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OGC Web Services Architectural Profile for the NSG

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i. Preface

Suggested additions, changes, and comments on this draft report are welcome and encouraged. Such suggestions may be submitted by email message or by making suggested changes in an edited copy of this document.

The changes made in this document version, relative to the previous version, are tracked by Microsoft Word, and can be viewed if desired. If you choose to submit suggested changes by editing this document, please first accept all the current changes, and then make your suggested changes with change tracking on.

ii. Submitting organizations

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2 November 2006	0.2	S. Urbanowski	All	Revisions and global modifications
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January 31, 2007	0.9.4	Urbanowski	All	Captured and incorporated comments
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July 22, 2007	1.3	Urbanowski	Terms & Defs	Added term definitions

v. Future work

A description of Web Map Context is necessary within the Section 4.3, OGC Web Services for the NSG. Ideally this material would be placed in to a new sub-section, 4.3.3.

It would be useful to include a discussion of how DoD Information Technology Standards and Profile Registry are represented within this profile. This work would provide use cases and DoDAF views and should fit into Section 4.1.1.

The initial sponsors of this document have requested that this work include a mapping of NSG Data Sources, or NGA Products, to OWS services and profiles. This information should be included in Section 4.1.2.

This document was originally intended to provide a section describing the Creating Features from Observations, Section 4.5.4. Resource limitations prevented this work from being done. The relevant NGA excerpt and applicable OGC specifications are shown below. This work should be provided as resource become available.

> Information Management. Today, the best NSG information is not always generated, visible or accessible to customers. This is a result of information management processes that occur independently, serve limited customer sets, and are not routinely understood by or available to customers. **The NSG will evolve from a product-oriented environment to a knowledge-centric enterprise, with an information management architecture to support the new paradigm.** An integrated information environment and a service-oriented architecture, with data-centric, networked capabilities, will provide assured customer access to GEOINT data, products, and services. It will provide **discovery, acquisition,**

management and delivery of the right information, in the right format, at the right time and classification.

Applicable OGC Specifications and developments

- Observations and Measurement specification (05-087)
- Schema Maintenance and Tailoring discussion paper (05-117)
- GML Spec (v3.1.1),
- Clause 8, GML schemas – feature model
- Clause 23. Rules for Application Schemes
- ISO 19110 General Feature Model
- Schema Tailoring and Maintenance - DIPR
- Workflow IPR from OWS-4 (06-187)

Foreword

The National Center for Geospatial Intelligence Standards (NCGIS) of the National Geospatial-Intelligence Agency (NGA) is participating in the Open Geospatial Consortium (OGC) Interoperability Program Open Web Services activity, Phase 4 (OWS-4). NGA/NCGIS is undertaking this activity in support of one of the modernization goals for the National System for Geospatial-Intelligence (NSG). This goal is to increase NGA's capabilities to leverage existing market driven Standards–based Commercial Off-The-Shelf (SCOTS) solutions for fulfilling analyst's needs in undertaking their missions. Part of NCGIS' mission is to ensure that commercial industry addresses NGA interoperable technology requirements.

The NCGIS, through efforts such as the OGC's Interoperability Program, works to ensure standards and standards-based commercial software developments are accelerated. The goal is for these standards and software elements, addressing NSG requirements, to be ready for implementation when the GeoScout contractor begins that phase of modernization of NGA's information technology (IT) infrastructure. As a part of the OWS-4 effort, OGC has developed this *OGC Web Services Architectural Profile for the NSG* to encourage industry vendors to develop, test and validate interface specifications. These interface specifications are anticipated to lead to commercial products suitable for use by NGA, its customers, and the broader federal geospatial community.

Executive summary

The purpose of this document is to generally describe how the various OGC specifications may be used to address the needs of a large enterprise system. It highlights the key elements of the OWS-4 effort as they relate to web service architecture implementation at NGA and in the NSG. The goal is that this document will enable organization that interface with the NSG to understand how to produce and consume data and services in an interoperable environment.

The document includes description of all applicable OGC specification, the relationship of theses specifications to NSG concepts, the relationship of these specifications to each other and architectural concepts related to the application of these specifications. Foundational concepts such as net-centric and service oriented architecture are presented. This is followed by a discussion of service models, information models, OWS-4 results and other OGC topics which are applicable to the NSG.

The technologies discussed as part of this profile include:

- OGC Service Framework
- OGC Web Services (WMS, WFS, WCS)
- Catalog (CS-W)
- Geospatial Digital Rights Management (GeoDRM)
- Sensor Web Enablement (SPS, SOS, SAS, WNS, SensorML, TransducerML)
- Geo-Processing Workflow
- Geo-Decision Support Services (GeoDSS)
- Compliance Testing

It is expected that the vendor community's support for these specifications will continue to increase, and this document will act as a guide for the NGS, NSG connected organizations and the broader federal geospatial community. This document is intended to complement other documents such as the Spatial Data Infrastructure 1.0 (SDI) in that it provides a comprehensive description of OGC specifications, a context of how they apply to the NSG domain and a description of how the specifications can be assembled to meet the needs of an enterprise.

OWS Implementation Profile includes the following elements:

- Executive Overview
- Technologies recommended.
- Required Standards for implementation.

1 Scope

OGC specifications capture general purpose capabilities independent of any particular operational environment. For many organizations, however, these general capabilities are not sufficient. Additional documentation is required to provide developers the guidance they need to apply OGC specifications and design patterns within their specific operational context. OGC Implementation Profiles provide that guidance.

This OGC Document defines an Implementation Profile of the OGC Web Services for use by the National Geospatial-Intelligence Agency (NGA) in the National System for Geospatial Intelligence (NSG).

This document is developed as part of the OGC Web Services, Phase 4 (OWS-4) Interoperability Initiative.

This document will be offered for consideration as a Best Practice Document by the OGC Specification Program.

2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

2.1 NGA documents

NSG Statement of Strategic Intent - March 2007

Geospatial Intelligence Standards; Enabling a Common Vision - November 2006

Joint Vision 2020 – June 2000

2.2 OGC Documents

OGC 04-021, Catalogue Service Implementation Specification

OGC 01-009, Coordinate Transformation Service Implementation Specification

OGC 04-095, Filter Encoding Implementation Specification

OGC 03-105, Geography Markup Language (GML) Encoding Specification

OGC 05-047, GML in JPEG 2000 for Geographic Imagery Encoding Specification

OGC 02-070, Styled Layer Descriptor (SLD) Implementation Specification

OGC 05-077, Symbology Encoding Implementation Specification

OGC 06-083, Web Coverage Service Implementation Specification

OGC 04-094, Web Feature Service Implementation Specification

OGC 05-005, Web Map Context Implementation Specification

OGC 06-042, Web Map Service Implementation Specification

OGC 06-121r3, OpenGIS® Web Services Common Specification

OGC 06-103, 06-104, Simple Feature Access Implementation Specification

OGC 06-086, SDI 1.0

3 Terms and definitions

The following terms and definitions are used in this document.

Application schema – set of conceptual schema for data required by one or more applications.
Business Process- an interaction between participants and the execution of activities according to a defined set of rules in order to achieve a common goal [Business Process Modeling Language Proposed Draft Specification]
Client - A software component that can invoke an operation from a server
Conceptual schemas (also called base schemas)
Coordinate reference system – coordinate system that has a reference to the Earth.
Coverage is a feature that associates positions within a bounded space (its spatiotemporal domain) to feature attribute values (its range)
DAFIF - Digital Aeronautical Flight Information File - database of aeronautical data, including information on airports, airways, airspaces, navigation data developed for the benefit of military aeronautical operations by the NGA.
DCP – Distributed Computing Platform – the collection of protocols, services and conventions that services use to invoke remote operations. Examples include CORBA, DCOM, WEB (SOAP) and Web (HTTP get/post)
DISR - Department of Defense (DoD) Information Technology Standards Registry - Online repository for a minimal set of primarily commercial IT standards formerly captured in the Joint Technical Architecture (JTA), Version 6.0. These standards facilitate integration of new systems into the Global Information Grid (GIG) are used as the "building codes" for all systems being procured in the Department of Defense.
DoDAF - Department of Defense's Architecture Framework - is the concepts presented in the Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Architecture Framework. The primary purpose is to provide guidance in describing both warfighting operations and business operations and processes. It provides guidance, rules and product descriptions of how to describe an architecture using four views. Each view is made up of various products for a total of 26 products.
F**eature** – abstraction of a real world phenomenon.

General feature model – metamodel of feature types
Geographic feature – feature associated with a location relative to the Earth.
GEOINT Discipline– encompasses all activities involved in the planning, collection, processing, analysis, exploitation and dissemination of spatial information in order to gain intelligence about national security or operational environment, visually depict this knowledge and fuse the acquired knowledge with other information through analysis and visualization processes. [NSG Statement of Strategic Intent]
GIG - Global Information Grid - provides authorized users with a seamless, secure, and globally interconnected information environment, meeting real-time and near real-time needs of both the warfighter and the business user.
GML – Geography Markup Language
Interface – named set of operations that characterize the behavior of an entity [6]
Interoperability - capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units [ISO 2382-1]
Map projection – coordinate conversion from a geodetic coordinate system to a planar surface.
Metadata – Information that describes, or supplements, the central data. It provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.
National System for Geospatial Intelligence (NSG) - Combination of technology, policies, capabilities, doctrine, activities, people, data and communications necessary to produce geospatial intelligence (GEOINT) in an integrated multi-intelligence, multi-domain environment. [NSG Statement of Strategic Intent]
OGC – Open Geospatial Consortium
Operation – Specification of an interaction that can be requested from an object to effect behavior. [ISO 19119]
Property - A facet or attribute or an object referenced by a name
ORM – OGC Reference Model
Service request - A request by a client of an operation from a service.
Service - A collection of operations, accessible through an interface that allows a user to evoke a behavior of value to the user. [ISO – 19119]
Service chain - sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the occurrence of the second action [ISO 19119]
Service Framework - a partially complete (sub-)system that is intended to be instantiated. It defines the architecture for a family of (sub-)systems and provides the basic building blocks to create them.
Spatial Reference System – As defined in the OpenGIS Abstract Specification Topic 2 and ISO 19111.
Viewpoint – form of abstraction achieved using a selected set of architectural concepts and structuring rules, in order to focus on particular concerns within a system. [ISO-10746-2]
VPF - Vector Product Format - is a standard format, structure, and organization for large geographic databases that are based on a georelational data model and are intended for direct use.

4 Requirements and objectives of the NSG OWS

This section documents Requirements and Objectives for achieving NSG objectives based on OGC Web Services. Excerpts from several documents provided to OGC as Government Furnished Information (GFI) are quoted to guide development of the OGC Web Services Architecture Implementation Profile for the NSG.

The **NSG Vision**: "An integrated, collaborative community of GEOINT professionals embedded with our operational and national partners to meet their warfighting and intelligence needs." [Excerpt from NSG Statement of Strategic Intent]

Ensure the integrated and optimized use of airborne, commercial, advanced geospatial intelligence, foreign and national satellite collection. Accelerate the standardization of sensor data, metadata, compression formats and file identifiers. Develop strategies and methods for addressing the exponential increase in data and information to ensure all relevant data is analyzed. [Excerpt from NSG Statement of Strategic Intent]

Implement a GEOINT Unified Operations Strategy through a formal network to facilitate integrated GEOINT operations. [Excerpt from NSG Statement of Strategic Intent]

Standardization efforts within the NSG are bringing together diverse national and international community members to implement geospatial data standards that, through a Service-Oriented_Architecture (SOA), enhance interoperability across these communities. [Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

Through strong collaboration and our understanding of the mission, we will focus outwardly and build enduring partnerships. Capitalize on the value-added collection and exploitation from GEOINT users in the field. [Excerpt from NSG Statement of Strategic Intent]

Achieve front-end/back-end alignment to address collection platforms, building a foundation knowledge base and comprehensive access to NSG products and services. Articulate NSG requirements for sensor platform development, data dissemination, data storage, and data exploitation to achieve an optimally balanced investment strategy. [Excerpt from NSG Statement of Strategic Intent]

Interoperability in a net centric environment is dependent on the development and industry-wide acceptance and implementation of non-proprietary standards and specifications for web-based applications. [Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

Interoperability is a mandate for joint force 2020 – especially in terms of communications, common logistics items, and information sharing. Information systems and equipment that enable a common relevant operational picture must work from shared networks that can be accessed by any appropriately cleared participant. [Excerpt from Vision 2020]

Ensuring a universally adopted and implemented set of **GEOINT standards** is crucial to our mission success. These standards need to ensure access to timely, relevant, and accurate GEOINT data, services, and products regardless of source, exploitation process, or production element. [Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

Reduce technology costs by increasing usage of standards-based commercial-off-the-shelf software (SCOTS), reduce custom solutions and associated maintenance costs. [Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

Expanding roles for multinational and interagency partners will require collaborative planning capabilities, technological compatibility/interoperability, and mechanisms for efficient information sharing. [Excerpt from Vision 2020]

5 Application OGC web services for the NSG

5.1 Introduction

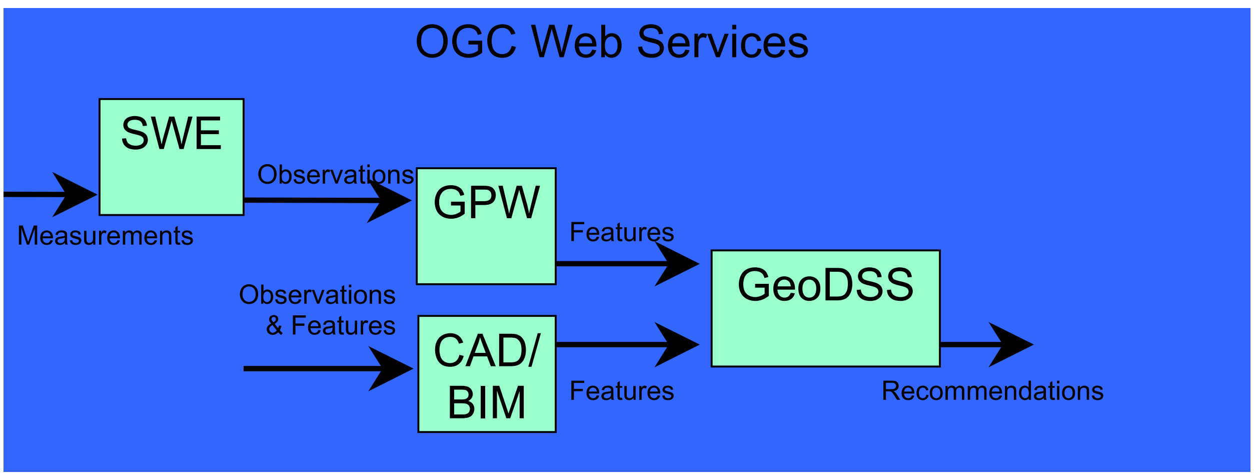

Figure 1 - Application of OWS to the NSG

Figure 1 shows some of the major OWS-4 work areas and how they relate to each other in an operational context. These work areas are:

- Sensor Web Enablement (SWE) - addresses the creation of sensor networks including services for tasking, processing and notification. The objective of SWE is to make measurements from any sensor readily available for exploitation.

- Geo-Processing Workflow (GPW) - addresses the interoperable processing of geospatial data. This includes traditional cartographic data as well as other positional data types such as sensor measurements and observations. Since most information has a location element, GPW represents the suite of services and data standards for integrating and processing almost any data source.

- Geospatial Decision Support Services (GeoDSS) - addresses the tools and applications used to implement the decision support process.

- Computer Aided Design (CAD) and Building Information Model (BIM) - The data sets used to design, build and maintain a building have strong similarities to geospatial data. An on-going CAD/GIS effort is working to integrate these two communities into an interoperable information framework. This will greatly expand the information available to the decision support analyst.

Subsequent sections of this document will explore these efforts and show their application to NSG objectives.

5.2 Foundation concepts

5.2.1 Requirements on OGC technologies

This section focuses on identifying key requirements on OGC technologies. Before listing these requirements, it is important to note that OGC technologies are not limited to the **specifications** formalized by the consortium; they also include working **implementations** of such specifications. As such, in order to support the geospatial information value chain, OGC technologies must:

- Be agile so as to be able to adapt to changing business rules and operational requirements;

- Support the easy and seamless introduction of new technologies and the evolution of existing ones;

- Provide for robustness and consistent error handling and recovery to support mission-critical systems development;

- Accommodate authentication, security and privacy features and support asset protection;

- Be platform independent (e.g., DCP, hardware, OS, programming language, encodings, etc);

- Support implementations of N-tiered, component architectures;

- Support standard interfaces and metadata while accommodating the use of other complementary standards and specifications in environments where OpenGIS specifications are implemented;

- Support interoperability by specifying interface definitions, service descriptions and protocols for software collaboration and negotiation;

- OGC and ISO TC211 have an agreement to sustain the technical alignment of their respective developments. OGC also maintains contact with a number of other standards organizations (W3C, IETF, OMG, AMIC and others), generally offering expertise related to spatial issues and receiving expertise necessary to ensure that OGC's standards framework is consistent with other IT standards frameworks.

- Accommodate independently developed implementations of a service and many independently provided instantiations of different types of services;

- Accommodate a wide range of data policies (e.g., data access and data use policies);

- Be vendor and data neutral;

- Be data content format independent.

5.2.2 Services, interfaces and operations

Key definitions for the Service Framework are:

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

- An **Interface** as a named set of operations that characterize the behavior of an entity,

- An **Operation** as 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.

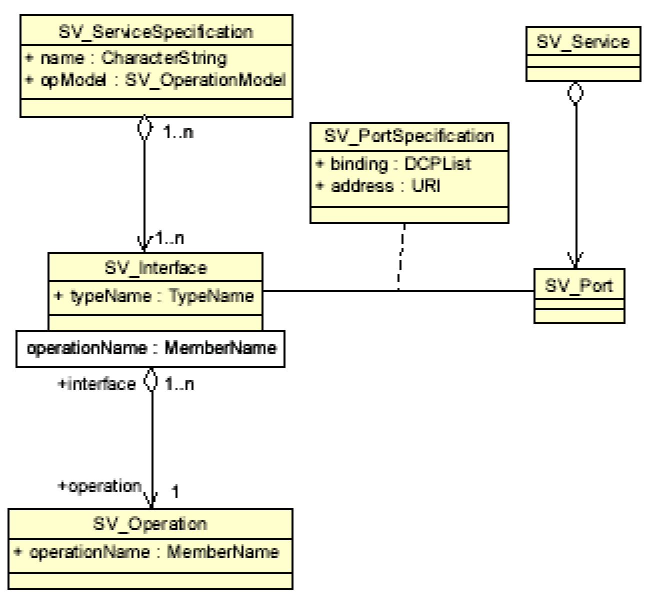

Figure 2 - Service definition relationships

A service may be expressed at various levels of granularity. A coarse-grained collaboration may be refined to produce a service that has a finer granularity. This is accomplished by expanding one or more operations from a high level collaboration into distinct lower level services, one for each operation.

An instance of a service may be associated with a specific instance of a dataset, or it may be a service that can be used to operate on multiple, unspecified datasets. The first case is referred to as a **tightly coupled data and service**. The second case is referred to as **loosely coupled service**. Service operations can be associated with data classes (data type) or with instances (data set).

5.2.3 OWS service framework

The OWS Service Framework (OSF) identifies services, interfaces and exchange protocols that can be utilized by any application. OpenGIS Services are implementations of services that conform to OpenGIS Implementation Specifications. Compliant applications, called OpenGIS Applications, can then "plug into" the framework to join the operational environment.

By building applications to common interfaces, each application can be built without a-priori or run-time dependencies on other applications or services. Applications and services can be added, modified, or replaced without impacting other applications. In addition, operational workflows can be changed on-the-fly, allowing rapid response to time-critical situations. This loosely coupled, standards-based approach to development results in very agile systems—systems that can be flexibly adapted to changing requirements and technologies

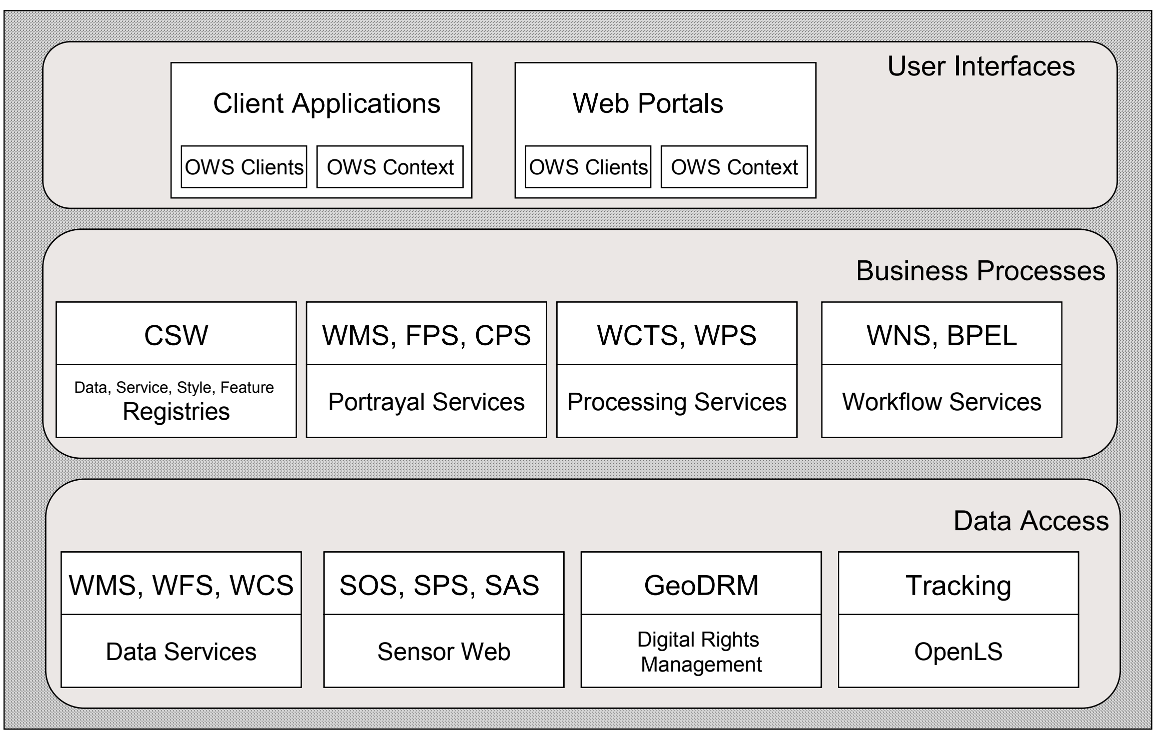

Figure 3 - OWS Service Framework

5.2.4 Publish-find-bind

The OWS Service Framework is based on the publish/find/bind pattern shown in Figure 4. This pattern enables dynamic binding between service providers and requestors. Dynamic binding is an essential capability for distributed environments where operational needs, sites and applications are frequently changing.

