Guidelines of Best Practice for the Acquisition, Storage, Maintenance and Dissemination of Fundamental Geo-Spatial Datasets

Editor: Derek Clarke

This document is distributed for comment and review. It includes only Part C of the guidelines. A list of all parts of the guidelines is provided below. For information about the other parts, contact Derek Clarke at dclarke@ruraldevelopment.gov.za [1]

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[1] Now: derek.clarke.dr@gmail.com

Part C:
Standards for fundamental geo-spatial datasets [2]

by
Serena Coetzee [3], Antony K Cooper [4] and Victoria Rautenbach [5]

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[3] Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa. Email: serena.coetzee@up.ac.za

[4] Smart Places, CSIR, Pretoria, South Africa & Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa. Email: acooper@csir.co.za

[5] Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa. Email: victoria.rautenbach@up.ac.za

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10. STANDARDS FOR THE ACQUISITION AND MAINTENANCE OF FUNDAMENTAL GEO-SPATIAL DATASETS

10.1 Introduction

The first part of this chapter provides background information on geo-spatial standardization. A standard and different types of standards are defined; the development and implementation of standards are described; and key standards bodies for fundamental geo-spatial datasets are introduced. The second part of the chapter introduces standards relevant for acquiring and maintaining fundamental geo-spatial datasets. An overview of a number of standards for geo-spatial data formats is provided; standards for data product specifications, data quality, quality assurance, hydrographical surveys and data models for fundamental geo-spatial datasets are described; and finally, a brief overview is provided of standards that one should be aware of when procuring or using products and tools for the acquisition and maintenance of geo-spatial datasets.

10.2 Types of standards

A standard is a document (or collection of documents), usually but not always published, that specifies requirements, recommendations, conventions and/or guidelines used consistently to ensure that a product, service, system or any other standardization target is fit for its purpose. Standards can be developed and implemented in different ways, and describe different things at different levels of abstraction and/or detail. Table 10.1 provides an overview of standard deliverables for different purposes. A profile is a set of one or more base standards or subsets of base standards, and, where applicable, the identification of chosen clauses, classes, options and parameters of those base standards, that are necessary for accomplishing a particular function [ISO 19106:2004]. In the geo-spatial community, profiles for international standards are sometimes developed for national and regional application. For example, SANS 1878-1: 2005, *South African spatial metadata standard, Part 1: Core metadata profile*, is a profile of ISO 19115:2003, *Geographic information – Metadata*, developed by the SABS for use in South Africa.

Table 10.1 ISO/IEC deliverables (Source: ISO/IEC Directives, Part 1 Consolidated ISO Supplement, 2014)

Deliverable	Description
Industry Technical Agreement (ITA)	An ITA aims to bridge the gap between the activities of consortia and the formal process of standardization represented by ISO and its national members. An important distinction is that the ITA is developed by ISO workshops and fora, comprising only participants with direct interest, and is therefore not accorded the status of an International Standard.
International Standard (IS)	An International Standard is a standard that is adopted by an ISO or IEC and made available to the public.
Publicly Available Specification (PAS)	A Publicly Available Specification is developed to respond to an urgent market need, representing either • a consensus in an organisation external to ISO or IEC; or • a consensus of the experts within a working group. A PAS is not allowed to conflict with an existing International Standard, but competing Publicly Available Specifications on the same subject are permitted.
Technical Report (TR)	A Technical Report contains collected data of a different kind from that normally published as an International Standard or Technical Specification. This may include, for example, data obtained from a survey carried out among the national bodies, data on work in other international organisations or data on the “state of the art” in relation to standards of national bodies on a particular subject.

Technical Specification (TS)	A Technical Specification is developed when there is the future possibility of agreement on an International Standard, but for which at present • the required support for approval as an International Standard cannot be obtained; • there is doubt on whether consensus has been achieved; • the subject matter is still under technical development; or • there is another reason precluding immediate publication as an International Standard.

A standard is concerned with one or more standardization targets (i.e. the object of standardization), for example, a data model, a web service, a system or a process. Table 10.2 lists different levels of abstraction at which standardization targets are described. Table 10.3 describes different types of heterogeneity, which geo-spatial standards aim to overcome. A geo-spatial standard may standardize geographic data, services or procedures at more than one level of abstraction and address more than one type of heterogeneity. However, often a single level and a single type of heterogeneity are prominent in the standard.

Table 10.2 Different levels of abstraction and detail in standards (Source: ISO 19101-1:2014)

Deliverable	Description
Meta-meta	Meta-meta standards cover the more general aspects of geo-spatial information and serve as foundations for other standards. Examples are ISO 19101:2002, Geographic information – Reference model, and ISO/TS 19103:2005, Geographic information – Conceptual schema language.
Meta	Meta standards standardize aspects of geo-spatial information that are used in other standards and applications. Examples are ISO 19107:2003, Geographic information – Spatial schema, and ISO 19110:2005, Geographic information -- Methodology for feature cataloguing.
Application	Application standards are directly implementable. Examples are ISO 19136:2007, Geographic information – Geography markup language (GML), and OGC KML Version 2.2.0.
Instance	Instance standards are concerned with the standardization of data and services or applications processing data. Examples are the different geo-spatial data formats described in 10.7.1.

Table 10.3 Four types of heterogeneity (Source: ISO 19101-1:2014)

Type of heterogeneity	Description
System	System heterogeneity exists at the 'lowest' level between hardware, operating systems and communication systems. Standards to overcome this type of heterogeneity are typically developed by organisations focusing on general-purpose information and communication technology, such as the ISO/IEC JTC 1, IETF and W3C.
Syntactic	Syntactic heterogeneity concerns the physical representation of data, i.e. the symbols and the grammar used to convey data within a message from a sender to a receiver. Syntactic heterogeneity is concerned with the appearance of the message but not in its content. Examples are different geo-spatial data formats, such as DXF and SHP.
Structural	Structural heterogeneity (also called schematic heterogeneity) is concerned with the differences related to conceptual modelling of geographic features. For example, a street name can be represented either by a single attribute (e.g. 'Church Street') or by two attributes, one for the name (e.g. 'Church') and the other for the type (e.g. 'Street').
Semantic	Semantic heterogeneity refers to the differences in meaning between concepts and data used to represent geographic features. For example, two individuals may perceive a bridge in different ways leading to different concepts: a road infrastructure, an obstacle for marine navigation, a point of interest, etc.

