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Interoperability & Open Architectures: An Analysis of Existing Standardisation Processes & Procedures

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1 Acknowledgements

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2 Interoperability & Open Architectures for Information Services

Interoperability and open architectures are core requirements for state of the art implementations of IT solutions. Service oriented architectures based on a commitment to using open standards enables a system of componentised building blocks which can be chosen, run and maintained according to their best match of user requirements, independent of vendor solutions or storage models. Such a commitment also ensures that relevant interface specifications and standards are adhered to. Since this approach is flexible and can easily adapt to changing requirements, operational costs are reduced and provides higher efficiency levels of the systems and greatly reduces the risk of future investment losses. To define what interoperability and open architectures are about and which processes and procedures are parts of the definition process, we will take a look at the work of the Open Geospatial Consortium.

The Open Geospatial Consortium, Inc. (OGC) is a not for profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services. Through a member-driven consensus process, OGC works with government, private industry, and academia to create open and extensible interface and encoding standards for geographic information systems (GIS) and other mainstream technologies. While the focus of the OGC activities is on geospatial themes, the many of the currently adopted OGC interface specifications are deeply rooted in the world of geographic information systems. More recently the organisation and its members have moved along with the changes in the IT world, focussing on the integration of geospatial requirements in mainstream IT solutions.

In the geospatial community, the meaning of “interoperability” remains somewhat ambiguous, as do many of the benefits of "being interoperable". Therefore, the following interoperability mandate is suggested.

> To be **interoperable**, one should actively be engaged in the ongoing process of ensuring that the systems, procedures and culture of an organization are managed in such a way as to maximize opportunities for exchange and re-use of information and services, whether internally or externally.

Based upon this definition, it should be clear that there is far more to ensuring interoperability than using compatible software and hardware, although that is of course important. Rather, assurance of effective interoperability will require often radical changes to the ways in which organizations work and, especially, in their attitudes to information. Within this context, there are many aspects related to interoperability. The focus of this White Paper is on Technical Interoperability:

This is the "nuts and bolts" of software and hardware interoperability. This is where the work of the OGC and other standards organizations can be leveraged. Technical interoperability typically consists of selecting and implementing the appropriate software and/or internet interface specifications, common content encodings for transmission, and so forth. Quite often, within the enterprise, technical interoperability is the easiest to achieve in any given business process.

With the advanced integration of geospatial intelligence in mainstream IT solutions, be it Location Based Services delivering the relevant traffic news and navigation details to your car or insurance companies evaluating crop damages from a hailstorm, the underlying technology requirements of Interoperability stay the same, just as the processes that drive interface specification and standards definition through OGC and ISO can be seen as model templates.

The majority of business and government information has some reference to location. Until recently the power of geographic or spatial information and location has been under-utilised as a vital resource for improving economic productivity, decision-making, and delivery of services. We are an increasingly distributed and mobile society. Our technologies, services, and information resources must be able to leverage location, (i.e., my geographic position right now) and the spatial information that helps us visualize and analyse situations geographically.

Products and services that are compliant to OGC's open interface specifications enable users to freely exchange and apply spatial information, applications and services across networks, different platforms and products, hence the mission statement:

The OGC leads the global development, promotion and harmonization of open standards and architectures that enable the integration of spatial and location-based data and services into user applications and advances the formation of related market opportunities.

Open interface specifications enable content providers, application developers and integrators to focus on delivering more capable products and services to consumers in less time, at less cost, and with more flexibility. Take an interoperability-oriented point of view and think of providing information services instead of raw data!

3 Standards Organisations & Initiatives

3.1 ISO/TC211 and OGC

Standards define the *lingua franca* or common agreements that are needed to achieve interoperability between IT components. Standardisation bodies like ISO or CEN are developing *de jure* standards, whereas organisations like the Open Geospatial Consortium (OGC) draft specifications that by a consensus process and their common acceptance become *de facto* standards. Since these positions mainly differ in terms of their legal implications and less in terms of their technical relevance, both are treated on equal terms.

Products and services compliant to OpenGIS® interface specifications enable users to freely exchange and apply spatial information, applications and services across networks, different platforms and products.

OGC recognizes the importance of the International Organization for Standardization (ISO) and has established a very active so-called Class A liaison with its Technical Committee 211 (TC 211) which is dedicated to Geographic Information and Geomatics. Though the two organizations operate in different ways and produce different kinds of standards, close harmonization of their efforts has resulted in an agreement that includes joint working efforts on items of common interest. For this specific purpose, a Joint Advisory Group (JAG) has been formed within TC 211and OGC that facilitates and manages the relationship.

Comparing OGC and ISO, OGC produces publicly available OpenGIS specifications through an open, consensus-based process among its members. The Technical Committee ISO/TC 211 produces ISO International Standards for Geographical Information/Geomatics through a National Body balloting process. The Class A liaison between OGC and ISO/TC 211 facilitates the OpenGIS specifications produced by OGC to formally go through the process of becoming ISO International Standards.

Thus OGC and ISO TC211 work in largely complimentary ways that have been aided by the large number of members who are active in both organisations. The formal definition of the relationship through the above-mentioned Class A Liaison grants OGC participation in TC 211 deliberations and access to the technical work. On the other hand, it grants the Chair of TC 211 a seat on the OGC Planning Committee.

Both organizations have spent considerable effort defining their worlds, e.g. “What is a feature?”, “What is a coordinate reference system” and so forth. OGC has adopted many ISO documents in what it calls the Abstract Specifications (e.g. (Metadata, Services, Spatial Referencing and Feature Geometry). These OGC Abstract Specifications and most ISO work items are 'design-to' specifications that set high-level requirements.

The arrangement also allows the OGC to submit new Work Item Proposals to ISO. These NWIPS tend to be in two categories 1.) suggested changes to an existing ISO TC 211 document or 2.) submission of an OGC adopted implementation specification for consideration as an ISO standard. The work on Coordinate Reference Systems (CRS) is an example of the former case and the work on Simple Features, Web Map Service (WMS), and Geography Markup Language (GML) are examples of the latter.

