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OGC® OWS-6 Sensor Web Enablement (SWE) Engineering Report

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Preface

This document summarizes the work done in the SWE thread of OWS-6.

Forward

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OWS-6 Testbed

OWS testbeds are part of OGC's Interoperability Program, a global, hands-on and collaborative prototyping program designed to rapidly develop, test and deliver Engineering Reports and Chnage Requests into the OGC Specification Program, where they are formalized for public release. In OGC's Interoperability Initiatives, international teams of technology providers work together to solve specific geoprocessing interoperability problems posed by the Initiative's sponsoring organizations. OGC Interoperability Initiatives include test beds, pilot projects, interoperability experiments and interoperability support services - all designed to encourage rapid development, testing, validation and adoption of OGC standards.

In April 2008, the OGC issued a call for sponsors for an OGC Web Services, Phase 6 (OWS-6) Testbed activity. The activity completed in June 2009. There is a series of on-line demonstrations available here: http://www.opengeospatial.org/pub/www/ows6/index.html The OWS-6 sponsors are organizations seeking open standards for their interoperability requirements. After analyzing their requirements, the OGC Interoperability Team recommended to the sponsors that the content of the OWS-6 initiative be organized around the following threads:

1. Sensor Web Enablement (SWE)
2. Geo Processing Workflow (GPW)
3. Aeronautical Information Management (AIM)
4. Decision Support Services (DSS)
5. Compliance Testing (CITE)

The OWS-6 sponsoring organizations were:

- U.S. National Geospatial-Intelligence Agency (NGA)
- Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD)
- GeoConnections - Natural Resources Canada
- U.S. Federal Aviation Agency (FAA)
- EUROCONTROL
- EADS Defence and Communications Systems
- US Geological Survey
- Lockheed Martin

- BAE Systems
- ERDAS, Inc.

The OWS-6 participating organizations were:
52North, AM Consult, Carbon Project, Charles Roswell, Compusult, con terra, CubeWerx, ESRI, FedEx, Galdos, Geomatys, GIS.FCU, Taiwan, GMU CSISS, Hitachi Ltd., Hitachi Advanced Systems Corp, Hitachi Software Engineering Co., Ltd., iGSI, GmbH, interactive instruments, lat/lon, GmbH, LISAsoft, Luciad, Lufthansa, NOAA MDL, Northrop Grumman TASC, OSS Nokalva, PCAvionics, Snowflake, Spot Image/ESA/Spacebel, STFC, UK, UAB CREAF, Univ Bonn Karto, Univ Bonn IGG, Univ Bunderswehr, Univ Muenster IfGI, Vightel, Yumetech.

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1 Introduction

1.1 Scope

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7/29/2009	0.3.0	Carl Reed	Variius	Prepare for publication

1.4 Future work

Improvements in this document are desirable to more completely document work completed in OWS-6/SWE thread.

2 References

The following documents are referenced in 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.

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

NOTE This OWS Common Specification contains a list of normative references that are also applicable to this Implementation Specification.

OGC 06-083r8, *OpenGIS Web Coverage Service (WCS) Implementation Specification*, Version 1.1.0.

OGC 07-067r2, *OpenGIS Web Coverage Service (WCS) Implementation Specification Corrigendum 1 (1.1.1 c1),* Version 1.1.1

OGC 06-043r3, *Change Request: WCS: Add Transaction operation (1.1.0),* Version 1.1.0

ISO/IEC 15444-9:2005, *Information technology -- JPEG 2000 image coding system: Interactivity tools, APIs and protocols*

OGC 07-022r1, *Observations and Measurements - Part 1 - Observation schema*, Version 1.0

OGC 08-022r1, *Change Request - O&M Part 1 - Move extensions to new namespace (1.0.0),* Version 1.0.0

OGC 07-002r3, *Observations and Measurements - Part 2 - Sampling Features (1.0),* Version 1.0

OGC 07-122r2, *OpenGIS SensorML Encoding Standard v 1.0 Schema Corregendum 1 (1.01),* Version 1.0.1

OGC 07-000, *OpenGIS Sensor Model Language (SensorML),* Version 1.0

OGC 06-009r6, *OpenGIS Sensor Observation Service*, Version 1.0

OGC 00-116, *The OpenGIS Abstract Specification, Topic 16: Image Coordinate Transformation Services,* Version 6

OGC 03-105r1, *OpenGIS Geography Markup Language (GML) Encoding Specification*, Version 3.1.1

OGC 05-008, *OGC Web Services Common Specification,* Version 1.1.0

OGC 05-047r3, *OpenGIS GML in JPEG 2000 for Geographic Imagery Encoding Specification*

OGC 05-096r1, *GML 3.1.1 grid CRSs profile* OGC 06-009r5, *Sensor Observation Service*

OGC 06-111, *GML 3.1.1 grid CRSs Profile Corrigendu*

OGC 05-099r2, *GML 3.1.1 simple dictionary profile*

OGC 05-103, *The OpenGIS Abstract Specification, Topic 2: Spatial Referencing by Coordinates*

OGC 06-010r6, *Transducer Markup Language (TML) Implementation specification*, Version 1.0.0.

OGC 07-006r1, *OpenGIS Catalog Service Implementation Specification*

OGC 07-022r1, *Observation and Measurements – Part 1 – Observation Schem*

OGC 07-030r1, *OpenGIS Image Geopositioning Service (IGS)*

OGC 07-031r1, *OpenGIS Image Geopositioning Metadata GML 3.2 application schema*

OGC 07-036, *OpenGIS Geography Markup Language (GML) Encoding Specification*, Version 3.2.1

OGC 07-055, *Web Coordinate Transformation Service (WCTS) draft Implementation Specification*

OGC 07-067r2, *OpenGIS Web Coverage Service (WCS) Implementation Specification Corrigendum 1 (1.1.1 c1)*

OGC 07-112, *GML 3.2.1 CR – Add implementation of ISO 19123 CV_Referenceable Grid to GML*

3 Terms and definitions

For the purposes of this report, the following terms and definitions apply.

Absolute Time (derived from ISO/IEC 18023:2006(E))
Provides 1) a means to specify an absolute time (UTC) for meta-information, and 2) a general-purpose mechanism for describing points in absolute (UTC) time.

