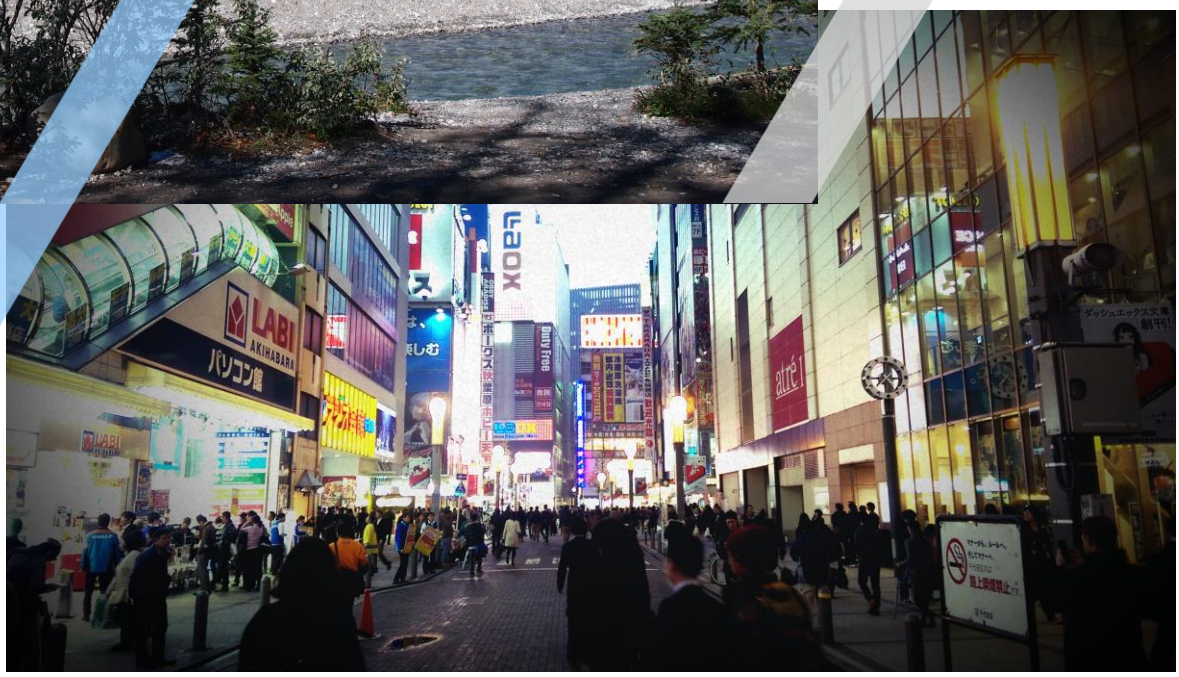
A Guide to the Role of Standards in Geospatial Information Management

Companion document on Standards Recommendations by Tier



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This Companion document on Standards Recommendations by Tier has been prepared cooperatively by the

Open Geospatial Consortium (OGC);

The International Organization for Standards (ISO)

Technical Committee 211 Geographic information/Geomatics;

and the

International Hydrographic Organization (IHO).

Excerpt from the decisions of the Fifth Session of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Held from 3-7 August 2015 at the United Nations Headquarters in New York.

5/108
Implementation and adoption of standards for the global geospatial information community

The Committee of Experts:

a. Welcomed the report by the Open Geospatial Consortium (OGC), Technical Committee 211 of the International Organization for Standardization (ISO/TC 211) and the International Hydrographic Organization (IHO), and thanked them and their many experts for their collaborative efforts in producing and finalising the Standards Guide and Companion Document.

b. **Adopted the final published "Guide to the Role of Standards in Geospatial Information Management" and the "Technical Compendium" as the international geospatial standards best practice for spatial data infrastructure, and encouraged all Member States to adopt and implement the recommended standards appropriate to their countries' level of spatial data infrastructure (SDI) maturity**.

c. Encouraged Member States to continue to work in cooperation with the international standards bodies, including participation, as appropriate, in the work programmes of the OGC, ISO/TC211 and the IHO, and requested the standards organisations to consider mechanisms to facilitate wider training programmes and to ensure the access to standards on reasonable terms, especially for developing countries;

