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OGC Reference Model

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Introduction

The OGC Reference Model (ORM) describes the OGC Standards Baseline focusing on relationships between the baseline documents. The OGC Standards Baseline (SB) consists of the approved OpenGIS® Abstract and Implementation Standards (Interface, Encoding, Profile, Application Schema) and Best Practice documents.

What is the purpose of the ORM?

- To provide an overview of OGC Standards Baseline;
- To provide insight into the current state of the work of the OGC;
- To serve as a basis for coordination and understanding of the documents in the OGC SB;
- To provide a useful resource for defining architectures for specific applications.

Why Read This Document?

- To better understand the OGC Standards Baseline;
- To better understand the ongoing work of the OGC;
- To gain an understanding necessary to make contributions to the OGC process;
- To aid in implementing one or more of the OpenGIS Standards.

How to read this document

- Interested in an overview of **the consortium**? – See Section 1.
- Interested in the geospatial **information standards**? – See Section 2.
- Interested in geospatial **service standards? –** See Section 3.
- Interested in OGC-based **development patterns**? – See Section 4.
- Interested in **implementations** of OGC-based systems? – See Section 5.

The ORM contains numerous links to OGC resources. For more detail on any topic be sure to select the link and access the detailed information. For example, definitions of terms used in the ORM are available in the on-line OGC Glossary

The OGC Reference Model provides just an overview of the results of extensive development by hundreds of OGC Member Organizations and tens of thousands of individuals who have contributed to the development of the OGC Standards Baseline.

The team listed here developed the ORM, Version 0.9:

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OGC Reference Model

1 The Enterprise View of OGC

1.1 Interoperability Is Essential

Standards are the basis for the success of the Internet and the World Wide Web. The Net has reshaped how we view and share information. Standards are a fundamental enabling technology of the Net. These standards allow thousands for applications, vendor solutions, and technologies to be **interoperab**le. The Net, via standards, is vendor and content-neutral. A standard describes a set of rules that have been agreed to in some industry consensus forum, such as the Internet Engineering Task Force (IETF), the International Organization for Standardization (ISO), or the Open Geospatial Consortium (OGC).

As described in The Importance of Going Open – an OGC White Paper – non-interoperability impedes the sharing of data and the sharing of computing resources, causing organizations to spend much more than necessary on geospatial information technology development.

The Havoc of Non-Interoperability – an OGC White Paper – identifies risks associated with non-interoperability. Today, lives and property depend on digital information flowing smoothly from one information system to another. Public safety, disaster management, and military applications increasingly depend on communication between dissimilar systems. No single organization produces all the data (so it's inconsistent) and no single vendor provides all the systems (so the systems use different system architectures, which are usually based on different proprietary interfaces).

Organizations like the OGC, the World Wide Web Consortium (W3C), the Internet Engineering Task Force (IETF), and others are open organizations in the sense that any individual or organization can participate, the topics of debate are largely public, decisions are democratic (usually by consensus), and specifications are free and readily available. An “open” process is necessary to arrive at an “open” standard. The openness that OGC promotes is part of this general progress.

The next section describes how one OGC standard evolved and now fulfills a major interoperability requirement in the OGC community.

1.2 An Example: Web Map Service (WMS)

OGC’s Web Map Service standard is an example of interoperability achieved through open standards. The Web Map Service standard began as discussion in the OGC Specification Program that became the first OGC Interoperability Program initiative, the Web Mapping Testbed, in 1998. The WMS candidate interface standard that was

developed in the WMS Testbed was adopted as an OpenGIS Implementation Specification in 2000 (WMS version 1.0). Since then, WMS has progressed in maturity with implementations numbering in the thousands. WMS is now also published as ISO 19128.

WMS provides a simple example of how topics are discussed in this reference model:

- Section 2.3 Spatial Referencing describes coordinate reference systems (CRSs) used in WMS. CRSs are vital to geospatial interoperability;
- Section 3.2 OGC Web Services describes several OGC geospatial web services, including WMS, as a coordinated service architecture implemented with common elements across services;
- Section 4.4 Spatial Data Infrastructures (SDIs) describes the use of WMS and other OGC Web Services in a reusable pattern for deployment for worldwide SDIs.
- Section 5.1 OGC Compliance Test Program describes the automated testing resources available for all approved OGC services; these resources allow implementers to determine compliance with the OGC specifications.

WMS has dramatically increased the use of on-line mapping. One issue of OGC User describes the use of the WMS standard in helping with disaster response to hurricane Katrina, soils data distribution in Europe, a statewide data center, and access via mobile phones. In another OGC User article, the number of WMS servers on the Internet is seen to rise each week as more organizations realize the power of using open standards. At the same time, the number of WMS clients – designed for use in a browser, or on the desktop or on a mobile device – is growing.

The next section describes how the use of OGC standards can provide value to businesses and enterprises.

1.3 Business Processes Benefit from Geospatial Standards

Integrating Geospatial Standards and Standards Strategies into Business Process – an OGC White Paper – identified that many business processes could benefit from the integration geospatial information and services currently do not. This is because geospatial information has been locked in non-standard systems using different information models and storage structures – often referred to as “stove pipes.” A commitment to interoperability and to implementing open standards unlocks this foundational information type, leveraging current information technology (IT) investments in unforeseen ways. However, with geospatial content and processing as with all types of data and processing, while technical interoperability is necessary, it is not sufficient. The use of standards and interoperable architectures is secondary to understanding business processes and how geospatial data and services – and by extension standards – can best be used. Typically what is required is a change in the corporate culture and this can be difficult: A tactical-only solution is a waste of money – you need to adopt an Enterprise solution that addresses business context and people.

For over a decade, the OGC has been promoting the benefits of open geoprocessing specifications. In the last several years, we have seen an increase in the number of policy statements regarding the use of OGC standards. The federal and national agencies involved are endorsing OGC standards.

The foresightedness of the OGC members is highlighted by studies that document and measure the enterprise benefits of developing and implementing standards. Examples of such studies include: "The Economic Benefits of Standardization," published by the DIN German Institute for Standardization, e. V. Beuth Verlag, in April, 2000; "The Value of Standards: A Delphi Study" published in June, 2003; and, most recently, the April, 2005 "Geospatial Interoperability Return on Investment Study," prepared by Booz Allen Hamilton, Inc. for the National Aeronautics and Space Administration (NASA) Geospatial Interoperability Office. These reports document in ROI terms the benefits and value that accrue for users, technology providers, and society when open standards are used. The enterprise "return on investment" in open interfaces is unquestionable today.

The following section provides a high level overview of the OGC and its programs.

1.4 The OGC Members and Programs

The Open Geospatial Consortium, Inc (OGC) is an international industry consortium of companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. The OGC is organized into three operational business areas.

- In the OGC Specification Program, the OGC Technical Committee and OGC Planning Committee work in a formal consensus process to create and revise member-adopted OpenGIS Standards.

- The OGC Interoperability Program is a series of hands-on engineering initiatives to accelerate the development and acceptance of OGC Standards.

- The OGC Outreach and Adoption Program offers resources to help technology developers and users take advantage of OGC's open standards. Publications, workshops, seminars and conferences help technology developers, integrators and procurement managers introduce OGC plug-and-play capabilities into their architectures.

The OGC Policies and Procedures guide the work of the OGC programs.

1.5 The OGC Standards and Specifications

The OGC technical documents have been developed by the membership to address specific interoperability challenges. The OGC documents are available at no cost to everyone.

The current OGC Documents are listed on the OGC Public Page.

Table 1 - OGC Document Types

OGC Document Type	Description
OpenGIS Implementation Standard	A document containing an OGC consensus, technology dependent standard for application programming interfaces and related standards based on the Abstract Specification or domain-specific extensions to the Abstract Specification. There are five subtypes: Interface, Encoding, Profile, Application Profile, and Application Schema.
Abstract Specification	A document (or set of documents) containing an OGC consensus, technology-independent standard for application programming interfaces and related standards based on object-oriented or other IT accepted concepts. It describes and/or models an application environment for interoperable geoprocessing and geospatial data and services products.
Best Practices	A document containing discussion related to the use and/or implementation of an adopted OGC document. Best Practices Documents are an official position of the OGC and thus represent an endorsement of the content of the paper.
Discussion Papers	A document containing discussion of some technology or standard area for release to the public. Discussion Papers are not the official position of the OGC and contain a statement to that effect.
White Papers	A publication released by the OGC to the Public that states a position on a social, political, technical or other subject, often including a high-level explanation of an architecture or framework of a solution.