Access control
Ability to enforce a policy that identifies permissible actions on a particular resource by a particular subject.

Accounting (OGC 07-097; RM-OA 2007)
Process of gathering information about the usage of resources by subjects.

Ad hoc Sensor Network
Sensor network in which communication links and/or nodes are not continually available or change dynamically. An ad hoc sensor network is often, but not necessarily, based on wireless communication between nodes with limited resources (energy supply, processing power). An ad hoc sensor network may include mobile sensors which belong to the network for a limited time or intermittently.

Alert
Synonym for notification.

Application (derived from http://www.opengeospatial.org/resources/?page=glossary)
Use of capabilities, including hardware, software and data, provided by an information system specific to the satisfaction of a set of user requirements in a given application domain.

Application Domain (OGC 07-097; RM-OA 2007)
Integrated set of problems, terms, information and tasks of a specific thematic domain that an application (e.g. an information system or a set of information systems) has to cope with.

Note: One example of an application domain is environmental risk management.

Application Schema (ISO 19109:2005)
Conceptual schema for data required by one or more applications.

Application Architecture (derived from OGC 07-097; RM-OA 2007)
Instantiation of a generic and open architecture (e.g. the ORCHESTRA Architecture) by inclusion of those thematic aspects that fulfil the purpose and objectives of a given application. The concepts for such an application stem from a particular application domain (e.g. a risk management application).

Architecture (of a system) (ISO/IEC 10746-2:1996)
Set of rules to define the structure of a system and the interrelationships between its parts.

Architecture Service (derived from OGC 07-097; RM-OA 2007)
Service that provides a generic, platform-neutral and application-domain independent functionality.

Assertion (SOA-RA**,** 2008)
An assertion is a proposition that is held to be true by a stakeholder. It is essentially a claim about the state of the world.

Note: In the context of SAML the term Assertion is used as a synonymous expression for Ticket.

Authentication (SOA-RA**,** 2008)
Concerns the identity of the participants in an exchange. Authentication refers to the means by which one participant can be assured of the identity of other participants.

Authorisation (SOA-RA**,** 2008)
Concerns the legitimacy of the interaction. Authorization refers to the means by which an owner of a resource may be assured that the information and actions that are exchanged are either explicitly or implicitly approved.

Catalogue (derived from http://www.opengeospatial.org/resources/?page=glossary)
Collection of entries, each of which describes and points to a collection of resources. Catalogues include indexed listings of resource collections, their contents, their coverages, and of meta-information. A catalogue registers the existence, location, and description of resource collections held by an Information Community. Catalogues provide the capability to add, modify and delete entries. A minimum Catalogue will include the name for the resource collection and the locational handle that specifies where these data may be found. Each catalogue is unique to its Information Community.

Component (OGC 07-097; RM-OA 2007)
Hardware component (device) or Software Component.

Conceptual model (ISO 19109:2005(E); ISO 19101)
Model that defines concepts of a universe of discourse.

Conceptual schema (ISO 19109:2005(E); ISO 19101)
Formal description of a conceptual model.

Confidentiality (SOA-RA, 2008)
Concerns the protection of privacy of participants in their interactions. Confidentiality refers to the assurance that unauthorized entities are not able to read messages or parts of messages that are transmitted.

Credential
Information used as proof of Identity (e.g. a password).

Note: During an Authentication process, credentials are presented to an Identity Provider to obtain related identity information (Ticket).

Discovery (derived from W3C: http://www.w3.org/TR/2004/NOTE-ws-gloss-20040211/#discovery)
Act of locating a machine-processable description of a resource that may have been previously unknown and that meets certain functional, informational or qualitative criteria. It involves matching a set of functional and other criteria with a set of resource descriptions.

End user (OGC 07-097; RM-OA 2007)
Members of agencies (e.g. civil or environmental protection agencies) or private companies that are involved in an application domain (e.g. risk management) and that use the applications built by the system users.

Error (of a measurement)
Difference between the measured value and the (in general unknown) 'true value' of the measured property.

Event
Anything that happens or is contemplated as happening at an instant or over an interval of time.

Environment (Oxford Dictionary)
1: (noun) the surroundings or conditions in which a person, animal, or plant lives or operates.

2: (the environment) the natural world, especially as affected by human activity.

3: (computing) Overall structure within which a user, computer, or program operates.

Feature (OGC 07-097; RM-OA 2007; derived from ISO 19101)
Abstraction of a real world phenomenon (ISO 19101) perceived in the context of an application.

Framework (http://www.opengeospatial.org/resources/?page=glossary)
An information architecture that comprises, in terms of software design, a reusable software template, or skeleton, from which key enabling and supporting services can be selected, configured and integrated with application code.

Generic (Service, Infrastructure…) (derived from OGC 07-097; RM-OA 2007)
Independent on the organisation structure and application domain, etc. For example, a service is generic, if it is independent of the application domain. A service infrastructure is generic, if it is independent of the application domain and if it can adapt to different organisational structures at different sites, without programming (ideally).

Geospatial (http://www.opengeospatial.org/resources/?page=glossary)

Referring to a location relative to the Earth's surface. “Geospatial” is more precise in many geographic information system contexts than "geographic," because geospatial information is often used in ways that do not involve a graphic representation, or map, of the information.

Identity (Dictionary, 2004)
Collective aspect of the set of characteristics by which a thing is definitively recognizable or known.

Identity Provider
Entity that issues identity information and possibly acts as authentication authority

Implementation (http://www.opengeospatial.org/resources/?page=glossary)
Software package that conforms to a standard or specification. A specific instance of a more generally defined system.

Integrity (SOA-RA**,** 2008)
Concerns the protection of information that is exchanged – either from unauthorized writing or inadvertent corruption. Integrity refers to the assurance that information that has been exchanged has not been altered.

Interface (ISO 19119:2005)
Named set of operations that characterize the behaviour of an entity.
The aggregation of operations in an interface, and the definition of interface, shall be for the purpose of software reusability. The specification of an interface shall include a static portion that includes definition of the operations. The specification of an interface shall include a dynamic portion that includes any restrictions on the order of invoking the operations.