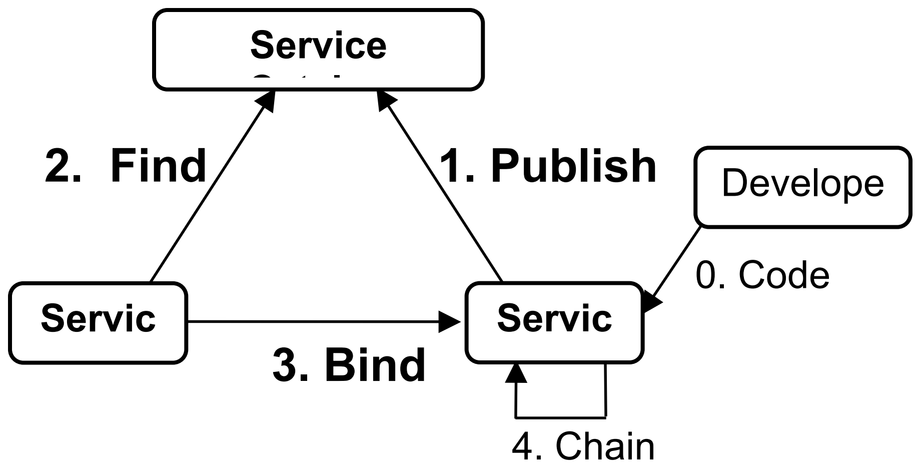

Figure 4 - Publish/Find/Bind Pattern

In Figure 4, there are three essential roles:

- **Service provider**: publishes services to a broker (registry) and delivers services to service requestors.

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

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

- **Bind**: used when a service requestor and a service provider negotiate, as appropriate, so the requestor can access and invoke services of the provider. A service requestor typically uses service metadata provided by the broker to bind to a service provider. The service requestor can either use a proxy generator to generate the code that can bind to the service, or can use the service description to manually implement the binding before accessing that service. Figure 4 also shows that services can be chained with various degrees of transparency to achieve larger tasks required by a service

5.2.5 Multi-platform implementation approach

Ensure discovery, access, dissemination and management of all GEOINT data stores through a web-enabled service-oriented-architecture. [Excerpt from NSG Statement of Strategic Intent]

A Distributed Computing Platform (DCP) is the collection of protocols, services and conventions that applications use to invoke remote operations. There have been many popular DCPs over the years including CORBA, DCOM and DCE. Each of these platforms have their strengths and weaknesses. Web Services must also be viewed as a DCP. Like the others, the web services model has its' strengths and weaknesses. There are applications for which web services are not appropriate. We can also expect that, with the development of new distributed computing technologies, web services will eventually become obsolete. Developers of interoperability standards must be prepared to deal with this continuous change in DCP implementing technology as well as the simultaneous fielding of multiple DCP implementations. The OGC addresses this problem by separating the business logic (conceptual specification) from the DCP specific implementation guidance (implementation specification).

In practice, COTS vendors have been able to use this model to develop applications that expose themselves over several DCPs simultaneously. They have also been able to rapidly add support for new DCPs since no changes to the application logic is required.

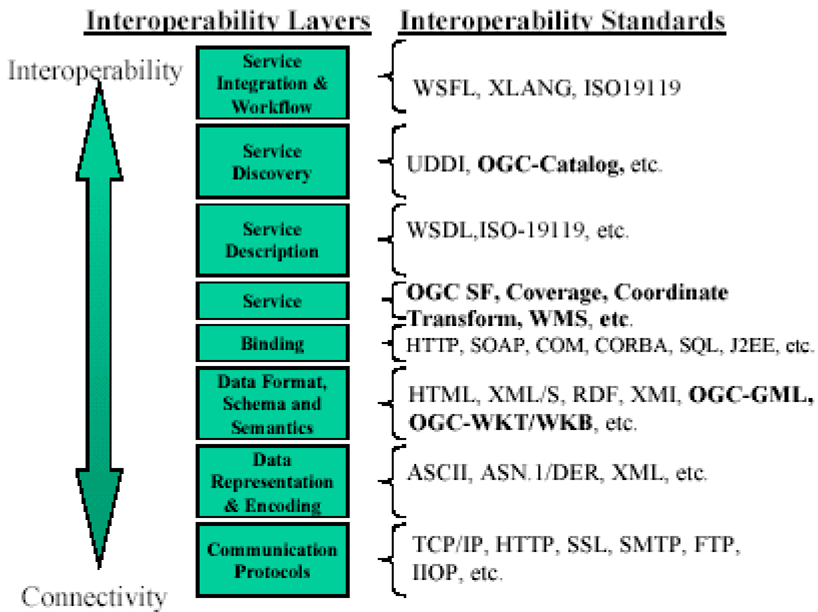

Figure 5 – Services Interoperability Stack

HTTP as Distributed Computing Platform

OGC has defined a suite of Web Service interfaces that have explicit bindings for HTTP. Specifically, there are two HTTP bindings for invoking operations of a service (i.e., Sending a message): GET and POST. Thus the Online Resource for each operation supported by a service instance is an HTTP Uniform Resource Locator (URL). Only the parameters comprising the service request itself are mandated by OGC Web Service Specifications for HTTP.

SOAP as an OGC Web Services Enabler

SOAP is an XML-based remote procedure call protocol that allows messages to be exchanged between different services. SOAP is used for the bind operation described above. Development of SOAP bindings for the existing OGC Web Service specifications is underway.

5.2.6 Multi-tiered architecture

Multi-tier architecture also known as n-tier architecture or sometimes n-tier computing refers to the number of logical levels or layers that the various components of an application occupy. Typical tiers include components for user presentation (GUI), presentation logic, business or application logic, data access, and data storage. Tiers can be physically located anywhere, including on a single computing platform (even in a single monolithic application). In single-platform applications the interaction between tiers is tightly coupled by the language the application is written in and/or the architecture of the host operating system. In net-centric, enterprise, Internet-based and Web-Service applications logical tiers are distributed physically across networks. In such distributed n-tier architectures interoperability between tiers is much more loosely coupled. Distributing tiers across several computing platforms presents several interoperability challenges managing interactions from tier to tier. Error handling, data exchange, and flow control are examples of transactions that can be more difficult as each tier may run on different operating systems, be written in multiple software languages, and communicate using several protocols. Technology-specific enterprise frameworks have been developed to address some of these challenges. Examples of these enterprise frameworks include J2EE or .NET, which address interoperability challenges of distributed computing by constraining options more narrowly around specific enterprise technologies. For example, J2EE is built around java-based technologies and .NET around Microsoft Windows.

The goal of OGC-based architectures is to provide interoperability beyond the technology viewpoint. This goal is accomplished by defining higher-level interface specifications that are independent of individual technical implementations. This approach helps meet the NSG's common vision for Geospatial Intelligence (see: Geospatial Intelligence Standards: Enabling a Common Vision http://www.nga.mil/NGASiteContent/StaticFiles/OCR/ncgis-eb.pdf). Distributed n-tier architectures have to address interoperability across tiers independent of technology if goals such as technology risk reduction, improved choice and competition in the marketplace, reduced technology costs, and the ability to rapidly insert new technology are to be achieved, (Ibid p.13).

In an earlier OpenGIS® best practices paper (OpenGIS® web services architecture description OGC 05-042r2), OGC has set out a web services architecture around OGC interfaces. This n-tier architecture shown in figure TBD defines three services types (or components) loosely arranged in four tiers, from Clients to Application Services to Processing Services to Information Management Services (but un-needed tiers can be bypassed.)

This Service Oriented Architecture is based on the fundamental roles of service provider and service consumer within a distributed computing system. This pattern emphasizes that desired computing can be realized by combining multiple services, for each of which only the service types (e.g., interfaces and abilities) and server data holdings (e.g. content) need be known. It focuses component definition on providing and/or consuming a defined service.

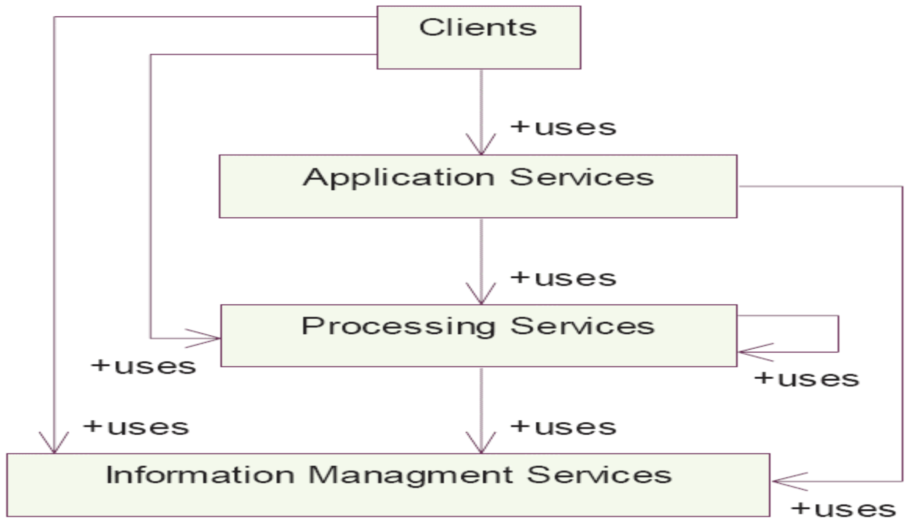

Figure 6 - Service tiers in OWS Architecture

As shown n the OWS Architecture service components are organized into multiple tiers.

1. All components provide services, to clients and/or other components, and each component is usually called a service (with multiple implementations) or a server (each implementation).
2. Services (or components) are loosely arranged in four tiers, from Clients to Application Services to Processing Services to Information Management Services, but un-needed tiers can be bypassed.
3. Services can use other services within the same tier, and this is common in the Processing Services tier.
4. Each tier of services has a general purpose, which is independent of geographic data and services.
5. Each tier of services includes multiple specific types of services, many of which are tailored to geographic data and services.

Information Management Services Tier

The Information Management Services tier contains services designed to store and provide access to data, with each server normally handling multiple separate datasets. In addition, metadata describing multiple datasets can be stored and searched. Access is usually to retrieve a client-specified subset of a stored dataset, or to retrieve selected metadata for all datasets whose metadata meets client-specified query constraints. (OGC 05-042r2 p 14.)

Examples of Information Management Services include:

Service Name	Service Description
Web Map Service (WMS)	Dynamically produces spatially referenced map of client-specified ground rectangle from one or more client-selected geographic datasets, returning pre-defined pictorial renderings of maps in an image or graphics format
Web Feature Service (WFS)	Retrieves features and feature collections stored that meet client-specified selection criteria. Must support GML for feature encoding
Web Coverage Service (WCS)	Retrieves client-specified subset of client-specified coverage (or image) data set.
Catalog Service for the Web (CSW)	Retrieves object metadata stored that meets client-specified query criteria
Gazetteer Service	Retrieves location geometries for client-specified geographic names
Universal Description, Discovery and Integration Service	Allows a client to find a web-based service

Table 1 - Information Management Services

Processing Services Tier

The Processing Services tier contains services designed to process data, sometimes both feature and image (coverage) data. The services in the Processing Services tier are used by clients and by services in the Application Services tier. These services can use other services in the Processing Services and Information Management Services tiers. (OGC 05-042r2 p 15-16.) There are many examples of Processing Services and exhaustive list is impossible to construct as news processing services are always being proposed and developed. Below are several examples.

SLD enabled Web Map Service (WMS): Dynamically produces spatially referenced maps from geographic feature and/or coverage data, returning client-specified pictorial renderings of maps in an image format (not actual feature data or coverage data)

Web Terrain Service (WTS): Dynamically produces client-specified perspective views from geographic feature and/or coverage data, returning client-specified pictorial renderings of data in an image or graphics format

Web 3D Service (W3DS): Dynamically produces client-specified perspective views from geographic feature data, returning perspectives of feature data in a graphical format

Web Coordinate Transformation Service (WCTS): Transforms the coordinates of feature or coverage data from one coordinate reference system (CRS) to another, including “transformations”, “conversions”, rectification, and orthorectification

Web Image Classification Service (WICS): Performs classification of digital images, using client-selected supervised or unsupervised image classification method

Feature Portrayal Service (FPS): Dynamically produces client-specified pictorial renderings in an image or graphics format of features and feature collections usually dynamically retrieved from a Web Feature Server (WFS)

Coverage Portrayal Service (CPS): Dynamically produces client-specified pictorial renderings in an image or graphics format of a coverage subset dynamically retrieved from a Web Coverage Service (WCS)

Topology Quality Assessment Service (TQAS): Execute logical domain constraints (semantic structure) consistency rules on features within a Web Services environment.

Web Processing Service (WPS): Provide services dynamic access across a network to pre-programmed calculations and/or computation models that operate on spatially referenced data. The calculation can be extremely simple or highly complex, with any number of data inputs and output Process P1 produces results R1-RN from input I1-Ii

Application Services Tier

The Application Services tier contains services designed to support Clients, especially thin client software such as web browsers. That is, these Application Services are designed for use by clients instead of each client directly performing these often-needed support functions. In “thicker” clients this tier is often contained within the application logic of the client and as a consequence concrete implementation specifications for most of these services have not yet been developed. The following, however are examples of a few of the types of services found in the application services tier.

- Web portal services: Services that allow a user to interact with multiple application services for different data types and purposes
- WMS application services: Services that allow a user to interact with a (WMS) to find, style, and get data of interest
- Gazetteer application services: Services that allow a user to interact with a Gazetteer service
- Geographic data discovery services: Services that allow a user to locate and browse metadata about geographic data, interacting with a catalog

- Geographic data extraction services: Services that allow a user to extract and edit feature data, interacting with images and feature data
- Geographic data management services: Services that allow a user to manage geospatial data input and retirement, interacting with Information Management Services
- Access control services: Services that control access to other servers, for privacy, intellectual property, and other reasons

Tying it all together: Service Interfaces

Components within and across tiers rely on service interface specifications to define the operations that characterize the behavior of the entity. OGC web service interfaces use open standards and are relatively simple. In addition to being well-specified, interoperable, and tested; the OGC-specified service interfaces are coarse-grained, providing only a few static operations per service. Several of these key service interfaces are included in the SDI 1.0 and are providing the foundation for NGA's interoperable net-centric environment.

5.2.7 Service oriented architecture

Build a responsive GEOINT IT infrastructure to promote transparency and information sharing in a multi-intelligence environment across the DoD and IC. Ensure discovery, access, dissemination and management of all GEOINT data stores through a web-enabled service-oriented-architecture. [Excerpt from NSG Statement of Strategic Intent]

Complementing the Real Time Infrastructure and executing on it will be an extensive suite of mission and corporate applications designed as interoperable elements of a **Service Oriented Architecture** (SOA). The SOA will draw upon services provided by other entities, entities both externally and within the NSG. It will also make available its defined services to those entities for incorporation in their respective mission activities. Developing an SOA as a subset to the overall enterprise architecture will serve as a key enabler for identifying and maximizing horizontal fusion opportunities and leverage economies of scale. It will allow for leveraging common line-of-business opportunities as well as creating efficiencies for overall IT services. To fully leverage the benefits of SOA, business managers must make it an integral part of IT management processes, including application development outsourcing, investment management and enterprise architecture. **Web services, a key element of an SOA,** promises to improve reuse of code and to enable **easier composition of new application functions** by drawing on established subsets of functionality available as services. By wrapping established applications in an interface, they can be turned into Web services whose functionality can then be leveraged by new applications and other users. The specific instantiations of the SOA are generally key IT elements supporting the other components of the OA and as such will be addressed as those components are added in future iterations of the ITSP.

Web services are self-describing, self-contained, modular units of software that define business functionality. Web services are consumable software services that typically include some combination of business logic and data. Web services can be aggregated to establish a larger workflow or business transaction. Inherently, the architectural components of web services support messaging, service descriptions, registries, and loosely coupled interoperability.

It's important to understand that SOA is a design pattern, not a specific technology. The particular technologies used and governance rules vary depending on the operating environment.

For example, the common practice of web-enabling the interfaces of existing applications can work well for a relatively small, centrally managed enterprise. For an environment like the GIG, however, such an approach will result in an overwhelming number of similar but incompatible services. Service consumers will have to code their clients for a limited selection of services, thus perpetuating the stovepipe model. This problem is further aggravated by the configuration management and security policies that govern DoD and IC systems. Once accredited, these systems cannot be modified. Therefore, DoD and IC systems can only use services that were known to the developer at the time the software was developed.

The OGC and ISO TC-211 have addressed this problem by creating a taxonomy of service interface types and rules for specializing those types as shown below. This approach provides developers with a finite number of well defined and tested interfaces to support. Service providers, in turn, are expected to implement their business logic behind one or more of those interfaces. As a result, the large scale many-to-many interactions that SOA promises become possible.

ISO 19119 Geographic services taxonomy:

- Geographic human interaction services
- Geographic model/information management services
- Geographic workflow/task management services
- Geographic processing services
    - Geographic processing services – spatial
    - Geographic processing services – thematic
    - Geographic processing services – temporal
    - Geographic processing services – metadata
- Geographic communication services
- Geographic system management services

Implementing technology, or Distributed Computing Platform (DCP), is also dependent on the operating environment. For example, GeoConnections Canada is a SOA implementation which integrates geospatial services across all of Canada. Due to the very loose coupling among the services and the budget constraints of the participating organizations, GeoConnections has opted for a simple HTTP get/put DCP. All service invocations are encoded using a URL with a set of key/value pairs representing the operation name and parameters. This approach has proven to be easy to implement and is easily adaptable to changes in the supporting technology.

For NGA and the GIG environment, a more complex approach is needed. While services in this environment are still loosely coupled, there are additional security, performance and reliability requirements. These requirements lead us to a SOAP based DCP. Effective July 2006, all future revisions of existing and new OWS interface specifications must include an optional SOAP messaging binding and the binding must be expressed in WSDL. While it is true that some OGC specifications do not currently have approved SOAP bindings, the separation of binding from service definition makes the development of SOAP bindings relatively straight forward. In fact, implementations of the draft OGC SOAP interfaces are available from some SCOTS vendors.

Applicable OGC Specifications:

- OGC Topic 12 which is also ISO 19119, Geographic Information Services. (02-112)

5.2.8 Information

Technology comes and goes but data lives forever.

The most valuable part of any IT enterprise is the data that has been accumulated. This value, however, depends on that data being sufficient, available, comprehensible and of acceptable quality. In other words:

- The data structures must be sufficiently rich to capture all of the information that users might need,
- There must be an easy way to find and access the data,
- Once accessed, the users' tools have to be able to process (understand) the data.
- Data being of acceptable quality may include a certain positional accuracy, a certain currency, a certain fitness for use.

Data sufficiency poses a problem, how do you know what information to include if you don't know who or how that data will be used? The OGC and ISO address this issue by approaching data definition from the producer perspective as opposed to the consumer. The question becomes not "what information do I need" but "what information can I provide". Data models are defined in terms of our ability to collect data regardless of how it my ultimately be used.

A producer focus can produce data models that are very complex. To manage this complexity, the OGC and ISO have developed a set of rules for creating Application Profiles of more complex data models. Application Profiles are tailored data models specific to a particular domain. To date application profiles have been created for several NGA data types. These are:

- Vector Product Format Level 0, 1 and 2.
- Local Mission Specific Data
- NSG Feature Catalog v 1.8
- DAFIF 9

Another consequence of the producer focus is that data models should not make any assumptions about how they will be used. In particular, data content is separated from the representation of that content. This runs counter to traditional geospatial products such as VPF. However, it is in line with current DoD data policy as documented in the DoD Data Strategy. It is also in line with the planned update of Common Warfighting Symbology (Mil-Std 2525).

5.3 OGC Web Services for NSG

5.3.1 OGC Web Map Service Overview

A Web Map Service (WMS) produces maps of spatially referenced data dynamically from geographic information. This International Standard defines a "map" to be a portrayal of geographic information as a digital image file suitable for display on a computer screen. A map is not the data itself. WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM) formats.

This International Standard defines three operations: one returns service-level metadata; another returns a map whose geographic and dimensional parameters are well-defined; and an optional third operation returns information about particular features shown on a map. Web Map Service operations can be invoked using a standard web browser by submitting requests in the form of Uniform Resource Locators (URLs). The content of such URLs depends on which operation is requested. In particular, when requesting a map the URL indicates what information is to be shown on the map, what portion of the Earth is to be mapped, the desired coordinate reference system, and the output image width and height. When two or more maps are produced with the same geographic parameters and output size, the results can be accurately overlaid to produce a composite map. The use of image formats that support transparent backgrounds (e.g., GIF or PNG) allows underlying maps to be visible. Furthermore, individual maps can be requested from different servers. The Web Map Service thus enables the creation of a network of distributed map servers from which clients can build customized maps.

This International Standard applies to a Web Map Service that publishes its ability to produce maps rather than its ability to access specific data holdings. A basic WMS classifies its geographic information holdings into "Layers" and offers a finite number of predefined "Styles" in which to display those layers. This International Standard supports only named Layers and Styles, and does not include a mechanism for user defined symbolization of feature data.

5.3.2 OGC Styled Layer Descriptor Overview

The ability for a human or machine client to define symbolization rules requires a styling language that the client and server can both understand. This styling language is called ***Symbology Encoding (SE*** [OGC 04-095](OGC 04-095)***)*** and it can be used to portray the output of Web Map Servers, Web Feature Servers and Web Coverage Servers.

Styling can be described using a user-defined XML encoding of a map's appearance called a Styled-Layer Descriptor (SLD). An SLD includes a **StyledLayerDescriptor** XML element that contains a sequence of styled-layer definitions. These styled-layer definitions may use named or user-defined layers and named or user-defined styling. The structuring of SLD **UserStyle**s into SE **FeatureTypeStyles/CoverageStyles** and **Rules** provides convenient packaging for this purpose, since rules identify each different kind of graphic symbolization that may be present in a map. Given the information in an SLD **UserStyle**, a map-viewer client could generate a legend entry for a layer.

There are two basic ways to style a data set. The simplest one is to color all features the same way. For example, one can imagine a layer advertised by a WMS as "hydrography" consisting of lines (rivers and streams) and polygons (lakes, ponds, oceans, etc.). A user might want to tell the server to color the insides of all polygons in a light blue, and color the boundaries of all polygons and all lines in a darker blue. This type of styling requires no knowledge of the attributes or "feature types" of the underlying data, only a language with which to describe these styles. This requirement is addressed by the `FeatureTypeStyle` element in the SE document.

A more complicated requirement is to style features of the data differently depending on some attribute. For example, in a roads data set, style highways with a three-pixel red line; style four-lane roads in a two-pixel black line; and style two-lane roads in a one-pixel black line. Accomplishing this requires the user to be able to find out what attribute of the data set represents the road type. SLD profile of WMS defines the operation that fulfils this need, called `DescribeLayer`. This operation returns the feature types of the layer or layers specified in the request, and the attributes can be discovered with the `DescribeFeatureType` operation of a WFS interface or the `DescribeCoverageType` of a WCS interface.