OGC develops information models, usually in the form of XML Schema documents. The general process for disseminating a model is to publish a specification (or standard) document, and publish the XML schema to a schema repository. Based upon the status of the specification or documentation, the schemas will be posted to one of several OGC Schema repositories.

2 Geospatial Information

2.1 Geospatial Information Is Fundamental or "Everything is somewhere"

Geospatial information is a ubiquitous element of almost all data. Whether represented as a map or an image, encoded as an address, zip code, or phone number, described in a text passage as a landmark or event, or any of the many other ways of representing Earth features and their properties; geography is pervasive.

Geospatial **location** and **time** are integral to all aspects of the work in the OGC and OGC standards. Geography is a foundational property for modeling the world in a coherent, intuitive way. Location and time can be exploited as a unifying theme to better understand the context of most real and abstract phenomena.

Section 2 of the ORM summarizes OGC standards that describe and communicate geospatial content. This model is defined in the OGC Abstract Specification and OGC Implementation Standards for Encoding. The work and the standards developed by the OGC are content neutral. The OGC Information Model provides a basis for communities to define the content specific using OGC standards that enable interoperability.

2.2 Information Specifications Architecture

The OGC Standards Development Process creates Abstract and Implementation specifications. The purpose of the Abstract Specification is to create and document a conceptual model to support the creation of Implementation Specifications. Implementation Specifications are unambiguous technology platform specifications for implementation of industry-standard, software application programming interfaces. Geospatial domain semantics defined in the Abstract Specifications are to be consistent across multiple technology platforms as defined in Implementation Specifications.

The Information Viewpoint section of the ORM describes both Abstract and Implementation specifications for geospatial information. For example, the key concepts used by Geography Markup Language (GML) to model the world are drawn from the OpenGIS Abstract Specification and the ISO 19100 series of International Standards.

OGC Information Specifications are used in conjunction with other information technology standards. The OGC Abstract Specifications are used to bring geospatial semantics to more general IT specifications, for example using the OGC Coverage specification with grid encoding formats. Elements of the OGC GML Implementation Specification are embedded in other specifications.

2.3 Spatial Referencing

Location is contextually simple and intuitive to most people. For example, people can relate to where they are on a map, follow directions to a place, readily grasping the spatial context of their local environment, and so forth. For computers to exchange geospatial data, clear definition of the location and the spatial referencing system is required.

Locations can be described by two types of spatial referencing systems:

1. Civic locations using geographic terms or identifiers;
2. Numeric values of coordinates of a coordinate reference system.

Civic locations may be unique identifiers or place names. Spatial referencing with identifiers occurs when the **identifier** uniquely indicates a location, such as a postal code. Place names may be ambiguous, such as "Springfield", requiring additional information so that this place name can be resolved into a specific location identified by coordinates. Gazetteers and geocoding are geospatial operations or processes used to convert a place name into a geographic coordinate. The OGC Gazetteer Service Best Practice utilizes a gazetteer data model defined in ISO 19112: "Spatial referencing by geographic identifiers." Turn to Section 3.2 for more about the OGC Gazetteer Service.

Coordinates are a sequence of *N* numbers designating the position of a point in *N*-dimensional space. Coordinates are always expressed using some coordinate reference system (CRS). A **coordinate reference system** is a coordinate system that has a reference to the Earth. A coordinate reference system consists of a coordinate system and a datum. Coordinate reference systems include these types: geocentric, geographic (including an ellipsoid), projected, engineering, image, vertical, temporal. The **datum** defines the origin, orientation and scale of the coordinate reference system and ties it to the Earth, ensuring that the abstract mathematical concept "coordinate system" can be applied to the practical problem of describing positions of features on or near the Earth's surface by means of coordinates.

Coordinate Reference Systems are defined in the OGC Abstract Specification: Topic 2 - Spatial Referencing by Coordinates. This document also describes coordinate transformations and coordinate conversions between two different coordinate reference systems. With such information, geographic data referred to different coordinate reference systems can be merged together for integrated manipulation. A **map projection** is a coordinate conversion from a geodetic coordinate system to a planar surface, converting geodetic latitude and longitude to plane (map) coordinates. The result is a two-dimensional coordinate system called a projected coordinate reference system.

The OGC membership has defined several methods for encoding Coordinate Reference Systems:

- The OpenGIS® Implementation Specification for Geographic Information - Simple feature access - Part 1: Common architecture, also published as ISO 19125-1, defines "Well-known Text Representation of Spatial Reference Systems." The specification provides a non-exhaustive list of Geodetic Codes and Parameters for defining the objects in the Well-Known Text Representation.
- The OGC Best Practices Paper for Definition identifier URNs in OGC namespace specifies Universal Resource Names (URNs) in the OGC URN namespace to be used for identifying definitions, including definitions of Coordinate Reference Systems (CRSs) and related objects, as specified in OGC Abstract Specification Topic 2: Spatial referencing by coordinates. This document specifies the formats

used by these URNs, including formats that can reference definitions recorded in the EPSG database and by other authorities.

There are a variety of practices, specifications, and standards for how spatial geometry coordinates (axes) are ordered. Geodesy, computational geometry, graphics processing, and computer-aided design – all have different rules for specifying or encoding axis order. The OGC is developing an "Axis Order Manifesto" defining strategies for coping with the axis order.

2.4 Maps and KML

A **map** is a portrayal of geographic information. Figure 1 shows how maps differ from other types of geospatial information. A map may be a digital image file suitable for display on a computer screen; a map is not the data itself. Examples of map encodings include jpg, gif and other file types.

OGC KML is an XML grammar used to encode and transport representations of geographic data for display in an earth browser. Put simply: KML encodes what to show in an earth browser, and how to show it. Geographic visualization includes not only the presentation of graphical data on the globe, but also the control of the user's navigation in the sense of where to go and where to look.

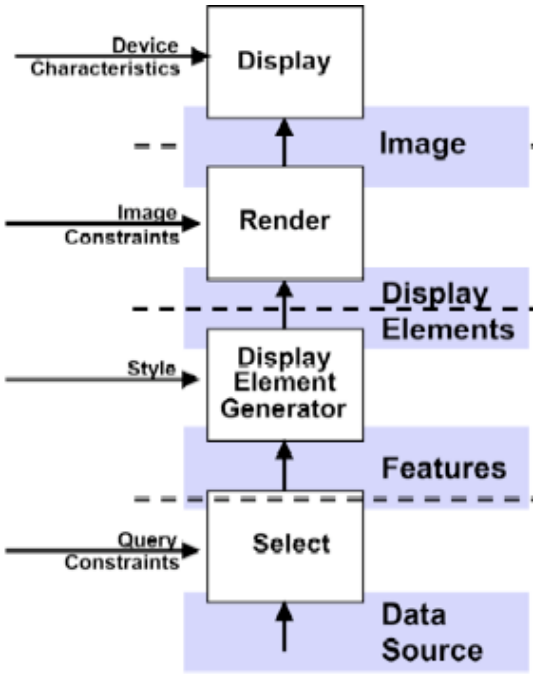

Figure 1 - Maps, Display, Features and Data

2.5 Geographic Features

A **feature** is an abstraction of a real world phenomenon. A **geographic feature** is a feature associated with a location relative to the Earth. A digital representation of the real world can be thought of as a set of features.

The OGC approach to feature modeling follows the principles specified in ISO 19109:2005, "Geographic information - Rules for application schema." As shown in Figure 2, **Conceptual schemas** define abstract feature types and provide the process for domain experts to develop **application schemas** that are used to encode content describing feature instances. The developer of an application schema may use feature definitions from feature catalogues that already exist.

The process for defining an application schema is described in Section 2.7.3.