Interoperability (ISO 19119:2005 or OGC; http://www.opengeospatial.org/resources/?page=glossary)
Capability to communicate, execute programs, or transfer data among various functional units in a manner that require the user to have little or no knowledge of the unique characteristics of those units (ISO 2382-1).

Meta-information (OGC 07-097; RM-OA 2007)
Descriptive information about resources in the universe of discourse. Its structure is given by a meta-information model depending on a particular purpose.

Note: A resource by itself does not necessarily need meta-information. The need for meta-information arises from additional tasks or a particular purpose (like catalogue organisation), where many different resources (services and data objects) must be handled by common methods and therefore have to have/get common attributes and descriptions (like a location or the classification of a book in a library).

Non-repudiation (SOA-RA**,** 2008)

Concerns the accountability of participants. To foster trust in the performance of a system used to conduct shared activities it is important that the participants are not able to later deny their actions: to repudiate them. Non-repudiation refers to the means by which a participant may not, at a later time, successfully deny having participated in the interaction or having performed the actions as reported by other participants.

Notification
Message that transports one or more events. Depending on the form of the event, the notification may resemble the event that it transports.

Observed Property (derived from OGC 07-022r1)
Identifier or description of the phenomenon for which the observation result provides an estimate of its value.

Observation (OGC 07-022)
Act of observing a property or phenomenon, with the goal of producing an estimate of the value of the property.

Open Architecture (OGC 07-097; RM-OA 2007)
Architecture whose specifications are published and made freely available to interested vendors and users with a view of widespread adoption of the architecture. An open architecture makes use of existing standards where appropriate and possible and otherwise contributes to the evolution of relevant new standards.

Operation (ISO 19119:2005; http://www.OpenGIS.org/docs/02-112.pdf)
Specification of a transformation or query that an object may be called to execute. An operation has a name and a list of parameters.

Phenomenon (OGC 07-022)
Concept that is a characteristic of one or more feature types, the value for which may be estimated by application of some procedure in an observation.

Policy (derived from SOA-RM, 2006)
Representation of a constraint or condition on the use, deployment, or description of a resource.

Purpose (of meta-information) (OGC 07-097; RM-OA 2007)
Describes the goal of the usage of the resources.

(Service) Platform (OGC 07-097; RM-OA 2007)
Set of infrastructural methods, technologies and rules that describe how to specify service interfaces and related information and how to invoke services in a distributed system.
Examples for platforms are Web Services according to the W3C specifications including a GML profile for the representation of geographic information or a CORBA-based infrastructure with a UML profile according to the OMG specifications.

Principal
See Identity

Profile
Information (set of attributes) describing a subject.

Reference Model (ISO Archiving Standards; http://ssdoo.gsfc.nasa.gov/nost/isoas/us04/defn.html)
Framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment. A reference model is based on a small number of unifying concepts and may be used as a basis for education and explaining standards to a non-specialist.

Representation (Richardson/Ruby 2007)
Comprises any useful information about the current state of a resource.

Resource (Richardson/Ruby 2007)
Anything that's important enough to be referenced as a thing itself.

Note: Applied to geospatial service-oriented architectures (derived from OGC 07-097; RM-OA 2007): Functions (possibly provided through services) or data objects (possibly modelled as features).

Security Domain
Set of resources protected in accordance with a common policy.

Sensor
Entity that provides information about an observed property at its output. A sensor uses a combination of physical, chemical or biological means in order to estimate the underlying observed property. At the end of the measuring chain electronic devices produce signals to be processed.

Sensor Network
A collection of sensors and optional processing nodes, in which information on properties observed by the sensors may be transferred and processed.

Note: A particular type of a sensor network is an ad hoc sensor network.

Sensor System
System whose components are sensors. A sensor system as a whole may itself be referred to as a sensor with an own management and sensor output interface. In addition, the components of a sensor system are individually addressable.

Service (ISO 19119:2005)
Distinct part of the functionality that is provided by an entity through interfaces.

Service Instance (derived from OGC 07-097; RM-OA 2007)
Executing manifestation of a software component that provides an external interface of a service according to an implementation specification for a given platform.

Service Network (derived from OGC 07-097; RM-OA 2007)
Set of service instances that interact in order to serve the objectives of applications. The basic unit within a service network for the provision of functions are the service instances.

Session
Also known as a *communication session*, is a semi-permanent interactive information exchange between communicating devices that is established at a certain time and torn down at a later time.

Signal
Any internal representation (i.e. internal to the sensor) of the observed property.

Software Component (derived from component definition of http://www.opengeospatial.org/resources/?page=glossary)
Program unit that performs one or more functions and that communicates and interoperates with other components through common interfaces.

Spatial Context
Specification of a spatial location of an observed property determined by a combination of a point, a line, an area, a volume and/or a vector field.

Note: As an example for the combination of an area and a point, consider a sensor that is capable of recording an image of an area. It may deliver both a spatial context for the area (e.g. the polygon of the area) and/or for several points within that area (e.g. a grid laid upon the area).

Subject (OGC 07-097; RM-OA 2007)
Abstract representation of a user or a software component in an application.

System (ISO/IEC 10746-2:1996)
Something of interest as a whole or as comprised of parts. Therefore a system may be referred to as an entity. A component of a system may itself be a system, in which case it may be called a subsystem.

Note: For modelling purposes, the concept of system is understood in its general, system-theoretic sense. The term "system" can refer to an information processing system but can also be applied more generally.

System User (OGC 07-097; RM-OA 2007)
Provider of services that are used for an application domain as well as IT architects, system developers, integrators and administrators that conceive, develop, deploy and run applications for an application domain.

Temporal Context
Specification of the temporal reference of an observed property based on the absolute time. It can be a single point in time, a time sequence, a time period or a combination of

these. In a sampling system for example several time periods and time points are needed to describe the time behaviour. However, a time point is already an abstraction which does not really exist. It means a very small time interval.

Uncertainty
Quantified description of the doubt about the measurement result.

Note: The error of a measurement may be small, even though the uncertainty is large.

User (OGC 07-097; RM-OA 2007)
Human acting in the role of a system user or end user.