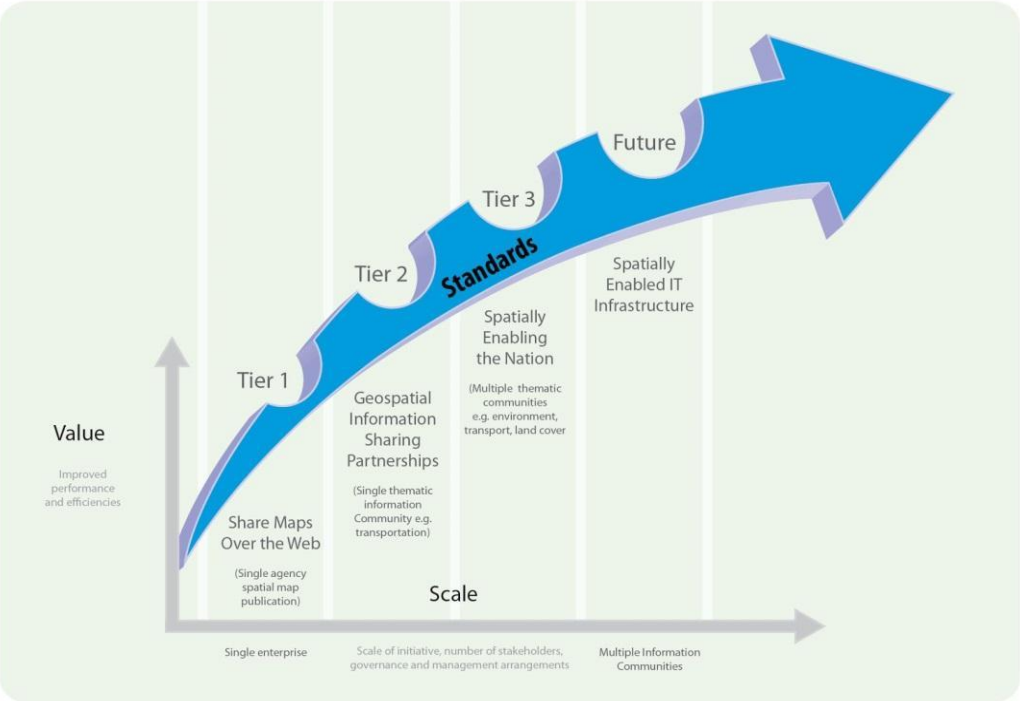
CONTENTS

A sequence of standards related to Tiers

This Companion Document describes which standards may be appropriate to use in each of the Tiers as identified in "A Guide to the Role of Standards in Geospatial Information Management". This Companion Document provides guidance on geospatial standards that could be used at each Tier in the maturity model. The list of standards provided is not intended to mean that every standard is mandatory at each Tier. Instead, these are meant as recommendations. For example, a number of standards are listed for Tier 1. Of the list provided for Tier 1, an initial Spatial Data Infrastructure (SDI) implementation may only implement one or two of the suggested standards. Further, standards recommended in Tier 2 could be implemented in Tier 1 and vice versa. The final decision as to which standards are implemented must be based on specific requirements and use cases.

The first three sections of this companion document recommend essential geospatial standards by Tiers as described in the "Guide to the Role of Standards in Geospatial Information Management". This discussion is followed by a final section that discusses "foundational" standards that should be consulted. These foundational standards represent two categories of standards:

- **General information technology and Internet standards** on which geospatial standards may be dependent. While not all of these standards may be required for implementation, they may be required within an implementing community's operational environment.
- **General Geospatial Standards** which include best practice standards regarding geospatial data definitions, representation, data quality, general architecture and other aspects of geospatial information and technology. They collectively provide guidance on geospatial data collection, production, and maintenance.



Tier 1 – Share Maps over the Web

Tier 1 Goal – The most fundamental requirement in Tier 1 is to enable the stakeholders and constituents (users) of an organization or institution to view and query interactive maps on the web. Closely associated with this fundamental requirement is the ability to discover, share and use geospatial information.

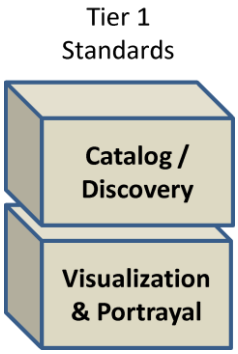


Figure 1: Standards Applicable to Tier 1

Visualization and Portrayal

The following Tier 1 standards are recommended. The most basic requirement in an SDI is to be able to easily and effectively access and display geospatial information that may be stored in one or more databases and using different vendor solutions and storage formats. Therefore, of the following list, Web Map Service (WMS) and Keyhole Markup Language (KML) are the most widely implemented. Using just WMS an organization can generate web based applications that provide access to spatial information holdings, regardless of the formats used or GIS technology deployed. Many organizations have implemented WMS first to provide seamless access to geospatial information. These deployments provide quick, short term success and return on investment. As the SDI matures, most organizations then enhance their SDI capability with discovery and metadata browsing capability.

The following Tier 1 standards are suggested to be considered for implementing a powerful access, browse, and display SDI capability. These standards provide the ability for the user to access and display geospatial information as images in any browser.

- OGC Web Map Service/ISO[1] 19128 Web Map Server Interface (WMS) – for access and display of geospatial information as a raster image. This is a very widely implemented OGC/ISO standard with thousands of instances providing access to hundreds of thousands of geospatial information layers.
    - http://www.opengeospatial.org/standards/wms
- OGC Web Map Tile Service (WMTS) If high speed access and rendering of geospatial information is required, then using the WMTS standard is suggested. This version of WMS pre-processes or (pre-tiles) data to support high volume / high speed display of raster data.

[1] Whenever the notation OGC/ISO is used, this indicated a standard that originated in the OGC and was submitted to ISO. These then become joint ISO-OGC standards documents

- http://www.opengeospatial.org/standards/wmts

Associated with visualizing geospatial information may be the requirement to portray the information using an organization's symbology or cartographic presentation rules. The ability to code, communicate and share visualization rules can be implemented using the following standards.

- OGC Styled Layer Descriptor (SLD)
  - http://www.opengeospatial.org/standards/sld
- OGC Symbology Encoding
  - http://www.opengeospatial.org/standards/se
- OGC Web Map Context (WMC) – for storing and communicating "pre-packaged" user displays. Using WMC is a convenient way to save and share the details of how to re-create a web map session.
  - http://www.opengeospatial.org/standards/wmc
- OGC Web Services Context Document (OWS Context) - A 'context document' specifies a fully configured service set which can be exchanged (with a consistent interpretation) among clients support the standard.
  - http://www.opengeospatial.org/standards/owc
- OGC KML – Visualization of geospatial information in earth browser applications
  - http://www.opengeospatial.org/standards/kml

Catalogue and Discovery

The ISO and OGC standards for catalogue and discovery are widely implemented in national, regional, and local SDIs. Most geospatial technology vendors, as well as open source solutions, support these standards. These standards should be implemented if the community requires the ability to search metadata holdings for the geospatial information they require. The metadata and catalogue searches also allow the user to determine if the geospatial information is fit for a particular use or purpose.