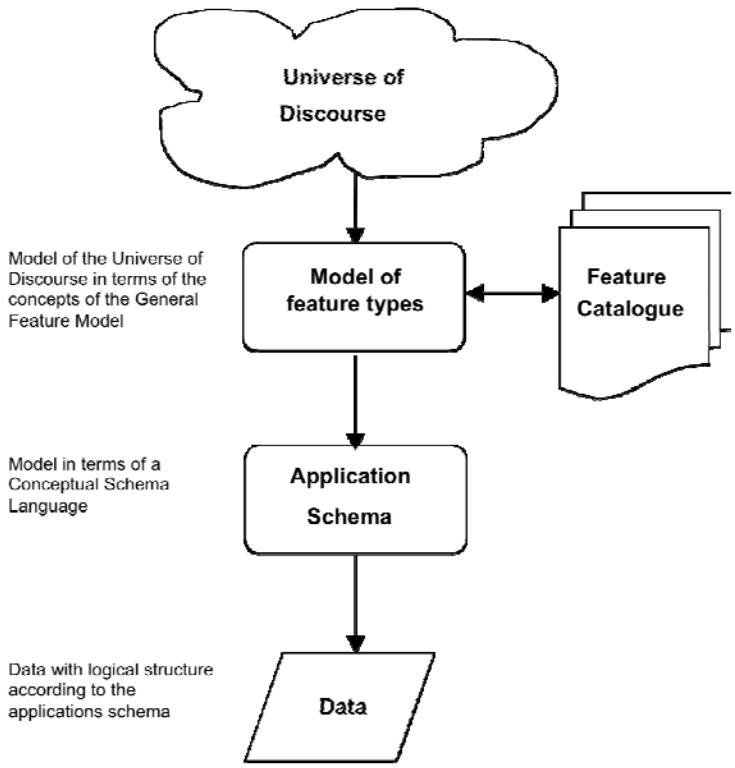

Figure 2 - Modeling Geographic Information

Any feature may have a number of **properties.** These properties may be operations, attributes or associations. Any feature may also have a number of **attributes**: Spatial, Temporal, Quality, Location, Metadata, Thematic. A feature is not defined in terms of a single geometry, but rather as a conceptually meaningful object within a particular information or application community, one or more of the feature's properties may be geometric. For example, a utility pole is an object that can be defined using multiple geometries and is comprised of other objects.

A feature collection is a feature that represents a collection of features that have common metadata and formal relationships. Collections possess all the characteristics of a feature.

Geographic phenomena fall into two broad categories, discrete and continuous. Discrete phenomena are recognizable objects that have relatively well-defined boundaries or spatial extent. Examples include buildings, streams, and measurement stations. Continuous phenomena vary over space and have no specific extent. Examples include temperature, soil composition, and elevation. A value or description of a continuous phenomenon is only meaningful at a particular position in space (and possibly time). Temperature, for example, takes on specific values only at defined locations, whether measured or interpolated from other locations. These concepts are not mutually exclusive. In fact, many components of the landscape may be viewed alternatively as discrete or continuous. Historically, geographic information has been treated in terms of two fundamental types called **vector** data and **raster** data.

"Vector data" typically deals with discrete phenomena, each of which is conceived of as a feature. "Raster data," on the other hand, deals with real world phenomena that vary continuously over space. OGC uses the term "**coverage**" for this second type of data. A coverage defines a data model that associates spatio-temporal positions to data values. The data attributes of a coverage vary across its spatio-temporal extent.

2.6 Geometry and Topology

Geometry provides the means for quantitative description of the spatial characteristics of features, including dimension, position, size, shape, and orientation. Topology is useful for characterizing relationships between geometric objects without concern for the size or exact shape of the objects.

The conceptual model for geometry and topology is contained in OGC Abstract Specification Topic 1 - Feature Geometry that is the same as ISO 19107:2003 Geographic information -- Spatial schema. OGC has implemented the conceptual model of ISO 19107 in the OGC Geography Markup Language as described in Section 2.7.

A **geometric object** is a combination of a coordinate geometry and a coordinate reference system. In general a geometric object is a set of geometric points, represented by **direct positions**. A direct position holds the coordinates for a position within some coordinate reference system. Typical geometric objects are points, lines, and polygons.

Geometric calculations such as containment (point-in-polygon), adjacency, boundary, and network tracking can be computationally intensive. A productive use of topology is to accelerate computational geometry. Another purpose is, within the geographic information domain, to relate feature instances independently of their geometry.

Spatial query operators are a mechanism for characterizing topological relations between different features. The operators are meant mainly for query evaluation and are defined in such a manner as to allow a variety of implementations to be assured of equivalent results against datasets with equivalent information content. The Simple Features Access

and the OGC Filter Encoding Implementation standards provide typical names for spatial query operators (See Figure 3). OGC Abstract Specification Topic 1 – Geometry provides a more exhaustive standardization of spatial operators.

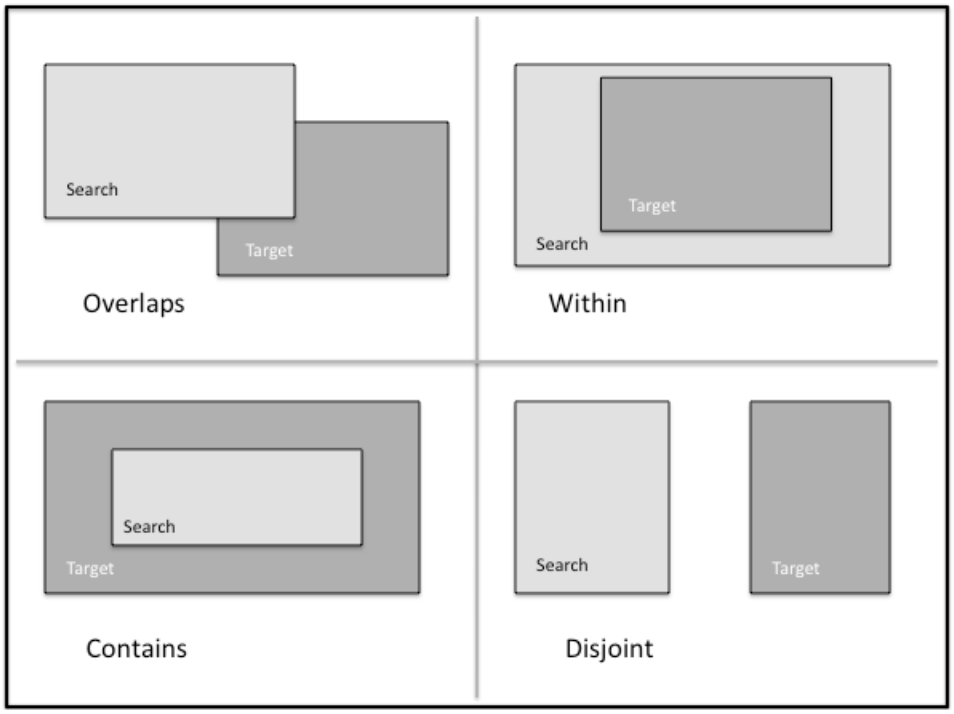

Figure 3 – Spatial query operator examples

2.7 Geography Markup Language

2.7.1 The GML Standard

The OpenGIS® Geography Markup Language (GML) Encoding Implementation Standard is an XML grammar to express geographical features. GML serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet. The GML information model is based on the ISO 19100 series of International Standards and the OGC Abstract Specification. In addition, GML provides XML encodings for additional concepts not yet modeled in the ISO 19100 series of International Standards or the OpenGIS Abstract Specification, for example, dynamic features, simple observations or value objects.

GML defines the XML Schema syntax, mechanisms and conventions that:

- Provide an open, vendor-neutral framework for the description of geospatial application schemas for the transport and storage of geographic information in XML;
- Allow profiles that support proper subsets of GML framework descriptive capabilities;

- Support the description of geospatial application schemas for specialized domains and information communities;
- Enable the creation and maintenance of linked geographic application schemas and datasets;
- Support the storage and transport of geospatial application schemas and datasets;
- Increase the ability of organizations to share geographic application schemas and the information they describe.

Implementers may decide to store geographic application schemas and information in GML, or they may decide to convert from some other storage format on demand and use GML only for schema and data transport.

The requirements of an application schema determine the XML Schema components from the GML schema to be included in a GML profile. GML defines a variety of conformance classes that apply depending upon the content of a specific profile. Examples of GML Conformance Classes for GML Profiles are shown in Table 2. See the GML standard for the full list.

Table 2 – Examples of Conformance Classes for GML Profiles

Geometric primitives: 0, 1, 2 or 3 dimensions	Topologic complexes: 0, 1, 2 or 3 dimensions
Coordinate reference systems	Coordinate operations
Temporal geometry — 0 or 1 dimensions	Temporal topology
Temporal reference systems	Dynamic features
Dictionaries	Units dictionaries
Observations	Abstract coverage
Discrete point coverage	Discrete curve coverage
Discrete surface coverage	Discrete solid coverage
Grid coverage	Continuous coverage

2.7.2 Profiles and Best Practices for GML

The OGC has defined several profiles of GML. In the OGC, a GML profile is a restricted subset of the full GML standard.