Three approaches are defined to allow a client to take advantage of SLD symbology:

a) The client interacts with the WMS using HTTP GET but the request can reference a remote SLD.

b) The client uses the HTTP GET method but includes the SLD XML document in-line with the GET request in an SLD_BODY CGI parameter (with appropriate character encoding).

c) The client interacts with the WMS using HTTP POST with the **GetMap** request encoded in XML , as described in section 9.2.3 and including an embedded SLD.

5.3.3 OGC Web Feature Service Overview

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, using HTTP as the distributed computing platform. Via these interfaces, a Web user or service can combine, use and manage geodata -- the feature information behind a map image -- from different sources.

The requirements for a Basic Web Feature Service are:

- The interfaces must be defined in XML.
- GML must be used to express features within the interface.
- At a minimum a WFS must be able to present features using GML.
- The predicate or filter language will be defined in XML and be derived from CQL as defined in the OpenGIS Catalog Interface Implementation Specification.
- 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.
- The use of a subset of XPath expressions for referencing

In addition to the Basic WFS there is an XLink WFS and WFS Transactional. An XLink WFS supports all the operations of a Basic WFS and in addition it implements the GetGmlObject operation for local and/or remote XLinks, and offers the option for the GetGmlObject operation to be performed during GetFeature operations. The result is that a WFS could service a request to retrieve element instances by traversing XLinks that refer to their XML IDs. In addition, the client may specify whether nested XLinks embedded in returned element data should also be retrieved.

Transactional WFS supports the Transactional operation. A transaction request is composed of operations that modify features; that is create, update, and delete operations on geographic features. Optionally, a transaction WFS could implement the GetGmlObject and/or LockFeature

5.3.4 OGC Web Coverage Service Overview

The Web Coverage Service (WCS) supports electronic retrieval of geospatial data as "coverages" – that is, digital geospatial information representing space-varying phenomena.

A WCS provides access to potentially detailed and rich sets of geospatial information, in forms that are useful for client-side rendering, multi-valued coverages, and input into scientific models and other clients. The WCS may be compared to the OGC Web Map Service (WMS) and the Web Feature Service (WFS); like them it allows clients to choose portions of a server's information holdings based on spatial constraints and other criteria. Unlike the WMS [OGC 04-024], which portrays spatial data to return static maps (rendered as pictures by the server), the Web Coverage Service provides available data together with their detailed descriptions; defines a rich syntax for requests against these data; and returns data with its original semantics (instead of pictures) which may be interpreted, extrapolated, etc. – and not just portrayed.

Unlike WFS, which returns discrete geospatial features, the Web Coverage Service returns coverages representing space-varying phenomena that relate a spatio-temporal domain to a (possibly multidimensional) range of properties.

A description of WCS and JPIP are provided in Section 5.5.3.

5.3.5 Catalog

- **Data Catalogs.** The regional data centers will each automatically maintain catalogs of the data and information they contain. When data searches are conducted, the queries will be responded to by data center catalog services and provide the requesters with all relevant information in response to the query. This information will include content parameters such as source and age of the data as well as management data such as when originally stored, last verified and last retrieved. Content metadata will convey the confidence level of data in terms of reliability, currency and accuracy.

A catalog is a database of information about geospatial resources (data, services, and related information objects) available to a group or community of users. A catalog typically stores descriptive information about the resource being described, and does not store the information resource itself. The interfaces on catalogs enable services that are collectively referred to as *Catalog Services* in OGC. We use the term "catalog" or "catalog services" to describe the set of service interfaces that support organization, discovery, and access of geospatial information. Catalog services help users or application software to find information that exists anywhere in a distributed computing environment. These resources function in this environment through interfaces that implement OpenGIS Specifications. Interaction with geospatial data collections via their metadata is done via catalog services. Catalog services are required to support the discovery and binding to registered information resources within an information community.

5.3.5.1 Catalog components

The OpenGIS Catalog Service Interface Specification enables diverse but conformant applications to perform discovery, browse and query operations against distributed and potentially heterogeneous catalog servers. The Catalog Interface specification uses metadata and spatial location to identify and select data sources of interest, and provides for interoperability in catalog update, maintenance, and other librarian functions.

The General Catalog Interface Model provides a set of abstract service interfaces that support the discovery, access, maintenance and organization of catalogs of geospatial information and related resources. The interfaces specified are intended to allow users or application software to find information that exists in multiple distributed computing environments, including the World Wide Web (WWW) environment. All behavior requiring sessions is expressed by a dynamic model of conversation state and state transitions. The model expresses the states and messages that trigger the changes in state.

An Application Profile is predicated on the existence of one protocol binding in the base specification. In the case of the Catalog Services Specification, a profile could reference CORBA, Z39.50, or HTTP protocol bindings. In most, but not all, protocol bindings, there may be restrictions or refinements on implementation of the General Model agreed within an implementation community.

Figure 7 - Catalog Reference Model Architecture, shows the Reference Architecture assumed for development of the OGC Catalog Interface. The architecture is a multi-tier arrangement of clients and servers. To provide a context, the architecture shows more than just catalog interfaces. The bold lines illustrate the scope of OGC Catalog and Features interfaces.

The Application Client shown in Figure 7 - Catalog Reference Model Architecture interfaces with the Catalog Service using the OGC Catalog Interface. The Catalog Service may draw on one of three sources to respond to the Catalog Service request: a Metadata Repository local to the Catalog Service, a Resource service, or another Catalog Service. The interface to the local Metadata Repository is internal to the Catalog Service. The interface to the Resource service can be a private or OGC Interface. The interface between Catalog Services is the OGC Catalog Interface. In this case, a Catalog Service is acting as both a client and server. Data returned from an OGC Catalog Service query is processed by the requesting Catalog Service to return the data appropriate to the original Catalog request.

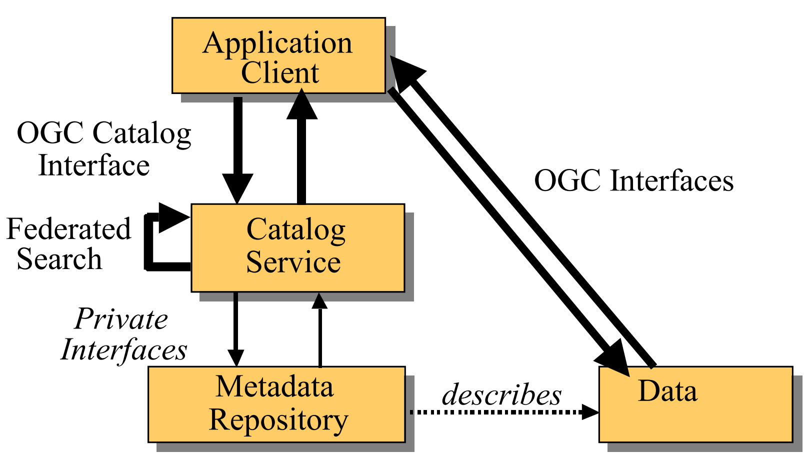

Figure 7 - Catalog Reference Model Architecture

Resources in a catalog are discovered using a filter. Queries can be temporally constrained using the standard scalar operators found in the Filter specification (PropertyIsBetween, PropertyIsEqualTo, etc ...). However, the Filter specification does not formally define temporal operators at the time; the operators like Inside, Overlaps, etc could be applied to temporal data to achieve this task.

Here is an example of a temporal query finding records modified between two specific dates that uses scalar operators to constrain the "modified" property:

```
<GetRecords
  xmlns="http://www.opengis.net/cat/csw"
  xmlns:rim="urn:oasis:names:tc:ebxml-regrep:rim:xsd:2.5"
  xmlns:ogc="http://www.opengis.net/ogc"
  outputFormat="text/xml; charset=UTF-8">
  <Query typeNames="rim:ExtrinsicObject">
    <Constraint>
      <ogc:Filter>
        <ogc:PropertyIsBetween>

<ogc:PropertyName>/rim:ExtrinsicObject/rim:Slot[@name="modified"]/rim:ValueList/ri
m:Value[1]</ogc:PropertyName>
          <ogc:LowerBoundary>
            <ogc:Literal>2005-05-24T08-00:00-05:00</ogc:Literal>
          </ogc:LowerBoundary>
          <ogc:UpperBoundary>
            <ogc:Literal>2005-05-24T08:30:00-05:00</ogc:Literal>
          </ogc:UpperBoundary>
        </ogc:PropertyIsBetween>
      </ogc:Filter>
    </Constraint>
  </Query>
</GetRecords>
```

5.3.5.2 Catalog as registry

Catalogs may be used to store information published as a result of a registration process. Such catalogs may reference and describe services, data types or schemas, semantic definitions, vocabularies, namespaces, or other common resources. The intrinsic features of a catalog service now include core registry functions, including:

- Life cycle management of metadata items (i.e. administrative status)
- Flexible classification of metadata items employing user-defined classification schemes (i.e. subject-based metadata)
- Asserting arbitrary relationships among metadata items (i.e. links or cross-references)
- Access control
- Change tracking (i.e. maintenance of audit trails)
- The discovery of resources pertaining to geospatial services and data requires ready access to several forms of metadata:

- Metadata that describes services, schemas, presentation rules, spatial reference systems, and other shared resources; Reference OGC GEOINT Structure Implementation Profile Schema Processing (07-028) for an example of DDMS 1.3 Metadata for GML.
- Content metadata that characterizes data sets and imagery resources through controlled and uncontrolled vocabularies;
- Links or associations between interdependent resources (or portions of resources);
- Annotations—perhaps transient—that are attached to a resource for a specific purpose or community of users.

A catalog that can accommodate all of these forms of metadata can be used to support a wide variety of discovery scenarios that involve multiple communities of practice.

5.3.5.3 Service publishing

A *service catalog, or service registry,* is a type of metadata catalog about service instances for use by software and human clients, published as a result of a registration process using pull (harvest) or push (registration API) techniques. A service catalog is thus an instance of an OGC Catalog with an administrative set of interfaces (e.g. add, update, delete) that permit registration of service metadata. Service catalogs can be global or private. Registration acts to *publish* the presence of a resource, providing for limited search and browsing and general "yellow pages" access. Formal *Web Service Registries* are implemented as catalogs of businesses, their services, and operations. Examples of public service catalog approaches include *ebXML*[i] and *UDDI*, with interface bindings available in various programming environments.

Any service-oriented architecture must support some fundamental interactions: registering service offers (publishing) and returning service offers upon request according to some criteria (finding). The service catalog provides interfaces for querying and managing a metadata repository. A catalog client is an application used to query the catalog or submit items to be registered.

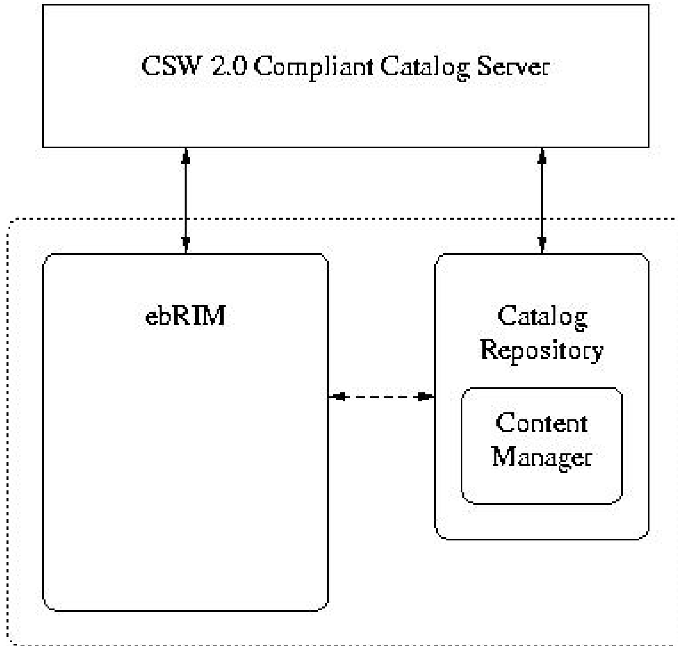

Figure 8 - Catalog ebRIM Model

A block diagram is presented that contains all the components of a catalog system: ebRIM model, CSW server, content repository and perhaps content manager.

The ebRIM Profile of the catalog server for the web provides a rich classification schema and user defined collection of classification nodes. This classification schema enables the creation of packages to logically organize objects such as heterogeneous collections of dataset descriptions, service offerings, application schemas, feature types, sensor description, and digital rights among others.

The OGC registry information model (ogcRIM) is based on the ebXML registry information model (ebRIM, v 2.1). A catalog service can be viewed as a type of management system that fulfills a basic repository function in open, distributed systems. Its core capabilities include:

- Provide persistent type information for use in service discovery;
- Facilitate dynamic (i.e. late or run-time) binding to service instances;
- Provide support for run-time type checking for safety;
- Be linked to—or federated with—other catalogs.

Every catalog instance implements an information model that provides a high-level schema that defines what types of objects are stored in the catalog and how they are organized. Prominent models within the web services realm include the UDDI data model as well as the ebXML registry information model (ebRIM). The APIs associated with both models support multiple query patterns: browse and drill-down (by category), or filtered queries against specified catalog objects. However, the ebRIM is more general and extensible—it draws on the ISO 11179 set of standards to provide comprehensive facilities for managing metadata.

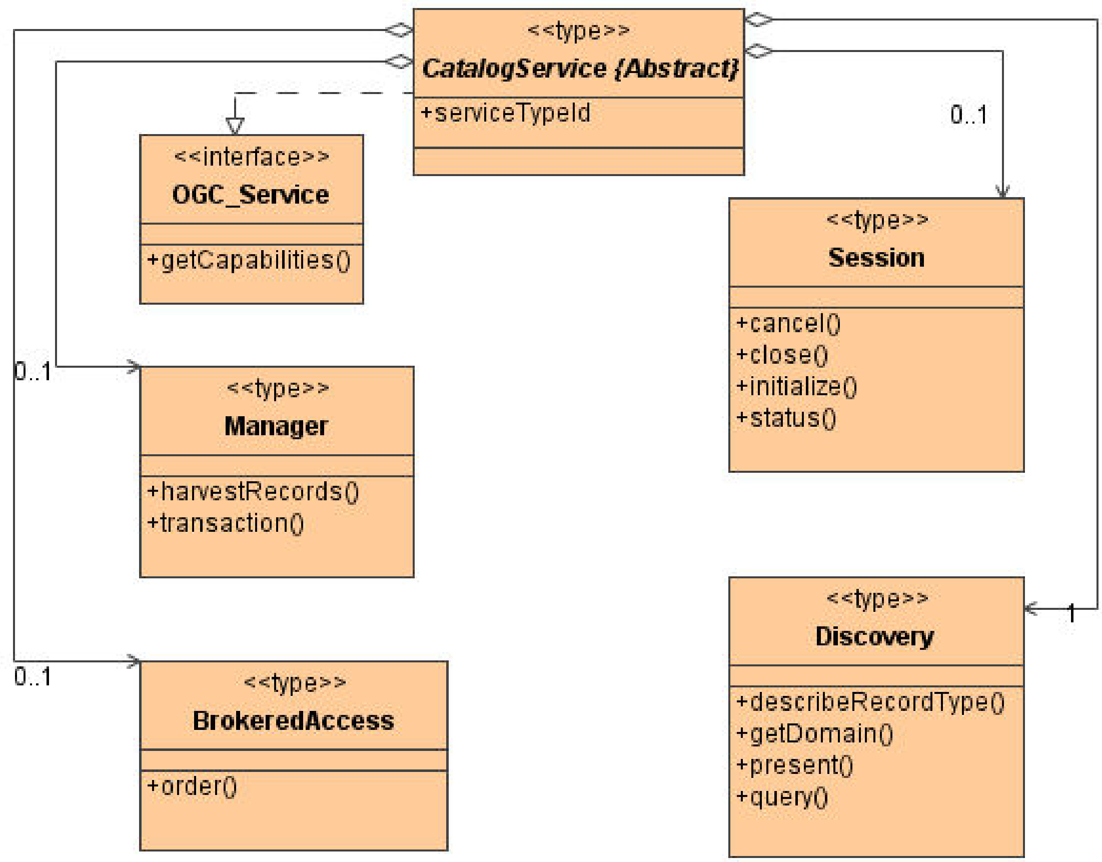

Figure 9 - Catalog Class Model

Above is a general UML model of OGC catalog service interfaces, in the form of a class diagram. This model shows the Catalog Service class plus five other classes with which that class is associated. A Catalog Service is a realization of an OGC Service. Each instance of the Catalog Service class is associated with two or more of these other classes, depending on the abilities included in that service instance. Each of these other classes defines one or several related operations that can be included in a Catalog Service class instance.

The OGC approach of using ebRIM as the metadata model for Catalogs provides an extensible approach for building registries of many types. Registries in the NSG are needed for datasets, services, feature catalogues, dictionaries, reports, pictures, etc. The ebRIM approach allows for the Catalog Service for the Web (CSW) to be extended to each of these additional registry types without major revision to the interface. In the past OGC has developed CSW profiles for specific items, e.g., CSW Profile for ISO 19115/19119 provides a CSW interface for datasets and services. As NSG has requirements for registries beyond just geospatial datasets and services, the best approach is to use the CSW-ebRIM Profile.

Applicable OGC Specifications and developments

- OGC Catalog (04-021)
- OWS-4 CSW ebRIM Modeling Guidelines IPR (06-155)
- EA-SIG Discovery White paper (04-086) focuses on the goals, objectives and recommendation for the Discovery Core Enterprise Service for the DoD.
- EA-SIG Mediation White paper (04-088) analyzes means to mediate incompatibilities between elements in the GIG enterprise.

5.3.6 Security and GeoDRM

All organizations have unique information assets that can contribute to the common relevant operational picture and support unified action. They also have unique information requirements. Sharing information with appropriately cleared participants and integration of information from all sources are essential. [Excerpt from Vision 2020]

Information assurance (IA) encompasses those capabilities that protect and defend information and information systems by ensuring their availability, integrity, authentication, confidentiality and continued operation. NSG information systems will operate in an increasingly complex and dynamic world as technologies, threats, and operational concepts evolve, and NSG organizations will operate with interconnected systems with multiple points of vulnerability. A risk assumed by anyone is a risk assumed by all. Many adversaries are seeking avenues for asymmetric force projection against the United States and its allies, and their strategies include attempts to disable, disrupt, or discredit information generation and management capabilities. These strategies may include passive monitoring of communications, active network attacks, direct attacks, exploitation of insiders, and attacks through industry information technology providers.

The domain is a fundamental concept for traditional approaches to information assurance. All enforcement of an organizations' security policy takes place within the domain. Systems and personnel within the domain are trusted, to a point. Systems and personnel outside of the domain are not trusted. Outside access to domain resources is only possible through a controlled interface (CI). Access is restricted to only those principals who can be trusted to comply with the security policy.

Use of OGC interfaces as part of the CI to a domain has been explored through several OGC initiatives, most notably the Critical Infrastructure Protection Initiative (CIPI). Under CIPI, OGC web services authenticated incoming users using DoD PKI certificates. A trusted path to the users' client was then established using an SSL session. Behind the interface, an X.509 based infrastructure supported the Identification & Authentication (I&A), policy enforcement and access control functions necessary to enforce a fine-grained discretionary access control security policy.

Under this model users only see a standards based interface. The actual data stores, network topology and even data structures are hidden behind the interface.

Additional work in the area includes the development of GeoXACML, a geospatially enabled version of XACML. (OGC - 05-036). Work on Security Assertions Markup Language (SAML) based PKI authentication has also been undertaken by OGC members, however progress through the OGC process requires the adoption of SOAP bindings. SAML makes use of statements which assert certain characteristics of a subject (claims), e.g. a subject's authentication, name and role. SAML can be used to encode qualified identity tokens and may be combined with XML-Signature. SAML is a very flexible XML based specification and can be used in a multitude of scenarios. One of the problems that it tries to solve is the Single Sign On problem and in this way it can be used for authentication in scenarios. Because it addresses Single Sign On, SAML is of course ideal for federation scenarios where users come from a different security domain than the one where the service provider is.

Under a net-centric model, mission applications make use of resources from anywhere on the network. Therefore, a significant portion of the processing will be done by services that the users' organization does not own. This sharing of resources requires that information travel extensively outside of the enclave. The information assurance model has to change from one of just protecting resources within the enclave to protecting resources as they travel around the network. The OGC is addressing this need by partnering with the developers of Digital Rights Management (DRM) standards.

The objective of DRM is to assure that only licensed holders of digital content can use that content and to control the ways in which the content is used. If we consider the license to be a security policy, the goals of DRM are complementary to those of Information Assurance. DRM will not provide the level of assurance needed to protect at the classification level (secret, TS, etc.) but may be sufficient for releasability caveats. OGC focus is how to Geo-enable these technologies and the ramifications of service chaining/orchestration on digital rights. By working with main-stream DRM efforts, the OGC has minimized the risk that their work is incompatible with the rest of the industry.

