharing also mature so that the most effective use can be made of these data.

GLOSSARY

ANSI	American National Standards Institute
CAT	OGC Catalogue Service
CRS	Coordinate Reference System
CT	OGC Coordinate Transformation Service
ESRI	Environment Systems Research Institute
FGDC	Federal Geographic Data Committee
GIS	Geographic Information Systems
GML	Geography Markup Language
GOS	Geospatial-One-Stop
HTTP	Hyper Text Transfer Protocol
HTTPS	Secure Hyper Text Transfer Protocol
ISO	International Organization for Standards
NSDI	National Spatial Data Infrastructure
O&M	OGC Observations & Measurements
OGC	Open Geospatial Consortium
PNG	Portable Network Graphics
SCS	OGC Sensor Collection Service
SDTS	FGDC Spatial Data Transfer Standard
SFS	OGC Simple Features Specification
SLD	OGC Stylized Layer Descriptor
SML	OGC Sensor Modeling Language
SOAP	Simple Object Access Protocol
SPS	OGC Sensor Planning Service
SVG	Scalable Vector Graphics
SWE	OGC Sensor Web Enablement activity
WCS	OGC Web Coverage Service
UDDI	Universal Description, Discovery and Integration
USGS	U.S. Geological Survey
WCS	OGC Web Coverage Service
WFS	OGC Web Feature Service
WMC	OGC Web Map Context Documents
WMS	OGC Web Map Service
WNS	OGC Web Notification Service
WSDL	Web Service Definition Language
XML	Extensible Markup Language