10.3 Development of standards

Conventionally, standards are developed by international or national standards organisations, such as the International Organization for Standardization (ISO) and the South African Bureau of Standards (SABS). However, industry consortia are playing an increasingly important role in standards development, both nationally and internationally. Typically, an industry consortium in standards development is a membership organisation formed to ensure performance and quality in a particular industry or economic sector. Examples in the IT industry are the Internet Engineering Task Force (IETF) and World Wide Web Consortium (W3C) and the Open Geospatial Consortium (OGC) in the geo-spatial industry. Industry consortia are seldom accredited by national or international standards organisations, but their standards usually have strong support within a relatively short span of time because they are developed by members of the industries concerned, by consensus of stakeholders and by using an open review and approval process.

A variety of definitions for open standards exist, emphasizing different aspects of openness. Generally, in the geospatial community open standards refer to standards developed according to the principles of open standards formulated by Bruce Perens (Wikipedia 2014). These include the ability of stakeholders to participate voluntarily in standards development, the use of consensus in the review and standards approval process, providing public access to all development documents, maximizing end-user choice by prohibiting vendor lock-in and ultimately providing access to the completed standards to allow royalty-free implementations and extensions. Legally, the developer of an open standard retains all related patents and intellectual property rights but third party users are free to support and create products that conform to it. Geo-spatial standards developed by the ISO, OGC and the International Hydrographic Organization (IHO), as well as IETF and W3C, are generally considered to be open.

Proprietary standards are developed by organisations for their products or services. Developers of proprietary standards have sole ownership and retain all patents associated with the standards, even though they might publish them. Third party users are sometimes allowed to use a proprietary standard, either by paying a prescribed licence fee or free of charge, but they do not play any part in its development and maintenance. In the geo-spatial domain, the Autodesk DXF (Drawing Exchange Format) and Esri shape (SHP) files are examples of proprietary data format standards that have been published.

Public domain standards are not owned or developed and maintained by a particular organisation, but developed collectively by a user community. GeoTIFF is an example of a public domain standard.

10.4 Implementation of standards

Standard implementation is either mandatory (*de jure*) through government legislation and regulations, or voluntary (*de facto*) through consensus and popular acceptance by the community. Sometimes standards developed by official standards bodies are also referred to as being *de jure.*

The scope usually appears at the beginning of a standard and defines without ambiguity the subject of the document and the aspects covered, thereby indicating the limits of applicability of the document or particular parts of it.

A standard contains informative and normative elements. Informative elements identify the document, introduce its content and explain its background, development and relationship with other documents; or provide additional information intended to assist the understanding or use of the document. Normative elements describe the scope of the document or set out provisions. Provisions are expressed as

- requirements, i.e. expressions conveying criteria to be fulfilled if compliance with the document is to be claimed and from which no deviation is permitted);
- recommendations, i.e. expressions conveying that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited;
- permission, i.e. a course of action permissible within the limits of the document; or
- statements of possibility or capability.

Typical verbal forms for requirements are ‘shall’ and ‘shall not’, while ‘should’ and ‘should not’ are used for recommendations. For example, ‘data quality shall be described using the [specified] data quality elements’ (ISO 19157:2013) and ‘a data quality evaluation method should be included for each applied data quality measure’ (ISO 19157:2013). Verbal forms for the expression of provisions are described in Annex H of ISO/IEC Directives Part 2 (2011).

10.5 Key standards bodies for fundamental geo-spatial datasets

The three international standardization organisations that produce most of the geo-spatial standards relevant to the acquisition, maintenance and dissemination of fundamental geo-spatial datasets are introduced in this section.

10.5.1 International Organization for Standardization (ISO)

ISO [6] is the world’s largest developer of voluntary International Standards. International Standards provide state of the art specifications for products, services and good practice, helping to make industry more efficient and effective. Developed through global consensus, they help to break down barriers to international trade. ISO was founded in 1947 and since then has published more than 19,000 International Standards covering almost all aspects of technology and business, from food safety to computers, and agriculture to healthcare, impacting on people’s daily lives. ISO aims to be as inclusive as possible when it comes to its membership.

Three member categories, each with a different level of access and influence over the ISO system, allow countries with limited resources or without a fully developed national standards system to still observe and keep up to date with international standardization in ISO. Full members (or member bodies) influence ISO standards development and strategy by participating and voting in ISO technical and policy meetings. Full members sell and adopt ISO International Standards nationally. Correspondent members observe the development of ISO standards and strategy by attending ISO technical and policy meetings as observers. Correspondent members can adopt ISO International

[6] www.iso.org

Standards nationally. Subscriber members keep up to date on ISO's work but cannot participate in it. They do not adopt ISO International Standards nationally.

Members have to clearly indicate their intended participation in each of the technical committees. There are two options. P-members participate actively in the work, with an obligation to vote on all questions formally submitted for voting within the technical committee, on new work item proposals, enquiry drafts and final draft International Standards and contribute to meetings. O-members follow the work as an observer and therefore receive committee documents and have the right to submit comments and to attend meetings.

Most African countries participate in ISO as full or corresponding members. These member bodies are typically the national standards organisations, such as the SABS in South Africa and Instituto Angolano de Normalização e Qualidade (IANORQ) in Angola. Three quarters of the 161 ISO members are from developing countries.

ISO technical work is carried out under the overall management of the Technical Management Board (TMB). The TMB reports to the ISO Council and its role is defined in the statutes of the organisation. TMB tasks include setting up technical committees, appointing chairs and monitoring the progress of technical work. ISO/IEC Directives Part 1 Consolidated ISO Supplement (2014) provide official procedures to be followed when developing and maintaining an International Standard and procedures specific to ISO. ISO/IEC Directives Part 2 (2011) details the principles to structure and draft documents intended to become International Standards, Technical Specifications or Publicly Available Specifications. ISO standards are developed by groups of experts within technical committees (TC). ISO/TCs are made up of representatives of industry, NGOs, governments, academia and other stakeholders, who are put forward by ISO's members. Each TC deals with a different subject.

Information about ISO is available at www.iso.org. Standards that are adopted by national member bodies are also available on their websites (sometimes cheaper than on the ISO website). See for example, www.sabs.co.za.

Cooperation with other standards organisations

The Vienna agreement (1991) ensures technical cooperation with the European Committee for Standardization (CEN). CEN Technical Committee for geographic information, CEN/TC 287, is the mirror committee to ISO/TC 211. It adopts their standards in order to make them mandatory within the European Union and produces technical guidance and best practice for spatial data infrastructures.

ISO/IEC JTC 1 [7] is a joint Technical Committee in which ISO and the International Electrotechnical Commission (IEC) collaborate on standardization in the field of information technology. Some of the standards developed in ISO/IEC JTC 1 are referenced in standards for geo-spatial information, for example, standards defining the Unified Modeling Language (UML) and the Structured Query Language (SQL).