- Metadata: Provides the metadata items for describing geospatial resources
  - ISO 19115, Geographic information – Metadata
    - Part 1: Fundamentals, provides a conceptual schema for defining metadata for collections of datasets (such as in a series, for a particular data capturing platform and/or sensor, or for an initiative), individual datasets and parts of a dataset, even down to individual features and attributes. The standard defines a comprehensive set of metadata elements from which to choose. https://www.iso.org/standard/53798.html See also 2018 Corrigenda https://www.iso.org/standard/73118.html
    - Part 2: Extensions for imagery and gridded data

      https://www.iso.org/standard/39229.html
    - Part 3: XML schema implementation for fundamental concepts
    - https://www.iso.org/standard/32579.html

- Catalogues: Catalogue services support the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects. The Catalogue Service Implementation Specification (also known as Catalogue services – Web or CSW) specifies the interfaces and bindings for creating catalogue services.
    - http://portal.opengeospatial.org/files/?artifact_id=20555
- There are two main profiles of the OGC Catalogue Service
    - OGC Catalogue Services Specification 2.0.2 - ISO Metadata Application Profile (1.0.0) http://portal.opengeospatial.org/files/?artifact_id=21460
    - OGC I15 (ISO 19115 Metadata) Extension Package of CS-WebRIM[2] Profile 1.0 https://portal.opengeospatial.org/files/?artifact_id=56905

The OGC Catalogue Service 19115 Metadata application profile is very widely implemented and is used in numerous operational SDIs worldwide. These include proprietary and open source based solutions. Some examples are:

- INSPIRE CSW Registry: http://inspire-geoportal.ec.europa.eu/INSPIRERegistry/
- GEOSS Registry: http://geossregistries.info/portaldeveloper.html#csrCSWAPI
- US data.gov: https://www.fgdc.gov/fgdc-news/geospatial-platform-catalog-api

Data content and management

To fully enable visualization and portrayal of geospatial information over the Web, an organization must have the capabilities to describe, organize, collect and manage its geospatial information. It is recommended to develop standardized applications schemas and feature catalogs to support these capabilities. Quite often, an organization has existing digital geographic information they wish to visualize and share over the web. In this case, the organization would use the referenced standards for maturing their geospatial content collection, management and update capabilities. These standards should be viewed in the context of the maturity of the SDI activity in the organization. The recommended standards are ISO 19109 (Rules for application schema) and 19110 (Methodology for feature cataloguing) and OGC Geopackage (Format for transferring Geospatial Information). They are described in more detail in the Foundation Standards section.

[2] OASIS/ebXML Registry Information Model v2.0 (ebRIM) is an OASIS standard. More information can be found here: http://docs.oasis-open.org/regrep/regrep-core/v4.0/regrep-core-rim-v4.0.html

Sequence of standards/implementation options within the Tier

At this initial tier of capability, data content management policies and processes may be somewhat informal. However, implementing organizations are encouraged to review the ISO/TC 211 Foundational standards at the end of this document for insight on establishing effective data management practices.

Organizations then need to determine which themes of geospatial information are to be shared. In this context, sharing could be "view only" (solves the majority of use cases) or actual publication and transmission of physical data. In this step, one or more organizations agree to collaborate and share specific data holdings. Standards at this step in the process would be sharing and access agreements, cartographic symbolizations rules, authentication/authorization rules, and policies that can be documented and communicated.

Within a portal context, the next step would be to use OGC/ISO Web Map Service interface instances to provide access to the shared data holdings. Implementation of WMS instances using common symbology rules encoded using the OGC Style Layer Descriptor and OGC Symbology encoding allow the ability to display geospatial information as a seamless, virtual map – even though the information is stored on multiple, geographically distributed servers using different geospatial technology.

In parallel, develop a registry of geospatial information that can be discovered, viewed, and published. This requires the collection and maintenance of metadata (see below). The metadata registry can be "exposed" to services, including clients, using one of the OGC Catalogue Service-Web (CSW) profiles (see above).

In parallel, collect and maintain metadata (there are profiles of ISO 19115 that can be used as a template for new SDI activities.) [3]

Once the desired geospatial information can be discovered and viewed as a seamless set of maps, then the infrastructure is mature enough to consider publishing content and transmitting physical data (content) to end users. Please note that publication of geospatial information requires that proper metadata be available (see above) so that end users can determine if specific sets of information are "fit for purpose". Further, please note that the semantics of the published data need to be available. For example, for roads: what are the feature codes (also known as properties or attributes) for the roads and what are the other attributes associated with a road segment?

Publication also assumes that one or more distribution formats are supported. There are vendor specific formats as well as international standards (de-facto or agreed to consensus standard). Common distribution formats are OGC/ISO Geography Markup Language application schemas, IHO S-57 - Electronic Nautical Charts, GeoTIFF, and Esri shapefiles. International standards are better than locally defined formats as they reduce costs and enhance collaboration with outside groups.

[3] See North American Profile of ISO19115:2003 – Geographic information – Metadata (NAP – Metadata) http://nap.geogratis.gc.ca/metadata/napMetadata-eng.html

Publication assumes a standard way for requesting geospatial information, packaging that information, and transmitting the information. For example, if the user wants the transportation theme as a GML application schema or a chart in S-57, then the server based software needs to be able to generate the information in the requested formats. These requests for publication are performed using simple web calls. Distribution can be in any number of standard formats, such as GeoTIFF or GML files. The required data can be streamed from the server to the client application or for very large files can be uploaded to an ftp site or a more flexible technology such as DropBox for downloading at any time.