UTC - Coordinated Universal Time (ISO 19108:2004 (E))
Time scale maintained by the Bureau International des Poids et Mesures (International Bureau of Weights and Measures) and the International Earth Rotation Service (IERS) that forms the basis of a coordinated dissemination of standard frequencies and time signals (ITU-R Rec.TF.686-1 (1997))

Viewpoint (RM-ODP)
Subdivision of the specification of a complete system, established to bring together those particular pieces of information relevant to some particular area of concern during the design of the system.

Web Service
Self-contained, self-describing, modular service that can be published, located, and invoked across the Web. A Web service performs functions, which can be anything from simple requests to complicated business processes. Once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service.

W3C Web Service (W3C, http://www.w3.org/TR/2004/NOTE-ws-gloss-20040211/#webservice)
Software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP-messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards.

4 Conventions

4.1 Abbreviated terms

AIM	Aeronautical Information Management
API	Application Programming Interface
BPEL	Business Process Execution Language
CBRN	Chemical, Biological, Radiological, Nuclear
CCSI	Common CBRN Sensor Interface
CR	Change Report
CSW	Catalog Service Web
ebRIM	Electronic Business Registry Information Model
EML	Event Pattern Markup Language
ER	Engineering Report
ESB	Enterprise Service Bus
GML	Geography Markup Language
GPW	Geo Workflow Processing
HTTP	Hypertext Transfer Protocol
ISO	International Standardization Organization
JPEG	Joint Photographic Experts Group
JPEO-CBD	Joint Program Executive Office for Chemical and Biological Defense
JPIP	JPEG 2000 Interactive Protocol
MathML	Math Markup Language
O&M	Observation and Measurements
OGC	Open Geospatial Consortium
OWS-6	Open Web Service Testbed 6
PAP	Policy Administration Point
PDP	Policy Decision Point
PEP	Policy Enforcement Point
PIP	Policy Information Point
POX	Plain Old XML
REST	Representational State Transfer
SAS	Sensor Alert Service
SDI	Spatial Data Infrastructure
SensorML	Sensor Model Language

SES	Sensor Event Service
SIS	Sensor Interface Service
SOS	Sensor Observation Service
SOS-T	Sensor Observation Service - Transactional
SPS	Sensor Planning Service
STS	Secure Token Service
SWE	Sensor Web Enablement
SWG	Standards Working Group
UML	Unified Modeling Language
UncertML	Uncertainty Markup Language
URI	Uniform Resource Identifier
WCS	Web Coverage Service
WCS-T	Web Coverage Service - Transactional
WG	Working Group
WNS	Web Notification Service
WPS	Web Processing Service
WPS	Web Processing Service
WS-*	Web Service - *
WS-N	Web Service Notification
WSDL	Web Service Description Language
XML	eXtensible Markup Language

5 OWS-6 Sensor Web Enablement (SWE) Engineering Report Overview

The participants in the SWE thread developed a set of engineering reports (ERs) and implementations as listed in the following table.

Plan	Results
Engineering Reports	
Georeferenceable Imagery ER	Published as OGC 09-034
SWE Information Model ER	OWS-6 SWE Information Model ER is published as OGC 09-031r1. In addition, the OWS-6 SensorML Profile for Discovery ER was developed and is published as OGC 09-033.
SWE UML Models	The UML Models are published as part of the SWE Information Model ER (OGC09-031r1).
SWE CRs	One change requests was published (addressing changes in SensorML to allow additional markup in SensorML instance documents)
Secure Sensor Web ER	Published as OGC 08-176
CCSI-SWE ER	Published as OGC 09-007
Event Architecture ER	Published as OGC 09-032
PulseNet™ ER	Published as OGC 09-073
Implementations	
SOS (georeferenceable imagery)	Implemented and successfully tested as part of the georeferenceable imagery workflow
P*P (PDP, PIP, PAP)	PDP and STS (Secure Token Service) have been implemented and successfully tested as part of the CCSI workflow. PIP and PAP services had not been required.
PEP for SWE Services	PEP for SOS, SAS, and SPS have been developed and successfully tested as part of the CCSI workflow
SOS, SPS; SAS for CCSI	Implemented and successfully tested as part of the CCSI workflow
Catalog Service for Sensor Web	Implemented and successfully tested as part of the CCSI workflow
SWE Clients (CCSI and georef. imagery)	CCSI client implemented and successfully tested as part of the CCSI workflow Georef. Imagery client implemented and successfully tested as part of the georeferenceable imagery workflow

Event Service	Implemented and successfully tested as part of the AIM scenario
WCS_T JPIP	Implemented and successfully tested as part of the georeferenceable imagery workflow
Additional Components identified and develop during the Testbed	
-	A Sensor Interface Service (SIS) API has been developed and successfully tested as part of the CCSI workflow
-	BPEL Workflow Engine has been used to manage the georeferenceable workflow
-	A Web Notification Service (WNS) has been used to deliver notification messages in the georeferenceable imagery workflow

6 Development of Engineering Reports

Overall, seven engineering reports have been developed in OWS-6. Though matching the initial plan in numbers, we slightly restructured the report portfolio. Instead of developing a separate engineering report, the UML models for SWE have been integrated into the SWE information model engineering report, as they manifest one essential component of the SWE information model itself. Further on, an additional engineering report was developed. It addresses discovery mechanisms in SWE. Originally planned to be part of the SWE Information Model ER, we decided to separate this part from the SWE Information Model ER, as it manifests the application of the SWE information models, but doesn't address the model as such. All other engineering reports have been delivered as planned.

6.1 Georeferenceable Imagery ER - OGC

Georeferenceable imagery is “a referenceable grid that has information that can be used to transform grid coordinates to external coordinates, but the transformation shall not be required to be an affine transformation”. Geolocation of georeferenceable imagery refers to the techniques described in ISO 19130, such as sensor models, functional fit models, and spatial registration using control points.