3.2 CEN TC287

The European Committee for Standardization, CEN[1], is multi-sectorial and develops European Standards for most areas. CEN contributes to the objectives of the European Union and European Economic Area with voluntary technical standards, which promote free trade, the safety of workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programmes, and public procurement. European Standards are voluntary agreements between 28 European countries, adopted by CEN, CENELEC or ETSI and carrying with them an obligation of implementation as an identical national standard and withdrawal of conflicting national standards. CEN’s mission is to foster the European economy in global trade, to uphold the welfare of European citizens and to protect the environment.

The standards programme is coordinated by the Technical Board of CEN. CEN has various types of deliverables: European Standard (EN), Technical Specification (CEN/TS), Technical Report (CEN/TR), CEN Guide, and CEN Workshop Agreement (CWA). Most standards and reports are drawn up in technical committees and their working groups. CEN Workshop Agreements are drawn up in Workshops. Of all the deliverables, only ENs are normative.

The scope of CEN/TC287 Geographic Information is standardization in the field of digital geographic information for Europe. The committee will produce a structured framework of standards and guidelines, which specify a methodology to define, describe and transfer geographic data and services. This work will be carried out in close co-operation with ISO/TC 211 in order to avoid duplication of work. The standards will support the consistent use of geographic information throughout Europe in a manner which is compatible with international usage. They will support a spatial data infrastructure at all levels in Europe. This is achieved by:

[1] http://ww.cenorm.be

1. adoption of the ISO 19100 series as European standards;
2. development and take-up of new standards, profiles of standards in cooperation with ISO/TC 211, needed for the immediate INSPIRE initiative and other collaborative programmes;
3. facilitating interoperability with related standards initiatives through necessary harmonization and associated agreements;
4. promotion of the use of and education on standards on geographic information.

NEN, the Netherlands Institute for Normalisation, is responsible for the secretariat of CEN/TC287. The chair of CEN/TC287 is Prof. Dr. Henri Aalders. CEN/TC287 has currently one working group, WG Spatial Data Infrastructure, which is charged with the following tasks:

1. Identification of standards and their profiles to be used for creating SDI in Europe,
2. Guidelines for implementers of SDI in Europe,
3. Conformance testing and registers for SDI in Europe,

taking into account the following priority:

a. Metadata profile of ISO 19115,
b. Web Map Service (WMS), IS 19128:2005
c. GI metadata catalogue service,
d. Others.

A technical report by CEN/TC287 WG SDI on the above topics is expected by July 2006.

To date (February 2005), nine standards produced by ISO/TC211 have become European Standards:

- EN ISO 19101:2005 Geographic information - Reference model (identical to ISO 19101:2002)
- EN ISO 19105:2005 Geographic information - Conformance and testing (ISO 19105:2000)
- EN ISO 19108:2005 Geographic information - Temporal schema (ISO 19108:200 2)
- EN ISO 19107:2005 Geographic information - Spatial schema (ISO 19107:2003)
- EN ISO 19111:2005 Geographic information - Spatial referencing by coordinates (ISO 19111:2003)
- EN ISO 19112:2005 Geographic information - Spatial referencing by geographic identifiers (ISO 19112:2003)
- EN ISO 19113:2005 Geographic information - Quality principles (ISO 19113: 2002)
- EN ISO 19114:2005 Geographic information - Quality evaluation procedures (ISO 19114:2003)
- EN ISO 19115:2005 Geographic information - Metadata (ISO 19115:2003)

3.3 NATO Standardization Agency (NSA)

The NSA is an independent NATO Agency that reports to the NATO Committee for Standardization (NCS) for general oversight and direction. (The NSA reports directly to the Military Committee, however, for issues relating to operational standardization.) The Agency's mission is to foster NATO standardization with the goal of enhancing the combined operational effectiveness of Alliance military forces. As a key part of the NATO Standardization Organization (NSO), the NSA takes an active interest in all standardization related activities in NATO.

Standardization is defined within NATO as the process of developing concepts, doctrines, procedures and designs to achieve and maintain the most effective levels of "compatibility, interchangeability and commonality" in the operational, procedural, materiel, technical and administrative fields. The primary products of this process and NATO's tools for the enhancement of interoperability are Standardization Agreements (STANAGs) between member nations.

The NSA, as the focal point for NATO standardization efforts, accomplishes its mission through the promotion of co-ordination among all NATO Committees/Working Groups dealing with standardization. Furthermore, it provides support to some 46 operationally oriented working groups that have been established by the Service Boards (Joint, Army, Naval and Air) pursuant to authority delegated by the Military Committee.

A small staff co-ordinates Agency activities and supports the Director of the NSA. The NSA is functionality organized into five branches (Policy and Co-ordination, Joint, Army, Naval, and Air) and an administrative support element. The DNSA chairs the Joint Service Board (JSB), which is supported by the Joint Service Branch. The NSA single service branches support the Army, Naval and Air Boards by providing the Chairman and four supporting Staff Officers. Under the sponsorship of each Board, specialist Working Groups of experts from nations and commands develop doctrine and procedures that are ultimately published as STANAGs and Allied Publications. NSA Staff Officers serve as the Secretaries to these Working Groups.

The NATO Policy for Standardization, which has been approved by the North Atlantic Council (NAC) in autumn 2000 emphasises the adoption of suitable civil standards for use within NATO.

Several nations have already implemented major reforms in their defence standards system in the 1990ies. They aimed at increasing industrial efficiency and lowering defence procurement costs by replacing wherever feasible military specifications with civil standards on a comprehensive scale. Considering that defence producers and customers of NATO allies, but also of Partner countries move inexorably towards using more and more civil standards and becoming involved in civilian standardization activities, NATO's standardization community too should be present and benefit from the recognised international standardization bodies' activities.

To that intent NSA has created this web-tool: It comprises seven distinct parts which allow users who dispose of a PC connected to the Internet to acquaint themselves with the most eminent standardization bodies worldwide and with their areas of work; International Standardisation Organisations, Regional Standardisation Organisations, National Standardisation Organisations, National Military Standardisation Organisations, World of Science, Useful Links and Documents.