GML Common CRSs profile	Profile
GML CRS support profile	Profile
GML Grid CRSs profile	Profile
GML Simple dictionary profile	Profile
GML Simple features profile	Profile
GML Point profile	Discussion Paper

2.7.3 GML Application Schemas

Designers of GML application schemas may extend or restrict the types defined in the GML schema to define appropriate types for an application domain. GML application schemas use applicable GML schema components, either directly or by specialization, and are valid in accordance with the rules for XML Schema. The OGC membership has approved a number of GML Application Schema as OGC Best Practices:

GML Application Schema for EO Products
GML PIDF-LO Geometry Shape Application Schema for use in the IETF
GML Encoding of Discrete Coverages (interleaved pattern)
CityGML

OGC maintains a list of all known GML Application Schemas. These schemas are not necessarily approved or endorsed by the OGC.

2.8 Sensor Web Enablement Information Standards

2.8.1 OGC SWE Standards

With sensors of all types becoming part of the global information infrastructure, the OGC has approved four Standards and several Best Practices designed to enable sensors to better interoperate with the Web and other information technology assets. The OGC Sensor Web Enablement (SWE) is a set of interfaces and protocols that enable a "Sensor Web" through which applications and services will be able to access sensors of all types over the Web. Foundational components for Sensor Web Enablement have defined, prototyped and tested:

- Observations & Measurements (O&M)
- Sensor Model Language (SensorML)
- Transducer Markup Language (TML)
- Sensor Observation Service (SOS)
- Sensor Planning Service (SPS)
- Sensor Alert Service (SAS)
- Web Notification Service (WNS)

The first three standards are described immediately following. The service standards are described in Section 3.3.

2.8.2 Observations and Measurements

The OpenGIS® Observations & Measurements (O&M) standard defines measurements and the relationships between them, mainly to improve the ability of software systems to discover and use data produced by measuring systems.

An observation is an act associated with a discrete time instant or period through which a number, term or other symbol is assigned to a phenomenon. The phenomenon is a *property*

of an identifiable object, which is the *feature of interest* of the observation. The observation uses a *procedure*, which is often an instrument or sensor but may be a process chain, human observer, an algorithm, a computation or simulator. The key idea is that the observation *result* is an estimate of the value of some property of the feature of interest, and the other observation properties provide context or metadata to support evaluation, interpretation and use of the result. Observations are modeled as Features within the context of the General Feature Model [ISO 19101, ISO 19109].

Observations and Measurements – Part 2 describes a conceptual model and encoding for sampling features. These feature-types are typically associated with making observations producing estimates of property values that are in some way representative of a domain feature. Sampling features embody a sampling strategy that is suitable for the observation procedure and the observed property. Hence, sampling features are artifacts of the observation process rather than the inherent domain semantics.

2.8.3 SensorML

Sensor Model Language: An Implementation Specification specifies models and XML encoding for the core SensorML, as well as the definition of several SWE Common data components utilized throughout the SWE framework. SensorML provides a framework within which the geometric, dynamic, and observational characteristics of sensors and sensor systems can be defined. Sensor types exist in great variety, from simple visual thermometers to complex electron microscopes and Earth-observing satellites. These can all be supported through the definition of atomic process models and process chains. Within SensorML, all processes and components are encoded as application schema of the Feature model in the Geographic Markup Language (GML) Version 3.1.1. The purposes of SensorML are to:

- Provide descriptions of sensors and sensor systems for inventory management
- Provide sensor and process information in support of resource and observation discovery
- Support the processing and analysis of the sensor observations
- Support the geolocation of observed values (measured data)
- Provide performance characteristics (e.g., accuracy, threshold, etc.)
- Provide an explicit description of the process by which an observation was obtained (i.e., its lineage)
- Provide an executable process chain for deriving new data products on demand (i.e., derivable observation)
- Archive fundamental properties and assumptions regarding sensor systems.

SensorML can, but generally does not, provide a detailed description of the hardware design of a sensor. Rather it is a general schema for describing **functional** models of the sensor.

SensorML enables robust definitions of **sensor models** for providing geolocation of observations from remote sensors. A rigorous sensor model is defined here as one that

describes the geometry and physical dynamics of the instrument and provides the ability to utilize this information along with position and orientation of the platform in order to derive geolocation of the sensor data. Mathematical sensor models are typically derived using a rigorous model, perhaps augmented by human interaction. These general mathematical models typically hide the physical characteristics of the sensor and allow for geolocation of sensor data through the use of polynomial functions. Different mathematical models can be designed to define a sample location within a variety of coordinate systems, including the local sensor frame, the local frame for the associated platform, or a geographic coordinate reference frame. Within SensorML, one may choose to model a sensor platform as a system, with its own Coordinate Reference System, to which on-board sensor positions can be referenced. One may also choose to provide relative positions between various sensors while ignoring the platform reference frame, by defining any sensor position relative to an onboard GPS sensor and an orientation (gimbal) sensor. Either way, for the case of rigorous sensor models, we allow one to separate the description of the sensor from that of its platform. Common platforms include: ground stations, automobiles, aircraft, Earth-orbiting satellites, ocean buoys, ships, and people. A deployed sensor is mounted on a static or dynamic platform (or an assembly of nested platforms).

2.8.4 Transducer Markup Language (TML)

Transducer Markup Language (TML) works within transducer exchange messages from multiple application domains (defense, weather, exploration, environmental, medical, industrial, security, etc.). To provide a complete picture within these messages, the TML sensor data description will be complemented with other domain-specific information. TML defines:

- A set of models describing the response characteristics of a transducer
- An efficient method for transporting sensor data and preparing it for fusion through spatial and temporal associations

TML response models are formalized XML descriptions of known hardware behaviors. The models can be used to reverse distorting effects and return artifact values to the phenomena realm. TML provides models for a transducer's latency and integration times, noise figure, spatial and temporal geometries, frequency response, steady-state response and impulse response.

Traditional XML wraps each data element in a semantically meaningful tag. The rich semantic capability of XML is in general better suited to data exchange rather than live delivery where variable bandwidth is a factor. TML addresses the live scenario by using a terse XML envelope designed for efficient transport of live sensor data in groupings known as TML clusters. It also provides a mechanism for temporal correlation to other transducer data.

2.9 GeoDRM and GeoXACML

The OGC Geospatial Digital Rights Management Reference Model (GeoDRM RM) defines a conceptual model for digital rights management of geospatial resources. The GeoDRM RM provides a metadata model for the expression of rights that associate users

to the acts that they can perform against a particular geospatial resource, and associated information used in the enforcement and granting of those rights, such as owner metadata, available rights and issuer of those rights. The GeoDRM RM also defines requirements that are placed on rights management systems for the enforcement of those rights. Finally the GeoDRM RM defines how this is to work conceptually in the larger DRM context to assure the ubiquity of geospatial resources in the general services market.

OGC GeoXACML is a policy language that defines a geo-specific extension to the OASIS standard eXtensible Access Control Markup Language (XACML). GeoXACML defines an extension to XACML for spatial data types and spatial authorization decision functions. Those data types and functions can be used to define additional spatial constraints for XACML-based policies.

GeoXACML defines a rule-based Policy Language suitable to express access rights. By using the GeoXACML Policy Language, an interoperable access control system for geospatial applications, such as Spatial Data Infrastructures, can be implemented. It is important to highlight that GeoXACML is not designed to be a Rights Expression Language.

2.10 Metadata

Metadata facilitates discovery, retrieval and reuse of network-accessible resources. The OGC Catalogue Services specification establishes a general framework for access to metadata. The OGC Catalogue specification defines both an information model and service model[1]. OGC has defined several profiles of the Catalogue specification to meet the needs of stakeholders in a wide variety of application domains.

ISO 19115:2003, Geographic information – Metadata defines the schema for the identification, extent, quality, spatial and temporal schema, spatial reference, and distribution of digital geographic data. These schemas are useful for the cataloguing of datasets, clearinghouse activities, and the full description of datasets; geographic datasets, dataset series, and individual geographic features and feature properties.

The OGC Abstract Specification Topic 12 - The OpenGIS Service Architecture, also published as ISO 19119:2005, defines a service metadata schema for use in a catalogue service as is done for dataset metadata.

The OGC ISO Metadata Application Profile of the OGC Catalogue Specification defines an application profile of the CSW for ISO 19115/ISO 19119 metadata with support for XML encoding per ISO/TS19139. This application profile specifies the interfaces, bindings, and encodings required to publish and access catalogues of metadata for geospatial data, services, and applications using the ISO 19115 and ISO 19119 standards.

[1] See Section 4.1 for a description of the Catalog service bindings, for example, the Catalog Service for the Web (CSW).

The OGC CSW-ebRIM profile of the OGC Catalogue Specification defines means to customize an OGC catalogue service using the OASIS ebXML registry information model (ebRIM) (see Figure 4). Using the profile, a catalogue service can be adapted to meet the needs of a community within the geospatial domain. For example, a 'Portrayal' package might include elements for working with the style descriptors and symbol collections used in map production. A 'Geodesy' package can include elements for defining coordinate reference systems and related components such as a datum and a prime meridian. A CSW-ebRIM package for ISO 19115 and ISO 19119 is under development.