Technical committees may establish liaison relationships with international or broadly based regional organisations working or interested in similar or related fields. Two categories of liaison are

[7] www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/jtc1_home.htm

possible at the technical committee level. Category A liaison organisations make an effective contribution to the work of the technical committee, have access to all relevant documentation and are invited to meetings. They may nominate experts to participate in working groups preparing drafts of standards. Category B organisations indicate a wish to be kept informed of the work of the technical committee or subcommittee and have access to reports on the work of a technical committee.

Development of standards

Once the need for a standard has been established, experts meet face-to-face or through online mechanisms to discuss and negotiate the draft standard. The draft is shared with ISO's members and liaisons who are asked to comment and vote on it. If consensus is reached, the draft becomes an ISO standard, if not, it goes back to the technical committee for further edits.

An ISO International Standard embodies the essential principles of global openness and transparency, consensus and technical coherence safeguarded through its development in a technical committee, representative of all interested parties and supported by a public comment phase (the ISO Technical Enquiry). Other ISO deliverables (ISO/TS, ISO/PAS, ISO/TR, see Table 10.1) require lower levels of consensus and therefore do not have the same status as an International Standard. Consensus is defined as general agreement, characterised by the absence of sustained opposition to substantial issues by any important part of the concerned interests and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments. Note that consensus does not imply unanimous approval.

ISO standards are developed following a project approach. The project stages, associated documents and a brief description of each stage are provided in Table 10.4. National member bodies may participate in or follow this project approach through representation in the relevant technical committees. ISO documents are reviewed systematically at three or five year intervals, depending on the type of document. Depending on the voting results of systematic reviews, a document is confirmed (retention without technical change), amended or revised (retention, with change/s), or withdrawn.

Table 10.4 ISO project stages

Project stage	Associated document	Brief description
Preliminary stage	Preliminary work item (PWI)	This stage is used for work that is not yet sufficiently mature for processing to further stages and for which no target dates can be established. For example, the stage can be used for the elaboration of a new work item proposal and the development of an initial draft.
Proposal stage	New work item proposal (NWIP)	The committee votes on the approval of a NWIP, which has to be within its scope. Ideally, a first working draft should be attached to the NWIP. A project leader is nominated in the NWIP. The NWIP is approved by simple majority of the committees P-members and if a specified minimum number of technical experts are nominated for the project.
Preparatory stage	Working draft(s) (WD)	During this stage a number of WDs are prepared. The stage ends when the WD is available for circulation to the members of the committee. The project leader is responsible for the development of the project and will normally convene and chair any meetings.
Committee stage	Committee draft(s) (CD)	This is the principal stage during which comments from national bodies are taken into consideration, with a view to reaching consensus on the technical content. An editing committee is convened, which shall supply responses to all comments. The stage ends when there is consensus that the

		document is ready for circulation in the next stage.
Enquiry stage	Enquiry draft (DIS)	During this stage the DIS is circulated to all national member bodies. The DIS is approved if a two-thirds majority of the votes cast by P-members are in favour, and not more than one-quarter of the total number of votes cast are negative. A DIS with no negative votes proceeds directly to publication.
Approval stage	Final draft international standard (FDIS)	The FDIS is again circulated to all national member bodies. The FDIS is approved if a two-thirds majority of the votes cast by the P-members are in favour, and not more than one-quarter of the total number of votes cast are negative.
Publication stage	International Standard	The document is published by the ISO Central Secretariat.

Standards development, from approval of a proposed project to final publication stage, takes between 24 to 48 months. Standard development can be fast-tracked under certain circumstances, e.g. the proposal, preparatory and committee stages are skipped and the standard is submitted for vote as an enquiry draft. Fast tracking is applied, for example, if an existing standard from another standardization organisation is submitted to ISO for publication as a standard. The technical committee leadership may advise that the approval stage is omitted if DIS voting results and comments suggest that no additional work in an FDIS stage is required. A resolution to confirm the intention to skip the FDIS stage is published.

Table 10.5 lists the informative and normative elements of an ISO document. Mandatory elements are indicated in bold; upright type elements are normative and italic type elements are informative.

Table 10.5 ISO document structure

Type of element	Element	Description
Preliminary informative	*Title page*	Title of the document, e.g. 'ISO 19157, Geographic information – Data quality'
	Table of contents	Mandatory if it makes the document easier to consult.
	Foreword	Information about the organisation (e.g. the technical committee) responsible for the document and a summary of significant changes from a previous version, if applicable.
	Introduction	Background information about the document and reasons prompting its preparation.
General normative	**Title**	
	Scope	The scope defines without ambiguity the subject of the document and the aspects covered, thereby indicating the limits of applicability of the document or particular parts of it. It shall not contain any requirements.
	Normative references	A list of the referenced documents cited in the document in such a way as to make them indispensable for the application of the document.
Technical normative	Terms and definitions	A list of terms and definitions necessary for the understanding of certain terms used in the document.
	Symbols and abbreviations	A list of the symbols and abbreviated terms necessary for the understanding of the document.
	Requirements	All characteristics relevant to the aspects of the standardization target covered by the document, either explicitly or by reference. For each requirement, either a reference to the test method

Type of element	Element	Description
		for determining or verifying the values of the characteristic, or the test method itself shall be provided.
	Normative annex	Provisions additional to those in the body of the document.
Supplementary informative	*Informative annex*	Additional information intended to assist the understanding or use of the document.
Technical normative	Normative annex	Provisions additional to those in the body of the document.
Supplementary informative	*Bibliography*	A list of referenced documents and information resources.
	Indexes	An index for the standard.

ISO/TC 211, Geographic information/Geomatics

ISO/TC 211[8] is the ISO technical committee responsible for standardization of geographic information. Its work aims at establishing a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. More specifically, it covers semantic, syntactic and service issues, as well as procedural standards, at various levels of abstraction. At the time of writing (17 October 2014), ISO/TC 211 had 35 participating members, 31 observing members and liaison relationships with more than 30 international organisations and more than 15 other ISO/TCs. African members are South Africa and Botswana who are a P-members; Kenya, Mauritius, Morocco, United Republic of Tanzania and Zimbabwe who are O-members; and Swaziland who is a corresponding member. ISO/IEC Directive Part 1 Consolidated ISO Supplement (2014) provides guidelines for twinning agreements, where developing country member bodies may establish P-member twinning arrangements with P-members from developed countries.