Applicable OGC Specifications and developments

- CICE Privilege Management IPR (OGC 03-077)
- OGC GeoDRM RM (OGC 06-004r4)
- GeoDRM Engineering Viewpoint and supporting Architecture (OGC 06 184)
- Trusted Geo Services IPR (06-107)

5.4 Sensor Web Enablement (SWE) for NSG

5.4.1 Introduction

A Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces (APIs). In much the same way that the HTML and HTTP standards enabled the exchange of information on the Web, the Open Geospatial Consortium's (OGC) Sensor Web Enablement (SWE) initiative is focused on standards that enable the discovery, exchange, and processing of sensor observations, as well as the tasking of sensor systems. These protocols are designed to work with a broad range of sensor types, ranging from in-situ sensors to space-borne sensors. The functionality that the OCG has included within SWE includes:

- **Discovery of sensors, observations, and processes** – to easily discover all sensor assets (sensor systems, simulations, and data processes) that are available for meeting users needs in a timely fashion; this is particularly important for facilitating situational awareness in dynamic environments.
- **Determination of a sensor's capabilities and an observation's reliability** – readily assess the capabilities of a sensor or simulation system, as well as provide sufficient lineage of an observation to determine its reliability for decision support
- **Access to parameters and processes that allow on-demand processing of observations** – provide the means to sufficiently support on-demand geolocation and processing of sensor observations by generic software, without the need for a priori knowledge of the sensor system
- **Retrieval of real-time or time-series observations in standard encodings** – to access and immediately utilize observations from newly discovered sensors within decision support tools, models, and simulations without needing to develop sensor-specific applications
- **Tasking of sensors and simulators to acquire observations of interest** – to task a sensor or simulation system, and to provide collection requirements, using a common interface; this interface supports tasking as simple as controlling a web cam, as well as something as sophisticated as a military surveillance asset
- **Subscription to and publishing of alerts based on sensor or simulation observations** - a means by which a sensor system or simulation can publish alerts to be issued by sensors or sensor services based upon certain criteria, and allow a user to subscribe to and receive these alerts when criteria are met; such criteria could be a simple as a measured value exceeding a certain threshold or as complex as pattern recognition within a single or multiple observations

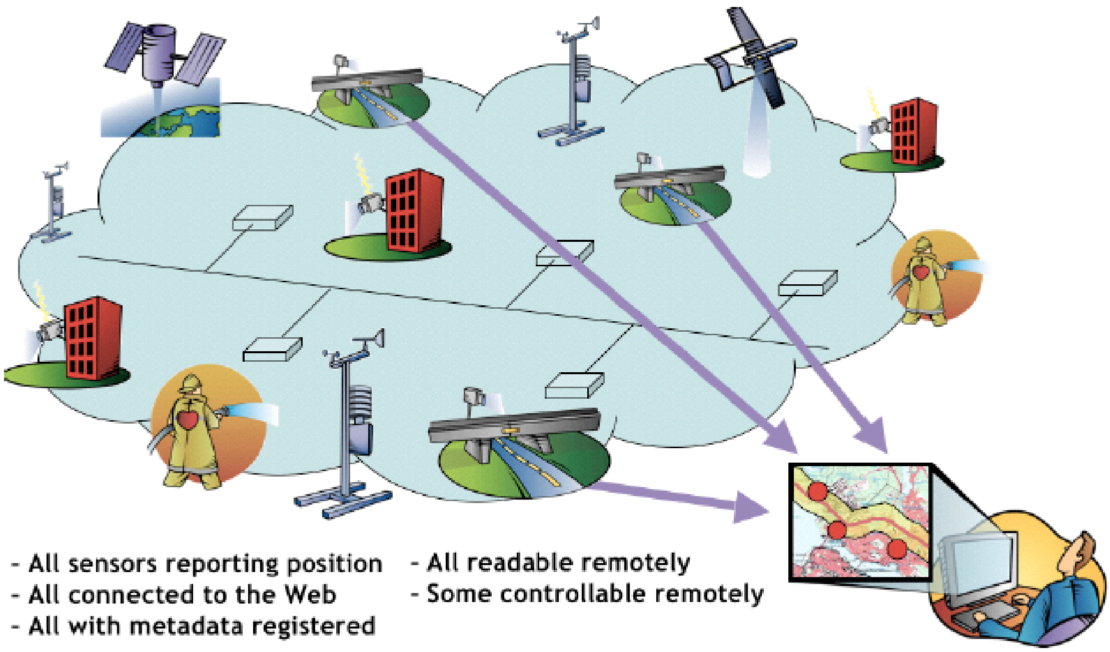

Figure 10 - Sensor Web Concept

Within the SWE initiative, the enablement of such sensor webs is being pursued through the establishment of several encodings for describing sensors and sensor observations, and through several standard interface definitions for web services. Sensor Web Enablement standards that have been built and prototyped by members of the OGC include the following OpenGIS Specifications:

1. **Sensor Model Language (SensorML)** – standard models and XML Schema for describing the processes within sensor and observation processing systems; provides information needed for discovery, georeferencing, and processing of observations, as well as tasking sensors and simulations.

2. **Observations & Measurements (O&M)** - The general models and XML encodings for observations and measurements made using sensors.

3. **Transducer Model Language (TML)** –XML encoding for supporting real-time streaming observations and tasking commands to and from sensor systems.

4. **Sensor Observation Service (SOS)** – An open interface for a service by which a client can obtain observations and sensor and platform descriptions from one or more sensors.

5. **Sensor Planning Service (SPS)** – An open interface for a service by which a client can 1) determine the feasibility of collecting data from one or more sensors or models and 2) submit collection requests to these sensors and configurable processes.

6. **Sensor Alert Service (SAS)** – An open interface for a web service for publishing of and subscribing to deliverable alerts from sensor or simulation systems.

7. **Web Notification Service (WNS)** – An open interface for a service by which a client may conduct asynchronous dialogues, or message interchanges, with one or more other services.

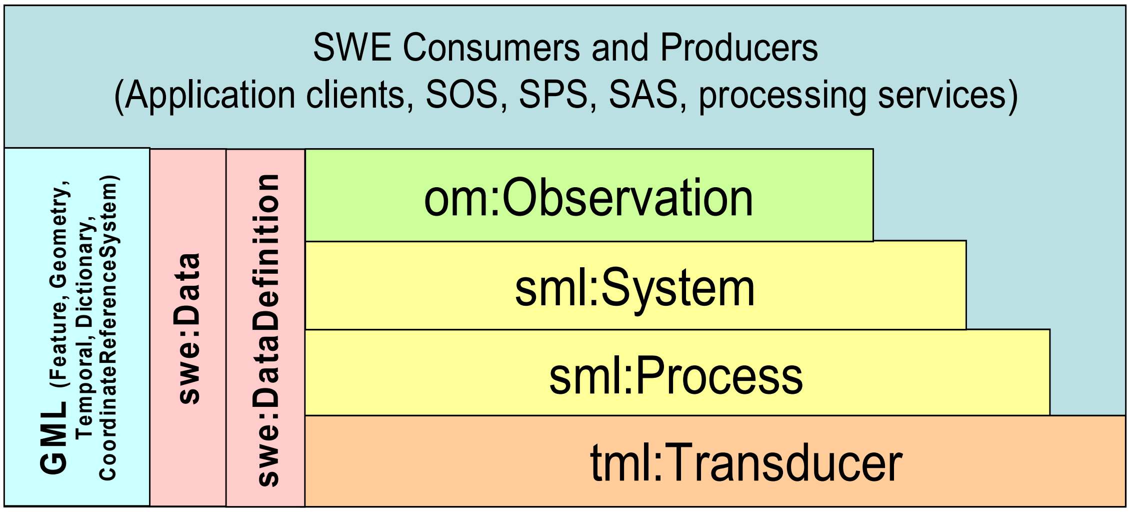

Figure 11 - SWE Information Models

The SWE standards infrastructure defined by these specifications constitutes a revolution in the discovery, assessment and control of live data sources and archived sensor data. The SWE architecture was designed to enable the creation of web-accessible sensor assets through common interfaces and encodings. Sensor assets may include the sensors themselves, observation archives, simulations, and observation processing algorithms. SWE not only enables interoperability among disparate networks of sensors and among disparate models and simulations, but it also enables increased interoperability between sensors and models, and between these and the decision support tools where the final application of observations occurs.

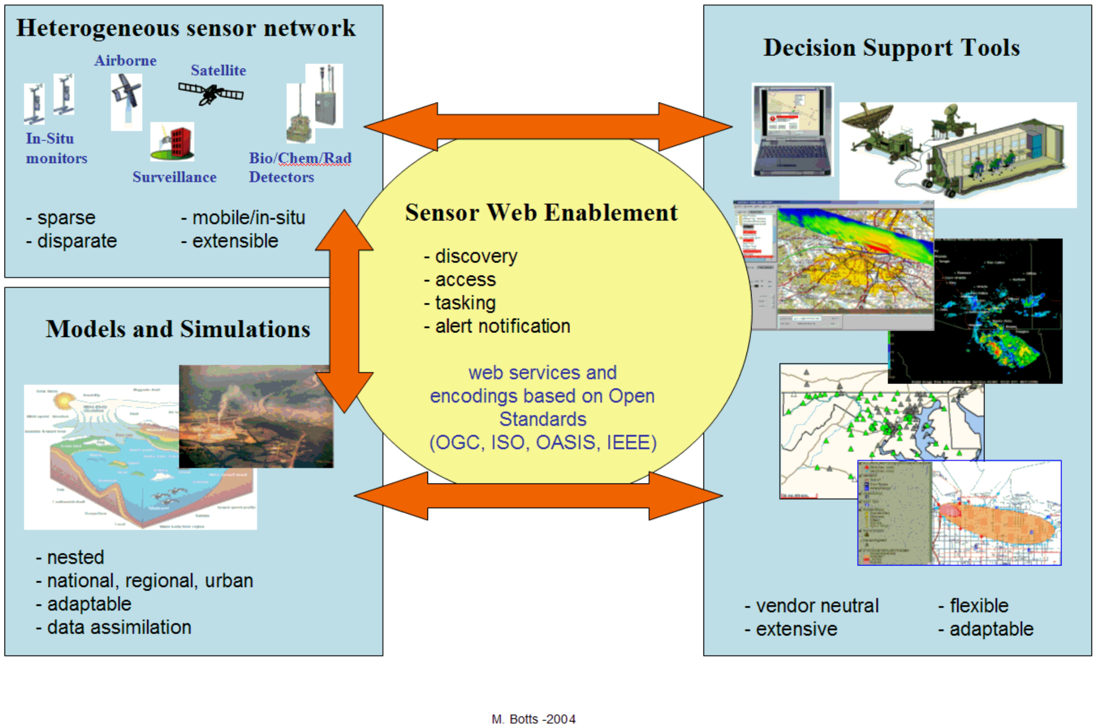

Figure 12 - OGC Sensor Web Enablement framework

The role of the OGC Sensor Web Enablement framework is to provide interoperability among disparate sensors and models, as well as to serve as an interoperable bridge between sensors, model and simulations, and decision support tools.

Integrate the collection and exploitation management of airborne, commercial, and advanced geospatial intelligence and satellite data. Accelerate the standardization of sensor data, metadata, compression formats and file identifiers. [Excerpt from NSG Statement of Strategic Intent]

It has long been recognized that the current state of sensor networks are developed around different communities of sensor types and user types, with each community typically relying on its own stovepipe system for discovery, accessing observations, receiving alerts, and tasking sensor systems and models. Even within fairly coherent communities, each type of sensor tends to be accompanied by its on metadata semantics, its own data formats, and its own software.

Within such stovepipe systems, the ability to discover and utilize a new sensor asset is typically hindered by incompatible encodings and services. Additionally, readily available information regarding the sensor system, the observation encodings, processing, and supporting services is typically lacking, scattered, or incomplete. Within these systems, adding support for a new sensor asset to an existing decision support tool or processing operation takes at best several days, and at worst many months or years, accompanied by high expense.

5.4.2 Sensor Model Language (SensorML) [OGC 05-086r2]

The measurement of phenomena that results in an observation consists of a series of processes, beginning with the processes of sampling and detecting and followed perhaps by processes of data manipulation. The division between measurement and "post-processing" has become blurred with the introduction of more complex and intelligent sensors, as well as the application of more on-board processing of observations. The typical Global Positioning System (GPS) sensor is a prime example of a device that consists of basic detectors complemented by a series of complex processes that result in the observations of position, heading, and velocity.

SensorML defines models and XML Schema for describing any process, including measurement by a sensor system, as well as post-measurement processing. SensorML supports a variety of needs within the sensor community, including:

Discovery of sensor, sensor systems, and processes - SensorML is a means by which sensor systems or processes can make themselves known and discoverable. SensorML provides a rich collection of metadata that can be mined and used for discovery of sensor systems and observation processes.

On-demand processing of Observations - Process chains for geolocation or higher-level processing of observations can be described in SensorML, discovered and distributed over the web, and executed on-demand without a priori knowledge of the sensor or processor characteristics.

Lineage of Observations - SensorML can provide a complete and unambiguous description of the lineage of an observation. In other words, it can describe in detail the process by which an observation came to be, from acquisition by one or more detectors to processing and perhaps even interpretation by an analyst. Not only can this provide a confidence level with regard to an observation, in most cases, part or all of the process could be repeated, perhaps with some modifications to the process or by simulating the observation with a known signature source.

Support for tasking, observation, and alert services - SensorML descriptions of sensor systems or simulations can be mined in support of establishing OGC Sensor Observation Services (SOS), Sensor Planning Services (SPS), and Sensor Alert Services (SAS). SensorML defines and builds on common data definitions that are used throughout the OGC Sensor Web Enablement (SWE) framework.

Plug-N-Play, auto-configuring, and autonomous sensor networks - SensorML enables the development of plug-n-play sensors, simulations, and processes, which seamlessly be added to Decision Support systems. The self-describing characteristic of SensorML-enabled sensors and processes also supports the development of auto-configuring sensor networks, as well as the development of autonomous sensor networks in which sensors can publish alerts and tasks to which other sensors can subscribe and react.

Archiving of Sensor Parameters - Finally, SensorML provides a mechanism for archiving fundamental parameters and assumptions regarding sensors and processes, so that observations from these systems can still be reprocessed and improved long after the origin mission has ended. This is proving to be critical for long-range applications such as global change monitoring and modeling.

Within SensorML, everything including detectors, actuators, filters, and operators are defined as process models. A *ProcessModel* defines the *inputs*, *outputs*, *parameters*, and *method* for that process, as well as a collection of metadata useful for discovery and human assistance. The inputs, outputs, and parameters are all defined using SWE Common data types. Process metadata includes identifiers, classifiers, constraints (time, legal, and security), capabilities, characteristics, contacts, and references, in addition to inputs, outputs, parameters, and system location.

These individual processes, as well as data sources, can the linked within a *ProcessChain* such that one can describe either the process by which an observation was derived (i.e. its lineage) or a process by which additional information can be derived from an existing observation. The SensorML *System* allows one to relate one or more processes to the "real world" by allowing one to specify relative locations and data interfaces.

SensorML is currently an OGC Implementation Specification version 1.0, document number 05-086r2.

5.4.3 Observations and Measurements (O&M) [OGC 05-087r4]

The O&M specification provides a standard XML-based package for returning observation results. Using a standard package in which to download observations from an SOS alleviates the need to support a wide range of sensor-specific and community-specific data formats. The O&M *Observation* provides a standard that combines the flexibility and extensibility provided by XML with an efficient means to package large amounts of data as ASCII or binary blocks.

As defined within the O&M specification, an *Observation* is an event with a result which has a value describing some phenomenon. The observation is modeled as a Feature within the context of the ISO/OGC Feature Model. An observation feature binds the result to the feature of interest, upon which it was made. An observation uses a procedure to determine the value, which may involve a sensor or observer, analytical procedure, simulation or other numerical process. This procedure would typically be described as a process within SensorML. The observation pattern and feature is primarily useful for capturing metadata associated with data capture.

The O&M specification allows for extension of the *Observation* object to support various styles of providing observation result values. This is an area of current research to define styles that adequately and efficiently support both simple and complex results, as well as perhaps legacy formats and out-of-band data.

As of December 2006, the O&M Specification OGC 05-87r4 has been approved for release as a Draft Implementation Specification with the intent to immediately begin the RFC process toward final approval as an OGC Technical Specification.

5.4.4 SWE Common [OGC 05-086r2; OGC 05-087r2]

There are several common core definitions used throughout the SWE framework that have been pulled from other SWE specifications, such as O&M and SensorML, and have been placed within the SWE Common namespace. These are currently not defined within a separate document, but rather are defined within SensorML or O&M specification documents. Future releases may separate SWE Common definitions into a separate document. The SWE Common data definitions are used throughout the SWE framework to provide a “common” means to specify expected or observed data components. The common definitions for data components, encoding, and phenomenon are currently used throughout every SWE component with the exception of TML. This issue has been identified as area requiring future harmonization work with SensorML and will be address in future efforts.

5.4.5 Transducer Model Language (TML) [OGC 06-010r5]

Transducer Markup Language (TML) is a method and message format for describing information about transducers and transducer systems and capturing, exchanging, and archiving live, historical and future data received and produced by them. A transducer is a superset of sensors and actuators. TML provides a mechanism to efficiently and effectively capture, transport and archive transducer data, in a common form, regardless of the original source. Having a common data language for transducers enables a TML process and control system to exchange command (control data) and status (sensor data) information with a transducer system incorporating TML technology. TML utilizes XML for the capture and exchange of data.

TML was designed with the express goal of facilitating the development of a “Common” Transducer Processing/Control machine while also facilitating interoperable machine-to-machine communications. For the purposes of data fusion and post analysis, it is paramount to preserve raw transducer data in as close a manner to the original form as possible. Although data would be ideally preserved in its raw format, it is impossible in some cases to do so. TML provides facilities to capture data at any stage, from raw production, to partially processed, to final data forms. Greater benefits of TML are realized the closer to the source raw data one gets.

Transducer Markup Language (TML) defines:

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

Sensor data is often an artifact of the sensor’s internal processing rather than a true record of phenomena state. The effects of this processing on sensed phenomena are hardware-based and can be characterized as functions.

TML response models are formalized XML descriptions of these 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. The TML cluster is a terse XML envelope designed for efficient transport of live multiplex sensor data. It also provides a mechanism for temporal correlation to other transducer data.

In March 2007, the TML specification document OGC 06-010r5 expected to be approved as an Implementation Specification.

5.4.6 Sensor Observation Service (SOS) [OGC 06-009r2]

The goal of SOS is to provide access to observations from sensors and sensor systems in a standard way that is consistent for all sensor systems including remote, in-situ, fixed, airborne, space-borne and other mobile sensors. This is a challenging task because the users of sensor data have historically been divided into those who primarily deal with in-situ sensors and those who primarily deal with remote sensors. The terminology, perspective, and expectations of these two broad groups are different. SOS leverages the Observation and Measurements (O&M) specification for modeling sensor observations and the SensorML specification for modeling sensors and sensor systems.

An SOS organizes collections of related sensor system observations into Observation Offerings. An Observation Offering is analogous to a "layer" in Web Map Service because each offering is intended to be a non-overlapping group of related observations. Each Observation Offering is constrained by a number of parameters including the following:

- Specific sensor systems that report the observations,
- Time period(s) for which observations may be requested (supports historical data),
- Phenomena that are being sensed,
- Geographical region that contains the sensors, and
- Geographical region that is the subject of the sensor observations (may differ from the sensor region for remote sensors)

The approach that has been taken in the development of SOS, and the SWE specifications on which it depends, is to carefully model sensors, sensor systems, and observations in such a way that the model covers all varieties of sensors and supports the requirements of all users of sensor data. This is in contrast to the approach that was taken with the Web Feature Service (WFS). WFS provides a generic definition of a geographic feature that is flexible enough to encompass any real-world entity. The WFS uses GML application schemas to define the specific properties of each type of feature. With this approach, interoperability requires organizations to agree on domain-specific GML application schemas. Clients that access a WFS in a particular domain must have a-priori knowledge of the application schemas used in that domain. The SOS approach defines a common model for all sensors, sensor systems and their observations. This model is not domain-specific and can be used without a-priori knowledge of domain-specific application schemas. In May 2007, the SOS specification document OGC 06-009r2 is expected to be approved as an Implementation Specification.

5.4.7 Sensor Alert Service (SAS) [OGC 06-028r3]

The SAS can be compared with an event notification system. An SAS might therefore provide a wide variety of alerts related to sensors and sensor observations including, as examples, measured values above a threshold, detected motion or the presence of a recognizable feature, or perhaps sensor status (e.g. low battery, shutdown or startup).

An SAS can *advertise* what alerts it can provide. A consumer (interested party) may *subscribe* to alerts disseminated by the SAS. If an event occurs the SAS will *publish* an alert and *notify* all clients subscribed to this event type through a messaging service, such as WNS.

The SAS specifies an interface that allows measurement or processing systems to advertise and publish observational data or its describing metadata respectively. It is important to emphasize that the SAS itself acts rather like a registry than an event notification system. A messaging server (which can be on the same server as the SAS or separate) is indeed responsible for issuing alerts.

Traditional OGC web services are not suitable for implementing this alert service. Instead of regular request/response protocols such as HTTP, the XMPP protocol is widely used, but it is important to emphasize that the SAS specification is agnostic regarding the alert protocol used.

The SAS specification has been developed under an Interoperability Experiment. The current SAS specification document OGC 06-028r3 is published as a Draft Interoperability Program Report.

5.4.8 Sensor Planning Service (SPS) [OGC 05-089r3]

The Sensor Planning Service (SPS) is intended to provide a standard interface to collection assets (i.e., sensors, and other information gathering assets) and to the support systems that surround them. Not only must different kinds of assets with differing capabilities be supported, but also different kinds of request processing systems, which may or may not provide access to the different stages of planning, scheduling, tasking, collection, processing, archiving, and distribution of requests and the resulting observation data and information that is the result of the requests. The SPS is designed to be flexible enough to handle such a wide variety of configurations. The SPS interface supports operations needed to determine the feasibility of a collection request, submit a collection request, determine the status of a collection request, cancel a collection request and change the parameters of a previously submitted request. The SPS interface also exposes the operations necessary to discover the schema associated with the other operations. The SPS is used in conjunction with the WNS and SOS. When a user submits a collection request they must provide a notification target or WNS. Once the collection has occurred a notification will be sent to the notification target. The user would then use a SOS to retrieve the results.

In May 2007, the SPS specification document OGC 05-089r3 is expected to be released as an Implementation Specification.

5.4.9 Web Notification Service (WNS) [OGC 06-095]

As services become more complex, basic request-response mechanisms need to contend with delays/failures. For example, mid-term or long-term transactions demand functions to support asynchronous communications between a user and the corresponding service, or between two services, respectively. A Web Notification Service (WNS) is required to fulfill these needs within the SWE framework.

The WNS Model includes two different kinds of notifications. First, the “one-way-communication” provides the user with information without expecting a response. Second, the “two-way-communication” provides the user with information and expects some kind of asynchronous response. This differentiation implies the differences between simple and sophisticated WNS. A simple WNS provides the capability to notify a user and/or service that a specific event occurred. In addition, the latter is able to receive a response from the user.

The basis on which notifications will be sent is defined by the service and will be described in its capabilities. The “way-of-notification” palette may include:

- e-mail
- HTTP POST: in case of sophisticated clients that act as web services themselves
- SMS
- Instant Message
- phone call
- letter
- fax

Once a client registers itself, along with the method of notification desired, the client receives a unique RegistrationID that can then be provided as input to other services (e.g. SPS or SAS).

The WNS specification document OGC 06-095 was approved for release as an OGC Best Practices Paper in December 2006.

5.4.10 Sensor Web Registry

A Sensor Web Registry is implemented using an OGC Catalog Service backed up by an ebRIM/ebXML engine. This service provides discovery capability throughout the whole sensor web infrastructure. Typical requests to this service are ‘GetRecords’ operations containing filtering parameters used to search a database for one or more matching objects of interest. These objects include SWE services (as well as other OGC services), sensor descriptions, process chains and dictionary entries such as phenomena or units, etc.

In order to be able to insert objects to a Catalog, each object type must be defined by a schema and a CSW harvest profile. This profile shall define what information needs to be parsed out of the object XML and advertised as searchable content.