The Georeferenceable Imagery workflow defined in OWS-6 addresses use cases that exercise the Sensor Web Enablement services, i.e. Sensor Planning Service (SPS), Sensor Observation Service with the optional transaction support (SOS-T), Web Processing Service (WPS), and Web Coverage Service with the transaction support (WCS-T). The technical foci have been to enable instant access to time-sensitive imagery at different processing levels, to geo-locate the imagery of interest, and to propagate uncertainty statistics. The uncertainty statistics are to be preserved and passed along the workflow by encoding them in the metadata section. The uncertainty statistics include both the quality information of sensing and encoding at sensors or processing nodes and covariance matrices introduced in the processing by comparing the input and outputs at the node. The metadata should be usable within sensor models to describe parameters uncertainty as well as in datasets to report geometric (and radiometric) accuracy.

The mechanism and strategy for uncertainty information to propagate along the workflow have been of the core concepts to be demonstrated in the OWS-6 Testbed. Both rectified imagery and unrectified imagery should have relevant uncertainty information. In the case of unrectified imagery, the metadata should consist of observation (O&M) metadata, sensor model with adjustable parameters, and parameter uncertainty information. In the case of rectified imagery, the metadata should consist of coverage metadata and geometric positioning uncertainty.

The uncertainty information has been proposed to be encoded in SensorML and SWE Common, following the Community Sensor Model WG profiles. A SensorML profile has been developed for this task.

The de-facto industrial workflow scripting language, Business Process Execution Language (BPEL), has been used as the main language for composing the workflow considering the accumulated experiences over several OWS initiatives and the wide support of design tools from either commercial or open-source. This leads to the requirement of adapting each OGC-compliant services to be used in the workflow. The practice to harmonize the service components and chain the services into a mega-service or a workflow can be helpful in the development of individual Web services.

6.2 SWE Information Model ER

The SWE Information Model ER discusses relations between SensorML, SWE Common and GML and investigates solutions for increased synergy between them. This effort has been supported by UML models of the data types used in SWE and GML.

In addition, the report discusses the integration of additional markup languages into OGC SWE. We experimented and documented the findings in the engineering report about the usage and integration of UncertML (has been integrated into different SWE encodings, namely SWE Common and Observations and Measurements), MathML and EML into the SWE environment with an emphasis on SensorML processes and processing.

After consultation with participants and sponsors, we decided to develop an additional engineering report that was initially not foreseen for this testbed: The OGC® OWS-6 SensorML Profile for Discovery Engineering Report defines a basic SensorML profile for discovery purposes. Besides a minimum set of metadata also the structure of according SensorML documents is defined in order to ensure a consistent metadata description. A set of Schematron rules allows validating if a given SensorML document complies with this profile.

6.3 SensorML Profile for Discovery ER

The SensorML Profile for Discovery ER specifies a profile of the SensorML OGC standard to be used by sensor and SWE service discovery services and clients. The profile is not restricted to any specific type of sensor or procedure. It can be used as a generic profile for sensor system descriptions with the purpose of being discoverable. The ER uses an exemplarily home weather station to explain the concept of the profile.

6.4 Change Requests

A single change request has been produced by the SWE thread of OWS-6. It addresses the integration of additional markups in SensorML. The change request has been posted to OGC pending documents as OGC document 08-192r1.

6.5 Event Architecture ER

The Event Architecture Engineering Report describes the first version of an OGC Event Architecture. It does so by defining an abstract architecture and by providing guidance how this architecture can be implemented using existing standards. Several existing OGC standards deal with aspects of an event architecture to a certain extent. These are, for example, the Sensor Alert Service (SAS), Sensor Event Service (SES) and Web Notification Service (WNS). While the former define a Publish/Subscribe approach for the Sensor Web domain in their specific ways, the latter provides functionality for relaying messages via various protocols.

6.6 Secure Sensor Web ER

The Secure Sensor Web Engineering Report represents the first effort ever to analyze security aspects in Sensor Web application. The report provides a detailed analysis of potential vulnerabilities and threats typical for OGC SWE services.

6.7 CCSI ER

This CCSI Engineering Report outlines the concepts, best practices, and lessons learned gathered from integrating Common Chemical, Biological, Radiological, and Nuclear (CBRN) Sensor Interface (CCSI) standard-compliant sensors into an OGC Sensor Web Enablement (SWE)-based architecture. The document also specifies a web service interface for interacting with CCSI sensors and defines the basis for a profile that can be used to represent CCSI sensor definitions, data, and commands in SWE formats.

6.8 PulseNet ER

The PulseNet ER describes Northrop Grumman's contribution from PulseNet™ to the Common Chemical, Biological, Radiological, and Nuclear (CBRN) Sensor Interface (CCSI) standard-compliant sensors into an OGC SWE-based architecture.

7 Development of Implementations

The following implementations were developed in OWS6.

7.1 Event Service for AIM

Based on the SWE services SAS and SES as well as the ideas and techniques described in the Event Architecture ER an Event Service was implemented. This task was a cross-thread activity between the SWE thread providing experience on alerting and notifications and AIM thread providing a comprehensive use case. In this use case the event service was used to filter and forward events regarding air traffic to subscribed pilots using user (pilot) defined spatial and temporal filter criteria.

7.2 Clients & Services for Georeferenceable Imagery

A number of Web services and corresponding clients have been developed to support the georeferenceable imagery workflow. The following figure illustrates this workflow.