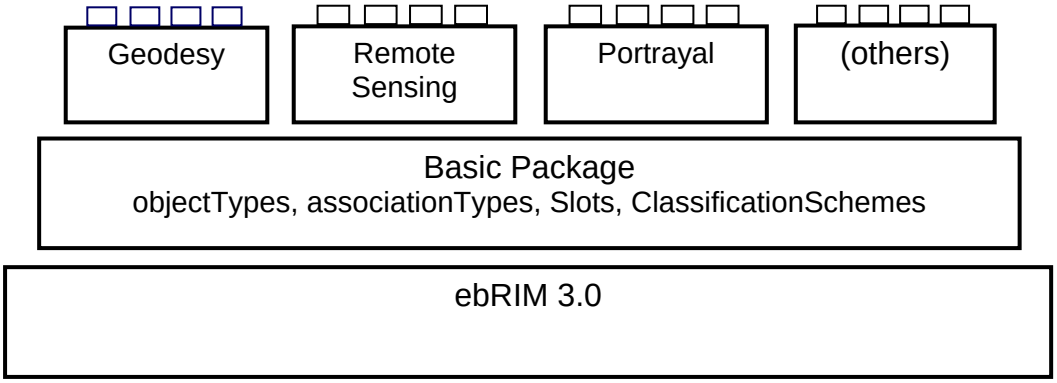

Figure 4 – Example extension packages

2.11 OGC Schema Repositories

Many OGC specifications include XML Schemas. The schemas appear in the specification document and are published in the OGC schema repository. Based upon the status of the specification or documentation, the schema will be posted to one of several repositories.

- OGC XML schema repository for Adopted Technology, i.e., Implementation Standards, such as OGC's GML, SensorML, or WMS
- Repository for XML schema documents related to OGC Best Practice documents.
- Repository for XML schema documents related to OGC Discussion Papers documents. Discussion Papers are not intended to be targets of acquisition descriptions. These papers do not represent the official position of the Open Geospatial Consortium nor of the OGC Technical Committee.
- Repository for experimental XML instance and schema documents. Documents posted here do not represent an official position of the OGC. This repository is for the convenience of developers in the OGC community, and is not necessarily on track for adoption as a standard.

3 Geospatial Services

3.1 Services Architecture

The widespread application of computers and use of information systems have led to the increased analysis of geospatial data within multiple disciplines. Geospatial datasets are increasingly being shared, exchanged, and used for purposes other than their producers' intended ones. Geographic information systems, sensors systems, automated mapping, facilities management, traffic analysis, geopositioning systems, and other technologies for geospatial information are entering a period of radical integration.

The OGC Abstract Specification Topic 12 - The OpenGIS Service Architecture provides a framework for developers to create software that enables users to access and process geospatial data from a variety of sources across generic computing interfaces within an open information technology environment.

- "a framework for developers" means that the OGC Standards are based on a comprehensive, common (i.e., formed by consensus for general use) plan for interoperable geoprocessing.
- "access and process" means that geodata users can query remote databases and control remote processing resources, for example in information systems using service oriented architecture.
- "from a variety of sources" means that users will have access to data acquired in a variety of ways and stored in a wide variety databases and knowledge bases.
- "across generic computing interfaces" means that OGC services enable reliable communication between otherwise disparate software resources that are equipped to use these interfaces.
- "within an open information technology environment" means that this OGC standard enables geoprocessing to take place outside of the closed environment of monolithic GIS, remote sensing, and automated systems that constrain access based on proprietary interfaces.

There are multiple choices of information technology for defining, developing and deploying service networks, i.e., distributed computing platforms. OGC standards are defined for multiple distributed computing platforms while maintaining common geospatial semantics across the underlying technology. OGC defines one conceptual specification as the basis for multiple platform-specific implementation specifications.

Development of standards may proceed from conceptual to implementation or from implementation to conceptual. In either case, a specification is not considered complete until it has a conceptual model and at least one implementation.

OGC services are defined using fundamental principles of service-oriented architecture:

- A **Service** is a distinct part of the functionality that is provided by an entity through interfaces,

- An **Interface** is a named set of operations that characterize the behavior of an entity,
- An **Operation** is a specification of a transformation or query that an object may be called to execute. Each operation has a name and a list of parameters.

Application and extension of the OGC Service Architecture is described in The Reference Model for the ORCHESTRA Architecture available as an OGC Best Practice.

3.2 OGC Web Services

OGC Web Services (OWS) are defined using open non-proprietary Internet standards; in particular the World Wide Web (WWW) standards of HTTP, Uniform Resource Locators (URLs), Multipurpose Internet Mail Extensions (MIME) types and the Extensible Markup Language (XML).

Recently, OWS services are becoming defined on the enterprise web service standards of WSDL (Web Services Description Language) and SOAP (this was originally an acronym for Simple Object Access Protocol but this was dropped in later versions of the standard). In parallel, OWS services are being defined for mass-market application using resource oriented or "RESTful" approaches including specifications such as geoRSS and KML.

OGC Web Service standards have been established for geospatial data:

- The OpenGIS® Web Map Service (WMS) Implementation Specification 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 remote and heterogeneous sources.

- The OpenGIS Web Feature Service (WFS) Implementation Specification allows a client to retrieve and update geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services. The specification defines interfaces for data access and manipulation operations on geographic features. Via these interfaces, a Web user or service can combine, use and manage geodata from different sources. A Transactional WFS includes the optional Transaction operation to insert, update, or delete a feature.

- The OpenGIS Web Coverage Service (WCS) Implementation Specification allows clients to access part of a grid coverage offered by a server. The data served by a WCS is grid data usually encoded in a binary image format. The output includes coverage metadata.

- The Catalogue Service for the Web (**CSW**) is one binding defined in the OpenGIS Catalogue Services Specification. The Catalog standard defines common interfaces to discover, browse, and query metadata about data, services, and other potential resources.

OGC Standards that support use of WMS, WFS, WCS and CSW include:

- The OpenGIS Web Map Context Implementation Specification defines how a specific grouping of one or more maps from one or more WMS servers can be described in a portable, platform-independent format for storage in a repository or for transmission between clients. A Context Document contains sufficient information 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.

- The OpenGIS Symbology Encoding Implementation Specification defines an XML language for styling information used to portray Feature and Coverage data.

- The OpenGIS Styled Layer Descriptor Profile of the Web Map Service Implementation Specification explains how WMS can be extended to allow user-defined symbolization of feature and coverage data. This profile defines how the Symbology Encoding specification can be used with WMS.

- The OpenGIS Filter Encoding Implementation Specification defines a common component that can be used by a number of OGC web services. Any service that can query objects from a web-accessible repository can make use of the Filter Encoding. For example, WFS may use Filter Encoding in a GetFeature operation.

- The OGC Gazetteer Service Best Practices Document defines an Application Profile of the WFS Implementation Specification by specifying a minimum set of Feature Types and operations required to support an instance of a gazetteer service. The information model of the specification is a GML application schema that defines a general feature type to be served by a Gazetteer Service.

To support coordination across the OWS specifications, OGC has developed these documents:

- The OGC Web Services Architecture Description Best Practice Document summarizes significant aspects of the OGC web services architecture. This architecture is a service-oriented architecture, with all components providing one or more services to other services or to clients.

- The OpenGIS Web Service Common Implementation Specification provides specifics that are common to OWS interface Implementation Specifications. These common aspects are primarily some of the parameters and data structures used in operation requests and responses. Each Implementation Specification details additional aspects of that interface, including specifying all additional parameters and data structures needed in all operation requests and responses.

3.3 Sensor Web Enablement (SWE) Services

The goal of OGC's Sensor Web Enablement (SWE) is to enable all types of Web and/or Internet-accessible sensors, instruments, and imaging devices to be accessible and, where applicable, controllable via the Web. The vision is to define and approve the standards foundation for "plug-and-play" Web-based sensor networks.

OGC had established Web Service standards for geospatial data:

- The OpenGIS Sensor Observation Service (SOS) Implementation Specification defines a web service interface for requesting, filtering, and retrieving observations and sensor system information. Observations may be from in-situ sensors (e.g., water monitoring devices) or dynamic sensors (e.g., imagers on Earth-observation satellites).

- The OpenGIS Sensor Planning Service (SPS) Implementation Specification defines an interface to task sensors or models. Using SPS, sensors can be reprogrammed or calibrated, sensor missions can be started or changed, simulation models executed and controlled. The feasibility of a tasking request can be checked and alternatives may be provided.