The development of a standard in ISO/TC 211 is assigned to one of six thematic working groups (WG): WG 1, Framework and reference model; WG 4, Geospatial services; WG 6, Imagery; WG 7, Information communities; WG 9, Information management; and WG 10, Ubiquitous public access. A number of maintenance groups ensure harmonization among the ISO/TC 211 standards: the Program Maintenance Group (PMG), the Terminology Maintenance Group (TMG), the Harmonized Model Maintenance Group (HMMG), the XML Maintenance Group (XMG) and the Group on Ontology Management (GOM). A control body for the ISO geodetic registry network is working towards an international registry of geodetic codes and parameters.

The TMG maintains a multi-lingual glossary of terms and definitions as they appear in ISO/TC 211 standards. At the time of writing (17 October 2014), the glossary was available on the ISO/TC 211 website and had been translated, in whole or in part, into Arabic, Chinese, Danish, Dutch, English, Finnish, French, German, Japanese, Korean, Polish, Russian, Spanish and Swedish. The HMMG maintains a harmonised model of the UML models and diagrams in all standards. This model is available for download, online access or online viewing on the ISO/TC 211 website.

[8] www.isotc211.org

10.5.2 Open Geospatial Consortium (OGC)

OGC[9] is an industry consortium that defines, documents and tests implementation standards for geo-spatial content and services. OGC standards leverage the abstract standards defined by ISO/TC 211. OGC work is driven by member organisation requirements, staff analysis of market trends and OGC Board of Directors guidance. In all cases, the mission is the integration of geo-spatial content and services into applications for the benefit of humankind.

OGC membership is open to any organisation or individual. Four types of membership (associate, technical, principal and strategic) provide increasing levels of influence on standards development. Reduced membership fees apply to lower income countries. OGC currently has 480+ members representing governments, the private sector, universities, NGOs, research communities and the open source community. OGC work is guided by member approved Policies and Procedures, that evolve in response to member and market requirements.

OGC standards are technical documents that detail interfaces or encodings. Software developers use these documents to build open interfaces and encodings into their products and services. Ideally, if OGC standards are implemented in products or online services by two or more different software engineers working independently, the resulting components can be used together (i.e. plug-and-play) without further debugging.

Development of standards

OGC standards work occurs primarily in two major activities: the Interoperability Program and the Standards Program. The Interoperability Program provides a facilitated, rapid engineering (agile) lifecycle approach to capturing interoperability requirements and then using those requirements and use cases to prototype applications (software) that either test existing OGC standards against those requirements, often providing change requests to existing standards; or develop new candidate standards or extensions to existing standards. The work of an interoperability initiative then feeds directly into the standards program.

Candidate standards are submitted by three or more member organisations. Candidate standards may have been developed outside OGC (such as KML), developed by a Standards Working Groups (SWG), or submitted as a result of an interoperability initiative. The Standards Program has Domain Working Groups (DWG) and SWGs. DWGs are open to any member, as well as the public (non-members). DWGs are open fora for discussion of requirements, use cases and issues, and for members to present implementations of OGC standards and lessons learned. SWGs are for members and invited guests. Standards documents are prepared and maintained by SWGs. The OGC Policies and Procedures and the OGC Intellectual Property policies guide the work in the SWGs.

All OGC standards, when approved, are freely and publicly available on a royalty free, non-discriminatory basis (RAND-RF) at www.opengeospatial.org. Any schemas (xsd, xslt, etc.) that support a published OGC standard can be found in the official OGC Schema Repository on the OGC website.

[9] www.opengeospatial.org

Compliance testing

In the OGC Compliance Program implementations of OGC standards are tested and certified if they comply with relevant standards. Vendors can certify their products to be compliant with OGC standards. This ensures that their products can be integrated with other products and services. Compliance testing is free, but an annual trademark licensing fee is due for using the "Certified OGC Compliant" Mark associated with an OGC Standard. Compliance testing is guided by the Compliance Testing Program Policies & Procedures. A list of compliant products is available on the OGC website.

10.5.3 International Hydrographic Organization (IHO)

IHO [10] is an intergovernmental consultative and technical organisation established in 1921 to support safety of navigation and the protection of the marine environment. Among its main objectives, IHO is to bring about the greatest possible uniformity (i.e. standardization) in nautical charts and documents. The establishment and maintenance of hydrographical standards rest with the IHO Programme 'Hydrographic Services and Standards', under the responsibility of the IHO Hydrographic Services and Standards Committee (HSSC). The provision of hydrographical and nautical chart services is one of the obligations of coastal State signatories to the International Convention for the Safety of Life at Sea (SOLAS) under the responsibility of the International Maritime Organization (IMO). The SOLAS Convention (IMO 2009) stipulates that 'Contracting Governments undertake to ensure the greatest possible uniformity in charts and nautical publications and to take into account, whenever possible, the appropriate resolutions and recommendations adopted by the International Hydrographic Organization'.

The current IHO membership is composed of 81 coastal states. The official representatives of member governments within IHO are normally the national Hydrographer, or Director of Hydrography, who, together with their technical staff, meet in Monaco at the International Hydrographic Conference (IHC). IHC holds ordinary sessions at five-year intervals and extraordinary sessions in the interim period as required. All IHO decisions are made by the member states during IHC sessions or by postal voting between IHC sessions. Each member state has one vote in ordinary decision-making.

Development of standards

The principles and procedures for developing IHO standards are laid out in a resolution, initially approved by IHO Member States in 2007. This resolution applies to "standards" and "guides" as defined by ISO. The development, consultation and approval process ranges from a very comprehensive regime for *new publications* and significant changes to existing publications (*new editions* or *revisions)*, requiring formal approval by a majority of the Member States, to approval at the level of a subordinate body (committee, sub-committee, working group) for simple *clarifications*.

Proposals to develop a *new publication*, a *new edition* or a *revision* are considered by the relevant IHO Committee, generally the HSSC, but not exclusively. When assessing the proposal, the Committee concerned considers the impact on relevant stakeholders, including a risk and feasibility analysis and an estimate of the resources needed for the development and the implementation of the new or revised standard. After the Committee has endorsed proposals and established a work priority, the relevant tasks are incorporated in the IHO work programme. Relevant stakeholders are notified of

[10] www.iho.int

the timetable for new work items and invited to comment and participate as appropriate. At the successful completion of the development and testing phases for new standards and proposed changes to existing standards, the Committee reviews the work done in terms of its impact on relevant stakeholders and whether the appropriate non-IHO stakeholder consultation process has been achieved. After endorsement by the Committee, the new or changed standard is submitted to the approval of member states (simple majority).