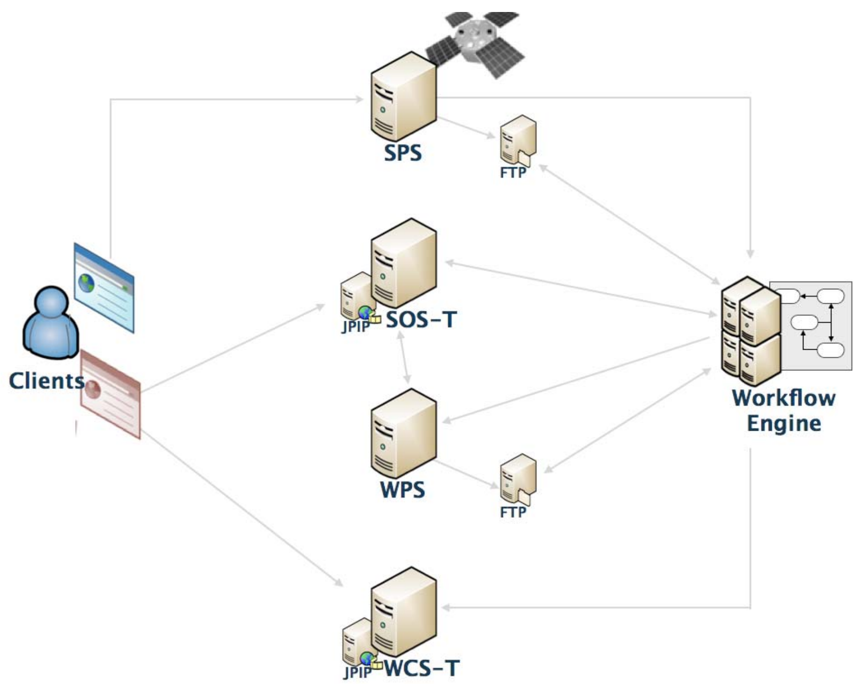

Figure 1: OWS-6 SWE Georeferenceable Imagery Workflow

7.2.1 SPS

A SPS was developed to task SPOT satellites. The interface design of this SPS reflected the new SPS 2.0 design to a large extent. The service was developed by SpotImage.

7.2.2 JPIP-enabled SOS-T

We implemented a transactional SOS for standardized access to georeferenceable. This SOS is coupled with a JPIP server to distribute and allowing fast access to the image data in the JPEG 2000 format. The SOS is also responsible to offer the metadata to the images. These metadata is encoded in SensorML and contains error and uncertainty statistics, which supports and improves the georeferencing of the imagery. The service was developed by 52°North.

7.2.3 WPS

A WPS was implemented to serve the georectified imagery. The service was developed by GMU.

7.2.4 WCS-T

A transactional WCS was implemented to store the rectified imagery and to serve it in JPEG2000 format using JPIP streaming server. The service was developed by GMU.

7.2.5 Workflow Engine

A workflow engine was used to execute and control the entire workflow. The workflow itself is encoded as a BPEL script. The existing workflow engine was enhanced to support to pass the security token in the workflow. The workflow engine was developed by GMU.

7.2.6 SPS Client

A client application based on the Space Time Toolkit was developed to task SPOT satellites. SpotImage developed the client.

7.2.7 Imagery Client

The imagery client supported access to image data provided by SOS and WCS. The client is based on OWS-5 work and can be used to display the imagery coming from a JPIP server. This work included TIE testing of the client with GMU's WCS. Further on, the client was enhanced to error statistics and adjustable parameters associated with a sensor process model. 52°North developed this client.

7.3 Clients & Services for CCSI

A number of Web services and corresponding clients have been developed to support the CCSI workflow. The following figure illustrates this workflow.

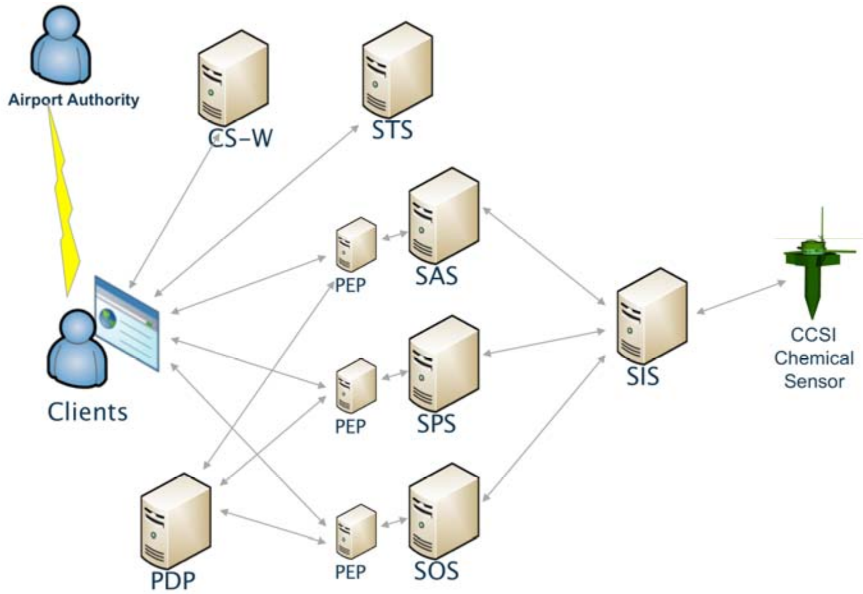

Figure 2: CCSI Workflow Overview

7.3.1 Catalog Service

The catalog service supported the discovery of CCSI sensors. Galdos developed the catalog, with registered services and clients from Compusult, Northrop Grumman, and JPEO-CBD.

7.3.2 STS

The secure token service provided secure tokens to be used with the policy enforcement and decision points. Con terra developed the STS.

7.3.3 SAS, SPS, SOS

All SWE Web services have been implemented to support security enabled SWE-workflows. Compusult developed those services.

7.3.4 SIS

The Service Interface Service, developed by Northrop Grumman, acts as a bridge between CCSI sensors and OGC SWE Web services.

7.3.5 PEP & PDP

The policy decision and enforcement points, together with the secure token service, provide a secure environment for SWE services. Con terra developed both services.

7.3.6 CCSI Sensors

JPEO-CBD provided a CCSI sensor emulator that was used to developed the SIS and to test the communication between various OGC SWE services and the CCSI sensors.

7.3.7 CCSI Clients

Two client applications have been developed. Compusult developed a Web based client, whereas Northrop Grumman provided a thick, .Net-based client. Both clients are "security enabled" and corresponded with all OGC SWE services.

8 Lessons Learnt

OWS-6 SWE was a complex thread with a number of sub-threads. The experiences we made, both positive and negative, are listed in the following table.