The page International Standardisation Organisations tries to complement also specialised standardisation organisations in fields of interest to our users. If users have special requests, they can contact the webmaster by e-mail to nsa.civstand@hq.nato.int. The website will be supplemented with the requested features within a reasonable timeframe.

Useful Links will guide users into web-based tools that support standards users and standards producers. Specific links into standardisation policies, e.g. of the European Union are equally shown on this page.

The new page NSA Ongoing Activities provides access to information and documents related to the activities of the NSA with Civil Standardization Organisations and which are the results from specific taskings of the NCSREPs. These pages are destined for national experts, who wish to contribute to workshops, where NATO's standardization community has been invited as an observer, namely the European Standardisation Committee's (CEN) BT/125 'Defence Procurement' , BT/126 'Humanitarian Mine Action' and BT/161 ‘Protection and Security of the Citizen’. A new feature, a short Activity Report to our community has been added too. It will be updated every three months and gives a handy two-page quick view on what is going on in the field of Civil Standards in NSA.

The page Documents gives instant online access to all Internet-releasable NSA documents related to the field of Civil Standards, including questionnaires and information notices. It is also regularly updated with links and downloadables on specific issues, for example user guides to ISO 9001:2000 or reference materials.

3.4 OASIS

OASIS (Organization for the Advancement of Structured Information Standards) is a not-for-profit, international consortium that drives the development, convergence, and adoption of e-business standards. OGC work intersects OASIS work at several levels:

- The OGC is a voting member of OASIS. OGC’s Chief Technology Officer is the OGC OASIS Technical Representative and gets to vote on all OASIS adoption votes.
- Several OGC members and staff are actively involved in various groups of OASIS, including ebRIM/XML, E-Government, and Emergency Services.
- OASIS is organized into many Technical Committees. The OGC Chief Technology Officer actively participates in the E-Government and Emergency Services Technical Committees and serves as the GIS SC Chair for the EM SC.
- The OASIS Common Alert Protocol (CAP) standard has elements that have been harmonized with OGC work - at least at a simple level. Future change proposals to CAP will incorporate OGC specifications as normative.
- The OGC specification work is now utilizing a number of OASIS standards, including UDDI, BPEL, ebRIM, and ebXML.
- OGC has also provided lessons learned documented back to various OASIS Technical Committees.

3.5 World Wide Web Consortium (W3C)

The World Wide Web Consortium (W3C) is an industry consortium dedicated to building consensus around Web technologies. OGC does not have an active or formal relationship with the World Wide Web Consortium (W3C). However, there is intensive bi-directional information exchange between senior staff members of both organisations every 6 months to discuss items of mutual interest. The work of the OGC is built on many of the W3C recommendations (specifications), including SVG, XML, XSLT, SOAP, WSDL, and soon more on RDF and OWL.

3.6 Internet Engineering Task Force (IETF)

The Internet Engineering Task Force (IETF) is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual. It is not membership based but the engagement is totally on a volunteer basis.

The OGC Chief Technology Officer is a member of the GeoPRIV working Group. The primary task of this working group is to assess the authorization, integrity and privacy requirements that must be met in order to transfer such information, or authorize the release or representation of such information through an agent. He regularly reviews and comments on documents in this WG. Also, the draft Internet standard (RFC) titled "A Presence-based GEOPRIV Location Object Format" uses GML 3.1 and references other OGC work.

Finally, OGC has recently submitted its own (OGC) RFC for consideration as an Internet standard. This is the OGC URN document titled, "A URN namespace for the Open Geospatial Consortium (OGC)". This document describes a URN (Uniform Resource Name) namespace that is engineered by OGC for naming persistent resources published by the OGC (such as OGC Standards, XML Document Type Definitions, XML Schemas, Namespaces, Stylesheets, and other documents. The formal Namespace identifier (NID) is "ogc".

In order for the larger IT community to be able to effectively implement applications that access OGC resources, a unique namespace is required. Currently there is no available namespace that will allow the OGC to uniquely specify and access resources that are required by organizations implementing OGC standards.

3.7 Object Management Group (OMG)

The Object Management Group (OMG) is an open membership, not-for-profit consortium that produces and maintains computer industry specifications for interoperable enterprise applications. The OGC Chief Technology Officer is the OGC representative to OMG and has just started the activities by participating in a number of standards coordination meetings that have been organized by various groups, such as the International Telecommunication Union (ITU) and the Open Group.

3.8 Institute of Electrical and Electronics Engineers (IEEE)

The IEEE is a non-profit, technical professional association of more than 360,000 individual members in approximately 175 countries. The full name is the Institute of Electrical and Electronics Engineers, Inc., although the organization is most popularly known and referred to by the letters I-E-E-E.

Through its members, the IEEE is a leading authority in technical areas ranging from computer engineering, biomedical technology and telecommunications, to electric power, aerospace and consumer electronics, among others.

Through its technical publishing, conferences and consensus-based standards activities, the IEEE

- produces 30 percent of the world's published literature in electrical engineering, computers and control technology,
- holds annually more than 300 major conferences and
- has nearly 900 active standards with 700 under development.

IEEE-1451 is a family of specifications that facilitate interoperability by defining standard ways to connect “smart” sensors and actuators to networks and systems. Sensor interoperability requires maximum use of commercial standards in order to tie sensors together on networks and provide seamless operation.