The following table shows what data can be mined from different XML documents used through the SWE framework:

Document Name	Searchable Sections/Tags
SOS Capabilities	OWS common section (like any other service) For each observation in the offering list: - observation id, name and description - observed property (association with O&M phenomenon object) - procedure id (association with SensorML sensor object) - feature of interest (association with GML feature) - time range - location (if fixed) - format
SPS Capabilities	OWS common section (like any other service) For each sensor system in the offering list: - phenomenon urn (association with O&M phenomenon object) - sensor id (association with SensorML sensor object) - area of service
SAS Capabilities	OWS common section (like any other service) For each subscription in the offering list: - alert id, name and description - observed property (association with O&M phenomenon object) - procedure id (association with SensorML sensor object) - feature of interest (association with GML feature) - time range - location (if fixed) - format
SensorML Sensor, System and Process	Most information is contained in the metadata group - description - identifiers - classifiers - time, legal and security constraints - characteristics - capabilities - contacts - inputs and outputs (association with O&M phenomenon) - taskable parameters (association with O&M phenomenon) ➔ eventually recurse for each sub components
O&M Phenomena	A phenomenon is intended to be a pure dictionary entry, so it should be parsed in its entirety, including: - description - name - base phenomenon (association with other O&M phenomenon) - constraint phenomenon (association with other O&M phenomenon) - constraint value - component if composite (association with other O&M phenomenon)

Table 2 - SWE Framework Data Elements

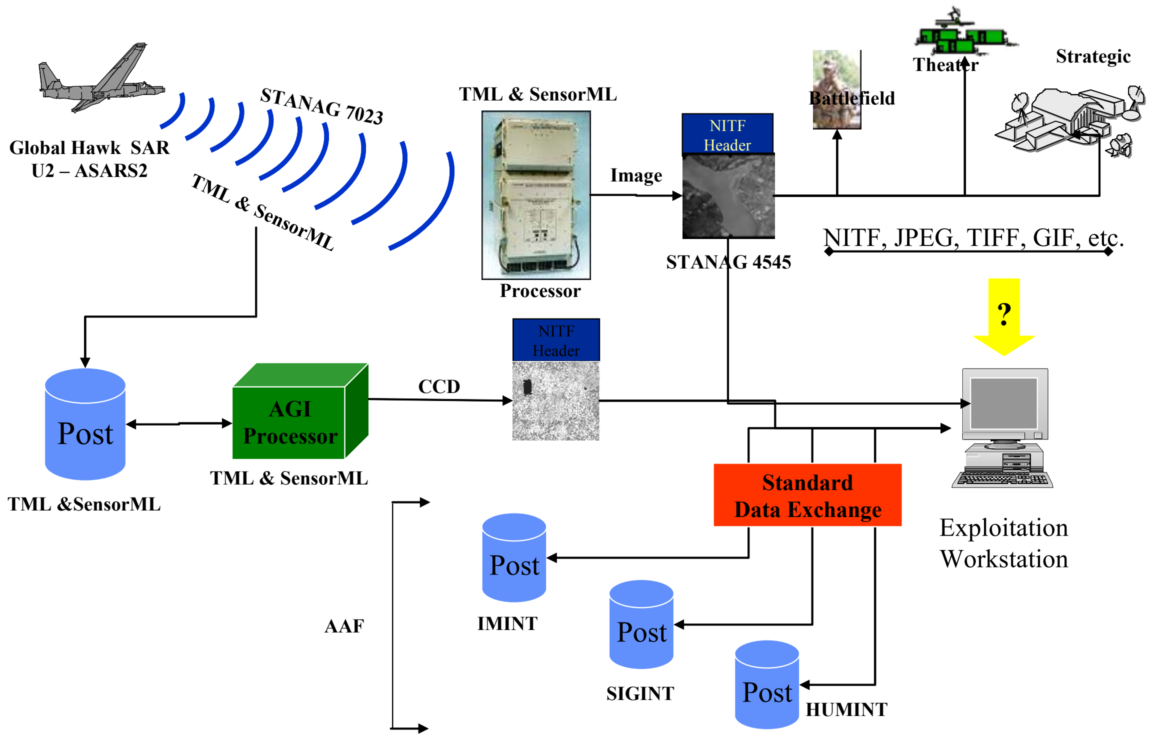

Figure 13 - Notional Standard Driven Architecture

SWE components depend on and extend core elements defined by the OGC's GML conceptual model and schema. All components of the SWE Information Model, including the top-most application layer, use these common components. The *swe:DataDefinition* and *swe:Data* components, defined in the SWE Common schema, specify common ways in which data values are described, encoded and used as process inputs, parameters and observation results. SensorML, O&M, SOS and SPS also use other GML elements such as *gml:EngineeringCRS*, *gml:FeatureType* and *gml:Location*.

5.4.11 Applicability to NSG

The SWE specifications are well suited for enabling efficient information collection, acquisition and management with in the NSG. SPS can serve as a standard interface that facilitates the optimization of available collection resources against user defined collection tasks. This is accomplished by having collection request submitted through a common SPS that can act as a central or distributed interface. This common interface allows request to be submitted, managed and scheduled in a regular manner regardless of the underling platform or sensor system. The service based interoperability provided by SPS supports fulfilling users' temporal and spatial needs by synchronizing Multi-INT collection activities with DoD elements and other national security community components. This common interface also supports the coordination of collection capability planning by providing a standard means to assess the feasibility of a request and submit a request. A cascading SPS can be implemented to manage tasking and planning of multiple systems.

SOS and SAS provide a common means by which different domains, service branches and agencies can provide notification of data availability and data access. This enables the leveraging of GEOINT data collection across a wider community (operational forces, homeland security and other operations). The SAS interface allows users to create standing queries in a platform independent way that can be federated across multiple systems. SOS provides a specialized interface which enables access to sensor data once it becomes available. These two interfaces used together constitute an interoperable data notification and data access tier that can facilitate inter-system data sharing and improve collection system responsiveness.

SWE provides an efficient means to incorporated foreign, commercial or partner sensor data into the NSG. Any system implementing the SWE standards can be accessed without the need for application customization. Provided that the necessary interfaces are provided by participating organizations, external data sources and sensors can be accessed using the same SWE interfaces. This means that an organization could use the same interfaces to access external and internal sensor resources. This would improve the efficiency of an organization by avoiding constrained vertical systems with ill defined and/or proprietary interfaces. SWE's focus on interoperability allows new sensors and sensor systems to be easily integrated into existing SWE compliant systems.

The broad range of capabilities defined in SWE enables a degree of automation. An in-situ sensor observation with a reading above a predefined threshold could act as an event that initiates the tasking of a sensor that can assist in collecting more detailed data. This process could enable automated cross-queuing or machine-driven tasking through the use of SOS, SAS, SensorML chain and SPS. SWE could also be used to enable other predictive, dynamic, integrated, and persistent sensor capabilities across the NSG,

SWE's sensor model is sophisticated enough to support encoding of all the parameters necessary for characterizing complex imaging devices such as those on orbiting earth imaging platforms. ISO and OGC have cooperated to develop two ISO standards that are relevant to the SWE effort: ISO 19130 Geographic Information – Sensor and Data Model for Imagery and Gridded Data and ISO 19101-2 Geographic Information – Reference Model – Imagery (OGC abstract Specification, Topic 7). OGC's SWE specifications will be key parts of an integrated framework for discovering and interacting with Web-accessible sensors and for assembling and utilizing sensor networks on the Web.

5.5 GeoProcessing Workflow (GPW) for the NSG

The OGC community has accumulated a significant body of knowledge in designing, building and operating Web Services. The full potential of Web Services as an integration framework will be achieved only when applications and business processes are able to integrate their complex interactions by using a standard process integration approach. The OASIS Business Process Execution Language for Web Services (BPEL-WS or BPEL) formally describes a business process that will take place across Web Services in such a way that any cooperating entity can perform one or more steps in the process the same way. OGC's Geo-Processing Workflow (GPW) activities develop and demonstrate how to interconnect geoprocesses through publish-find-bind and the use of BPEL to meet workflow requirements, resulting in the creation of valued-added enterprise systems that demonstrate the power of interoperability and service-oriented architectures.

Earlier OWS activities started investigating geo-processing workflows, in particular the OWS-2 Common Architecture work used BPEL and WSDL to implement, test and demonstrate OGC Web Services for Image Handling and Decision Support; there, initiative participants were able to chain several services using the Oracle BPEL product. It was recognized in the subsequent initiative (OWS-3) that workflows were not fully engaged. Therefore, there was a desire to focus on workflows in OWS-4, and in particular coordinate with specific thematic topics. Further, it was recognized that modifications to existing specifications as well as creation of new specifications might be needed to support robust and extensible service chaining. For example, many OGC services logically fit at the end of a service chain where operations such as getMap, and getFeature return the results of a geospatial process. Support for transactions, portrayal and additional processing services are needed to create more comprehensive and robust process chains. In OWS-4, transactional capability was added to the WCS and explored further with the WFS. Support for temporal data was investigated in both the WCS and WFS. Finally new processing services were built by wrapping an existing image handling toolkit behind a Web Processing Service (WPS).

As part of the workflow activities it was also necessary to develop GML application schemas for the NGA data products to be used in the OWS.

5.5.1 GML application schemas

Ease of Moving Data. To support the need for greater timeliness, readiness and accessibility of data for analysts and customers, as well as to support collaboration, the NSG community will require a robust net-centric environment that capitalizes on the capabilities afforded by evolving e-business technologies. Future technologies, greater network speed and flexibility, and improved network security will enhance analytic information generation and secure data sharing across security domains. Community-funded networks will link, and **web services** will act upon, GEOINT data that is organized for community-wide access and sharing, using **community-vetted data models and standards**.

Applicable OGC Specifications and developments

- GML 3.2.1 (OGC 07-036)
- GML 3.2 (OGC 05-108r1)
- GML 3.1 (OGC 03-105)
- AIXM Mapping IPR (OGC 07-029)
- Application Schema Tailoring and Maintenance Discussion Paper (OGC 05-117)
- Image Geopositioning Metadata GML Application Schema (OGC 06-055r2)

Discussion of applying OGC specifications to meet NSG objectives

Application schemas based on OGC's Geography Markup Language Version 3.2 (GML3) were developed as part of OWS-4 to test the feasibility of GML3 to encode NGA data and serve as a standards-based vector data transfer format. This work built upon earlier OWS efforts that utilized GML2 application schemas and data instances.

This section describes the development of GML3 and UML application schemas to support the NSG Feature Catalog (NSG FC), NGA's Mission Specific Data (MSD) as well as NGA's Aeronautical data content to support Vertical Obstructions (VOs), Stereo Airfield Collection (SAC) and Digital Aeronautical Flight Information File (DAFIF) data.

Note: The term NSG Feature Catalog (NSG FC) was originally used to denote the source of the information that fed into the application schema development process. The NSG FC contains much more information than is described in ISO 19110, and therefore the use of the term was not appropriate in the context of application schema development process. The term "GEOINT Structure Implementation Profile" (GSIP) will be used when referring to the inputs of the schema development process. The term NSG FC will only be use when actual Feature Catalog is referenced.

Mapping an ISO 19100 UML Application Schema to a GML Application Schema
Various OWS activities have lead into the development and refinement of the XMI-based UML-to-GML-Application-Schema (UGAS) conversion tool "ShapeChange." (see: http://www.ogcnetwork.net/ugas). The tool has been updated several times through experience in OWS-2 and OWS-3 initiative. Most recently in OWS-4 the tool was upgraded to support GML 3.2 application schemas. The process is described graphically in the figure 11 below.

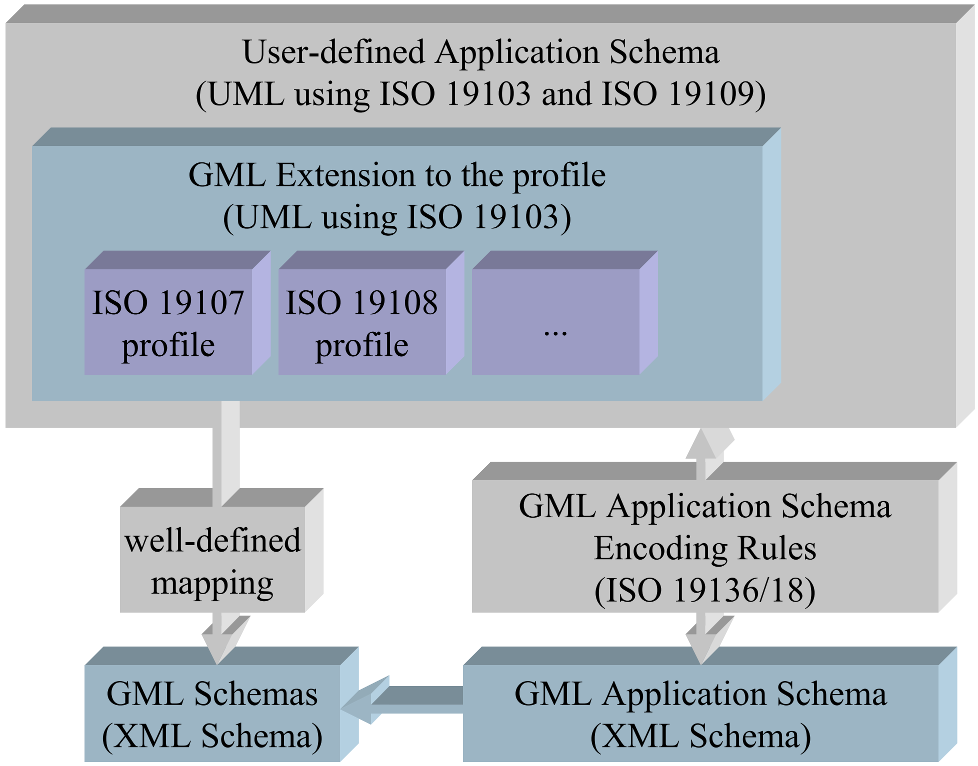

Figure 14 - UML to GML Schema Conversion

For NSG application schemas can be created based on product profiles derived from the GSIP. The schemas developed thus far (as part of OWS4) include Local MSD prototype, and DAFIF. The product profiles are all strict subsets of the GSIP, which is based on the NSG FC as the common feature Catalog for NGA data (and the GKB). A GML 3.2 encoding of the entire NSG FC is also part of the OWS-4 deliverables.

Schemas include metadata based on the requirements of the DDMS 1.3 and ISO TC/211-19139. Schemas are capable of addressing the following requirements for:

1. Attributes with complex data types -- the value of an attribute may be a complex multi-field data structure, including a list or array of values or structures.

2. Both entities/classes and data types may reference other entities/classes through associations with cardinalities and optional ordering.

3. Entities/classes that have no geometry, although all entities/classes are associated in some way to an entity/class that does have geometry.

4. Entities/classes that may have many geometries, including many uses of the same geometry, simultaneously.

5. Temporal requirements.

The following outlines the high-level status and decisions of the GSIP based application schema developments in OWS-4. .

NGA updated the OWS-3 scripts to create a Rose UML model from the GSIP or one of the derived product profiles. A mapping was specified from the GSIP metamodel to the UML application schema taking the ISO 191xx rules and the GML application schema derivation into account.

The GSIP identifies a whole series of feature level metadata. This will be captured within the schema as metadata not as feature attribution.

The ShapeChange UGAS tool was updated as required to address all information encoded in the UML model and the target GML version of GML 3.2.1.

A GML profile for GSIP was created and documented (as part of the Interoperability Program Reports).

An initial version of GSIP as a UML application schema is available at http://www.nga.mil .

A version of the GSIP including the Aero information is available.

The goal is to go from the GSIP profiles to the GML application schemas in a fully automated way. This will likely occur in iterations over the OWS-4 period to identify issues and improve the process and the resulting schemas.

Schema metadata to be published in the OWS-4 Catalogs for every schema needs additional work. In OWS-3 DDMS 1.2 metadata for application schemas and feature types was created. OWS-4 was based on DDMS 1.3 and include more resources, details about the resource descriptions are in the process of being specified.

The following IPRs document the complete activity in detail:

1. OWS-4 GSIP Schema processing IPR: Update of the OWS-3 IPR based on the mapping rules from the GSIP metamodel

2. Local MSD Data Content Specification IPR: Target a data product specification as far as the MSD can provide the contents

3. AIXM mapping IPR: Documentation of the AIXM mapping to DAFIF.

5.5.2 Processing, exploitation and workflow services

Provide the tools and processes to fuse and manage data sources, from multiple producers, at all required security levels. Develop strategies and methods for addressing the exponential increase in data and information to ensure that all relevant data is analyzed. [Excerpt from NSG Statement of Strategic Intent]

GEOINT ANALYTIC INFORMATION GENERATION MODEL IN 2015: FUNCTIONS AND TECHNOLOGY LEVELS
The analytic information generation process model in 2015 will include four information generation functions that will occur on three technology levels.
• Information generation - 1) extraction, 2) fusion, 3) analysis and 4) production
• These functions will occur across three levels of technology: 1) fully human information generation, 2) tool-assisted information generation, and 3) fully automated information generation.

Workflow Management. NSG components will use a set of interoperable workflow management, supply-chain management, and decision- support software applications to coordinate information generation, storage, and transport activities within the NSG and across the broader national security community. Workflow management will ensure tasks are addressed to the proper locations. Workflow management capabilities will facilitate analysts' ability to more quickly acquire stored data and analysis support materials as well as request new collection. Workflow management will also notify customers of the scheduling or executing of data collection or storage retrieval actions. Advanced automated security features will protect sensitive information while allowing appropriate selective access by any national security community member or customer.

Applicable OGC Specifications and developments

- WPS specification (05-007)
- Web Coordinate Transformation Service (WCTS) (05-013)
- Topology Quality Assessment (07-007r1)
- Web Processing Service IPR (06-182)
- WCS-T IPR (06-098)
- OWS-4 Workflow IPR (06-187r1)

The OGC Web Processing Service (WPS) can be configured to offer any sort of GIS functionality to clients across a network, including access to pre-programmed calculations and/or computation models that operate 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, or available at the server. (OGC 05-007r4)

Note: The Web Processing Service (WPS) was originally named Geoprocessing Service (OGC document number 04-043)

From the NSG perspective the WPS offers an option for "wrapping" legacy toolsets and applications such as GEOTRANS, a NGA application which converts geographic coordinates among a wide variety of coordinate systems, map projections, and datums. GEOTRANS could be ported to a WPS wrapped application which would provide a well documented, tested, standards-based web interface. This interface specification provides mechanisms to identify the spatially-referenced data required by the calculation, initiate the calculation, and manage the output from the calculation so that it can be accessed by the client. This WPS is targeted at processing both vector and raster data.

In the most recent OWS initiative several WPS profiles were tested, including: a Generalization Processing Service, GML Feature Fusion Service, Binary Grid Processing Service (Observation Driven Processing Service), and a Feature Clipping Service. Also, OWS4 demonstrated the wrapping of the open-source GRASS GIS and Image Processing package into the OGC WPS. An alternative to wrapping a legacy application in the OGC WPS is to use the W3C WSDL/SOAP/UDDI/BPEL based approach. George Mason University performed this work and already created a SOAP-based chainable web service around GRASS to construct the value-added service chain. Modifications to the SOAP wrapping were necessary since the OGC WPS specification has some differences from W3C WSDL/SOAP/UDDI/BPEL web service standards. The GMU work, detailed in OWS-4 Workflow IPR (06-187r1), shows an example of both approaches.

The data reduction example shown below in figure 12 was intend to meet a use case where a user requires a small sub-set of data due to limited bandwidth or processing limitations. Data from the "Gold" database is generalized (thinned) and clipped to a specific area of interest before delivery to a user constrained by low bandwidth. This process is automated through the use of a BPEL workflow.

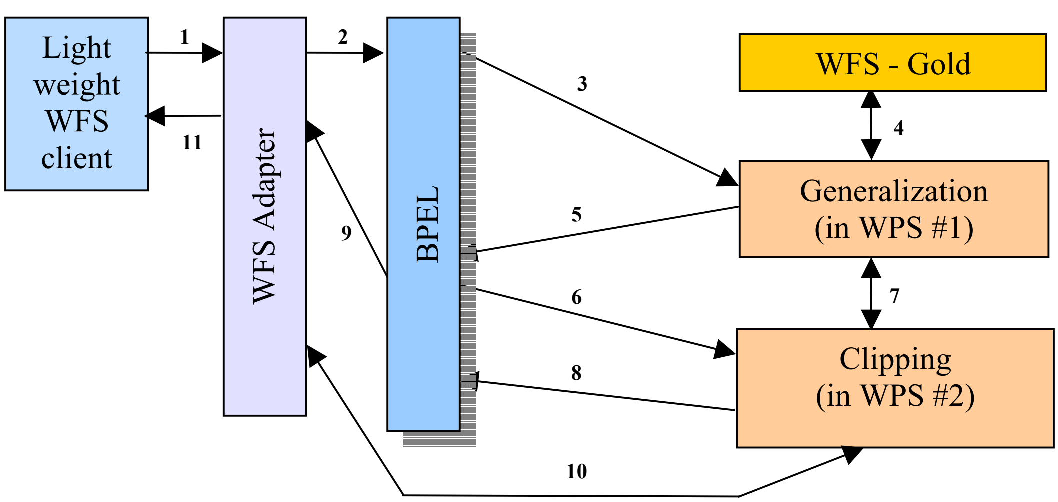

Figure 15 - Data Reduction

The following diagram shows an additional processing workflow demonstrated as part of OWS-4. Here a feature update workflow involved a modification of data sent from a remote analyst in the field that had to be quality checked with a topological quality assessment service before applying the feature transactions to the database. This workflow demonstrates the verification of a certain level of data quality requirements against a "value-added" data submission prior to its being accepted in to the "gold" database. In this case the data extraction was verified for topological consistency through the Topology Quality Assessment Service (TQAS). If errors were found the data could be cleaned up by NGA analysts working in the temporary "silver" database. Once verified as clean the data could then be processed in to the gold database.

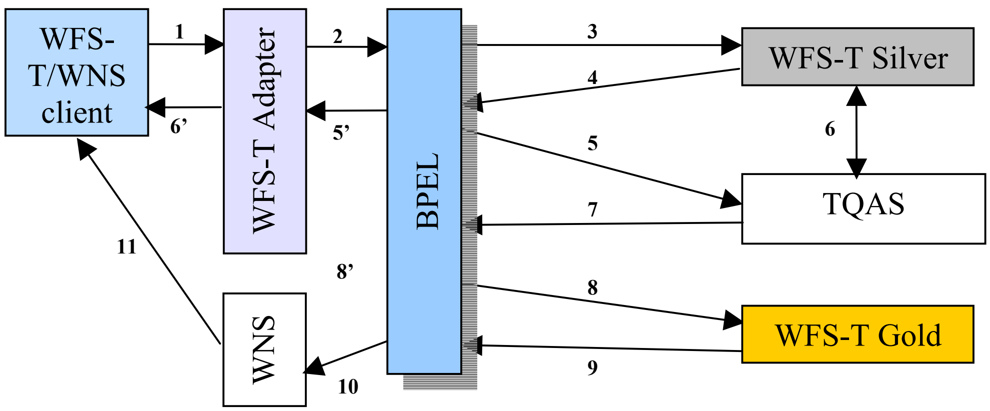

Figure 16 - TQAS Workflow

Both these workflows are fully discussed in the OWS4 Workflow IPR (06-187r1) and are intended to show some simple examples of the types of processing and exploitation services applicable to NSG.