- The OGC Sensor Alert Service (SAS) Best Practice Document defines a web service interface for publishing and subscribing to alerts from sensors. Sensor nodes advertise with an SAS. If an event occurs the node will send it to the SAS via the publish operation. A consumer (interested party) may subscribe to events disseminated by the SAS. If an event occurs the SAS will alert all clients subscribed to this event type.

3.4 Processing Services and Service Chaining

The OpenGIS Web Processing Service (WPS) Implementation Specification defines an interface that facilitates the publishing of geospatial processes, and the discovery of and binding to those processes by clients. Processes include any algorithm, calculation or model that operates on spatially referenced data. A WPS may offer calculations as simple as subtracting one set of spatially referenced numbers from another (e.g., determining the difference in influenza cases between two different seasons), or as complicated as a global climate change model. The data required by the WPS can be delivered across a network using OGC Web Services.

A WPS process may be an atomic function that performs a specific geospatial calculation. Chaining of WPS processes facilitates the creation of repeatable workflows. WPS processes can be incorporated into service chains in a number of ways:

- A BPEL engine can be used to orchestrate a service chain that includes one or more WPS processes. Business Processing Execution Language is a standard issued by OASIS.
- A WPS process can be designed to call a sequence of web services including other WPS processes, thus acting as the service chaining engine.

- Simple service chains can be encoded as part of the execute query. Such cascading service chains can be executed via the GET interface.

OGC Abstract Specification Topic 12: OpenGIS Service Architecture defines service chaining as the combination of services in a dependent series to achieve larger tasks. Topic 12 addresses the syntactic concepts of service chaining, e.g., data structure of a chain, and the semantic concepts, e.g., does a specific chain produce a valid result? Service chaining enables users to combine data and services in ways that are not pre-defined by the data or service providers.

3.5 Mass Market Services

OGC is defining services for the Mass Market in order to broaden the use of location-aware technologies in mainstream consumer and business IT infrastructures. This work seeks to understand the implementation barriers for these interest groups and document them in a format that can guide future technology design. For example this effort is defining the relation of geospatial to Web 2.0 and IETF.

OGC is defining services and information encodings that complement the existing OGC specifications, but are directly tailored to the requirements discovered in understanding the needs of the mass market. Development currently centers on the following topics:

- The OGC KML Standard defines an XML grammar used to encode and transport representations of geographic data for display in an earth browser. Put simply: KML encodes what to show in an earth browser, and how to show it.

- GeoRSS (Geographically Encoded Objects for RSS feeds) is a proposal for geo-enabling, or tagging, "really simple syndication" (RSS) feeds with location information. Currently, there are two GeoRSS serializations: GeoRSS GML and GeoRSS Simple. GeoRSS GML is a formal GML Profile, and supports a greater range of features than GeoRSS Simple, notably coordinate reference systems other than WGS84 latitude/longitude. Additional information can be found in the OGC White Paper: An Introduction to GeoRSS.

KML and the existing OGC Web Map Context encoding specification have a lot in common. Both encodings support the specification of a location on Earth, dynamic access to certain geospatial Web resources and services, and inline inclusion of geospatial data along with simple styling.

3.6 Open Location Services

This OpenGIS Location Services (OpenLS): Core Services Implementation Specification defines five Core Services and multiple Abstract Data Types (ADT) that comprise the GeoMobility Server, an open location services platform. It also outlines the scope and relationship of OpenLS with respect to other specifications and standardization activities. The five Core OpenLS services are: Directory Service, Gateway Service, Location Utility Service (Geocoder/Reverse Geocoder), Presentation Service, and Route Service.

The GeoMobility server is an element offering basic functions on which location-based applications are built (the OpenLS Core Services). This server uses open interfaces to access network location capacity and provides a set of interfaces allowing applications hosted on this server, or on another server, to access the OpenLS Core Services. The GeoMobility Server also provides content such as maps, routes, addresses, points of interest, traffic, etc. It can also access other local content databases via the Internet.

3.7 Fine-Grained Services

OGC specifications apply to environments as diverse as the Internet and to workgroup clusters. For web services, the client and server have very little knowledge of one another. Specifications designed for this environment are classified as coarse-grained profiles. At the other extreme, the interface between a client and server is fine-grained exposing greater detail on the server's holdings. OGC has standardized several fine-grained specifications:

- The OpenGIS® Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture, also published as ISO 19125-1, describes the common architecture for simple feature geometry. The simple feature geometry object model is Distributed-Computing-Platform neutral and uses Unified Modeling Language (UML) notation. The base Geometry class has subclasses for point, curve, surface and geometry collection. Each geometric object is associated with a coordinate reference system, which describes the coordinate space in which the geometric object is defined.

- The OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 2: SQL option, also published as ISO 19125-2, defines a Structured Query Language (SQL) schema that supports storage, retrieval, query and update of features. This standard is dependent on components defined in Part 1 of this standard. In an SQL-implementation, a collection of features of a single type is stored as a "feature table" usually with some geometric-valued attributes (columns). Each feature is primarily represented as a row in this feature table.

- The OpenGIS Coordinate Transformation Service Implementation Specification defines interfaces for general positioning, coordinate systems, and coordinate transformations. The specification provides an abstract model in UML along with profiles for Java and Interface Description Language (IDL).

- The OpenGIS Geographic Application Objects Implementation Specification defines an abstract model for describing, managing, rendering, and manipulating geometric and geographic objects within an application-programming environment. The document provides both an abstract object specification (in UML) and a programming-language specific profile (in Java).

4 Reusable Patterns for Deployment

Previous sections defined the information and services standards that serve as building blocks for deployments. To support reusable deployments several patterns are defined that use the OGC standards in ways that accomplish many typical tasks.

4.1 Publish, Find and Bind Pattern

OGC web services utilize the popular publish/find/bind pattern shown in Figure 5 for dynamic binding between service providers and in a distributed environment.

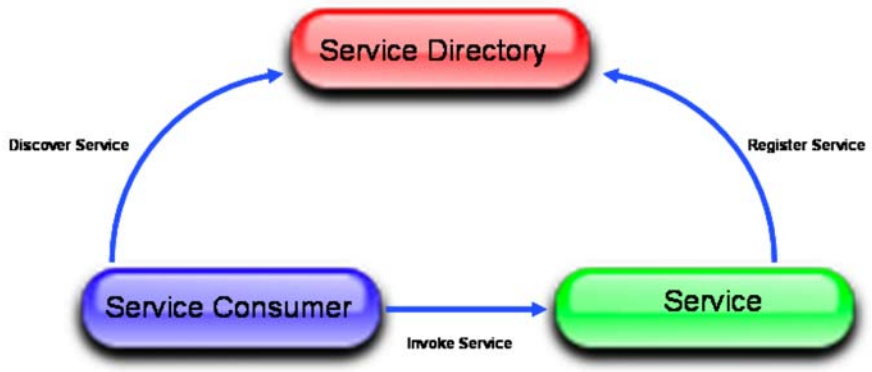

Figure 5 - Publish/Find/Bind Pattern

In Figure 5, there are three essential roles:

- **Service**: publishes services to a broker (registry) and delivers services to service requestors.
- **Service Consumer**: performs service discovery operations on the service broker to find the service providers it needs and then accesses service providers for provision of the desired service.
- **Service Directory**: helps service providers and service requestors to find each other by acting as a registry or clearinghouse of services.

As shown, there are three essential kinds of operations performed by services:

- **Publish**: used to register data and services to a directory (such as registry, catalog or clearinghouse). A service provider contacts the service directory to publish (or unpublish) a service. A service provider typically publishes service metadata describing its capabilities and network address.

- **Find**: used by service consumers to discover specific service types or instances. Service consumers describe the kinds of services they're looking for to the directory and the directory responds by delivering the results that match the request. Service consumers typically use metadata published to find services of interest.

- **Bind**: used when a service consumer invokes a services. A service consumer typically uses service metadata provided by the registry to bind to a service provider. The service consumers can either use a proxy generator to generate the code that can bind to the service, or can use the service description to implement the binding before accessing that service.

OGC has developed a framework for defining specialized catalogues that support registration processes such as those described in ISO 19135: establishing, maintaining, and publishing registers of identifiers and meanings that are assigned to items of geographic information. The Catalog Service for the Web (CSW) – as defined in the OGC Catalogue Specification (CAT) – has been augmented by an ebRIM Information Model to establish an OGC framework for registration of geospatial information.