The US National Institute of Standards and Technology (NIST) characterizes the motivations and objectives for the IEEE-1451 standard in this way:

> “Transducers, defined here as sensors or actuators, serve a wide variety of industry's needs, manufacturing, industrial control, automotive, aerospace, building, and biomedicine are but a few. Since the transducer market is very diverse, transducer manufacturers are seeking ways to build low-cost, networked smart transducers. Many sensor control networks or field bus implementations are currently available, each with its own strengths and weaknesses for a specific application class. Interfacing the smart transducers to all of these control networks and supporting the wide variety of protocols require very significant efforts and are costly to transducer manufacturers. However, using digital communication schemes, networked transducers can eliminate a large number of lengthy parallel analogue wiring and thus reduces the installation, maintenance and upgrade costs of measurement and control systems. And the use of microprocessors to handle the digital communication has also opened the opportunity for adding intelligence to sensors. One problem for transducer manufacturers though, is the large number of networks on the market today. Currently, it is too costly for transducer manufacturers to make unique smart transducers for each network on the market. Therefore a universally accepted transducer interface standard, the IEEE P1451 standard, is proposed to be developed to address these issues.”[2]

The goals for IEEE-1451 are therefore to:

- Develop network-independent and vendor-independent interfaces between sensors/actuators and instruments and networks
- Provide standardized Transducer Electronic Data Sheets (TEDS) that contain manufacture-related data in a small memory attached to sensor/actuator.
- Support a general model for transducer data, control, timing, configuration, and calibration
- Allow transducers (sensors or actuators) to be installed, upgraded, replaced or moved with minimum effort
- Eliminate error prone, manual entering of data and system configuration steps, ultimately achieving Plug and Play
- Be able to get wired or wireless sensor data seamlessly from the network or host system
- Provides an infrastructure for open system distributed architecture

[2] NIST IEEE P1451 web page http://www.motion.aptd.nist.gov/

Key elements of the IEEE 1451 information model:

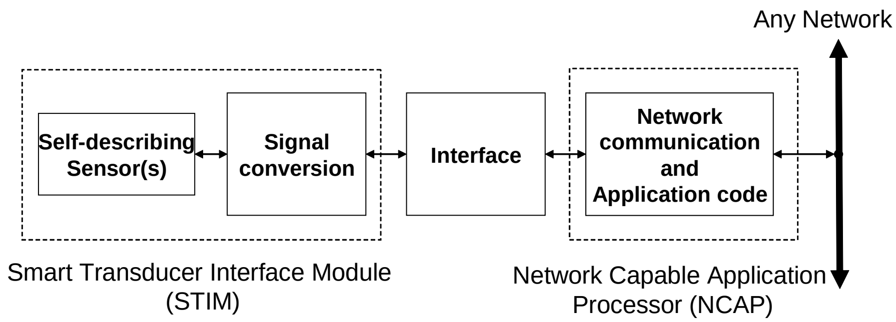

Figure 1. IEEE-1451 Integrated Network Sensor Model

- Transducer: A device converting energy from one domain into another; may either be a sensor or an actuator.
- Sensor: A transducer which converts a physical, biological, or chemical parameter into an electrical signal.
- Transducer Electronic Data Sheet (TEDS): A data sheet describing a transducer stored in some form of electrically readable memory
- Smart Transducer Interface Module (STIM): A module that contains the TEDS, logic to implement the transducer interface, the transducer(s) and any signal conversion or signal conditioning. It consists of 1 to 255 sensors or actuators or any combination of them.
- Transducer channel: A single flow path for digital data or an analogue signal, usually in distinction from other parallel paths.
- Network Capable Application Processor (NCAP): A device between the STIM and the network that performs network communications, STIM communications, data conversion functions, application functions, provides power to the STIM circuitry, may contain a controller and the interface to the broader network that may support other nodes, and from the TEDS, it knows how fast it can communicate with a STIM, how many channels a STIM contains, the data format of each STIM's transducer, what physical units are being measured, and how to convert the raw readings into corrected SI units, etc.

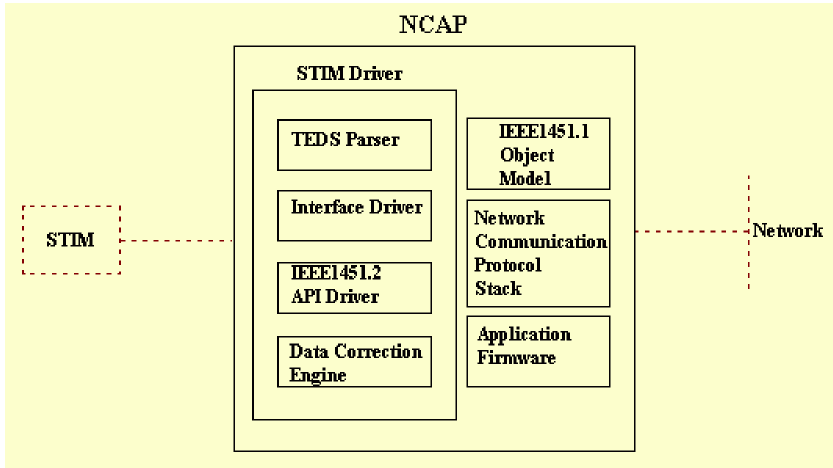

Figure 2. IEEE-1451 NCAP Model

Transducer Electronic Data Sheets (TEDS) provide descriptive information about the sensors in order to enable self-identification and self-description of sensors and actuators, ease sensor system configuration, reduce human error in manual system configuration, simplify field installation, upgrade, and maintenance of sensors by simple “plug and play” of devices to instruments and networks, and provide self-documentation. Transducer Electronic Data Sheet (TEDS) contain these elements:

- Meta-TEDS. Includes: 1) data structure related information such as version number, number of channels, future extension keys and 2) identification related information such as manufacturer ID, model number, serial number, revision number, date code, product description, etc.
- Channel TEDS. Includes information describing the: 1) transducer, such as lower/upper range limit, physical unit, unit warm-up time, uncertainty, self test key, etc and 2) data converter, such as channel data model, channel data repetitions, channel update time, channel read/write setup time, data clock frequency, channel sampling period, trigger accuracy, etc.
- Calibration TEDS. Includes calibration information such as TEDS length, last calibration date-time, calibration interval, number of correction input channels, data integrity checksums, etc.
- Frequency Response TEDS. Provides in a table the frequency response data for a single transducer channel.
- Transfer Function TEDS. Provides the frequency response data as an algorithm for a single transducer channel to enable users to compensate the data by combining this information with the desired response.
- Command TEDS. Allows manufacturers to define new commands.
- Manufacturer Defined TEDS. Allows the manufacturer to define additional features
- Text-based TEDS. Allows manufacturer to provide textual information (e.g., instructions, specifications, etc) with the device.
- End-user application specific TEDS. Written by the user with user data.
- The IEEE 1451 family of standards consists of these specifications (note: their

status is shown in bold italics):