The IHO Secretariat maintains an on-line register of IHO stakeholders used to inform and seek input from stakeholders. Stakeholders include other international organisations, maritime administrations, equipment manufacturers, data distributors, users and professional organisations. IHO standards are freely available at www.iho.int.

10.5.4 Cooperation between IHO, ISO/TC 211 and OGC

The guidelines in this and the following chapter include standards from IHO, ISO/TC 211 and OGC. It is important to note that some of these standards are joint publications, cross-reference each other or depend on each other. Therefore this section provides a brief overview of the cooperation between the three standardization organisations.

OGC and IHO are category A liaisons of ISO/TC 211. Category A liaisons are organisations that make an effective contribution to the work of the technical committee for questions dealt with by the technical committee. Such organisations are given access to all relevant documentation and are invited to meetings. They may nominate experts to participate on the development of standards in working groups.

OGC and ISO/TC 211 have a long history of collaboration and development of joint standards documents. Selected OGC standards are submitted to ISO/TC 211 for consideration for approval as International Standards. OGC develops standards that can be directly implemented. Many of these implementation standards are based on the conceptual (or abstract) models defined by ISO or jointly by OGC and ISO.

The cooperation between IHO and ISO/TC 211 has been driven by the development of standards for digital hydrographical information and products. IHO recognised the benefits of developing standards based on some or all of the parts of the ISO 19100 series or other related standards and both organisations agreed to formalise their cooperation through a Memorandum of Understanding in order to strengthen the joint development of international standards and to avoid duplication of work on standards related to hydrography and nautical charting and related data, products and services.

IHO members, IHO technical staff and IHO nominated experts attend ISO/TC 211 working groups and plenary meetings and participate in the work in a non-voting capacity. IHO's Category A liaison with ISO/TC 211 provides overall co-ordination of this activity within IHO. Conversely, ISO/TC 211 representatives participate as non-voting liaison members in IHO committees and working groups so that reciprocal liaison is achieved.

10.5.5 Other standards developing organisations

Geo-spatial standards refer to and depend on standards developed in other organisations. A brief introduction to the three most important organisations is provided below.

The Geomatics Committee of the International Association of Oil and Gas Producers (OGP)[11], previously known as the Surveying & Positioning Committee, was formed in 2005 by the absorption into OGP of the now-defunct European Petroleum Survey Group (EPSG). The OGP Geomatics Committee, through its Geodesy Subcommittee, maintains and publishes a dataset of parameters for coordinate reference system and coordinate transformation description. The EPSG Geodetic Parameter Dataset is referenced in various data formats, including the GeoTIFF interchange format for geo-referenced raster imagery (see Table 10.13). EPSG codes are used to uniquely identify a coordinate reference system in various IHO, OGC and ISO standards for geo-spatial data, for example, ISO 19128:2005, Geographic information – Web Map Server interface, and OpenGIS Web Map Server Implementation Specification.

The Internet Engineering Task Force (IETF)[12] develops and promotes standards for the Internet. Its mission is to make the Internet work better by producing relevant technical documents that influence the way people design, use and manage the Internet. The IETF is an open standard organisation with no formal membership, membership requirements or fees. Some of the IETF standards are referenced in standards for geo-spatial information, especially where geo-spatial information is made available over the Internet, for example, IETF RFC 3986, *Uniform Resource Identifier (URI): Generic Syntax.*

The World Wide Web Consortium (W3C)[13] develops technical specifications and guidelines for web applications. W3C members are organisations or individuals. Membership fees vary depending on the annual revenues, type and location of headquarters of an organisation. Some of the W3C standards are referenced in geo-spatial information standards, for example, W3C XML, *Extensible Markup Language (XML) 1.0 (Second Edition)*, W3C Recommendation (6 October 2000).

Two regional African standardization organisations are worth mentioning. The SADC Cooperation in Standardization (SADCSTAN)[14] is the sole body mandated by the Council of Ministers of countries in the Southern African Development Community (SADC) to promote the coordination of standardization activities and services in the region, with the purpose of achieving harmonization of standards and technical regulations (with the exception of the legal metrology regulations) in support of the objectives of the SADC Trade Protocol. The protocol aims to facilitate trade, economic liberalization and development for deeper regional integration and poverty eradication as well as the establishment of the SADC common market. To date, a technical committee on geo-spatial information has not been established.

The African Regional Organisation for Standardization (ARSO)[15] aims to facilitate global trade through harmonised standards and conformity systems and procedures. Paid subscription membership is open to all African countries through their national standards bodies or departments dealing with standards and quality. Thirteen Technical Harmonisation Committees deal with standards ranging from Agriculture and Food Products to Electro-technology and Traditional Medicine. Currently,

[11] www.ogp.org.uk
[12] www.ietf.org
[13] www.w3.org
[14] www.sadcstan.co.za
[15] www.arso-oran.org

there is no Technical Harmonisation Committees dealing with standards on geo-spatial information specifically.

10.6 Standards on which other standards are based

This section provides a tabular overview of standards, which are not implemented directly when working with geo-spatial data. These standards provide the foundation on which other standards are based. Other parts of the guidelines refer to these standards and therefore an overview is included here.

Table 10.6 Reference model (ISO 19101:2002 and ISO ISO 19101-1:2014)

Full name	ISO 19101:2002, Geographic information – Reference model ISO 19101-1:2014, Geographic information – Reference model – Part 1: Fundamentals
Version	Edition 1 Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19101:ed-1:v1:en https://www.iso.org/obp/ui/#iso:std:iso:19101:-1:ed-1:v1:en
Type of standard	ISO International Standard Meta-meta level
Related standard(s)	ISO 19101-2:2008, Geographic information -- Reference model -- Part 2: Imagery
Application	Geographic information standardization is a large and complex field that requires a reference model to ensure an integrated and consistent approach. ISO 19101 defines a reference model of the requirements for standardization and the fundamental principles that apply in developing and using standards for geographic information. This reference model was established in ISO 19101 as a guide to structuring geographic information standards that facilitate the use of digital geographic information. ISO 19101-1:2014 replaces ISO 19101:2002, but the latter is still available as it is still normatively referenced in many standards.