4.2 Geospatial Portal and Clients

For users to achieve the value of geospatial data and services, user interfaces must exist that allow access. Portals have become a regular and familiar user interface to web-based users. Client applications hosted on user hardware continue to serve a large portion of the user community. Portal and application clients are discussed in this section.

The OGC Geospatial Portal Reference Architecture Discussion Paper was developed to assist the global geospatial technology community in implementing standards-based geospatial portal solutions. The document is a resource for rapid development and informed acquisition of portals and portal-exploiting applications that can plug and play with geospatial data and services in your organization and other organizations in your community and around the world.

A Web portal is a single point of access to information, which is linked from various logically related Internet-based applications and is of interest to various types of users. Portals present information from diverse sources in a unified way; they provide a consistent look and feel with access control and procedures for multiple applications, which otherwise would have been different entities altogether. Since all the applications share information through portals, there is better communication between various types of users. Another advantage of portals is that they can make event-driven campaigns.

The OWS Integrated Client Discussion Paper describes the core concept of providing a unified environment that allows a user to visualize, analyze, and/or edit data from numerous OGC Web Services simultaneously. An Integrated Client unifies common service discovery, feature production, imagery exploitation, portrayal management, processing, and sensor web enablement functionalities, and provides an environment for visualizing, analyzing and/or editing data from these sources/services.

Portals and application clients represent just the tip of geospatial Decision Support Services (DSS) which aim to provide interoperable access to distributed geospatial web services to aid decision makers in forming, analyzing, and selecting alternatives, see Figure 7. GeoDSS includes workflow management to produce context-specific results from information and knowledge from multiple communities. One objective of geospatial web services is to allow decision makers to access and use information that may have been collected for other purposes.

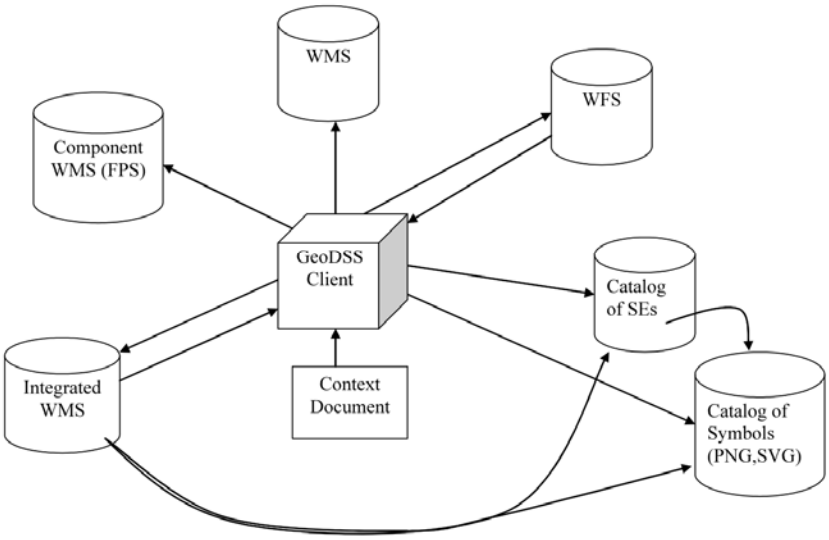

Figure 6 – GeoDSS Integrated OWS Client

4.3 Multi-Tier Architectures

The OpenGIS Web services architecture description describes how OGC services (or components) are loosely organized in four tiers, as shown in Figure 7. This organization is called loose because clients and services can bypass un-needed tiers, as indicated by some arrows. Services can use other services within the same tier, and this is common especially in the Processing Services tier. Also, some services perform functions of more than one tier, when those functions are often used together and combined implementation is more efficient. Assignment of such combined services to tiers is somewhat arbitrary.

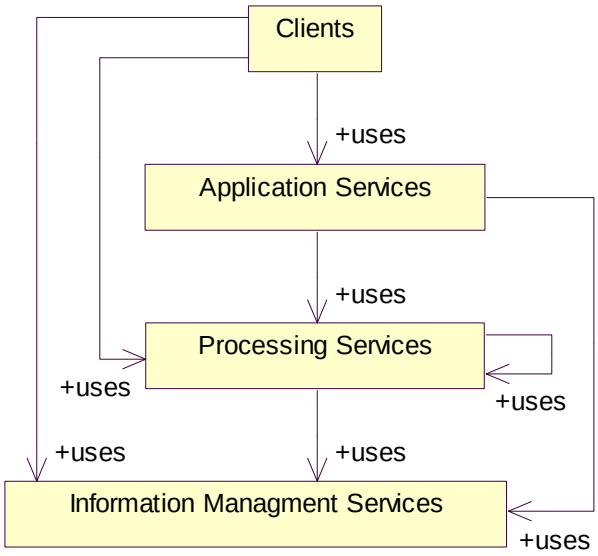

Figure 7 —Service tiers in OWS architecture

Each tier of services has a general purpose, as indicated by the names in Figure 7. That tier name is independent of geographic data and services, since some tier services are not specific to geographic data or services. Each tier of services includes multiple specific types of services, many of which are tailored to geographic data and services. Services included in each tier are defined for OGC services in Section 3; some services are defined by other standards bodies and others are yet to be defined.

4.4 Spatial Data Infrastructures

OGC standards are key elements of the interoperability strategy of several Spatial Data Infrastructures (SDIs).

The SDI Cookbook, published by the GSDI, remarks that "SDI" is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. An SDI must be more than a single data set or database: an SDI hosts geographic data and attributes; sufficient documentation (metadata); a means to discover, visualize, and evaluate the data (catalogues and Web mapping); and some method to provide access to the geographic data.

The OGC Web Services Architectural Profile for the NSG describes how the various OGC specifications relate to the web service architecture implementation at the US National Geospatial-Intelligence Agency and the National System for Geospatial-Intelligence (NSG). The document enables organizations that interface with the NSG to understand how to produce and consume data and services in an interoperable environment.

The Geospatial Profile of the US Federal Enterprise Architecture (FEA) is a tool for chief architects to determine how and where place-based approaches and associated geospatial

resources fit into their enterprise architectures as they implement the FEA reference models. The Geospatial Profile of the FEA recognizes that the value of a component increases in proportion to the number of places it can be used. Standards, both technical and domain, affect this utility in a number of ways. First, component interfaces based on industry standard practices and technologies is most likely to be shared. Further, if the interface is based on a domain industry standard such as GML (Geography Markup Language), even greater reuse is likely, as many organizations have agreed to use those standards. Common standards also help ensure a compatible execution environment, which in turn benefits implementation. For example, if a component is written to Web Services Interface Standards, such as many OGC specifications, it can be deployed in a broad set of execution environments.

GeoConnections helps decision-makers "use online location-based (or "geospatial") information, such as maps and satellite images, to tackle some of Canada's most pressing challenges." GeoConnections strongly advocates the use of standards endorsed for the Canadian Geospatial Data Infrastructure (CGDI) to achieve interoperability for richer and more useful information than a single data set can provide. GeoConnections was an early supporter of WMS development and was an early adopter of the WMS standard. Recently the OGC Canadian Geospatial Data Infrastructure WFS and GML Best Practices gives guidelines and recommendations for administrators, users and implementers of WFS serving GML-encoded response documents. This OGC document is applicable to the design, implementation and operation of Web Feature Service networks.

The Directive of the European Parliament and Council establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) directs Member States to establish and operate a network of services for discovery, viewing, and transformation. The services are to be easy to use, available to the public and accessible via the Internet. Implementation of the directives by the European Commission is proceeding with significant uptake of OGC standards envisioned.

The GEOSS 10 Year Plan, published by the Group on Earth Observations, states that to enable implementation of the GEOSS architecture, GEOSS will draw on existing Spatial Data Infrastructure (SDI) components as institutional and technical precedents in areas such as geodetic reference frames, common geographic data, and standard protocols. The GEO Architecture Implementation Pilot is defining and deploying the GEOSS Core Architecture for exchange and dissemination of observations including considerable uptake of OGC web services.

The OGC Federated Earth Observation Missions (FedEO) Pilot Discussion Paper describes the application of OGC services to Earth Observation. The FedEO Pilot was conducted in conjunction with and in support of the GEOSS Architecture Implementation Pilot. The FedEO pilot used and extended the GEOSS Architecture with additional services, e.g., Product Programming, Service Orchestration, Processing Services, Orthorectification and Reprojection Services and Order Service.

4.5 Sensor Webs

The OpenGIS Sensor Web Enablement Architecture Document provides a description of the general architecture that applies to the Sensor Web Enablement (SWE). The goal of SWE is to make all types of components – network-resident sensors, instruments, imaging devices and repositories of sensor data – discoverable, accessible and, where applicable, controllable across scalable networks. That is, the goal is to enable the creation of Web-based sensor networks.