- IEEE Std 1451.1-1999, Network Capable Application Processor (NCAP) Information Model for smart transducers -- Published standard, being revised
- IEEE P1451.0, Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats -- In progress
- IEEE Std 1451.2-1997, Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – Published standard, being revised
- IEEE Std 1451.3-2003, Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems - Published standard
- IEEE Std 1451.4-2004, Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – Published standard
- IEEE P1451.5, Wireless Communication and Transducer Electronic Data Sheet (TEDS) Formats – In progress
- IEEE P1451.6, A High-speed CANopen-based Transducer Network Interface – In progress

3.9 INSPIRE

Following three years of intensive collaboration with Member States experts and stakeholder consultation, the Commission has adopted in July 2004 a “proposal for a Directive of the European Parliament and of the Council establishing an Infrastructure for Spatial Information in the Community (INSPIRE[3])” (COM (2004) 516 final). INSPIRE lays down general rules for the establishment of an infrastructure for spatial information in Europe, for the purposes of environmental policies and policies or activities which may have a direct or indirect impact on the environment.

INSPIRE shall be based on infrastructures for spatial information established and operated by the Member States. The components of those infrastructures shall include: metadata, spatial data sets (described in three Annexes of the proposal), spatial data services; network services and technologies; agreements on sharing, access and use; co-ordination and monitoring mechanisms, process and procedures.

INSPIRE will require the Member States to implement various measures. Some of these measures shall be transposed by the Member States, while others require more detail which will be provided in ‘Implementing Rules’. In order for Member States to be able to respect the roadmap for the implementation of INSPIRE, those Implementing Rules must be available in due time.

On the basis of the INSPIRE Roadmap, priority should be given to Implementing Rules expected to be adopted in 2007 such as:

- Implementing Rules for the creation and up-dating of the metadata
- Implementing Rules for network services
- Implementing Rules on third parties use of the upload services
- Implementing Rules for monitoring and reporting
- Implementing Rules governing access and rights of use to spatial data sets and services for Community institutions and bodies

[3] http://inspire.jrc.it

In addition priority is also given to Implementing Rules expected to be adopted in 2009 but requiring significant efforts:

- Implementing Rules for the use of spatial data sets and services by third parties, by 2009
- Implementing Rules for harmonised spatial data specifications of Annex I and for the exchange of Annex I, II and III spatial data, by 2009.

From a service architecture point of view the INSPIRE proposal distinguishes the following service types:

- Upload Services
- Discovery services
- Data view services
- Download services
- Transformation services
- “invoke spatial data services” services

Following the INSPIRE proposal, Member States shall provide access to these services through the European Community geo-portal. The definition of appropriate technical specifications requires that considered interface specifications are mature and proved by implementations and operational usage including performance consideration. The first tasks in this will have to provide a more detailed description as a basis for the common understanding about these network services.

Table 1 – interdependencies table

IR = Implementing Rule	MS = Member States	▼ = Milestone		= Implementation period

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Entry into force Directive (X)	▼								
Implement sharing between public bodies	↳		▼						
Responsible MS public authority designated			▼						
Commission report								▼	
Committee Kick-off (X+3m)	▼								
Technical Implementing Rules									
Metadata									
Adopt metadata IR	↳ ▼								
Implement Metadata Annex I - II	↳			▼					
Implement Metadata Annex III	↳						▼		

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Network Services									
Adopt IR Network Services									
Network Services Operational									
Harmonised specifications									
Adopt IR Annex I									
Implement for new/updated Annex I									
Adopt IR Annex II - III									
Implement for new/updated Annex II - III									
Procedural Implementing Rules									
Adopt IR Third Party Upload									
Implement IR Third Party Upload									
Adopt IR Third Party Use									
Implement IR Third Party Use									
Adopt IR Community bodies									
Implement IR Community bodies									
Adopt IR monitoring and reporting									
Implement monitoring and reporting									
Member States Report									

As the implementation of INSPIRE should not be undertaken in isolation from international global initiatives to which many EU Member State institutions participate, the organisational framework has to take into account cross-references with initiatives such as GMES, Galileo and GEO to name but a few.

The design of the different technical and policy measures in the proposal for a Directive requires intensive stakeholder participation. Therefore the concept of Spatial Data Interest Communities (SDIC) has been introduced, which provides stakeholders the mechanism to participate in the development of the draft Implementing Rules.

The establishment of draft Implementing Rules will be set up in 3 different phases:

- Association phase. In this phase Drafting Teams will be created and available reference material will be collected as input for the drafting;
- Drafting phase. In this phase the Drafting Teams will establish the draft Implementing Rules;
- Review phase. In this phase a review mechanism will be set up to include stakeholder feedback through the SDICs, as well as implementation feasibility feedback from the Legally Mandated Organisations, who will be responsible for implementation of INSPIRE in the public authorities in the Member States. Finally a public consultation will be organised.

After the Review Phase the Implementing Rules will be submitted to the INSPIRE Committee[4] for adoption, and will become directly applicable in Member States, as a Commission Regulation or Decision.

On February 2005, the Commission published the INSPIRE work programme[5] for the Preparatory Phase (2005-06). This work programme builds on the INSPIRE proposal and bases on a first draft, prepared by a Task Force and discussed and commented during the 10th and 11th INSPIRE expert group meeting (June and December 2004).

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[4] INSPIRE requires the formal adoption of those Implementing Rules by the Commission following the "Comitology Procedure" (Council Decision (1999/468/EC). The regulatory nature of the Implementing Rules requires the Commission to present them to a Regulatory Committee of Member States representatives, referred to as the INSPIRE Committee, which will officially start its activities at the beginning of the Transposition Phase.