Table 10.7 Conceptual schema language (ISO 19103:2005)

Full name	ISO 19103:2005, Geographic information – Conceptual schema language
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:ts:19103:ed-1:v1:en
Type of standard	ISO International Standard Meta-meta level
Related standard(s)	ISO 19150-1:2012, Geographic information -- Ontology -- Part 1: Framework ISO 19150-2, Geographic information -- Ontology -- Part 2: Rules for developing ontologies in the Web Ontology Language (OWL) S-100 IHO Universal hydrographical data model
Application	ISO 19103 specifies rules and guidelines for the use of UML, the preferred Conceptual Schema Language (CSL) in the ISO/TC 211 suite of standards. The ISO/TC 211 suite of standards aims to create a framework in which data interchange and service interoperability can be achieved across multiple implementation environments. The adoption and consistent use of a CSL is fundamental to achieving this goal because it allows the specification of unambiguous schemas, which form the basis for data interchange and definition.

Table 10.8 Conformance and testing (ISO 19105:2000)

Full name	ISO 19105:2000, Geographic information -- Conformance and testing
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19105:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19106:2004, Geographic information – Profiles ISO/IEC Guide 25:1990, General requirements for the competence of calibration and testing laboratories ISO/IEC TR 13233:1995, Information technology — Interpretation of accreditation requirements in ISO/IEC Guide 25 — Accreditation of Information Technology and Telecommunications testing laboratories for software and protocol testing services
Application	ISO 19105 specifies the framework, concepts and methodology for conformance testing of the ISO/TC 211 suite of standards. Requirements for specifying abstract test suites (ATS) and the procedure for testing conformance to the ISO/TC 211 standards are defined. ISO/TC 211 standards implement ISO 19105 to specify requirements for claiming conformance to a specific standard.

Table 10.9 Profiles (ISO 19106:2005)

Full name	ISO 19106:2005, Geographic information – Profiles
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19106:ed-1:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19101:2002, Geographic information — Reference model ISO 19105:2000, Geographic information — Conformance and testing ISO/IEC TR 10000-1:1998, Information technology — Framework and taxonomy of International Standardized profiles — Part 1: General principles and documentation framework ISO/IEC TR 10000-3:1998, Information technology — Framework and taxonomy of International Standardized profiles — Part 3: Principles and Taxonomy for Open System Environment Profiles ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards
Application	ISO 19106 provides guidelines on how to develop a profile of an ISO/TC 211 standard. ISO 19106 specifies two types of profiles that can be developed: the first is a subset of the standard; the second is an extension of the standard for a specific application field for example.

Table 10.10 OGC Abstract Specification

Full name	OGC Abstract Specification or OpenGIS Abstract Specification
Version	Edition 1
Amendments	None
Corrigenda	None

Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/as
Type of standard	OGC specification Multiple levels
Related standard(s)	OGC Reference model
Application	The OGC Abstract Specification is the OGC Technical Committee's vision of geospatial technology and data interoperability. It provides 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 implementation specifications in OGC. Many of the ISO standards described in these guidelines are included in the OpenGIS Abstract Specification.

Table 10.11 OGC Reference Model

Full name	Open Geospatial Consortium Reference Model
Version	2.1
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/orm
Type of standard	OGC specification Multiple levels
Related standard(s)	OGC Abstract Specification
Application	The OGC Reference Model (ORM) describes the OGC Standards Baseline focusing on relationships between the baseline documents. The OGC Standards Baseline consists of the approved OGC Abstract and Implementation Standards (Interface, Encoding, Profile and Application Schema – normative documents) and OGC Best Practice documents (informative documents). The purpose of the reference model is • to provide an overview of the OGC Standards Baseline; • to provide insight into the current state of the work of the OGC; • to serve as a basis for coordination and understanding of the documents in the OGC SB; and • to provide a useful resource for defining architectures for specific applications.

10.7 Standards for acquiring and maintaining fundamental geo-spatial datasets

10.7.1 Geo-spatial data formats

This section provides a tabular overview of standards for geo-spatial data formats.

Table 10.12 Esri Shapefile (SHP)

Full name	Esri Shapefile Technical Description
Version	1998
Amendments	None
Corrigenda	None
Published by	Esri
Languages	English

Online overview	http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf
Type of standard	Proprietary standard (published and freely available) Instance level
Related standard(s)	None
Application	This document defines the shapefile (.shp) geo-spatial data format and describes the format's importance. Typically used for (non-topological) vector geometry with associated attribute data. For example, street centrelines or points of interest.
Implementation benefits	The shapefile stores non-topological geometry and the associated attribute data for the features of a dataset. The geometry is stored as a set of vector coordinates that create a shape. The lack of topology speeds up rendering and editing. However, there are drawbacks when performing complex spatial analysis. The shapefile is a relatively small file and requires little storage space. The shapefile is the *de facto* standard for geo-spatial data exchange and import and/or export functionalities are implemented in most GIS software.

Table 10.13 GeoTIFF

Full name	GeoTIFF Format Specification
Version	1.8.2
Amendments	None
Corrigenda	None
Published by	Public domain
Languages	English
Online overview	http://trac.osgeo.org/geotiff/
Type of standard	Public domain standard Instance level
Related standard(s)	Adobe TIFF
Application	The specification defines a set of TIFF tags to describe all geo-spatial information associated with TIFF imagery that originates from satellite imagery systems, scanned aerial photography, scanned maps, digital elevation models, or as a result of geographic analyses. GeoTIFF is commonly used for satellite imagery, scanned aerial photography, scanned maps, digital elevation models, or as a result of geographic analyses.
Implementation benefits	GeoTIFF uses a small set of reserved TIFF tags to store a broad range of georeferenced information, catering to geographic as well as projected coordinate system needs. Projections include UTM, US State Plane and National Grids, as well as the underlying projection types, such as Transverse Mercator and Lambert Conformal Conic.

Table 10.14 HDF-5

Full name	Hierarchical Data Format (HDF-5)
Version	Edition 5
Amendments	None
Corrigenda	None
Published by	The HDF Group
Languages	English
Online overview	http://www.hdfgroup.org/HDF5/whatishdf5.html
Type of standard	Proprietary standard (published and freely available) Instance level
Related standard(s)	netCDF
Application	This document specifies the Hierarchical Data Format (HDF-5) data and programming model. HDF5 is used to store a variety of scientific data.
Implementation benefits	HDF5 is a Hierarchical Data Format specification and provides a supporting library implementation. HDF5 file is a self-describing format and a single file can store up to 20 000 complex objects. Some disadvantages are that data models of HDF5 are not consistent; and data types can be restrictive.