Tier 2 – Partnerships

Partnerships - Share, Integrate and Use Geospatial Data from different Providers

Tier 2 Goal - An information community wishes to provide access to geospatial information over the web, provide geospatial information download services, and in addition, may provide specific data themes, such as roads, from multiple sources that conforms to an agreed, common data model[4] to create a consistent and integrated 'view' of the geospatial information for users. Tier 2 builds on the infrastructure, policies, technologies, and standards deployed and matured in Tier 1.

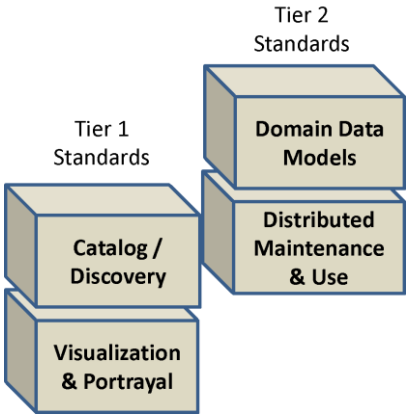


Figure 2: Standards Applicable to Tier 2

In this Tier, the community and infrastructure have matured to the point that the services are well used and stable but the community is requesting more and more functionality. Further, more partners wish to participate and integrate into the SDI infrastructure. As such, increased capability as well as additional reliance on standards will be required. For example, as more partners (public and private) wish to join the SDI community, the infrastructure will need to accommodate the use of additional international technology standards and community information model standards. The following key standards are recommended for possible use in Tier 2.

Distributed Maintenance and Use

There are two key types of geospatial standards the reader needs to be aware of: information (or content) standards, and technology (interface, API[5]) standards.

The concept of information model standards is introduced in Section 2 of "A Guide to the Role of Standards in Geospatial Information Management". An information model in software engineering is a representation of concepts and the relationships, constraints, rules, and operations to specify data

[4] An OGC White Paper (Data Models and Interoperability) provides an excellent discussion on establishing agreed upon data models for data sharing and enhancing interoperability.
http://portal.opengeospatial.org/files/?artifact_id=3805&version=2&format=pdf

[5] API: application programming interface. APIs specify how software components should interact with each other.

semantics for a chosen domain of discourse, such as transportation, hydrology, or aviation. The goal of such models is to allow multiple stakeholders across many jurisdictions to have an agreement on how to express data for a specific domain, such as weather, geology, or land use. Such agreements significantly enhance interoperability and the ability to share geospatial information at any time and as required.

Information modelling and encoding: GML is the primary OGC/ISO standard used for modelling, encoding, and transporting geospatial information. In addition, a number of OGC standards reference and use OGC/ISO 19156 Observations and Measurements (O&M) is discussed as part of the Tier 3 standards recommendations. While O&M is used by a number of Tier 2 recommended standards, knowledge of this standard is not required until Tier 3.

- OGC/ISO 19136 Geography Markup Language (GML) - XML grammar for expressing geographical features. GML serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet.
    - ISO 19136-Part 2: Extended and encoding rules

      https://www.iso.org/standard/61585.html
    - OGC Geography Markup Language and it's extensions

      http://www.opengeospatial.org/standards/gml

Geospatial information query and access: The following standards allow the application and user to specify geographic and attribute queries and request that the geospatial information be returned as an encoding.

- OGC/ISO 19142 Web Feature Service 2.0 – an interface allowing requests for geographical features across the web using platform-independent calls.
    - https://www.iso.org/standard/42136.html
    - http://www.opengeospatial.org/standards/wfs
- OGC/ISO 19143 Filter Encoding 2.0 – allows the user/application to specify and communicate geospatial information queries using a standard language.
    - https://www.iso.org/standard/42137.html
    - http://www.opengeospatial.org/standards/filter
- OGC Web Coverage Service (WCS) 2.0 – A WCS specifies standard rules and operations for access to coverage data such as digital elevation models, multi-spectral satellite images, and other surface covering tessellations.
    - http://www.opengeospatial.org/standards/wcs

A very important consideration for the Tier 2 standards is their reliance on a number of abstract standards or models that describe such geographic information elements as geometry (points, lines, etc), coordinate reference systems, data quality, time, and so forth. These fundamental ISO abstract standards are recommended and discussed in the Foundation Standards- General Geospatial Information Standards section, Domain Data Models

More specifically in the context of maturing SDI applications, we now also introduce the concept of domain data modelling. Domain modelling extends information modelling by enabling the reuse of concepts, semantics and information organization (schemas) between related systems.

While information modelling typically refers to modelling just one system, domain modelling involves the practice of creating definitions of concepts which are reused between multiple systems. In the standards

context this is further extended to imply interoperability of models and platform independence. Both information models and domain models are relevant to Tier 2 and Tier 3 in the evolution of an SDI.

Using such information (or content) standards helps to guarantee that geospatial information can be encoded and shared with consistent semantics, geometry, quality, and provenance. Further, data models tend to be encoding tool agnostic, meaning the content can be encoded using XML, JSON, and other encoding technologies. Examples of these models include:

Example Domain Data Model Standards

- OGC CityGML
    - For managing and Sharing Urban 3d models
    - http://www.opengeospatial.org/standards/citygml
- ISO 19144, Geographic information -- Classification systems
    - Part 1: Classification system structure (along with ISO 19144-1:2009/Cor 1:2012)
        - Establishes the structure of a geographic information classification system
        - http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=32562
    - Part 2: Land Cover Meta Language (LCML)
        - Provides a metamodel that allows different land cover classification systems to be described based on the physiognomic aspects
        - http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=44342
- ISO 19152, Geographic information -- Land Administration Domain Model (LADM)
    - Defines a reference Land Administration Domain Model (LADM) covering basic information-related components of land administration (including those over water and land, and elements above and below the surface of the earth)
    - http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51206
- ISO 19160, Addressing
    - Part 1, Conceptual model
    - Part 4, International postal address components and template language
- GeoSciML – Geological structure and bore holes
    - http://www.geosciml.org/
- OGC WaterML 2.0 - Sharing in-situ sensor water observations
    - http://www.opengeospatial.org/standards/waterml
- S-57 - IHO Transfer Standard for Digital Hydrographic Data
    - Http://www.iho.int/iho_pubs/standard/S-57Ed3.1/31Main.pdf

- The future "Common Maritime Data Structure" which will support the implementation of the e-navigation concept adopted by the International Maritime Organization (IMO). It will be based on the IHO Standard S-100 - Universal Hydrographic Data Model
    - https://www.iho.int/iho_pubs/standard/S-100/S-100_Info.htm

Most of these models are encoded using Geography Markup Language (GML).