Aspect	Works fine	Needs further improvements
X-thread coordination	X-thread coordination is a complex and very time-consuming task. This is mainly due to the different schedules within the different threads. For that reason, X-thread activities have been minimized without loosing interoperability aspects. The late integration into the demo scenario was not an issue.	none
Timing	The timing of a large project such as a Testbed is always an issue. Nevertheless, the SWE thread finished perfectly in time, with final delivery of demo material end of March and delivery of engineering reports by April 17. If the timing is clear at the beginning of the project, timely delivery works fine.	Timely delivery has to be ensured across all threads to allow better planning for all participants. For some participants, it is in an issue if demos etc. get delayed due to late delivery by other threads. Some aspects, such as additional change requests, only become visible by reviewing the final engineering reports. Therefore, the overall schedule shall provide some spare time to work on those changes requests. Thus, the final date shall not be identical with the delivery of the engineering reports. Another four weeks seem to be appropriate.
Final Event	Although the final event was somewhat undefined at the beginning of the project, it worked out well for SWE.	An earlier definition of the final event would help to optimize the preparation.

9 Recommendations for future work

The participants in the OWS6 SWE thread recommend the following work items be addressed in the next phases of SWE.

9.1 Event Architecture

Work on the Event Architecture report revealed several work items that should be incorporated in future OGC SWG work and Testbeds.

9.1.1 Development of an Event Service Specification

The OGC should consider the development of an Event Service specification that builds upon the concepts of the abstract Event Architecture and clearly defines a Pub/Sub service model and its implementation in various architectural styles. While the Event Architecture report deals with the general architecture, the Event Service specification could deal with the implementation details of an OGC Pub/Sub service. The specification will define a standalone service (either a simple notification producer or a broker service) and will at the same time define how other services implement Pub/Sub functionality. So it is envisioned to define all the specific implementation details that need to be defined for the geospatial domain. This work will need to take into account existing standards and cope with the various flavors of architectural styles that are important to the OGC.

The Event Service specification should ideally define interfaces or resources, which can easily be added to OGC service specifications. Profiles or extensions could be defined to handle specific usage scenarios.

9.1.2 Revision / Extension of OGC Baseline

The report examines the definition of the term event and its model with respect to the OGC baseline. Events are a special form of feature, where the temporal aspect is the most important one.

Coverages and observations have already been identified as important feature specializations and are explicitly mentioned in according documents, e.g. ISO 19101. In OWS-6, we performed a thorough investigation of events with respect to the General Feature Model. The results should be discussed by the OGC community, especially if the concept of events is significant enough to include it in the definition of features in ISO 19101. In addition, it would be appropriate to develop a dedicated abstract specification that deals with the special aspects of events and event-driven systems. This would provide a basis for further developments in the area of event-driven geospatial data infrastructures and could use the results of the Event Architecture report as a foundation.

9.1.3 Enhancement of Bounding Information in Feature Encodings

ISO 19136 / GML encodes features with a boundedBy property that is of spatial (gml:Envelope) or spatio-temporal type (gml:EnvelopeWithTimePeriod). The boundedBy property should explicitly allow pure temporal types, like TM_Primitive (encoded as gml:AbstractTimePrimitive), to support the encoding of events as features.

9.1.4 Enhancement of Gazetteer to Handle Temporal Locations

The gazetteer specification needs to be extended so that also temporal locations can be identified (like "Backup 28278", "Version 2.0 Release Date"), just like spatial locations.

This feature would enable usage of temporal identifiers, which is especially useful for events. As an example, think of events that happened at a well-known point in time. Humans refer to this time usually by using an identifier. “9/11” is the latest most prominent example; “French Revolution” or “Independence Day” are others. A given domain usually assigns identifiers, so that ambiguities can be avoided.

9.1.5 Investigation and Improvement of Subscription Models and Filter Languages

The Event Architecture ER provides an overview of different subscription models that can be applied in Pub/Sub scenarios. One of them is using filters to define the events of interest. The OGC Filter Encoding is one candidate for per-message content filters, while the Event Pattern Markup Language (EML) is an example of an OGC standard for enabling complex event processing. The applicability of these and other filter and processing languages (e.g. XPath 1.0 / 2.0, XQuery etc.) needs to be investigated in more detail and enhanced or adapted if required.

To improve support of event processing functionality in an OGC Event Architecture, the EML will need to be revised and extended. New versions of the EML should take into account the newest version of the OGC Filter Encoding and include spatial views and better support invocations of other services like a WPS. This will enable a higher flexibility when composing event processing models and lead to more reactivity of service oriented architectures. Enabling event processing in OGC services and SDIs will be of high interest in the future.

Group, channel and type based subscription models are other ways to define which notifications a client is interested in. In WS-Notification, these models are supported with subscription topics. In the future we need to investigate how exactly we need to model these topics to suit our needs. Various types of metadata can be added to a WS-Topic.

9.1.6 Testing and Implementing the Event Architecture

The report describes possible ways to event-enable existing OGC services. We suggest that an upcoming OGC Testbed should have a dedicated thread with the goal to prototypically realize the event architecture. This Testbed thread could deal with common architectural aspects, not only with eventing but also with aspects of different architectural styles.

These different styles are also of interest for the realization of the Event Architecture. While the report presents an approach to realize the architecture for POX and SOAP / WS-* using WS-Notification, it does not give a solution for REST. In addition, that WS-Notification works for POX has to be proven – a good topic for a Testbed, especially because many OGC service implementations use the POX style. We also explained in the report that WS-Eventing, another approach for doing Pub/Sub, is in the process of finalization at W3C. A comparison of OASIS WS-Notification and W3C WS-Eventing standards needs be performed once WS-Eventing has reached the final status. This will show which of these standards better supports the OGC requirements. These requirements need to be investigated in more detail in the future. Again, performing tests – like in the AIM thread of OWS-6, best solves this.

Both WS-Notification and –Eventing come together with other WS-* standards to manage resources. An investigation of the relationship of these standards with REST should be performed, especially under the aspect of best compatibility between the two approaches when HTTP is the application protocol / transport binding used.

SOAP 1.2 outlines how a web friendly use of SOAP would look like, using HTTP GET for information retrieval only, while POST should be used to invoke real operations. By constraining the resource identification information into the URI part of a WS-Addressing endpoint and not into its reference parameters, higher web friendliness could be achieved. This should be experimented with in an OGC Testbed, to improve the understanding of the different architectural styles, their commonalities and the options for harmonization when HTTP is used.