[5] http://inspire.jrc.it

4 Open Architecture Models

4.1 The RM-ODP as a Reference Model for GI Service Architectures

The **Reference Model for Open Distributed Processing** (RM-ODP, ISO/IEC 10746) is an international standard for architecting open, distributed processing systems. It provides an overall conceptual framework for building distributed systems in an incremental manner. The RM-ODP standards have been widely adopted: they constitute the conceptual basis for the ISO 19100 series of geomatics standards (see, for example, ISO 19101 and ISO 19119), and they also have been employed in the OMG object management architecture.

The application of RM-ODP in the design of ORM is two-fold: 1) a way of thinking about architectural issues in terms of fundamental patterns or organizing principles, and 2) a set of guiding concepts and terminology. It should be noted though that none of the GI applications of RM-ODP make use of the Viewpoint Languages. Both ISO TC211 and OGC use UML to develop the artefacts in the RM-ODP viewpoints. The viewpoint languages are in the RM-ODP specification and they have been overtaken by UML.

RM-ODP defines standard concepts and terminology for open, distributed processing. In a generic way, the model identifies the top priorities for architectural specifications and provides a minimal set of requirements—plus an object model—to ensure system integrity. Five standard *viewpoints* are defined; the viewpoints address different aspects of the system and enable the ‘separation of concerns’ (see Table 2).

Table 2 - RM-ODP viewpoints

Viewpoint Name	Definition of RM-ODP Viewpoint
Enterprise	Focuses on the purpose, scope and policies for that system.
Information	Focuses on the semantics of information and information processing.
Computational	Captures component and interface details without regard to distribution
Engineering	Focuses on the mechanisms and functions required to support distributed interaction between objects in the system.
Technology	Focuses on the choice of technology.

A graphical depiction of the relationships between the viewpoints is provided in Figure 3.

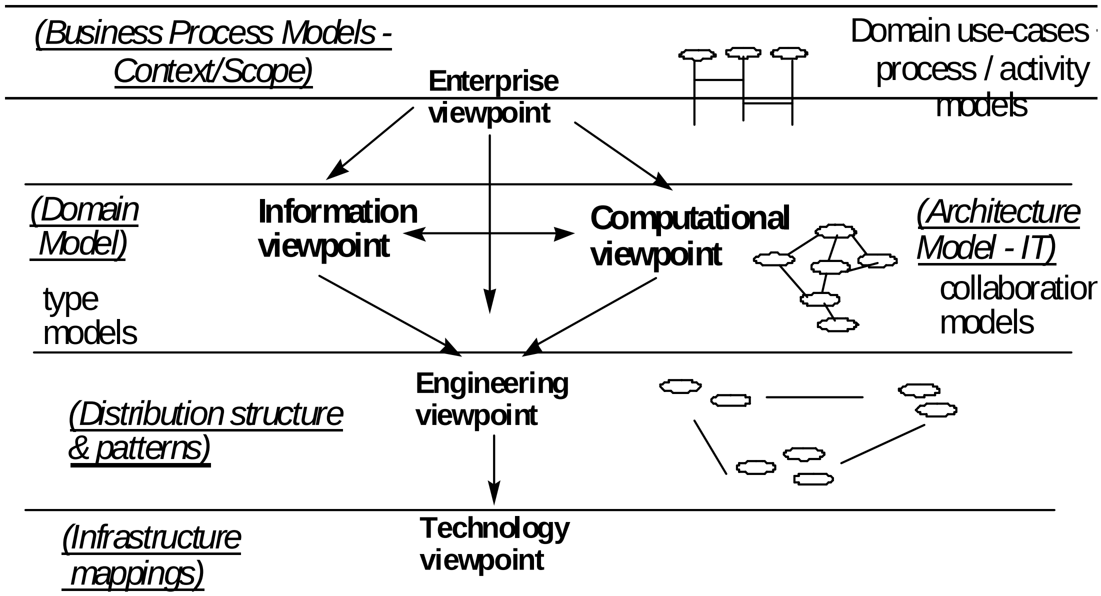

Figure 3 - RM-ODP Viewpoints

4.2 ISO 19101 – Reference Model of the ISO 19100 series of International Standards

ISO 19101 specifies the Reference Model of the ISO 19100 series. It defines a framework for standardization in the field of geographic information, sets forth the basic principles and describes how the contents of the different standards are related.

Although structured in the context of information technology and information technology standards, ISO 19101 is independent of any application development method or technology implementation approach.

The basic approach of ISO 19101 is shown in the following figure:

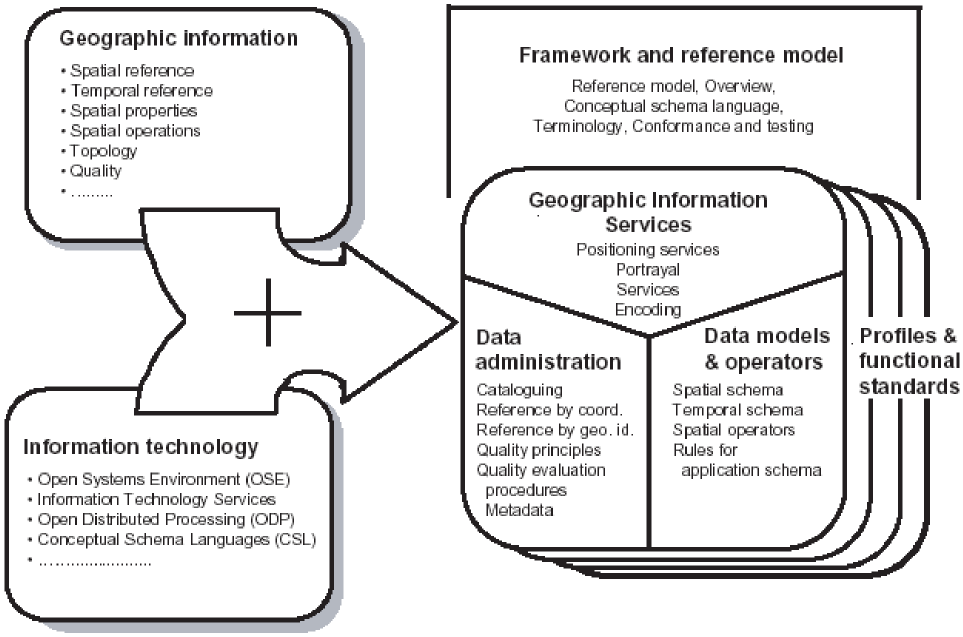

Figure 4 – Overview of the approach taken by ISO 19100

A key concept of ISO 19100 is the conceptual model. ISO 19101 defines conceptual modeling as the process of creating an abstract description of some portion of the real world and/or a set of related concepts. Such an abstract description of the real world is called a conceptual model and is described in a conceptual schema using a conceptual schema language. See the following figure:

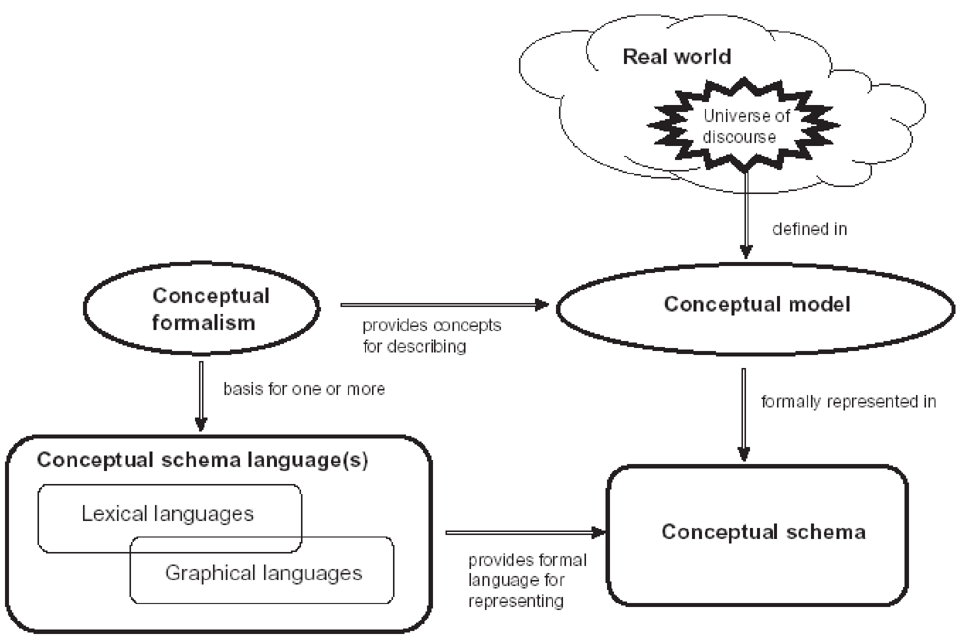

Figure 5 – Conceptual Modelling

An example would be the set of features that are important for an application dealing with the management of risks related to forest fires. The rules for such conceptual application schemas are specified in ISO 19109, Rules for Application Schemas.

The rules for using UML as the conceptual schema language in the ISO 19100 series are specified in ISO/TS 19103.

A set of spatial or temporal constructs, such as points, lines, instants, and periods, used to describe the properties of these features might be a set of related concepts. Commonly used concepts are described in other standards of the ISO 19100 series. For example: ISO 19107 Spatial Schema, ISO 19108 Temporal Schema, ISO 19115 Metadata, etc.

Currently, ISO/TC 211 is developing a Part 2 of ISO 19101 dealing with imagery.

5 Geospatial Interoperability Standards and Specifications

Table 3 contains a list of specifications published by the ISO and the OGC pertaining to GI interoperability services, along with – where possible – a description of the relationship between the two sets of standards.

Within the ISO, ISO/TC211 oversees the establishment of a structured set of standards for GI methods, tools, and services. ISO/TC211 produces the ISO 19100 series of base standards This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth.

ISO/TC211 standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital / electronic form between different users, systems and locations.

Where possible, the work shall link to appropriate standards for information technology and data, and provide a framework for the development of sector-specific applications using geographic data.

The OGC specifications are divided into *Abstract Specifications* and *Implementation Specifications*. The Abstract Specifications provide the conceptual foundation for most OGC specification development activities. Open interfaces and protocols are built and referenced against the Abstract Specification, thus enabling interoperability between different brands and different kinds of spatial processing systems. The Abstract Specification provides a reference model for the development of OpenGIS Implementation Specifications.

OGC *Implementation Specifications* target a technical audience and detail the structure of the interfaces between the distributed software components. The implementation of these specifications is determined to be at the proper level of detail if plug-and-play interoperability occurs between two software components that were engineered without knowledge of each other. The interfaces defined in the OGC's Implementation Specifications encourage loosely-coupled component architecture that is bound dynamically based on discovery and availability of services. However, not all OGC implementation specifications are loosely coupled: the Simple Features, Grid Coverage and Coordinate Transformation Implementation Specifications are fine grained, tightly coupled specs. In January 2005 the OGC Technical Committee (TC) confirmed the intent to continue work on fine grained specs in addition to Web Services.