To summarize, content models refer to community agreements on the elements, relationships between elements, semantics and so forth for a specific data set in a given domain. Further, content models are implementation independent and vendor neutral. In order to automate and make the exchange of domain specific geospatial data seamless, consensus needs to be built among the community participants on:

- A shared data model for data exchange, in terms of a common understanding and agreement for how different systems "understand" each other;
- Common definitions of the different data entities and their properties; and
- Common controlled vocabularies and taxonomies.

Consider a transportation network. Common agreements and vocabularies mean that:

- All stakeholders agree to how to display (symbolize) the transportation network;
- All stakeholders agree to what each property, such as road width, means in terms of the shared view of the transportation network;
- All stakeholders agree to a common view of the road classification system

This use of common data models is part of the natural evolution and progression of an SDI that leads to the concept of foundation or framework SDI data themes. This evolution is described in greater detail in the Tier 3 discussion. Very good references on the domain modelling and content models are *ISO 19109, Geographic information – Rules for application schemas*[6] and the *OGC® OWS-8 Domain Modelling Cookbook*[7]. These documents describe rules and best practices for building and maintaining inter-related domain models, which have dependencies on multiple systems. They describe how to build interoperable, maintainable domain models, the challenges and pitfalls faced in building these models, the techniques and patterns that should be applied, and specific tools that can be used.

These agreements do not mean that any specific organization needs to change software or processes, only that they agree on the shared model and the semantics (vocabulary, terms and definitions, etc.) used in the model. There are currently many such models available that have been developed and agreed to by international organizations or communities. These models should be considered first prior to thinking about developing new data models.

Additional Implementation standards for consideration

- GeoRSS Simple and GML - GeoRSS was designed as a lightweight, community driven way to extend existing feeds with geographic information. Many SDIs use GeoRSS for quickly communicating basic geospatial information or for alerting applications.
    - http://www.georss.org/

[6] See Foundational standards section
[7] https://portal.opengeospatial.org/files/?artifact_id=47479

Tier 3 – Spatially Enabling the Nation

Tier 3 Goal - Multiple organizations share foundation/framework geospatial information and services with each other and the broader community to improve knowledge and understanding, thereby contributing to evidence-based decision making, situational awareness, and improved societal outcomes.

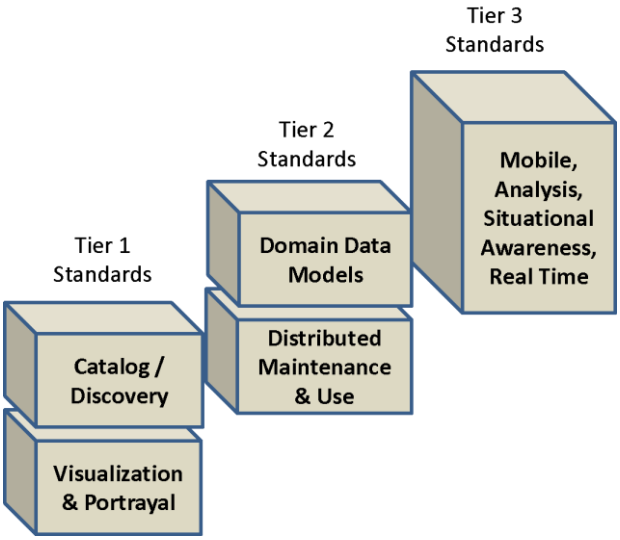


Figure 3: Standards Applicable to Tier 3

In this Tier, the infrastructure is mature enough to support deployment of more and more applications to enhance value, provide increased citizen benefit, increase collaboration between organizations, and much more. We also see the introduction and integration of an increasing number of geospatial information resources, included volunteered and real time sensor feeds. We will also see mature deployment of mobile applications.

Geospatial Processing & Analytics

- OGC Web Processing Service (WPS) – provides rules for standardizing how inputs and outputs (requests and responses) for geospatial processing services, such as polygon overlay.
    - http://www.opengeospatial.org/standards/wps

Grid Systems

- OGC Discrete Global Grid Systems (DGGS) an Abstract Specification and extension mechanism. A DGGS is a spatial reference system that uses a hierarchical tessellation of cells to partition and address the globe. DGGS are characterized by the properties of their cell structure, geo-encoding, quantization strategy and associated mathematical functions. The OGC DGGS Abstract Specification supports the specification of standardized DGGS infrastructures that enable the integrated analysis of very large, multi-source, multi-resolution, multi-dimensional, distributed

geospatial data. Interoperability between OGC DGGS implementations is anticipated through implementation standards, and extension interface encodings of OGC Web Services. This specification has particular benefit in the context of integrating Geospatial and Statistical Information and has been referenced in the Global Statistical Spatial Framework