The purpose of building the Topology Quality Assessment Service (TQAS) was to discover the extent to which it is possible to express, measure and record results of executing these logical consistency rules on features within a Web Services environment.

TQAS has been implemented as a number of stateful web services each of which manage a distinct set of entities within the system, such as datastores or rules. In each case, the service has been exposed using a standardized SOAP binding with request/response messages in RPC/literal form. In addition, for the benefit of clearer demonstration, a thin, javascript, browser-based client was written to facilitate interaction with each of the service components.

Each data store has two schema mappings associated with it – one input and one output. Output mapping is not needed if TQAS is being used only for checking rules without changing data. It is also possible to input from one store and output to a different store. TQAS also provides integrated support for externally defined ontologies which describe the structure of the data in a specific data store. This is achieved by interfacing with the open source Jena ontology library (see http://jena.sourceforge.net/), allowing ontologies in various formats such as RDF and OWL to be read into TQAS and used for rules authoring and rules-based reasoning.

A rule is a logical expression which can be used to test the logical consistency of a feature. The rule is expressed using a rules language which is an XML encoding of first order logic, incorporating binary predicates (Boolean operators) for scalar comparisons such as greater or less than and also testing spatial relationships such as containment or within distance. Rules are managed within TQAS by a dedicated web service – the TQAS RuleManager Service. This service allows rule expressions, along with suitable metadata, to be stored and their definitions retrieved and used within conformance checking and data reconciliation tasks.

During OWS-4 the TQAS was demonstrated, the browser-based TQAS Client application was used to instruct the TQAS Server to access the schema of a remote WFS-T and select the relevant feature types and attributes for validation. Shared access to the MSD3 feature data was provided by a single WFS-T. These features were updated using a transactional WFS-T update client. Modifications included changes to the Runway and Aerodrome feature types which have a specific set of constraints mandated by the MGCP Semantic Information Model. A rule conformance validation session was created using the TQAS client, nominating the WFS-T as the feature source and indicating a predefined set of aeronautical validation rules from the Multi-Global Co-production (MGCP) working group. The TQAS client was used to execute the conformance checking session on the TQAS server, to monitor progress of the session and display the conformance result via the browser. The aeronautical rules from MGCP expressed abstractly in TQAS's rules language were capable of applying this abstract knowledge to concrete feature data obtained via the WFS and return pertinent data quality information to the user updating the data in a fully location transparent way.

5.5.3 Imagery handling

> Accelerate the standardization of sensor data, metadata, compression formats, and file identifiers. Integrate airborne with NTM and other sources. [Excerpt from NSG Statement of Strategic Intent]
>
> The number of remote imaging sensors being deployed is increasing each year. The fidelity and resolution of the imagery being collected is also increasing dramatically. Managing the collection and dissemination of the ever-larger volumes of digital imagery can be daunting. Sorting through the collected data to find information of interest to a particular need is time-consuming. In a world where a single digital image can be multiple gigabytes in size, significant time delays can result as large files are exchanged across networks having various bandwidth capabilities. Often an entire file must be downloaded when the user needs only a small portion (region of interest) from the imagery coverage. Enter the JPIP… [Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

Applicable OGC Specifications and developments

- WCS (06-083)
- GML in JPEG 2000 for Geographic Imagery (05-047)

- OWS-4 IPR for WCS Support for JPEG 2000 (06-128)

The OGC image handling services were first demonstrated in OWS1.2 (See: OGC 04-052). Early efforts specified the requirements for both the image archive and catalog services. Later work refined development of the Web Coverage Service (WCS) and developed associated imaged processing services as part of image processing workflows. (See figure 14 below).

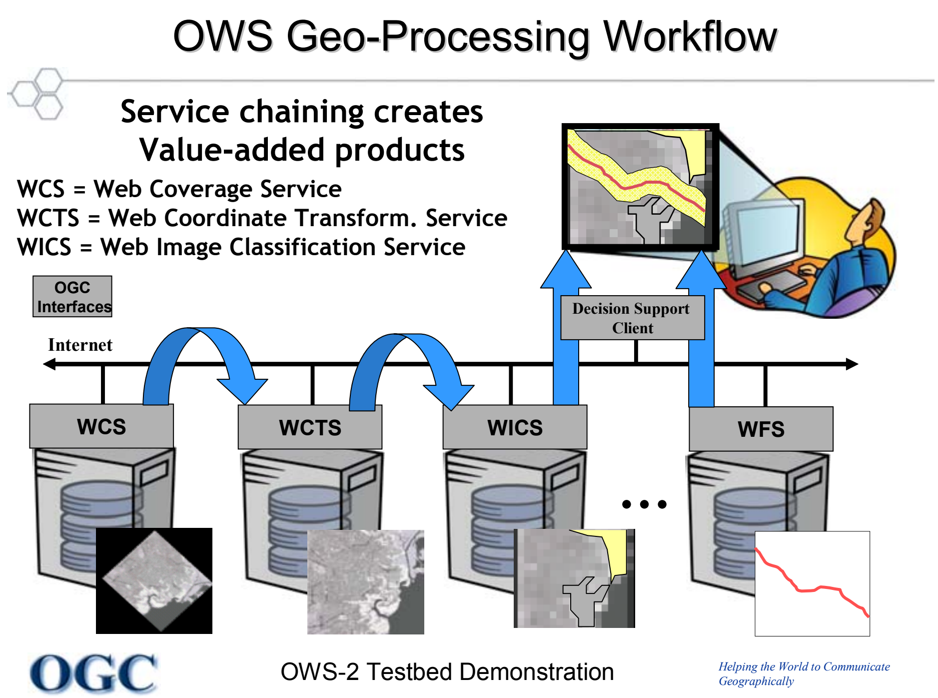

Figure 17 – Geo-Processing Workflow

The WCS is now part of SDI 1.0 as is the ISO JPEG 2000 (JP2) standard (http://www.jpeg.org/jpeg2000). The JP2 standard is a wavelet based encoding for imagery that provides the ability to include XML data for description of the image within the JPEG 2000 data file. The most recent OWS activity extended version 1.0 of the WCS specification to add support for returning coverage data formatted in the JP2 format, both as a static image and as a JPEG 200 Interactive Protocol (JPIP) stream, encoded using the GMLJP2 standard.

The JP2 image format has several advantages over other file formats such as GeoTIFF, including: image data can be compressed to a high degree while still remaining visually lossless; arbitrary sub-scenes can be extracted from the entire image; image data can be extracted at various resolutions (scales). Furthermore, JP2 is well suited for the sort of large-scale imagery demands typically required to conduct NGA's mission. However, JP2 does not a natively support geo-referencing or other forms of geospatial metadata. For this reason, OGC worked to create a standard specification (GMLJP2) to describe the method of using GML within JP2 images for geographic imagery (http://www.opengeospatial.org/standards/gmljp2). The GMLJP2 specification defines the:

1. Specification of the uses of GML within JPEG 2000 data files.
2. Packaging mechanisms for including GML within JPEG 2000 data files.
3. Specific GML application schemas to support the encoding of OGC coverages within JPEG 2000 data files.

While JP2 encoding greatly compresses the size of imagery files, a single image used by a GeoINT analyst can still be several gigabytes in size. These very large file sizes make it prohibitive to provide complete image files to the large numbers of users that are potentially made available through a net-centric distributed environment. NGA estimates that there are 100,000s of extended information users and operators that would benefit from access to this imagery, but that are constrained in terms of bandwidth and computing resources to exploit these images. (Geospatial Intelligence Standards: Enabling a Common Vision, November 2006, p.15)

The JPIP portion of the JP2 standard (JPIP is part nine of the JPEG 2000 standard) addresses the bandwidth and computational constraint that affect delivery of JP2 data. (http://www.jpeg.org/jpeg2000/j2kpart9.html)

JPIP can interactively access and deliver portions of a JP2 image in essentially arbitrary order, in response to real-time application requests. Typical user actions like zooming and panning are supported dynamically over the network without the need to download the entire image from the repository. The dynamic efficiency enabled by JPIP allows significant savings of bandwidth, reduces computer processing and storage requirements on both the server and client, and dramatically improves the timely access to the relevant portions of the collected data. While important to the strategic networks, deployment of JPIP will also give tremendous mileage to the bandwidth-constrained nature of the tactical, warfighting environments. (Geospatial Intelligence Standards p.15).

The power of standards is often magnified when they are combined as building blocks in larger systems providing more complete capabilities. Figure 18 below describes the use of JPIP in a WCS implementation delivering GMLJP2 imagery.

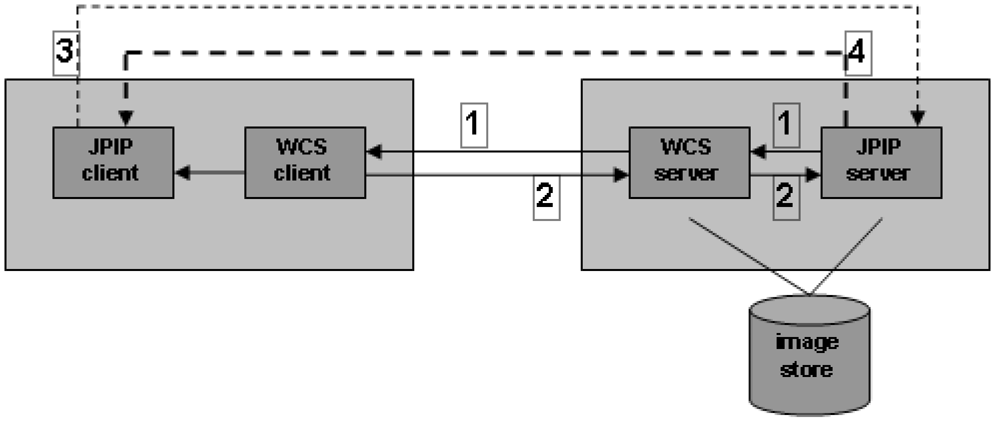

Figure 18- WCS/JPIP Architecture

(1 .the coverage server request, 2.the coverage server response, 3. the JPIP server request, and 4.the JPIP client response)

NGA contributed to the development of the JP2 standard and supported its adoption in ISO. NGA has recently sponsored an OGC activity to integrate JPIP into the OGC SDI 1.0 baseline.

5.5.4 GeoSemantics and GEOINT knowledge base

• The **GEOINT Knowledge Base.** The GEOINT knowledge base will be a virtual repository, encompassing all GEOINT information maintained at the regional data centers, as well as providing transparent interface to databases maintained by the various NSG members and other partner data repositories. The knowledge base will be key to supporting analytic information generation activities in a unified operating environment and furthers the integrated information environment. There will be access to data across security and communication domains. The GEOINT knowledge base will provide the foundational base for reference, positioning, comparison, and visualization, as well as the contextual base for in-depth analysis of intelligence issues. GEOINT knowledge base content will include the tools and data frameworks required to use the knowledge base effectively. **These will include symbology frameworks, a data dictionary, thesauri, taxonomies, ontologies, conceptual models, a feature catalog, robust catalog services using comprehensive metadata, information views including templates and recipes for queries and view generation, and standard product templates.**

5.5.4.1 Applicable OGC specifications and developments

- *Geospatial Semantic Web Interoperability Experiment Report*, edited by Joshua Lieberman, OGC Public Discussion Paper 06-002r1

- *OpenGIS® Catalog Service Implementation Specification* (CSW) and complementary CSW profiles:

- *ebRIM (ISO/TS 15000-3) Application Profile of CSW*

5.5.4.2 Discussion of applying OGC specifications to meet NGA objectives

OGC services, by enabling the Geospatial Web, have made an immense variety of localized and specialized geospatial information and concepts accessible with one or two mouse clicks. The farther that information and services travel from their origin, though, the less likely it is that remote users will also have access to the local context in which to find, evaluate, and interpret such resources. The success of syntactically interoperable Web services connections has created significant semantic gaps in what can be utilized. Both users and their client software may lack the tools to work with the diverse information which Geospatial Web standards have made nominally obtainable.

Semantic technology seeks to make the meaning as accessible as the material, by enabling connections– which are both logical and (machine) actionable–between concepts which a user presently understands and those which may be new and foreign. The Geosemantics extends this capability to both content and concepts which are specifically spatial, temporal, and geographic in nature, giving both people and machines true access to a wider range of knowledge. The GEOINT Knowledge Base describes a goal in which a diverse range of information is joined together by a maximal variety of connections which computers can assist users to traverse, regardless of the physical location or originating community of a particular piece of information.

Aspects of work with OGC specifications which support development of the Knowledge Base include:

- Development / encoding of formal, connected, and machine-processable geospatial ontologies, including feature type descriptions;
- Geospatial service capabilities formulated in the OWL-S and other semantic expression languages which reference those ontologies;
- Geospatial service profiles which operate on requests for ontologically expressed service and content descriptions;
- Semantic query language processing interfaces for WFS, FE and other OGC services which operate on combinations of the above ontologies, service information and queries;
- Processes for discovering semantically expressed geospatial information and services; including use of the CS/W ebRIM metamodel to store ontologies and to express classifications and associations of geospatial resource descriptions and artifacts.

- Implemented "Semantic" WFS / FE, CS/W, and other components for use in processing geospatial queries which leverage Knowledge Base connections.

Semantic Service-oriented Architecture

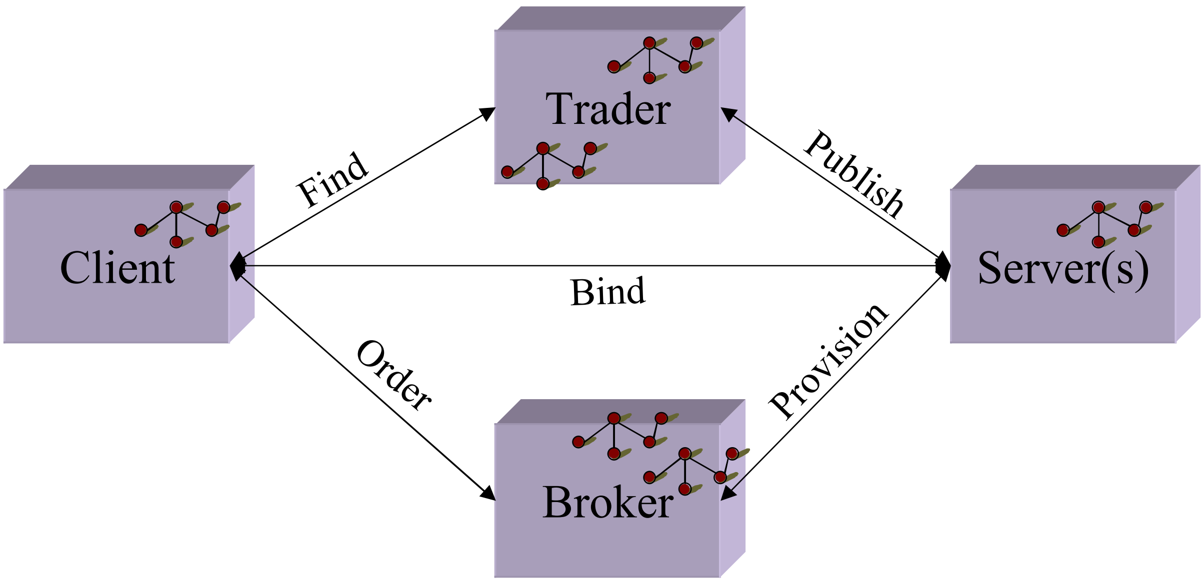

Figure 19 - Four roles and their relationships comprising a basic SSOA (Semantic Service-oriented Architecture).

Applications of OGC services are generally focused around the concept of a service-oriented architecture, in which service consumers bind dynamically to useful instances of standard services through a process of service discovery. This process is usually facilitated through a trading component, which may be represented by an OGC catalog.

Semantic interoperability across the Knowledge Base introduces a new requirement, since merely discovering and binding to useful geospatial information resources may not be sufficient for effectively exploiting them. A broker function is often required, which is able to perform *semantic translation* from the knowledge context in which the resource was created, into the context of the GEOINT user who may be widely separated in both a physical and intellectual sense from that resource. This broker function may be implemented as a catalog ordering operation and/or through schema translation performed by a Web Feature Server.

Multiple ontologies

An essential aspect of the GEOINT Knowledge Base, as a distributed system serving multiple information communities, is the use of multiple ontologies or distinct representations of bodies of knowledge. There is no single harmonized and integrated ontology representing all human knowledge of the world (as yet). The Knowledge Base must leverage OGC concepts, services and encodings to manage multiple ontologies which are distinct yet spatially, temporally, and conceptually overlapping.

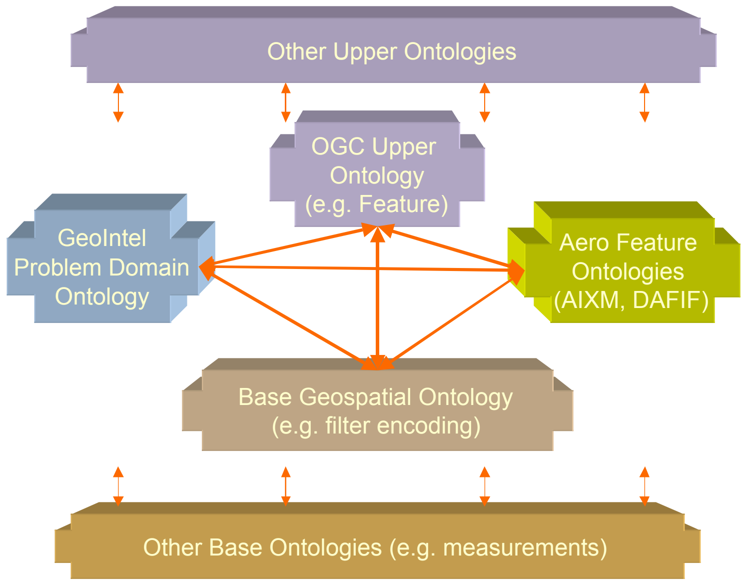

Figure 20 - Schematic representation of multiple ontologies used to perform a geospatial semantic (cross-domain) query.

Just as the communities they represent remain separate but overlapping, so these ontologies are expected to maintain separate identities but be linked (e.g. via subsumption or mapping) into a knowledge base (either physical or virtual) capable of providing answers to cross-domain queries.

5.6 Geo-Decision Support Services (GeoDSS) for NSG

5.6.1 Integrated information environment and OWS portal architecture

Multiple levels of service will be available to answer the GEOINT portion of customer information needs. NSG data holdings will be managed dynamically in a manner to facilitate content reuse and customization of GEOINT. Customers will have universal access to these data holdings at the NSG level through a **web-enabled standardized enterprise portal,** providing a one- stop point of access. GEOINT portal operations will be characterized by use of:

- Data standards, metadata tagging, and data at multiple levels of security and releasability,
- Tools that support data discovery and data mining,
- Shared, common services designed to operate as part of a larger national security community repository,
- Interfaces to other NSG, DoD, IC, commercial, and academic portals, and
- Enhanced bandwidth.

- An Integrated Information Environment. Information management and sharing across the NSG are disconnected among intelligence disciplines and national, theater, and tactical levels, and do not provide horizontal integration. By 2015, the nation must have an integrated information environment, requiring comprehensive capabilities for information generation and management. Initiatives critical to providing a fully integrated and agile approach for sharing collection and analytic resources and exchanging GEOINT across the enterprise must be given programmatic priority. In addition to information generation and information management capabilities, **a horizontally integrated information environment will require standards, interoperability, and data sharing.**

5.6.1.1 Applicable OGC specifications and developments

- *Geospatial Portal Reference Architecture* Discussion Paper
- *OpenGIS® Catalog Service Implementation Specification* (CSW) and complementary CSW profiles:
  - *ISO19115/ISO19119 Application Profile for CSW*
  - *ebRIM (ISO/TS 15000-3) Application Profile of CSW*
  - *Earth Observation Application Profile for CSW*
- Information access standards
  - *Web Feature Service Implementation Specification*
  - *Web Coverage Service Implementation Specification*
  - *Web Mapping Service Implementation Specification*
  - *Simple Feature Access Implementation Specification*
  - *Feature Portrayal Service* Discussion Paper
  - *Sensor Alert Service* Discussion Paper
  - *Sensor Observation Service* Discussion Paper
  - *Sensor Planning Service* Discussion Paper
  - *Style Management Services* Discussion Paper
  - *Symbology Encoding Implementation Specification*
  - *Styled Layer Descriptor profile of the Web Map Service Implementation Specification*
  - *Feature Styling* OWS-4 Interoperability Program Report

  - *Multilingual Open Web Services* OWS-4 Interoperability Program Report

- Network Infrastructure and Security
  - *Geospatial Digital Rights Management Reference Model* (GeoDRM RM) Discussion Paper
  - *GeoDRM Thread Activity* OWS-3 Discussion Paper
  - *Trusted Geoservices Model* OWS-4 Interoperability Program Report
  - *GeoDRM Engineering Viewpoint* OWS-4 Interoperability Program Report
  - *OGC Web Services SOAP Experiment* Discussion Paper
  - *OGC Web Services UDDI Experiment* Discussion Paper
  - *Gazetteer Service - Application Profile of the Web Feature Service* Best Practices
  - *Web Coordinate Transformation Service* Discussion Paper
  - *Web Processing Service* Discussion Paper

5.6.1.2 Discussion of applying OGC specifications to meet NGA objectives

The concept of a single portal is one that is falling out of favor as the industry's experience with deploying Web services in large organizations, and even more so in multi-organization contexts, evolves. We are moving towards envisioning systems of systems, or dynamic information sharing architectures that allow individual agencies and departments to leave and join information networks as required by organizational and operational needs. That being said, the flexibility of a Web services-based architecture, and OGC's expression of that architecture in its geospatial services, is well equipped to evolve along these lines.