Table 3 - List of current ISO and OGC standards and specifications relating to GI Interoperability

ISO Number	Name	Status
ISO 6709:1983	Standard representation of latitude, longitude and altitude for geographic point locations	Pub
ISO 19101:2002	Reference model	Pub
ISO/WD 19101-2	Reference model – Part 2: Imagery	Dev
ISO/PRF TS 19103	Conceptual schema language	Dev
ISO/DIS 19104	Terminology	Dev
ISO 19105	Conformance and testing	Pub
ISO 19106	Profiles	Pub
ISO 19107	Spatial schema	Pub
ISO 19108	Temporal schema	Pub
ISO/FDIS 19109	Rules for application schema	Dev
ISO 19110	Methodology for cataloguing	Dev
ISO 19111	Spatial referencing by co-ordinates	Pub
ISO/CD 19111	Spatial referencing by co-ordinates	Dev
ISO 19112	Spatial referencing by geographic identifiers	Pub
ISO 19113	Quality principles	Pub
ISO 19114	Quality evaluation procedures	Pub
ISO 19115	Metadata	Pub
ISO/WD 19115-2	Metadata – Part 2: Extensions for imagery and gridded data	Dev
ISO 19116	Positioning services	Pub
ISO/FDIS 19117	Portrayal	Dev
ISO/PRF 19118	Encoding	Dev
ISO 19119	Services	Dev
ISO/TR 19120	Functional standards	Pub
ISO/TR 19121	Imagery and gridded data	Pub
ISO/TR 19122	Qualifications and certification of personnel	Pub
ISO/FDIS 19123	Schema for coverage geometry and functions	Dev

ISO 19125-1	Simple feature access – Part 1: Common architecture	Pub
ISO 19125-2	Simple feature access – Part 2: SQL option	Pub
ISO/CD 19126	Profile – FACC Data Dictionary	Dev
ISO/PRF TS 19127	Geodetic codes and parameters	Dev
ISO/DIS 19128	Web Map Server Interface	Dev
ISO/CD 19130	Sensor and data models for imagery and gridded data	Dev
ISO/CD 19131	Data product specification	Dev
ISO/NP 19132	Location based services possible standards	Dev
ISO/DIS 19133	Location based services tracking and navigation	Dev
ISO/CD 19134	Multimodal location based services for routing and navigation	Dev
ISO/DIS 19135	Procedures for registration of geographic information items	Dev
ISO/CD 19136	Geography Markup Language (GML)	Dev
ISO/DIS 19137	Core profile of the spatial schema	Dev
ISO/CD 19138	Data quality measures	Dev
ISO/CD TS 19139	Metadata – XML schema implementation	Dev
ISO/WD 19141	Schema for moving features	Dev

OpenGIS Abstract Specifications	
Number	**Name**
Topic 0	Overview
Topic 1	Feature Geometry
Topic 2	Spatial Reference Systems
Topic 3	Locational Geometry
Topic 4	Stored Functions and Interpolation
Topic 5	The OpenGIS Feature
Topic 6	The Coverage Type
Topic 7	Earth Imagery
Topic 8	Relations between features
Topic 10	Feature Collections
Topic 11	Metadata
Topic 12	The OpenGIS Service Architecture
Topic 13	Catalog Services
Topic 14	Semantics and Information Communities
Topic 15	Image Exploitation Services
Topic 16	Image Coordinate Transformation Services

OpenGIS Implementation Specifications	
Acronym	**Name**
CAT	Catalog Interface
CT	Coordinate Transformation Services
Filter	Filter Encoding
GML	Geography Markup Language
AOS	GO-1 Application Objects
GC	Grid Coverages
Common	OGC Web Services Common Specification
OLS Core	OpenGIS Location Services: Core Services [Parts 1-5]
SFC	Simple Features – CORBA
SFS	Simple Features – SQL
SFO	Simple Features – OLE/COM
SLD	Styled Layer Descriptor
WCS	Web Coverage Service
WFS	Web Feature Service
WMC	Web Map Context Documents
WMS	Web Map Service

6 Interoperability Testing

ISO-Standards and abstract specifications of the OGC provide rather theoretical instructions, while the practical implementation is defined in the OpenGIS Implementation Specifications. All OGC Implementation Specifications are public, free of charge and non-proprietary. These facts led to a fast distribution of the specifications within existing GI software which are listed in this section.

Software products can be "compliant to" or "implementing" OGC standards. If software is "compliant to" an OGC standard, this means that it has passed a formal compliance test. A compliance test determines that a product implementation of a particular Implementation Specification fulfills all mandatory elements as specified and that these elements are operable, but it will not ensure, or even test, interoperability of software products. Compliance tests can be done via the OGC's CITE portal (http://www.opengeospatial.org/resources/?page=testing).

Interoperability Testing determines that a product implementation of an Implementation Specification interoperates with other product implementations of the same Implementation Specification, related Implementation Specification(s), or within a particular computing environment.

By the time both tests have been successful, software can be referred to as "compliant to" a specific OpenGIS Implementation Specification. OGC will charge a fee for trademark licensing for Candidate Products that successfully pass a compliance test under the Testing Procedure. This fee is termed the Trademark License Fee, see http://www.opengeospatial.org/resources/?page=testing&view=testdocs#ctpdoc.

At http://www.opengeospatial.org/resources/?page=products a list of software products can be found which are registered as being “compliant to” or “implementing” one or more OpenGIS Implementation Specifications.

7 EU Project Work

Interoperable spatial services and their underlying architecture are the technical foundation of a Spatial Data Infrastructure. In the last decade GI research and technology development shifted from the standardization of data exchange formats for geospatial information (GI) to the standardization of interfaces of geoinformation services. GI services are meant to deliver GI according to the users needs and to allow the efficient use of GI by removing the burden of tedious file exchange and data integration tasks between non-interoperable, monolithic GIS.

ISO as a standardization and the Open Geospatial Consortium as an association of GI-Industry, -Users, and –Researchers are the main drivers in the process of specifying interoperable GI services and the related architecture. Several prototypes prove the feasibility of these solutions. Thus a starting point for work on open interoperable architectures and information services is clearly defined. However the specification work is far from being comprehensive and in lacks partly maturity. Topics like geoprocessing, geosimulation, semantics of geoinformation, as well as service chaining, service quality, and seamless integration into mainstream IT infrastructures (e.g. for service registries, authorization, authentication and access security) define some of the future challenges e.g. for the current projects under the 6th Framework Programme of the European Union, dealing with the implementation of open reference architectures. European requirements (expressed within Framework Programmes and large-scale European initiatives) need to be taken in and addressed by these standardisation processes.

The INSPIRE initiative to realize a legal framework of the European SDI becomes an important force for the developments of SDIs in Europe. In the next two years a number of Implementing Rules will be developed within INSPIRE. These Implementing Rules will also define in the technical context on how interoperability for the European SDI will be achieved.