- http://docs.opengeospatial.org/as/15-104r5/15-104r5.html

Mobile Devices

Increasingly, mobile devices are a becoming a key source for geospatial data capture, maintenance and application. These capabilities are in addition to the simple ability to display maps to a mobile device as required in Tier 1. While OGC web services standards noted above work in the mobile internet environment, we note that there are other adopted and in-work standards that may be of relevance to Tier 3:

- OGC Open GeoSMS (www.opengeospatial.org/standards/opengeosms) – is a recently adopted OGC standard that defines a standard approach to encoding a geo-tag for an SMS message. Open GeoSMS enables mobile users to transparently send location information in the header of their mobile text messages.
- OGC GeoPackage (www.opengeospatial.org/standards/requests/115): The OGC GeoPackage GPKG) standard is an open, app-independent, platform-independent, portable, interoperable, self-describing data container and API. Designed for the mobile world, this standard is intended to support multiple mapping and geospatial applications such as fixed product distribution, local data collection, and geospatially enabled analytics.

Real time

Increasingly, geospatial information is being generated as the result of real time observations being captured by in-situ and dynamic (moving) sensor systems. These information resources provide the ability to enhance decision making, situational awareness, quality of life, sustainability, and so on. Anyone with a smart phone is already using or accessing real time sensor information, such as the current temperature at a particular location.

The OGC has a suite of standards that allow applications and services to describe, task, and request observations from one or more sensors. This suite of sensors standards is called Sensor Web Enablement (SWE). The OGC uses the following definition for a sensor:

An entity capable of observing a phenomenon and returning an observed value

The type of observation procedure determines the estimated value of an observed property as its output. A web or internet accessible sensor is any sensor that has an IP address that can provide or be tasked to provide an observation. Sensors can be in a fixed position or mobile. An excellent example of an OGC SWE implementation is the US NOAA Integrated Ocean Observing System (IOOS)[8]. This system provides real time access to mobile and in-situ Ocean observing sensor systems. These sensors are obtained from numerous different technology providers, all described, tasked, and accessed using OGC SWE standards. Other excellent examples of operational use of OGC SWE standards are:

[8] http://www.ioos.noaa.gov/observing/welcome.html

- Sensors Anywhere (SANY) [9] - SANY aims to improve the interoperability of in-situ sensors and sensor networks, allowing quick and cost-efficient reuse of data and services from currently incompatible sources in future environmental risk management applications.
- The Heterogeneous Missions Accessibility (HMA)[10] initiative aims to harmonize ground segment interface activities for Earth observation (EO) missions.
- Sensor Web Enablement Application for Debris Flow Monitoring System in Chinese Taipei. This program uses SWE standards integrated into a monitoring, modelling, and alerting infrastructure.

The main SWE suite of standards is:

- **OGC/ISO Observations & Measurements Schema (O&M) / ISO 19156** – An OGC adopted standard that defines conceptual models for encoding observations and measurements from a sensor, both archived and real-time.
- **OGC Observations and Measurements XML (OMXML)** – GML/XML encoding of the abstract O&M model.
- **OGC Sensor Model Language (SensorML)** – An OGC adopted standard that defines standard models and XML Schema for describing sensors systems and processes; provides information needed for discovery of sensors, location of sensor observations, processing of low-level sensor observations, and listing of task able properties.
- **OGC Sensor Observations Service (SOS)** - An OGC adopted standard that specifies a standard web service interface for requesting, filtering, and retrieving observations and sensor system information. This is the intermediary between a client and an observation repository or near real-time sensor channel.
- **OGC Sensor Planning Service (SPS)** – An OGC adopted standard that specifies standard web service interface for requesting user-driven acquisitions and observations. This is the intermediary between a client and a sensor collection management environment.

More and more SDIs are integrated real time sensor feeds. This real time information is used to enhance situational awareness or is fused with other geospatial information resources to enhance decision support. Another key use for real time sensor information is to feed modelling systems that are used to predict severe weather events, tsunamis, debris flows, and other potential catastrophic events that impact human lives.

A further standard to consider is the **OGC SensorThings API**. The OGC SensorThings API is an OGC standard specification for providing an open and unified way to interconnect IoT devices, data, and applications over the Web. The SensorThings API is an open standard, builds on Web protocols and the OGC Sensor Web Enablement standards, and applies an easy-to-use REST-like style. The result is to provide a uniform way to expose the full potential of the Internet of Things. http://www.opengeospatial.org/standards/sensorthings

GeoSemantics

- ISO 19150 Geographic information – Ontology
    - Part 1: Framework

[9] http://eprints.soton.ac.uk/355932/1/355932.pdf
[10] http://www.esa.int/About_Us/ESA_Publications/ESA_TM-21_Heterogeneous_Missions_Accessibility

        - http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=57465
    - Part 2: Rules for developing ontologies in the Web Ontology Language (OWL)
        - https://www.iso.org/standard/57466.html

Tier 4 – Spatial Data integrated with Global Data Ecosystem

As our global web of information continues to increase with both data and technology, our capacity to share geospatial data increases towards becoming a *spatially enabled web of data***.**

For general understanding of the industry trends the reader is referred to the UN-GGIM report, "Future Trends in geospatial information management: five to ten year vision"[11] for details on what we believe to be the technological, legal, policy, and consumer trends impacting the collection, use, and visualization of geospatial information.

To assist in understanding these trends in a geospatial standards context, the OGC has worked with its membership, alliance partners and others to develop and maintain the OGC Technology Trends. This research informs the road-mapping for standards development, thus ensuring that necessary standards are developed at pace with technology development. This information is updated on a quarterly basis and is publicly available for review and consideration at https://github.com/opengeospatial/OGC-Technology-Trends

These trends are driving requirements for enhancing existing geospatial standards, rethinking and crafting a new generation of standards based on the lessons learned of the existing baseline, and incorporating new suites of standards required to leverage the value of the emerging technologies and user requirements.