Table 10.15 Transfer standard for digital hydrographic data (S-57 IHO)

Full name	S-57, IHO transfer standard for digital hydrographic data
Version	Edition 3.1.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English
Online overview	http://www.iho.int/iho_pubs/standard/S-57Ed3.1/31Main.pdf
Type of standard	IHO International Standard Application level
Related standard(s)	ISO/IEC 8211:1994, Information technology — Specification for a data descriptive file for information interchange
Application	S-57 describes the requirements for exchange of digital hydrographical data between national hydrographical offices and for its distribution to manufacturers, mariners and other data users. All hydrographical data should adhere to the specifications set out in S-57.
Implementation benefits	S-57 describes a data model and data structure to be followed to ensure that data are interoperable between hydrographical offices.

Table 10.16 Geography Markup Language (GML) (ISO 19136:2007)

Full name	ISO 19136:2007, Geographic information – Geography Markup Language (GML) (also published as OpenGIS Geography Markup Language (GML) Encoding Standard)
Version	ISO: Edition 1 OGC: V 3.2.1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211 and OGC
Languages	English, French
Online overview	http://www.opengeospatial.org/standards/gml
Type of standard	ISO International Standard and OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19118:2011, Geographic information -- Encoding ISO 19137:2007, Geographic information – Core profile of the spatial schema
Application	GML is an Extensible Markup Language (XML) encoding for transport and storage of geographic information. It is typically used for vector geometry with associated attribute data, such as, a road network or cadastral data. GML is specifically powerful for web processing of geo-spatial data.
Implementation benefits	GML is a human readable and machine 'processable' encoding with makes it ideal for web data dissemination. GML is based on XML, which brings a number of advantages, such as, XML providing a method for verifying data integrity; the XML structure allowing easy integration of GML data with non-spatial data; and XML transformations. GML allows topology to be encoded in the schema.

Table 10.17 Well known text representation of coordinate reference systems (ISO 19162)

Full name	ISO 19162, Geographic information – Well known text representation of coordinate reference systems
Version	Draft International Standard
Amendments	None

Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not available yet
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19111:2007, Geographic information -- Spatial referencing by coordinates ISO 19125-1:2004, Geographic information – Simple feature access – Part 1: Common access
Application	ISO 19162 defines the structure and content of a text string implementation of the abstract model for coordinate reference systems as described in ISO 19111. Well Known Text (WKT) is commonly used in database implementations to store and transport geo-spatial data.
Implementation benefits	WKT offers a compact machine- and human-readable representation of geometric objects. This standard extends earlier WKT to allow for the description of coordinate operations.

Table 10.18 JPEG 2000 image coding system: Core coding system (ISO/IEC 15444-1:2004)

Full name	ISO/IEC 15444-1:2004, Information technology -- JPEG 2000 image coding system: Core coding system
Version	Edition 2
Amendments	Amendment 6
Corrigenda	Corrigenda 6
Published by	ISO
Languages	English, French
Online overview	Not available yet
Type of standard	ISO/IEC International Standard Instance level
Related standard(s)	GeoTIFF
Application	The standard defines a set of lossless (bit-preserving) and ‘lossy’ compression methods for coding bi-level, continuous-tone grey-scale, palletised colour, or continuous-tone colour digital still images. JPEG 2000 is used for satellite imagery, scanned aerial photography, scanned maps, digital elevation models, or as a result of geographic analyses.
Implementation benefits	JPEG 2000 has a number of advantages, such as better compression quality, scalable by resolution, quality and colour channel, lossless encoding, up to 38 bit depths and it is considered to be error resilient.

Table 10.19 Specification for a data descriptive file for information interchange (ISO/IEC 8211:1994)

Full name	ISO/IEC 8211:1994, Information technology -- Specification for a data descriptive file for information interchange
Version	Edition 2
Amendments	None
Corrigenda	None
Published by	ISO and IEC
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso-iec:8211:ed-2:v1:en
Type of standard	ISO International Standard Instance level
Similar standard(s)	None
Related standard(s)	S-57 IHO transfer standard for digital hydrographic data

Application	ISO/IEC 8211 specifies an interchange format to facilitate the moving of files or parts of files containing data records between computer systems. The intended use of the format is for physical recorded media and communication files. This standard is used in S-57 to define the data format, ensuring data interoperability and exchange.
Implementation benefits	ISO/IEC 8211 specifies medium-independent and system-independent file and data record formats to ensure interoperability of information. The data format can store elementary data, vectors, arrays and hierarchies.

Table 10.20 OGC GeoPackage Encoding Standard

Full name	OGC GeoPackage Encoding Standard
Version	V 1.0
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/geopackage
Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO/IEC 9075-11:2011, Information technology -- Database languages -- SQL -- Part 11: Information and Definition Schemas (SQL/Schemata) ISO 19125-2:2004, Geographic information – Simple feature access – Part 2: SQL option
Application	This OGC encoding standard defines *GeoPackage for exchange* and *GeoPackage SQLite extension* for direct access of vector and raster images for enterprise production platform and mobile hand-held devices. A GeoPackage is a platform independent SQLite database file comprising of the data and metadata tables. The extended GeoPackage allows the addition of any data elements or SQL constructs outside of this encoding standard.

Table 10.21 OGC KML

Full name	OGC KML
Version	2.2.0
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/kml
Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19118:2011, Geographic information -- Encoding ISO 19136:2007, Geographic information – Geography Markup Language (GML)
Application	KML (formerly Keyhole Markup Language) is an XML grammar used to encode and transport representations of geographic data for display in an earth browser. KML is mainly used in earth browsers, such as digital globes, to display and style 2D and 3D data.
Implementation benefits	KML is a human readable and machine ‘processable’ encoding which makes it ideal for web data dissemination. What sets KML apart from GML is that styling of the feature or object is included in the encoding. KML allows the user to define different camera positions, encode hyperlinks in the data, embed images and define textured 3D objects.

Table 10.22 OGC Network Common Data Form (netCDF)

Full name	OGC Network Common Data Form (netCDF) Core Encoding Standard
Version	V 1.0

Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/netcdf
Type of standard	OpenGIS Implementation Specification Instance level
Related standard(s)	None
Application	OGC NetCDF defines the netCDF data model and the core set of requirements to which every netCDF encoding must adhere. netCDF is popular in atmospheric sciences and oceanography.
Implementation benefits	netCDF is a machine-independent format for representing scientific data. It is a self-describing, portable, scalable, interoperable data format. The format is popular for data archiving. The combination of the netCDF interface, library and format support the creation, access and sharing of scientific data.