Figure 8 depicts concepts of SWE networks enabled with open, standardized Web service interfaces and data encodings.

Figure 8 shows multi-level integration to access and share resources over common or interconnected networks. Each of these sensor-system and processing nodes may be owned and operated by different organizations and for different purposes such as chemical-biological-nuclear-radiological-explosion (CBRNE) detection, perimeter intrusion detection, environmental monitoring, scientific research, etc.

Figure 8 also shows sensor-observation value chains as the lifecycle of sensor-produced observations, from raw unprocessed data granules to information products and services delivered to applications and consumers. Depending on the requirements, sensor data may be delivered to the user in its most elemental unprocessed form, processed into an observation object complete with the metadata and processes used to estimate a value describing a phenomenon, or processed further, for example, into single-valued geographic feature or multi-valued coverage representations.

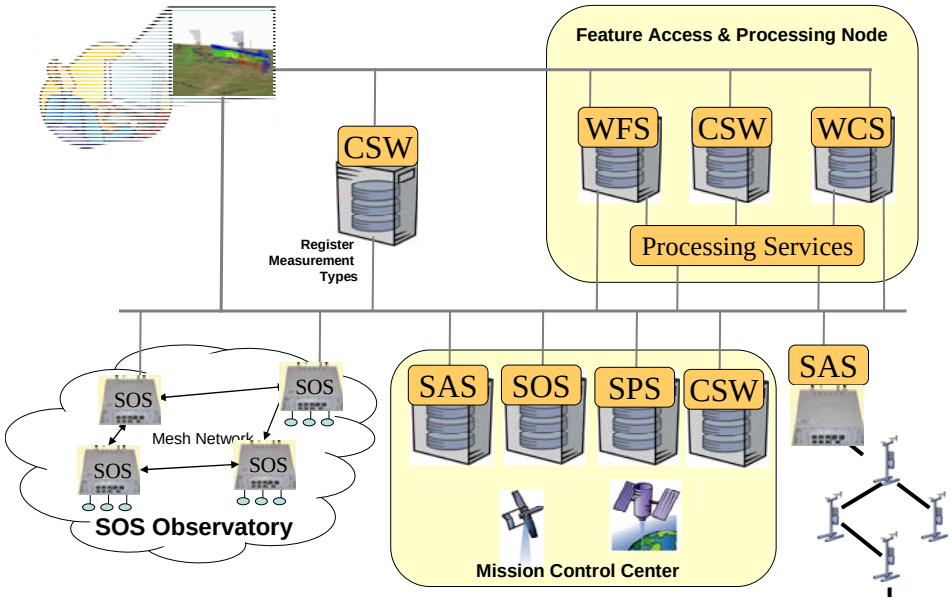

Figure 8 – The SWE Concept

4.6 Workflow and Service Chaining

OGC has implemented workflow and service chaining beginning with the first OGC Web Services Testbed. Several reports from the OGC Interoperability Program document these results. Most recently the OWS-4 Workflow Report, now an OGC Discussion Paper (URL), provides workflow descriptions and lessons learned. Five workflows were implemented during the course of the OWS-4.

- Several of the workflows related to processing discrete features. For example, Figure 9 shows a process of generalizing and clipping a large set of features before transferring them to a lightweight WFS Client. In a separate workflow, features were inserted into a "gold" WFS only after performance of a topological quality assessment test.
- Several workflows were performed to process sensor data available via SWE services. An Earth-observations workflow processed imagery from SWE services, resulting in information suitable for decision support. Figure 8 shows the services involved in these workflows.

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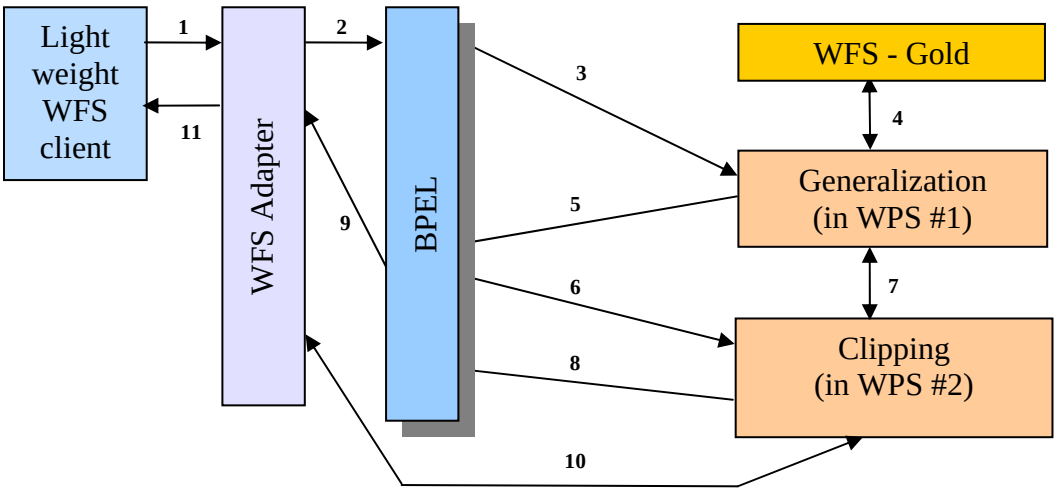

Figure 9 – Data reduction workflow sequence

5 Implementations of OGC Standards

OGC supports the implementation of OGC standards through several activities as described below.

5.1 OGC Compliance Test Program

The purpose of the OGC Compliance Testing Program is to permit vendors and users to take advantage of the standards that OGC has created. The program provides a process for testing compliance of products to OpenGIS® Implementation Specifications.

When a vendor has completed compliance testing and OGC has confirmed its successful completion, vendors who agree to the terms of the OGC Trademark License Agreement that accompanies this program, and who have paid their trademark license fees, may use OGC's marks (trademarks or certification marks) to indicate to their customers that they have achieved compliance with OpenGIS Implementation Specifications.

The OGC Compliance Testing Portal is the home of the OGC's on-line compliance testing resources. The portal provides test scripts in an automated test environment for the adopted OGC Standards for OGC web services. In addition, the OGC provides a tool to validate Geography Markup Language (GML). If you want to try out compliant software, take a look at the Reference Implementations as open-source applications.

The Compliance Test engine is an open-source application allowing integrators and software developers to host the compliance test tools in their own development laboratories. Although only tests performed at the OGC compliance site can be used as the basis for certification, organizations find it valuable to perform the same tests in their labs to support development and integration.

Previously developed off-line Compliance Test Suites for download include: Catalog Service Interface 1.0, Coordinate Transformation 1.0, Gridded Coverages 1.0, Simple Features SQL 1.1, Simple Features COM 1.1, Simple Features CORBA 1.0. Those suites are hosted on the OGC site.

In addition, OGC provides on-line tools for GeoRSS, Geography Markup Language (GML) 2.1.2, and Web Map Context (WMC) 1.1.0 validation. These validation tools are not associated with official OGC Compliance Certification and are simply provided as a community resource.

5.2 Registered Implementations

Implementations of OGC Specifications can be registered on the OGC website including those that have been certified OGC Compliant. The lists of Compliant and Implementing Products identify publicly available products and services that either implement or have been tested Compliant to OpenGIS Specifications. You may also Register Your Products at this site.

OGC Cookbooks are free, online, easy-to-use technical documents for developers.

On-line demonstrations of OpenGIS Specifications and interoperable software are available from previous OGC Interoperability Program initiatives.

5.3 Operational Networks using OGC Standards

The OGC Network™ is an online infrastructure of Internet-accessible networks that implement OpenGIS specifications. The OGC Network supports communities-of-interest for research in geospatial interoperability and provides a persistent demonstration capability. OGC Network components are provided by OGC members and non-members, with organization and leadership provided by OGC members and staff.

In the past, most of OGC's efforts have been geared towards members—with highly detailed, technical resources that require an in-depth background with OGC's work to understand—or towards interested observers who want more of a high-level, business-oriented view of geospatial interoperability efforts. OGC Network seeks to serve a middle audience, such as the geospatial professional looking to try out OGC members' products, or begin to develop clients and services that rely on existing, deployed services. OGC Network is designed first and foremost as a window onto the dynamic, constantly changing geospatial web.

A postscript on development and persistence from "On the Nature of Things" by Titus Lucretius Carus (c.99-55 BCE):

> No single thing abides; but all things flow.
> Fragment to fragment clings-the things thus grow
> Until we know and name them. By degrees
> They melt, and are no more the things we know.