The following are a few of the trends driving new areas of standards development or new applications of existing standards:

- **Internet of Things (IoT)**: The ability to integrate a vast array of sensors and sensor networks into the infrastructure. Observations from these sensors will enhance decision making, simulation and modelling, quality of life, sustainability, and many other aspects of the value of geospatial information. The development of IoT standards is in flux as the market and technology evolves. OGC Sensor Web Standards (SWE) and SWE for IoT are relevant to providing standards based solutions for IoT.
- **UAVs and CAVs:** A major new potential source of geospatial data is from Unmanned Aerial Vehicles (UAVs) and Connected Autonomous Vehicles (CAV). Until recently, the use and availability of such assets were expensive and difficult to procure. However, there is now a new generation of small, easily transported UAV/CAV platforms that can carry high resolution digital cameras and other sensor assets. Additional UAV/CAV remote sensing functions include electromagnetic spectrum sensors, gamma ray sensors, biological sensors, and chemical sensors. A UAV's electromagnetic sensors typically include visual spectrum, infrared, or near infrared cameras as well as radar systems. Similar developments are in progress for maritime applications with Autonomous Surface or Underwater Vehicles (ASV/AUV). Existing OGC, IHO, and ISO standards are highly relevant in this application area. For example, the OGC SWE standards have been used with onboard UAV sensor systems for several years.
- **Full Motion Video:** Over the last few years, the need (and the ability) to collect, analyze, and integrate full motion video assets into decision support and situational awareness applications have escalated. A key requirement for using full motion video is change detection. However, a much more standards based approach is required.

[11] http://ggim.un.org/docs/Future-trends.pdf

- **Big Data and Big Science:** In order to properly address many sustainability issues, the world of big science needs to be fused with the SDI and Earth Observation communities. Some of this collaboration and fusion is happening in the Open Geospatial Consortium in the Meteorology, Hydrology, and Emergency and Disaster Management Working Groups. These working groups are defining best practices for integrating domain specific observations, modeling, and scientific research into current and future information infrastructures using existing standards
- **3DModels:** With concepts such as the "Digital Twin" for our world increase in interest and popularity so too does the need for richer and more detailed 3D models to assist us in understanding the world around us. This area covers a broad range of tasks including 3D Computer graphics and 3D Modelling.
- **APIS for the Web**: The explosive growth of public APIs for geospatial applications, and the accompanying variability in API practices across the IT industry, as well as in geospatial APIs specifically, has created new opportunities and challenges in supporting geospatial services. For greater understanding in this areas please see the OGC Geospatial APIs Whitepaper http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html
- **Volunteered Geographic Information (VGI)**: Geo Crowdsourcing includes Social Media and Voluntary Geographic Information (VGI). Crowdsourcing refers to the process of obtaining geo inspired services, ideas, or content by soliciting contributions from a large group of people, especially an online community, rather than from employees or suppliers[12]
- **Data Science Analytics**: refers to a number of data science advances including Machine Learning (gives computers the ability to learn without being explicitly programmed), Anomaly detection (he identification of items, events or observations which do not conform to an expected pattern or other items in a dataset[13]
- **Linked Data:** Related to Big Data and other newer sources if geospatial content is "linked data". Linked data is a concept related to the semantic web. From W3C, "The Semantic Web isn't just about putting data on the web. It is about making links, so that a person or machine can explore the web of data. With linked data, when you have some of it, you can find other, related, data." Wikipedia defines Linked Data as "a term used to describe a recommended best practice for exposing, sharing, and connecting pieces of data, information, and knowledge on the Semantic Web using URIs and RDF."

In addition to the standards discussed and recommended above, the following are suggested standards that are relevant to a spatially enabled web:

- **GeoSPARQL**: supports representing and querying geospatial data on the Semantic Web. GeoSPARQL defines a vocabulary for representing geospatial data in RDF, and it defines an extension to the SPARQL query language for processing geospatial data. In addition, GeoSPARQL is designed to accommodate systems based on qualitative spatial reasoning and systems based on quantitative spatial computations.
- **Spatial Data on the Web Best Practice**: is a joint document between the OGC and the World Wide Web Consortium (W3C) that identifies best practices for publishing spatial data on the Web. http://www.opengeospatial.org/projects/groups/sdwwg

[12] **OGC Technology Trends input from DSTL https://github.com/opengeospatial/OGC-Technology-Trends/blob/master/chapter-06.adoc as at July 2018**

[13] **OGC Technology Trends input from DSTL https://github.com/opengeospatial/OGC-Technology-Trends as at July 2018**

General IT and Internet Standards

The following "foundational" standards are generally required to implement any web or internet based solution. No information technology standards exist in isolation. There is a rich standards stack that supports ALL internet, web, and/or mobile applications. The following table is extracted from the Global Spatial Data Infrastructure (GSDI) Cookbook, chapter 10 and is enhanced with additional foundation standards. Please note that not all of these standards are required for implementation, but they may be required or expected to be present in a community's operating environment. Furthermore, most OGC standards reference one or more of these foundational standards.