For testing and furthering the implementation of the Event Architecture, a larger use case that ideally integrates as many of the existing OGC web service standards as possible is envisioned. Data processing workflows, as have been demonstrated before, could be the basis of such a use case. The implementation of the event architecture could benefit by leveraging Enterprise Service Bus (ESB) technology. The scenario could also be used to demonstrate on-the-fly (complex event) processing and transformations between different encodings and protocols.

The definition of an event taxonomy or hierarchy in support of the implementation of the OGC Event Architecture would be another aspect of the envisioned Testbed thread. For this, the taxonomy examples presented in the report can be used as a starting point. Such developments could be done together with the development of topics and topic namespaces for OGC services.

9.1.7 Develop and Implement Policies for OGC Web Services

Policies for web services are a means to specify the behavior of a service instance. This may for example enable clients to define whether notifications that match their subscriptions should be transmitted reliably or not. Policies allow services to indicate the executed behavior but also which options clients have to modify the behavior. Clients may use policies to request specific behavior. It has to be investigated which behavior definitions (i.e., policies) are needed by OGC services today and how they can be integrated into the architecture. Policies to define subscription, caching, filter precision etc. can be imagined.

9.2 SWE Information Model

We discussed several potential topics for future Testbeds in regard to the SWE information model and its derivable discovery mechanisms. The following aspects are the most important:

9.2.1 Optimization of OGC Catalog Service Web with Sensor Web requirements

It is necessary to extend the OGC Catalogue in certain parts to the specific needs of sensor/sensor data and SWE service discovery. The CSW developments within the SWE thread of OWS-6 are a good foundation - though they do not yet sufficiently support the various Sensor Web characteristics. Still missing are thoroughly defined mechanisms for dealing with e.g. specialized metadata harvesting, improved adaption to SWE data encodings and especially the handling of the implicitly highly dynamic sensor characteristics.

9.2.2 Metadata profile for sensor discovery

Further work on the SensorML profile for discovery (see OWS-6 ER) is necessary. In addition, it will be necessary how such an advanced metadata profile for sensors can be matched to Catalogue data models (ebRIM, ISO 19115). Formal documents and specifications are necessary.

9.2.3 Dictionaries for identifiers

For example, URIs identify the phenomena measured by a sensor within a SensorML document. In order to ensure a consistent use of these phenomenon identifiers and to make the definitions that are assigned to these URIs accessible, it is necessary to provide a phenomenon dictionary or registry. An important functionality would be an operation providing access to the phenomenon definitions (e.g. resolving the URIs) but also for exploiting semantic relationships (e.g. finding equivalent or similar definitions).

9.3 CCSI

The integration of CCSI technologies and sensors was the first time that OGC addressed the integration of a specific domain into OGC SWE. We made essential findings during this process and recommend to address the following aspects in future Testbeds:

- Enhance the Sensor Interface Service (SIS) and the CCSI-SWE plug-in to include full documentation and delivery of the source code to the JPEO-CBD
- Modularize SIS by developing a Plugin for SIS and test the SIS and CCSI-SWE plug-in to obtain OGC certification of the CCSI-SWE plug-in as an official OGC release of a CCSI-SWE interface
- Perform the demonstration with actual CBRN sensors
- Review/update/improve mappings from CCSI sensor descriptions and data to SensorML and O & M and vice versa. Review and improve mappings from SPS InputDescriptor format to CCSI command format.
- Improve the integration of security components into the architecture and evaluate more complex security scenarios using CCSI sensors.

9.4 Georeferenceable Imagery

The following issues have emerged in the context of OWS-6 and shall be addressed in future Testbeds.

9.4.1 WSDL / BPEL for OGC Web Services

Workflow WSDLs: One of the main operations is to refine the WSDL for each individual service and associate proper schemas. This is necessary to pass parameters from one service to another service. Currently, the BPEL engine and designer cannot use the rich GetCapabilities information for every OGC-service. It is recommended that OWS-7 open a thread, under either the GPW or the SWE or a cross-thread, to develop a specification and techniques specifically to handle the OGC geospatial Web services and workflows with the BPEL specification. This would reduce the work of refining WSDL.

Extensions to the current BPEL scripts are clearly needed for dealing with security or other information that must be embedded in the header of the SOAP message. The current BPEL specification does not support embedding, retrieving, and passing the information available in the SOAP header. If the invocation of the service does not recognize the WS-Security policy tag in the header, the information is ignored and lost. If BPEL is the choice of scripting language, a revision with support for accessing the optional header information must be provided. It is also necessary to support the newly-emerged WSDL 2.0 and to comply with the new WS-Addressing and WS-Security standards, to achieve asynchronous/stateful Web services and security of information. In summary, the areas security, asynchronous communication, and WSDL 2.0 should be reconsidered and extended.

9.4.2 Uncertainty and Error Propagation

Error propagation is a new addition to the SWE workflow. UncertML may be a candidate to describe the quality of service and data. The problem of describing and propagating the uncertainty information along a workflow can become unworkable under the current system when the following aspects are considered.

a. Appending of an error matrix to the collection of error matrices and growing the collection along the workflow

b. Inserting a self-introduced error matrix into the collection of error matrices.

c. SWE Common might be extended to contain a data type dedicated to provide statistical information (e.g. distributions) but no specific value.

9.4.3 Events in Workflows

With the introduction of SES, the use of SES in the workflow should be studied. On the error propagation along the workflow, the solution should be standardized across different OWSs, i.e. either SOS, WCS, or WPS should have a common mechanism to introduce, pass along and accrue error information. This should be especially important when the workflow becomes very complicated. At the end, users may be interested in knowing all the error sources and re-evaluating the errors themselves when necessary. A common mechanism would simplify the user experience.

9.5 Secure Sensor Web

Implementation of a secure Sensor Planning Service in order to eliminate the explored vulnerabilities and possible attacks as described in the OWS-6 Secure Sensor Web ER (OGC #08-176).

The implementation shall aim to guarantee all relevant requirements in order to pass assurance evaluation tests as specified in "Common Criteria" (ISO 15408) or the TCSEC (Trusted Computer System Evaluation Criteria – also known as "The Orange Book"). For further information, please see the section "Recommendations" in OGC document 08-176.