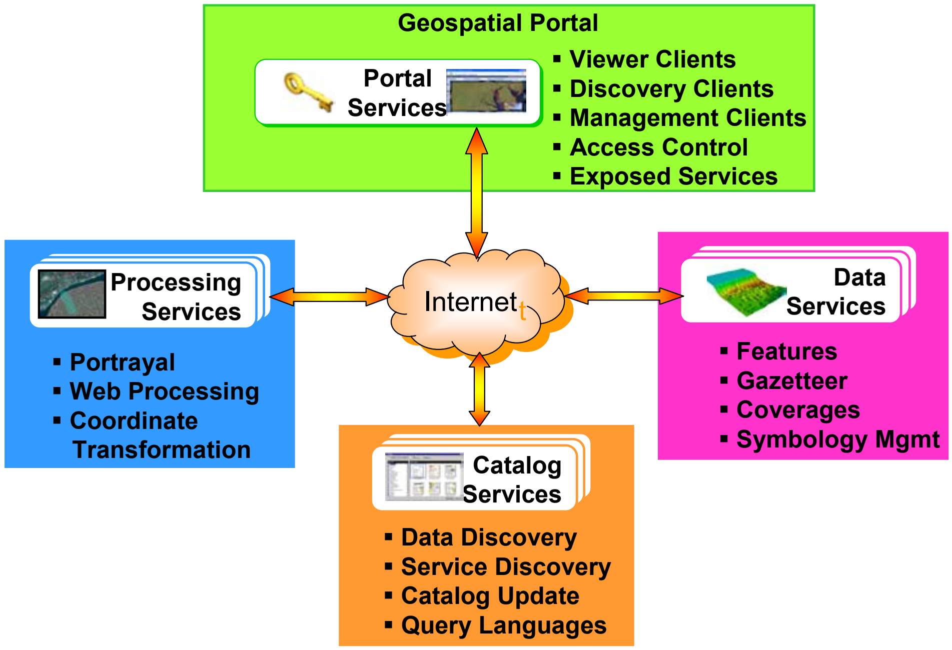

Figure 21 - OWS Portal Reference Architecture

With that theoretical background, we can still talk about a portal architecture as *one instance* of an infrastructure that may actually be more dynamic in nature than is initially envisioned. The backbone of a portal infrastructure, as it relates to decision support, is the ability to quickly and accurately discover geospatial services and data, allowing an analyst to make highly informed decisions. This requirement is supported by the OGC's work on catalogs, which is fulfilled by the *OpenGIS® Catalog Service Implementation Specification* (CSW) along with the profiles of CSW mentioned above. The OGC catalog work specifies the way in which catalog servers can collect, or "harvest", information about geospatial feature data, imagery and symbology, as well as map services. These information access standards are listed above. Catalog servers can share and aggregate this information using a catalog-to-catalog harvesting interface. Clients can exploit catalogs by using their query interface.

A key layer of this information discovery work is security—access rights, authentication and encryption. This requirement has been taken up by the OGC in recent years. While it is still an emerging area of work, the theoretical foundation for robust digital rights management has been laid, and operational services are being prototyped. The relevant documents are listed above.

5.6.2 Integrated client

There will be a significant increase in available data and data types. The greater volumes, varieties, and velocities of information in the future, when combined with nontraditional and asymmetric threats, will challenge our ability to extract relevant data to support leaders, policymakers, war fighters and other customers with timely, accurate, and current GEOINT. For example, there will be more dwell capability by 2015. This capability will be enhanced through use of new collection platforms and several emerging intelligence applications (e.g., full motion video, Surface Moving Indicator (SMTI)) and will require comprehensive capabilities to manage analytic information generation. There will also be more GEOINT-related SIGINT and HUMINT. Effective use of new collection capabilities will require the establishment of comprehensive reference databases holding of a variety of information. **The NSG ability to handle this increase of information will depend on an integrated information environment with improved models for generating and managing information, improved horizontal integration, standards, and a converged architecture**, as described below.

The core purpose of an integrated client is to provide a unified environment that allows a user to visualize, analyze, and/or edit data from feature, imagery, video and sensor web data sources within a single client. Within the context of the OGC, this means that the integrated client allows a user to publish, discover, access, integrate and apply all types of spatial data (e.g., raster, vector, coverages and sensor observations) from a wide range of vendor "web services" through OGC standard interfaces.

The speed and ease with which information can be integrated and bought to bear on a problem may be as important as the information available for analysis. In order to facilitate this process, OGC has done work on standardizing the way in which service access points are stored, or to use a term borrowed from Web browsers, "bookmarked". This work started with Web Mapping services with the WMS Context standard. A WMS Context document is an XML file that describes one or more WMS services, their layer ordering, their styles, and optionally a geographic viewing extent. The functionality proved popular and it is being expanded in OWS Context to support all OGC's data access and symbology standards. Context documents allow an analyst to save the state of their visualization efforts to quickly restart where they left off, or share the Context with a colleague.

5.6.2.1 Applicable OGC specifications and developments

- *Web Map Context Documents Implementation Specification* (WMS Context, *05-005*)
- *Web Map Context Documents Implementation Specification (05-005)*
- *Geographic Objects Implementation Specification* (GeoAPI, 03-064)

5.6.2.2 Discussion of applying OGC specifications to meet NGA objectives

GeoAPI aims to increase the speed and quality of Java and C++ client development work around OGC standards. OGC implementation specifications are built around the platform and language-neutral Web services stack of technologies. However, applications must be developed in a specific language, leaving many degrees of freedom—and room for error—in the software development process. GeoAPI addresses this concern by specifying a standard set of client interfaces for consuming OGC Web services, adding one more layer of quality assurance to the process.

The functionality of an integrated client can be divided into the following five categories:

- Service Discovery & Binding
- Feature Production
- Imagery Production/Exploitation
- Sensor Web Planning/Exploitation
- Project Persistence and Sharing

For each integrated client, the implementation must harness specific technologies and adopt particular architectural approaches. Each technology/architecture pairing presents different reliability, availability, serviceability, usability, security, and performance characteristics. And as such, different technology/architecture pairings may be more or less suitable for various purposes across an enterprise.

Service Discovery & Binding

A service registry is a software component that supports the run-time discovery and evaluation of available service offerings. The Service Discovery & Binding functionality of the integrated client provides, as a minimum, a tool for finding data and services by querying service registries.

There are a number of existing service registries in use, and as the number of available registries grows it will become increasingly difficult for users to find all the possible data of interest and choose the best data for the task at hand. The functionality provided by the integrated client is intended to assist the user in maintaining persistent knowledge of a set of service registries, executing queries against these registries, and creating service chains to provide discovered data to the client in the desired form.

The Service Discovery & Binding functionality can be divided into the following 5 functions:

A) Registering a service to a Service Registry

Once geospatial data is published in an OGC web service instance (W*S), its presence must be announced so that geospatial data analysts can find it. A geospatial data provider can do this by using an integrated client to register the service with a catalog. A URL endpoint pertaining to the service is sent the catalog service. When the catalog receives the request, it then queries the W*S service for its capabilities.

B) Querying a Service Registry for OGC Web Services.

A geospatial analyst must be able to locate OGC Web Services. The analyst can use an integrated client to query a Catalog Service – Web (CS-W) for available services based on location and other parameters. The CS-W returns an XML document containing capability metadata for the available services. The client should present these results in such a way that the analyst could select a specific service and view its capabilities.

C) Querying a Service Registry for data layers.

Service registries not only contain information on the services registered, they also contain metadata on the data layers contained by each service. A geospatial analyst can query a registry using an integrated client to discover not only services but also data layers. The client retrieves metadata for these layers from the service registry so that the analyst can filter the results in order to find available data that meets time-of-collection and data quality requirements.

D) Assembling Service Chains to provide data layers for the client.

Integrated clients, no matter how complex, will never be able to render every possible data source. Therefore, additional services may be required to generate an appropriate data layer. The client can be used to discovery additional data transformation and portrayal services that can be chained together to produce a data layer that can be supported.

E) Managing a collection of Service Registries.

Instead of querying a specific CS-W, an integrated client could potentially query multiple CS-W services simultaneously. This has the potential of increasing the breadth of the search, but there are ramifications for performing this operation. Since each query returns an XML document which may be quite large, bandwidth restrictions may make this operation impractical. There is also the potential for retrieving multiple duplicate entries and the complexity of organizing the results from multiple servers.

Imagery Production/Exploitation

The Imagery Exploitation functionality serves to provide retrieval and viewing of imagery. This includes querying for imagery based on geometry and attributes and creation of service chains to utilize additional services to render the imagery in a specific manner. The user will use this component to find and use imagery data, and then find and use imagery application services to operate on the imagery data. The Imagery Production functionality requires support of some or all of the following OGC interfaces: WMS, WCS, Coverage Portrayal Service (CPS), ICS, and IAS. It can be divided into the following 4 functions:

A) Querying an Imagery Catalog.

The client must have search tools to specify, find, and retrieve data. The client must also provide the user the means to view and interact with the data. The client must have tools to select and invoke imagery application services, and to invoke service chains (e.g. Image Catalog→Image Archive→Coordinate Transformation Service→Web Coverage Service). The client might access map data to depict their study area, view imagery footprints from an Image Catalog, select imagery coverage, etc. This also involves using Web Map Servers and Web Feature Servers.

B) Retrieving Imagery from an Imagery Archive.

The user wants a recent imagery over the disaster area. The user formulates a request based upon the well-known Imagery Metadata Model employed by the Image Catalog. The user employs the client to access an Image Catalog to find recent satellite, aerial and ground imagery of the area. (As described here, the client knows about the Image Catalog Service, but the client might also discover this service through a service registry that operates as a broker for several Image Catalogs.)

The user finds the Image Metadata they want through the catalog search and now must access the appropriate Imagery Archive Service to fetch the imagery and imagery support data. The client formulates the request to the archive, stipulating where the data are to be delivered for the client to later exploit. This process might take some time, if for example the archive has to fetch the data from tape storage. The Imagery Archive Service completes its assignment by delivering the imagery data to the appropriate Web address. Optionally, the Imagery Archive Service might employ a Notification Service to alert the User about the availability of their requested data. The data is now available for exploiting, although it is still in its tiled archive format. (The archive service likely supports mosaicing, re-tiling, and re-sampling to deliver the imagery in a form that is ready for exploitation.)

C) Assembling a Service Chain to retrieve raster data from a WCS and rendered according to client specified styles and parameters by a CPS.

D) Local manipulation of imagery (translucency, edge detection, etc.)

Feature Production

The Feature Production functionality serves to provide retrieval and viewing of feature geometry and attributes, supporting complex querying for features based on geometry and attributes, cartographic portrayal of feature data, feature analysis, and feature editing capabilities. The Feature Production functionality requires support of one or more of the following OGC interfaces: WMS, WFS, FPS, SLD, Style Management Service, and Feature Fusion Service. It can be divided into the following 2 functions:

A) Managing/editing features contained in a WFS-T.

A Transactional Web Feature Server (WFS-T) allows users to retrieve and modify feature data. For example, a geospatial data producer employs recent imagery as a source for feature analysis and update. The integrated client employs an Image Catalog Service and Image Archive Service to access the imagery. Next, the user browses and queries Web Service Registries for feature metadata. The user employs this metadata to select the appropriate feature data for use in disaster response. Having discovered the appropriate feature data, the client then employs a Transactional Web Feature Service (WFS-T) to access the feature data. The client then uses feature extraction tools to update the data.

B) Assembling a Service Chain.

The client provides the means to view, filter, and interact with feature data rendered according to client-defined styles and client-specified parameters.

Sensor Web Production

A number of remote sensors, both in-situ and mobile, are in use today. The data from these sensors can be analyzed for their spatial and temporal patterns and visualized through maps either statically or via animation. A number of OGC services were created to provide a common framework for working with sensors that are connected to the Internet. The Sensor Web Exploitation functionality requires support of some or all of the following service types: SPS, SOS, WNS. It can be divided into the following 3 functions:

A) Retrieving sensor data from a SOS.

Support for a Sensor Observation Service (SOS) allows users to retrieve data from a remote sensor. Sensors may be queried by location, time, and coordinate system. The SOS responds to a query with an XML document containing the sensor observation data.

B) Managing a sensor plan through a Sensor Planning Service.

The Sensor Planning Service (SPS) is used to generate and edit collection plans. Pre-collection prediction capability is used to help develop the plans required for mobile sensors to provide the needed sensor coverage. This service accepts location information identifying the region/target of sensor coverage. The prediction capability considers the physical environment, communications environment, sensor, and platform to determine the relevant area, path, time, duration, and/or similar parameters, and acceptable deviations that the platform must take into account to correctly position the sensor. In a UAV scenario, the pre-collection prediction capability may determine the collection geometry, which may be represented in 2D or 3D to help identify possible flight area/path, speed, and elevation in a way users can insure that the planned sensor flight provides the needed sensor coverage. Displaying similar information for a series of regions/targets can help the user identify a complete flight circuit appropriate for single sensor collection against multiple targets. This service allows a UAV collection plan to be generated and then saved. In addition to the flight plan details, corresponding sensor Collection Requests are also specified. This information is used to fly the UAV and task the air quality sensor to perform collections.

C) Handling sensor plan notifications from a Web Notification Service.

When a request is made through an SPS and it is not immediately known whether the requested action can be performed, a WNS is used to notify the user that the collection has been successful. The user is then free to utilize the SOS functionality to retrieve the data.

6 Compliance

Key consumers in the geospatial industry are modernizing their enterprises based on the interoperability of OGC web services and, in particular, the Spatial Data Infrastructure (SDI) 1.0 (see http://www.nga.mil/NGASiteContent/StaticFiles/OCR/nga0518.pdf). NGA serves the role of functional manager for GEOINT. SDI 1.0 includes the following implementation specifications: WMS, WFS-T, WCS, CS/W, GML, SLD and Context. OGC document 06-086 details the specifications and associated version of the SDI suite of specifications. As the OGC web services technology stack has matured, the SDI 1.0 group of interfaces has emerged representing a baseline of technology needed to implement a fully interoperable, end-to-end spatial data infrastructure. The SDI 1.0 infrastructure serves in NGA's mission within the NSG to:

- Firmly establish leadership in providing GEOINT through OGC Web Services
- Firmly establish leadership in providing browser-based GEOINT analysis and visualization
- Streamline development and deployment while reducing redundancy in data stores and web sites
- Maintain consistency in provisioning and coordination with customers

Major geospatial industry consumers require verifiable proof of compliance with OGC specifications. This is a critical step towards the desirable outcome of interoperability that is possible through implementation of the SDI 1.0 web services, which are standards-based and vendor neutral.

Validating compliance with an OGC specification means verifying that a software product has implemented the specification correctly by testing the software interface for response and behavior that is outlined in the specification. Verifying compliance to the standard is necessary in order to achieve interoperability. As a result, geospatial application vendors desire to provide their potential costumers a means to verify adherence to OGC standards as a measurable discriminator for the interoperability of software products. Vendors can achieve this goal through OGC's online Compliance Test Program, which is described in Section 5.2 below and at http://www.opengeospatial.org/resource/testing.

Major geospatial enterprises, like NGA, desire assurance that acquired software components will interoperate with their existing investments in geospatial data, geospatial systems, and OGC-compliant technology on their own internal networks with their own Implementation Profiles and their own specific data sets. Enterprises like NGA can expect that vendor products should go through the OGC Compliance Test Program and have been certified. This is only the first step towards creating a truly interoperable geospatial enterprise. NGA should also implement a program, methodology and tools which will test compliance with OGC web services inside of NGA networks and with unique NGA data and system requirements in mind.

NGA REQUIREMENTS FOR COMPLIANCE TESTING OGC WEB SERVICES	
"One of NGA's obligations as functional manager of GEOINT is to ensure that interoperability is achieved through standards testing and enforcement." "Working under the guidance of the NGA Chief Architect, the NCGIS will establish this environment to accomplish two primary goals: Ascertain the degree to which architectural design, principles, guidelines, concepts and standards, if deployed, will satisfy NSG: •Functional capability objectives •User agency requirements •Interoperability criteria Validate, establish confidence in, and sustain the GEOINT functional manager's architectural and standards guidance to the IC and NSG communities"	From "Geospatial Intelligence Standards: Enabling a Common Vision, Nov 2006"
"Implement a compliance program to ensure compatibility of industry SCOTS to NSG mandated standards."	Action ID GC7.1 from Geospatial Standards Management Authority Strategic Implementation Plan

6.1 Recommendations for NGA Web Services compliance test program

The following is a list of recommendations for a successful NGA OGC Web Services Compliance Test Program

- NGA should require that vendor products are certified through OGC's compliance test program in order to be implemented on NGA programs
- NGA should establish an instance of the OGC web services compliance test engine to be made available on NGA classified networks and inside of NGA test labs for compliance testing of software products developed or tailored for NGA programs and to verify that vendor products are configured correctly within those environments.
    - NGA should establish a central authority to coordinate and oversee use and results of testing with the OGC web services compliance test engine
    - This instance of the test engine should be made available to the NGA software development community on programs like ESP, GSP, SMARTS, and others where rapid web services development is required
    - This instance of the test engine should be made available to NGA's test labs to be used prior to deployment of systems based on the OGC Web Services or SDI 1.0 specifications
    - This instance of the test engine should be made accessible through the NCGIS Standards Knowledge Base; documentation of all testing activities and results

should be kept in the SKB; the SKB should also be used as an internal collaboration site for NGA development community (staff or contractors) to collaborate on any changes desired or made to the web services compliance engine

  - NGA should establish an approach to utilize the compliance engine in conjunction with interoperability testing events to move towards validating interoperability; NGA should require passing the compliance tests as a prerequisite for participating in an interoperability event.

  - NGA should consider enhancing the OGC compliance test engine to allow for testing web services without reliance on static test data. This would provide a mechanism to test web services implementations serving NGA specific data (for example, GGMA data being served through OGC Web Services). The current OGC web services compliance test engine relies on a static test data set, which may be limiting for the type of testing NGA will require. The engine could be enhanced to allow for compliance testing against NGA specific data and implementation profiles of the services.

  - NGA should consider leading the community in development of an approach and technologies for client side OGC Web Services compliance testing. The current OGC Compliance Test Program and associated tools are focused entirely on compliance testing server side components. One element of the client side compliance testing may include NGA standing up Reference Implementations of server products (described in detail below) on their networks against which client tool compliance can begin to be validated.

- NGA should establish an NGA OGC Web Services Compliance Test Program Policy Document as an element of NGA's SOA Governance Program

  - NGA should analyze current testing processes and revise where necessary to support web services testing in a SOA

  - The OGC Web Services Compliance Engine should be considered one testing tool among the other SOA validation tools used within the SOA Governance Program

  - NGA should consider utilizing the OGC Web Services Compliance Engine as the compliance test engine for testing all NGA Web Services (including non-OGC web services); additional test scripts would need to be developed for non-OGC web services using the documented Compliance Test Language (CTL) written for the OGC Web Services Compliance Engine; the engine is open source and can be extended with custom Java programming if necessary

  - NGA should ensure that compliance tests are developed for all of the implementation specifications in the SDI 1.0 suite. As the SDI 1.0 suite evolves, it will be necessary for NGA to continue to work with the OGC community to mature the state of the Compliance Test Program to include the current SDI 1.0 specifications.

- NGA should nominate a single point of contact to coordinate with OGC to update the NGA instance of the compliance engine with any updates released by OGC

- NGA should use the OGC point of contact to ensure no alterations are made to OGC approved web services compliance tests; if NGA staff encounter any problems with the OGC approved compliance test baseline, the point of contact should work with OGC to submit an appeal

6.2 Compliance testing overview

OGC Compliance Tests are developed via OGC initiatives typically funded by outside sponsors. A participant is selected to develop a compliance test for a specific OGC implementation specification. The participant first documents an Abstract Test Suite (ATS) to indicate what elements of the implementation specification will be tested. The ATS is reviewed by the OGC Technical Committee (TC) community and feedback is incorporated into the ATS. In addition, any ambiguities in the specification are indicated and change proposals against those implementation specifications are developed and worked through the OGC process as needed. From the ATS, an Executable Test Suite (ETS) is developed. The ETS runs within the OGC Compliance Test Engine. The ETS is reviewed by the OGC TC and feedback or appeals from the TC are reviewed. Any required changes are incorporated into the ETS. Reference Implementations (RI) are open source implementations of an OGC Web Service which is 100% compliant with the associated compliance tests. RIs are developed in tight conjunction with development of the ETS. The RI development team collaborates closely with the ETS developer to ensure that the RI is fully compliant to the ETS. At the point at which all feedback has been incorporated into the ETS and the RI is 100% compliant, the compliance package (including the ATS, ETS and RI) are submitted to the OGC Planning Committee (PC) for approval as official OGC compliance tests. The following is a diagram of the previously described process.

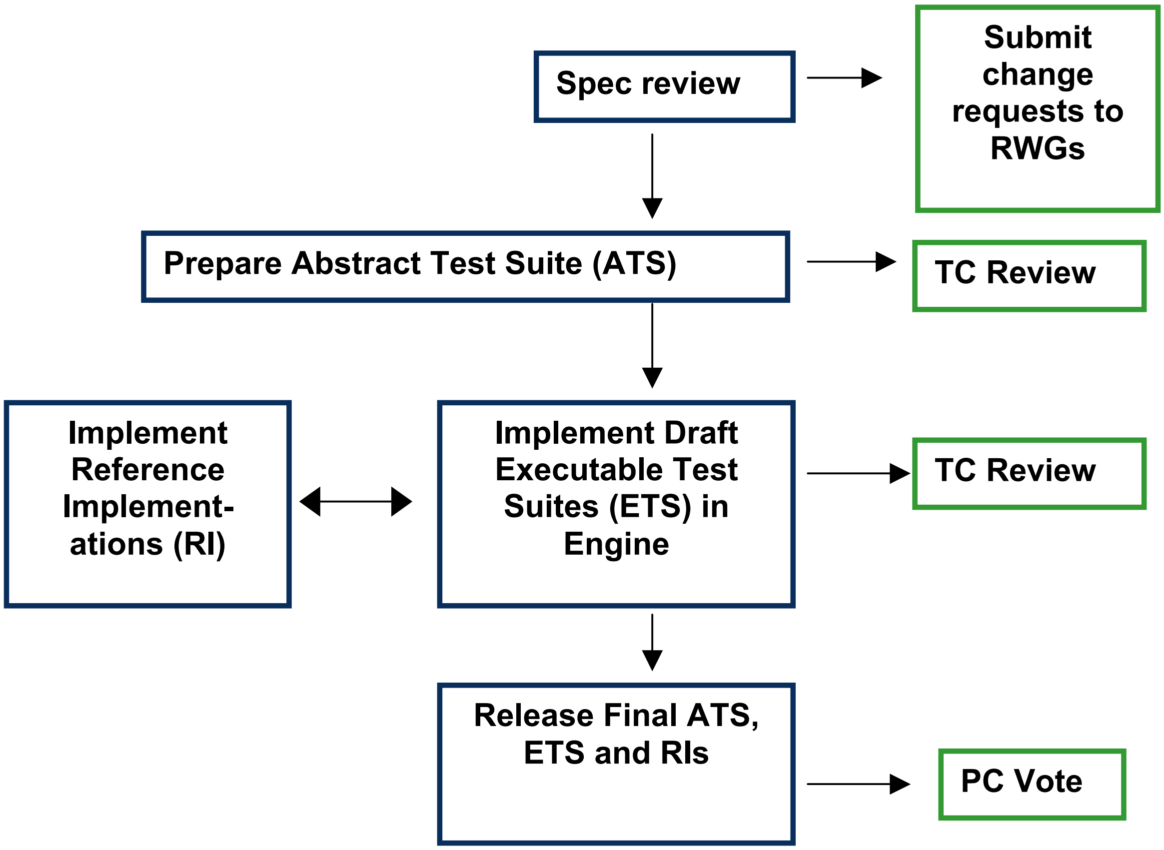

Figure 22 - Compliance Testing Process

Upon approval by the PC, compliance tests become part of the official OGC Compliance Test Program and are made available via the OGC website (http://cite.opengeospatial.org). 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.