- IETF RFC 2141 (May 1997), URN Syntax, R. Moats, http://www.ietf.org/rfc/rfc2141.txt
- IETF RFC 2396 (August 1998), Uniform Resource Identifiers (URI): Generic Syntax, Berners-Lee, T., Fielding, N., and Masinter, L., eds., http://www.ietf.org/rfc/rfc2396.txt
- IETF RFC 2616 (June 1999), Hypertext Transfer Protocol – HTTP/1.1, Gettys, J., Mogul, J., Frystyk, H., Masinter, L., Leach, P., and Berners-Lee, T., eds., http://www.ietf.org/rfc/rfc2616.txt
- IANA, Internet Assigned Numbers Authority, MIME Media Types, available at http://www.iana.org/assignments/media-types/
- ISO 3166-1 - Codes for the representation of names of countries and their subdivisions -- Part 1: Country codes http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=63545 and http://www.iso.org/iso/country_codes.htm
- ISO 8601:2004 – Data elements and interchange formats -- Information interchange -- Representation of dates and times http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=40874
- Unified Code for Units of Measure (UCUM) – Version 1.8, July 2009
- W3C Recommendation: eXtensible Markup Language (XML) Version 1.1
- W3C Recommendation: XML Schema Version 1.0
- W3C Recommendation: Hyper Text Transport Protocol (HTTP) Version 1.1
- W3C XLink 1.1 Schema
- W3C Recommendation (16 November 1999): XML Path Language (XPath) Version 1.0 http://www.w3.org/TR/xpath.html
- Oil and Gas Producer (OGP, formerly EPSG) Geodetic Parameter Dataset, Version 6.9 (2006)
- Geographic Tagged Image File Format (GeoTIFF) Version 1.0
- JPEG-2000 (ISO/IEC 15444-1:2004)
- Information retrieval (Z39.50)—application service definition and protocol specification (ISO 23950:1998)
- ISO/IEC 27001:2005 – Information technology – Security techniques – Information security management systems – Requirements.

The above list is meant as a reference and is by no means all-inclusive. For example, there are many possible IETF, W3C, and OASIS standards for authentication, authorization, and security that could be used when implementing an SDI. The choice of which security standards to use should be determined as part of the system requirements analysis.

General Geospatial Information Standards

These Geographic Information standards may be useful as background and guidance on key concepts of geospatial information definition, organization and architectural representation:

- ISO 6709 and 6709/Cor1, Standard representation of geographic point location by coordinates
- ISO 19102, Reference model – Part 1: Fundamentals and Part 2: Imagery
- ISO 19103, Conceptual schema language
- ISO 19104, Terminology
- ISO 19105, Conformance and Testing
- ISO 19106, Profiles
- ISO 19107, Spatial schema, provides the geometry and topology concepts for describing geographical phenomena, http://www.iso.org/iso/catalogue_detail.htm?csnumber=26012
- ISO 19108 and 19108/Cor 1, Temporal schema, provides the temporal concepts for describing geographical phenomena, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=26013
- ISO 19109, Rules for application schema, defines the General Feature Model which provides a standard structure for the description of geospatial features, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=39891
- ISO 19110, Methodology for feature cataloguing. This standard is based on the General Feature Model and defines the standard structure for the description of geospatial feature in a feature catalogue, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=39965
- ISO 19111, Spatial referencing by coordinates, defines the conceptual schema for describing spatial referencing by coordinates, optionally extended to spatio-temporal referencing, used in geographic information systems and on maps and charts to store and depict geographic information, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=41126
- ISO 19111-2, Spatial referencing by coordinates-Part 2: Extension for parametric values
- ISO 19112, Spatial referencing by geographic identifiers, provides the structure for the development of gazetteers, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=26017
- ISO 19119, Services (Architecture), a high-level standard that describes service architectural patterns, presents a taxonomy for geographic services, and provides guidelines for the selection of services, http://www.iso.org/iso/catalogue_detail.htm?csnumber=39890
- ISO 19123, Schema for Coverage Geometry and Functions, provides the conceptual schema for the spatial aspects of coverages, which includes all forms of imagery, gridded and raster data, such as remote sensing, photogrammetry, image processing, digital elevation and terrain models and modelling using discrete surfaces (polygons with homogenous values) or continuous surfaces, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=40121

- ISO 19125-1, Simple Feature Access -- Part 1: Common architecture, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=40114
- ISO 19125-2, Simple Feature Access – Part 2: SQL option, standardizes the names and geometric definitions of the SQL types for the Geometry class, and names, signatures and geometric definitions of the SQL functions for Geometry. The implementation of ISO 19125-2 is an extension of SQL and is a very effective method of querying a database or performing complex analysis.
- ISO 19126, Feature concept dictionaries and registers
- ISO 19127, Geodetic codes and parameters
- ISO 19131 and 19131 Amd 1, Data product specifications. This standard specifies requirements for the specification of geographic data products, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=36760
- ISO 19132, Location-based services-Reference Model
- ISO 19133, Location-based services- Tracking and navigation
- ISO 19134, Location-based services – Multimodal routing and navigation
- ISO 19148, Linear Referencing, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32566
- ISO 19156, Observations & measurements / OGC Observations & Measurements, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32574

Or http://www.opengeospatial.org/standards/om

- ISO 19157 and 19157-2, Data quality and Data Quality XML schema implementation. Provides the quality elements for describing geospatial resources, http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=32575
- ISO 19158, Quality assurance of data supply
- ISO 19162, Well-known text representation of coordinate reference systems
- ISO 19163-1, Content components and encoding rules for imagery and gridded data –content model.
- OGC GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial information. http://www.geopackage.org/

The following IHO foundational standards are specific to marine geospatial information:

- S-4 - Regulations for International (INT) Charts and Chart Specifications of the IHO, http://www.iho.int/iho_pubs/standard/S-4/S-4_e4.4.0_EN_Sep13.pdf
- B-6 - Standardization of Undersea Feature Names

  http://www.iho.int/iho_pubs/bathy/B-6_e4.1.0_2013_EF.pdf
- S-23 - Limits of Oceans and Seas,

  https://www.iho.int/iho_pubs/standard/S-23/S-23_Ed3_1953_EN.pdf