This goal of the compliance testing process is to determine that a product implementation of a particular Implementation Specification fulfills all mandatory elements as specified and that these elements are operable. Compliance testing may become more stringent over time, especially as a particular Implementation Specification matures.

OGC compliance tests are available for some but not all OpenGIS Implementation Specifications. Currently OGC hosts tests suites for the following specifications:

AVAILABLE FOR DOWNLOAD	AVAILABLE FOR ONLINE TESTING
Catalog Service Interface 1.0	**Web Coverage Service 1.0.0**
Coordinate Transformation 1.0	**Web Feature Service 1.0.0**
Gridded Coverages 1.0	**Web Map Service 1.1.1**
Simple Features SQL 1.1	**Catalog Service/Web 2.0.1 (will seek approval Apr 2007)**
Simple Features COM 1.1	**Web Feature Service 1.1 with GML 3.1.1 Simple Features Profile 1.0 validation (will seek approval Apr 2007)**
Simple Features CORBA 1.0	**Web Map Service 1.3 (will seek approval Apr 2007)**
	GeoRSS Validator Schema v.1.0 (will seek approval Apr 2007)
	Web Map Context 1.1.0 (will seek approval Apr 2007)

A vender may use OGC's marks (trademarks or certification marks) to indicate to their customers that they have achieved compliance with OpenGIS Implementation Specifications after completing the following steps:

- Submitting a Candidate Product to OGC’s Compliance Testing Program,
- Successfully passing compliance testing,
- Receiving a certificate stating such success,
- Receiving a fully executed license from OGC to use the trademark,
- Paying the trademark license fee, and
- Providing a fully functional, licensed copy of the tested software to OGC.

Compliance testing, in its present phase does not ensure, or even test, interoperability of software products. However, as the specifications mature the likelihood of interoperability will be higher.

SDI 1.0 identifies a set of interoperable OGC specifications. For NSG implementation purposes the SDI 1.0 will not mandate specification version numbers, the DISR (DoD Information Technology Standards and Profile Registry) will identify the specific versions mandated for use within the DoD. There are several criteria for determining which specifications are in the SDI. The criteria include maturity of the implementations along with dependencies between the specifications. Future SDI suites will be identified by studying successful implementations and through interoperability test efforts.

SDI Suite 1.0 Candidate
OGC WMS
OGC WFS
OGC WCS
OGC Filter Encoding
OGC GML
OGC Catalog Services Z39.50 Protocol Binding
FGDC Content Standard for Digital Geospatial Metadata (CSDGM, 1998)
SDI Suite 1.0 Supplemental
ISO Metadata Standard 19115:2003
ISO DTS 19136:2006
OGC Styled Layer Descriptor
OGC Web Map Context
OGC Catalog Service HTTP Protocol Binding (CS-W)

Figure 23 - Draft SDI 1.0 Suite

As recommended in Section 5.1 above, NGA should require that vendor products be certified through OGC's Compliance Test Program in order to be implemented on NGA programs. This is a first step towards ensuring interoperability when those vendor products are implemented. Beyond that, NGA should adopt the OGC compliance testing tools (described in the following section) within the NGA enterprise for additional NGA system, implementation, and data specific compliance and interoperability testing. Passing a compliance test shows that an implementation has followed the specification; this is a step towards ensuring interoperability. The compliance tests do not fully guarantee interoperability - there are other factors like interaction with other specifications/services, specific data and installation in user environments that need to be "tested" to determine if interoperability has been achieved. Therefore, recommendations were included in Section 6.1 above for NGA to host Interoperability Events, to enhance the engine to use dynamic data and to consider client-side compliance testing.

6.3 Compliance testing tools overview

The following are the elements of the OGC Web Services Compliance Test Program

COMPONENT	DESCRIPTION
Compliance Test Engine	Open Source Test Evaluation And Measurement (TEAM) engine
Abstract Test Suite	Testable assertions extracted from specification document; defined as mandatory or optional; test cases are specified independently of any particular test procedure (ISO 19105, 4.4); may be used to create an ETS for a particular test harness
Executable Test Suite	Compliance test which is executed by the Compliance Test Engine
Compliance Test Language (CTL)	Compliance Test Language is an XML grammar for documenting and scripting suites of compliance tests for verifying that an implementation of a specification complies with the specification. A suite of CTL files is installed in the compliance test engine, which executes the scripts and determines whether the implementation being tested passes or fails.
Reference Implementation	Open source implementation of an OGC Web Service which is 100% compliant with the associated compliance tests.
Test Data	Static dataset provided through OGC test program; loaded into service implementation to be tested; this data is necessary for the ETS to test the service implementation
ETS Translator	Converts OGC compliance tests originally developed for The Open Group Engine into CTL and produces wrappers to enable use of TEAM engine custom functions and translators

The following sections describe the major software components involved in running compliance tests.

6.3.1 Compliance test engine overview

As a work item in the OWS4/Conformance and Interoperability Test and Evaluation (CITE) project, Northrop Grumman Information Technology (NGIT) provided an open source web services compliance engine (referred to throughout this section as the OGC Compliance Test Engine). NGIT refers to this engine as the Test Evaluation And Measurement (TEAM) Engine.

6.3.1.1 Compliance test engine technical description

The TEAM Engine has a web interface (thin client) that runs in Tomcat. The thin client is made available through OGC's website. It is also available to be installed on other networks with an easy-to-use web interface. The thick client interface is intended for use by developers; it is easy to install and update tests. The desktop version (thick client) runs in a standalone Java environment and does not require setting up a web server. The desktop interface is a basic command line interface with Swing forms.

This engine is an open source software product, available for download from SourceForge at http://sourceforge.net/projects/teamengine.

The following graphic depicts the compliance test engine and its interface to executable tests and services to be tested.

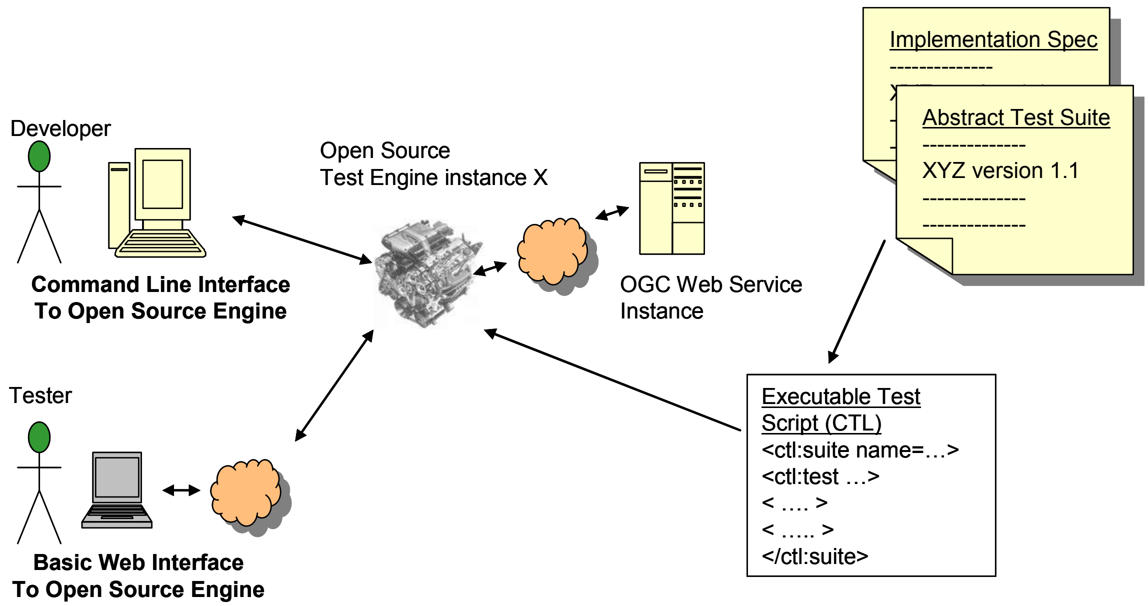

Figure 24 - Compliance Test Engine

6.3.1.2 Compliance test engine licensing

TEAM Engine is released under the Mozilla Public License. No license key is required and the source code is publicly available. Test Script developers can modify the engine if necessary when developing new Executable Test Scripts. Configuration management of the source code will be managed by the OGC through SourceForge.

6.3.2 Compliance Test Script Notation Overview

Compliance Test Language (CTL) is the TEAM Engine script notation. CTL is based on XSL, which allows the use of a full range of looping and decision constructs and variable declarations. Extension functions can be written in XSL or Java using integrated Java datatypes and standard W3C DOM XML datatypes. Tests can be arranged in a hierarchy, allowing reuse of generic tests and reducing the number of times requests must be made to the service. These advantages should lead to a flexible, intuitive, open and easy-to-maintain test scripts.

6.3.3 Reference implementations

The development of compliance test suites plays a crucial role in the implementation of interoperable Spatial Data Infrastructures. Open Source Reference Implementations support this task by "testing the tester" and working as freely available example implementations for all kinds of implementers.

OGC has defined a reference implementation as an open source, fully functional implementation of a specification in reference to which other implementations can be evaluated. The OGC provides open source reference implementations for every implementation specification that has a compliance test. This is to ensure maximum transparency of its specifications for both vendors and customers.

The following is a list of reference implementations developed as part of the OWS4 project. Links to the open source software behind these implementations will be available through OGC's website (www.opengeospatial.org) upon approval by the Planning Committee.

- **WMS 1.3**
  - Developed by: lat/lon
  - Product Name: deegree
  - Protected by: GNU Lesser General Public License (GNU LGPL)
  - The deegree WMS is configured to be both a 1.1.1 and a 1.3.0 WMS. The respective GetCapabilities requests are:
    - http://havola.lat-lon.de/deegreeows4wms/ogcwebservice?request=GetCapabilities&version=1.1.1&service=WMS
    - http://havola.lat-lon.de/deegreeows4wms/ogcwebservice?request=GetCapabilities&version=1.3.0&service=WMS
- **WFS 1.1**
  - Developed by: The Open Planning Project (TOPP)
  - Product Name: GeoServer
  - Protected by: GPL 2.0 license
  - http://geo.openplans.org:8080/geoserver/wfs?request=GetCapabilities&version=1.1.0&service=wfs
- **CS/W 2.0.1**
  - Developed by: United Nations Food and Agriculture Organization (UN FAO)
  - Product Name: GeoNetwork
  - Protected by:GNU GPL
  - The GeoNetwork CSW is available online for review and online testing at: http://www.crisalis-tech.com:8081/geonetwork/srv/en/csw?request=GetCapabilities

The following describes OGC's officially approved reference implementations prior to development in OWS4:

- **WMS 1.0 & WCS 1.0.0**
    - Developed by: lat/lon
    - Product Name: deegree
    - Protected by: GNU Lesser General Public License (GNU LGPL)
    - http://deegree.sourceforge.net/src/demos.html
- **WFS 1.0**
    - Developed by: The Open Planning Project
    - Product Name: GeoServer
    - Protected by: GPL 2.0 license
    - http://geoserver.org

6.4 Maturing OGC compliance test program for the benefit of the NSG

Compliance testing of OGC web services is a critical element in the OGC community's ability to release implementable web services specifications. The process of developing compliance tests improves the quality of the implementation specifications by reducing ambiguities in the specs. The process of running executable tests against vendor products has proven to be a critical step in interoperability in the marketplace.

As the NSG rapidly implements the OGC Web Services in the SDI 1.0 suite of technologies, the need for a solid web services compliance test program is accentuated. It will be mutually beneficial to NGA, as functional manager for GEOINT, and the OGC community to continue to collaborate on tools and approaches for the OGC Compliance Test program to ensure that compliance tests are developed for the web services implementation specifications that are most critical to the NSG's Enterprise Architecture. In particular, NGA should ensure that there are compliance tests for all of the implementation specifications in the SDI 1.0 suite. In addition, as the OGC community adds SOAP and WSDL profiles to the existing RESTful web services, NGA should ensure compliance tests are developed quickly so that the NSG can implement these services with a high probability of success.

6.5 Compliance testing documentation

The OGC Compliance Test program documentation can be found at the following URL:

http://www.opengeospatial.org/resource/testing

Documentation related to the OWS4 compliance testing efforts, including development of the new open source compliance test engine and test scripts for WFS 1.1, WMS 1.3

and CS/W 2.0.1 can be found via the OGC portal (account required) at the following URL:

https://portal.opengeospatial.org/wiki/twiki/bin/view/OWS4/OWSComplianceTest#Compliance_Test_Engine

These documents are initially draft Interoperability Program Reports. They will be submitted through the OGC document process and request approval as official Interoperability Program Reports (IPRs) at the April 2007 Technical/Planning committee meetings. After they have been approved, the documentation will be available from the OGC web site (http://www.opengeospatial.org/standards).

Issues or appeals to the OGC compliance tests and the compliance test engine are registered and tracked via OGC's online issue tracker. The issue tracker can be accessed (account required) via the following URL:

http://portal.opengeospatial.org/index.php?m=projects&a=view&project_id=85&tab=6

7 Development and governance

7.1 Standards adoption

By 2015, interoperability standards will be adopted that enable seamless sharing of GEOINT across the NSG, IC and the national security community. GEOINT will be accessed and managed through net-centric operations, using standards in compliance with the DoD Net- Centric Data Strategy.

The U.S. national standards strategy encourages development of market supported, open, net-centric standards. DoD policy supports the U.S. national standards strategy and establishes partnerships with relevant national and international organizations that develop and set standards, with the objective of adopting the most cost-effective, efficient, and timely commercial standards available to meet DoD needs.

In addition to establishing standards for use within the NSG, the NCGIS will engage in the development of common information handling and management standards that will be key to achieving interoperability across the NSG and the national security community. These activities will include supporting the selection and/or development and implementation of **standards associated with workflow management; needs, requirement, and task prioritization; decision support applications for automated asset allocation; applications for use in accomplishing automated techniques, analysis, and fusion of multi-INT and operations data; and the formatting of multi-INT products resulting from use of these automated exploitation, analysis and fusion capabilities. Also included will be establishing standards for foundation data accuracy and new product types, including standards for operations and multi-INT information view recipes and information views.**

As the functional manager for GEOINT, NGA created the Geospatial Intelligence Standards Working Group (GWG) in partnership with the Defense Information Systems Agency Information Technology Standards Committee. The NCGIS chairs the GWG and provides secretariat support. The GWG serves as the community's advocate for information technology standardization activities related to GEOINT. At the opening meeting of the GWG, the keynote speaker, Bobbi Lenczowski, Senior Executive, NGA West, highlighted the practical needs and difficulties in achieving standardization and recognizing that "…interoperability cannot happen without standards and standards agreements. We have an awesome responsibility before us."

The GWG is open to all National System for Geospatial-Intelligence personnel interested in facilitating the adoption, promulgation and use of GEOINT standards for enabling technologies, data architecture and software.

The GWG serves as the community forum for the coordination of GEOINT standards for NSG. The primary responsibilities of the GWG are to 1) coordinate population of the DoD IT Standards Registry (DISR) with GEOINT standards and 2) serve as the NSG Community of Interest for all standardization activities and functions related to GEOINT. The GWG focuses on GEOINT standards that enable interoperability in net- and data-centric environments and standards that support enabling technologies, data architectures, and software tools.

The GWG has identified OGC specifications among those critical baseline standards that the GEOINT community must adopt. GWG has emphasized critical need for NSG to use SCOTS that adhere to the Spatial Data Infrastructure 1.0 Baseline (SDI 1.0). SDI 1.0 includes multiple OGC implementation specifications including WMS, WCS, WFS, CSW, GML, etc.

OGC is an Associate Member of the GWG. Associate Members serve as subject matter experts and technical advisors to the GWG.

NGA is a Strategic Member of the Open Geospatial Consortium (OGC). Strategic Membership is the consortium's highest level of membership, involving significant participation in the OGC's Management Committee, Technical Committee and Interoperability Program.

The reason for NGA's continuing participation was explained by Christopher D. Cuppan, NSG Chief Architect, Office of Geospatial Intelligence Functional Management, "We at NGA share with the OGC a common architectural vision for 'a world in which everyone benefits from geographic information and services made available across any network, application, or platform.' Our mission, 'Know the Earth, Show the Way,' benefits substantially from the work that the OGC has accomplished since its inception, and we recognize that increasingly, the future success of the National System for Geospatial Intelligence (NSG) is intertwined with the success of the Consortium."

Strategic membership in OGC allows NGA to direct requirements in the OGC Interoperability Program, including requirements for Interoperability Testbeds where most OGC Implementation Specifications have originated.

7.2 Prototyping and testbeds

Advance basic and applied research and development (R&D) of leading-edge science and technology and accelerate the incorporation of results into the operational environment. [Excerpt from NSG Statement of Strategic Intent]

Capitalize quickly on promising GEOINT R&D activities to solve current and emerging intelligence and operational challenges. [Excerpt from NSG Statement of Strategic Intent]

Develop a GEOINT R&D roadmap – align with the DNI Scientific& Technical Plan – to achieve technology breakthroughs to address the most difficult and enduring intelligence problems. [Excerpt from NSG Statement of Strategic Intent]

Ensure that the NSG acquires and retains access to consistent, high quality subject matter expertise for core GEOINT science areas. [Excerpt from NSG Statement of Strategic Intent]

Ascertain the degree to which architectural design, principles, guidelines, concepts and standards, if deployed, will satisfy the NSG:

- Functional capability objectives
- User agency requirements
- Interoperability criteria

[Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

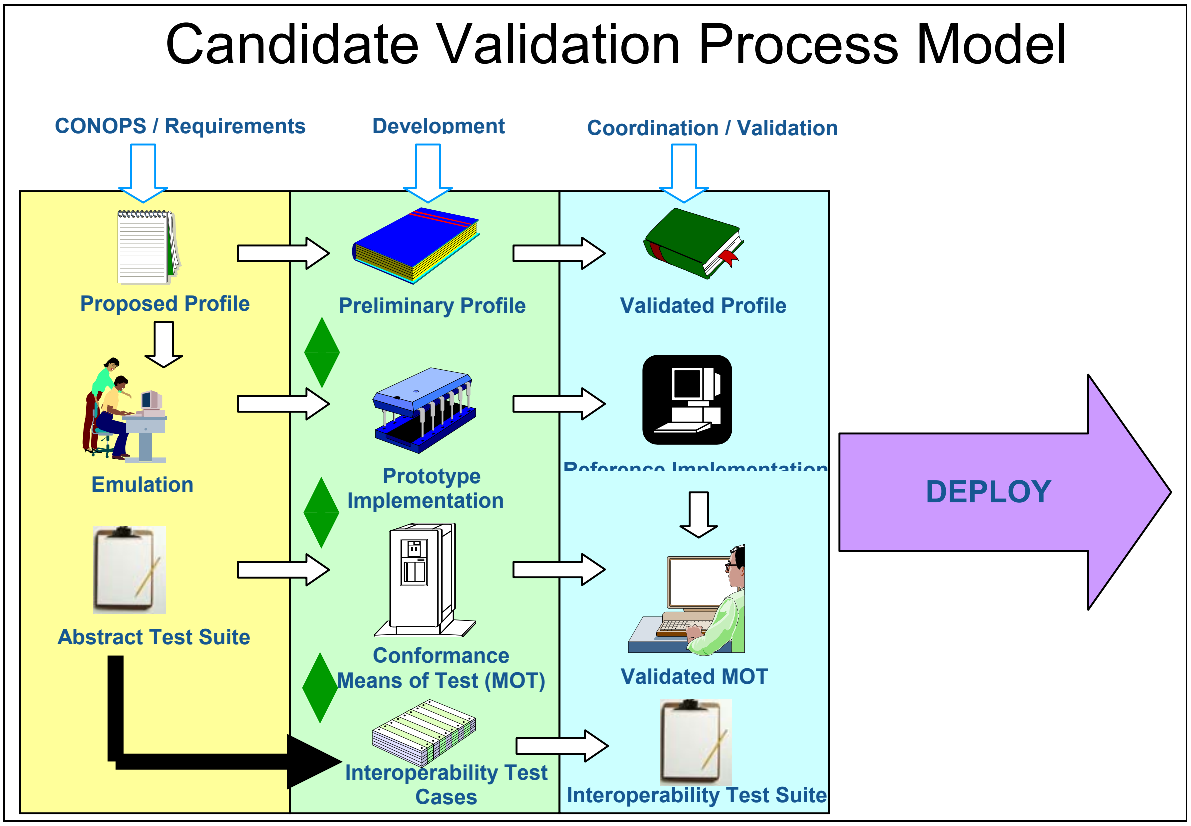

Figure 25 - Candidate Validation Process Model

[Excerpt from Geospatial Intelligence Standards; Enabling a Common Vision]

Consistent with their Strategic Membership in OGC, NGA has been a continuing sponsor of the OGC Interoperability Program. The specification resulting from the OGC Interoperability Program initiatives have resulted in Adopted OGC Specifications that meet NGA and the NSG needs and have been implemented by industry. The GWG has adopted the OGC specifications into the DISR baseline.

NGA should continue to sponsor OGC testbed and pilot initiatives. Based upon a review of the NSG References for this profile (See section 2.1) a set of potential requirements groups for consideration for NGA sponsorship in figure OGC Interoperability Initiatives is as follows:

- Feature Modeling concepts and best practices
- Knowledge management
- Fusion of aggregation of observations;
- Semantic reasoning for data mining;
- Models to predict observations

- Semantic-enabled Services: how to create valid service chains
- Decision support: collaborative methods, query & response methods

8 Summary

The profile described above meets many of the needs related to the NSG, NGA and other large federal organizations. Topics such as OGC Web Services, Sensor Web Enablement, Geo-Processing Workflow, Geo-Decision Support, and Compliance are described and integration concepts are also presented. Although the specifications presented here are useful there is need for improvement. The OGC Web Services test-bed has served as an efficient means to develop many of the specifications mentioned in this profile and will continue to improve the capabilities and relevance of these specifications. Some of the topics currently planned to be addressed in the 2007 test-bed (OWS-5) activities are:

- Development of Compliance and Integration Testing for more specifications, specifically SWE.
- Refining Catalog profiles to enable sensor discovery through the use of semantics descriptions
- Development of a consistent, OWS-wide security model for user identity, harmonized w/ GeoDRM
- Better understand the non-functional quality attributes (e.g. reliability, performance, scalability) of OWS
- Demonstrate integration of multiple OWS specifications with existing systems