Table 10.23 Well known binary (WKB)

Full name	Well known binary (WKB), defined in ISO/IEC 13249-3:2011, Information technology -- Database languages -- SQL multimedia and application packages -- Part 3: Spatial
Version	Edition 4
Amendments	None
Corrigenda	None
Published by	ISO/IEC JTC 1/SC 32, Data management and interchange
Languages	English
Online overview	Not available yet
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19125-2:2004, Geographic information – Simple feature access – Part 2: SQL option
Application	WKB is defined in ISO/IEC 13249-3:2011. WKB is a hexadecimal encoding that can be used to define geometry. Geometries are expressed as a stream of bytes that is not human readable. The type of geometry is specified followed by the coordinates of the nodes.
Implementation benefits	In ISO 19125-2, WKB is an option of describing geometries. This is an optimal format for databases, since the geometry is expressed as a stream of bytes and can easily be exchanged. However, the encoding does not support any analysis, such as measurements.

10.7.2 Data product specifications (ISO 19131:2007)

Table 10.24 Overview of ISO 19131:2007

Full name	ISO 19131:2007, Geographic information – Data product specifications
Version	Edition 1
Amendments	ISO 19131:2007/Amd 1:2011
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19131:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19115:2003, Geographic information -- Metadata

Application	The standard is essentially the inverse of ISO 19115 and uses the metadata concepts, elements and entities in ISO 19115. ISO 19131 describes what the user wants (datasets, services, etc.) – the product specification – in a structured way so that it can be compared directly to the metadata of candidate offerings or used to create a new product that meets the specification.
Conformance classes	Data product specification sections Mandatory items Item details

Scope

ISO 19131:2007 describes requirements for the specification of geographic data products, based upon the concepts of other ISO 19100 International Standards. It also provides help in the creation of data product specifications, so that they are easily understood and fit for their intended purpose.

Implementation benefits

ISO 19131:2007 describes in a structured way what the user wants, that is, the specification of the product required. While aimed primarily at specifying required datasets, the standard can also be used to specify services and other geospatial products. The standard is essentially the inverse of ISO 19115:2003 and uses the concepts and metadata elements and entities in ISO 19115:2003. Hence, it means that one can compare a product specification directly and in detail with the metadata of candidate offerings.

As the specification and metadata are both structured and contain many encoded elements, much of the matching can be done automatically, to filter out candidates that do not meet the specification. Candidate products can be obtained from within a user's domain, but also from elsewhere. Hence, even an expert user might not be aware of possible sources for suitable products. This powerful capability enables of the ISO 19115:2003 and ISO 19131:2007 combination to filter out suitable candidates automatically.

An ISO 19131:2007 product specification can also be used to guide the development of a new product that meets the specification, and for others needing a similar product to see if the proposed product will also meet their needs. In South Africa, for example, the Committee for Spatial Information (CSI) is using ISO 19131:2007 for developing the form to be used by data custodians for informing the CSI of their planned data capture programmes, such as for aerial photography.

Implementation guidelines

While ISO 19131:2007 does include annexes with UML class diagrams and data dictionaries as tables (as is done in ISO 19115:2003), it is probably still necessary for the user to consult ISO 19115:2003 when using ISO 19131:2007, as ISO 19115:2003 has more details about the metadata (and hence, product specification) concepts, elements and entities.

ISO 19131:2007 specifies that a data product specification shall describe the following aspects of the product:

1. Overview: source and provenance of the specification, relevant terminology and an informal description of the required product, such as the dataset content, spatial and temporal extents, purpose, sources, production processes and maintenance.

2. Specification scopes: the scope of the required product, in terms of spatial and temporal extent, feature types, property types, property values, spatial representation, product hierarchy and partitioning (e.g. between the dynamic and static sorts of data in the required product), The concept 'product hierarchy' is not defined in the standard, but this applies to each of the partitions of the product being specified, as they can be at different levels: attribute, attribute type, feature, feature type, tile, dataset, series, etc. For each partition, the level code, level name, level description, extent and coverage are to be specified.

3. Data product identification: title, abstract, topic category (one of the pre-defined themes that applies to the required product, such as farming, boundaries, elevation or transportation) and geographic description (actually, spatial extent) shall be provided and alternate title, purpose, spatial representation type (e.g. vector or raster), spatial resolution and supplemental information may be provided.

4. Data content and structure: feature-based, coverage-based or imagery data. The content of a feature-based product shall be described in terms of an application schema (content, structure and constraints applicable) and a feature catalogue (or classification system). The application schema can be very complicated, catering for relationships between feature, property and attribute types, such as feature operations, feature association, inheritance relations and constraints. Imagery data are a form of coverage and a coverage is a sub-type of a feature, which behaves like a function returning one or more feature attribute values for some point within a spatiotemporal domain. A coverage requires an identifier, a description, the type and additional information.

5. Reference systems: the spatial reference system (using coordinates or geographic identifiers) and the temporal reference system.

6. Data quality: the data quality requirements, acceptable conformance quality levels and corresponding data quality measures. In ISO 19131:2007, the data quality requirements are specified in terms of ISO 19113 and ISO/TS 19138, but these have now been revised by ISO 19157:2013 (described in 10.7.3).

7. Data capture: an optional specification of the sources and processes that shall or may be used for the data capture.

8. Data maintenance: an optional specification of the principles and criteria to be applied in maintaining the product, such as maintenance and update frequency.

9. Portrayal: an optional specification of the portrayal rules and a set of portrayal specifications, for specifying how the data may be represented graphically. This could be particularly important for a web service, for example.

10. Data product delivery: delivery format (e.g. transfer standard) and delivery medium (e.g. CD-ROM). The delivery format details may include the name and version of the format; subset, profile or product specification; structure of the delivery file; language(s) and character encoding. The delivery medium details may include units of delivery (how the

data are arranged on the medium), estimated sizes, name of the delivery medium and other delivery information.

11. Additional information: a catchall for anything else to be specified for the product, such as constraint information regarding access and use.

12. Metadata: the metadata that shall be provided with the product, defined in terms of ISO 19115:2003.

With the publication of ISO 19117:2012, Geographic information – Portrayal, ISO 19157:2013, Geographic information – Data quality, and ISO 19115-1:2014, Geographic information – Metadata – Part 1: Fundamentals, ISO 19131:2007 is due to be revised.

10.7.3 Data quality (ISO 19157:2013)

Table 10.25 Overview of ISO 19157:2013

Full name	ISO 19157:2013, Geographic information – Data quality
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19157:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19115-1:2013, Geographic information – Metadata – Part 1: Fundamentals ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data ISO 19158:2012, Geographic information – Quality assurance of data supply
Application	The standard specifies the description, evaluation and reporting of the quality of geographic data.
Conformance classes	Data quality evaluation process Data quality metadata Standalone quality report Data quality measure

Scope

ISO 19157:2013 establishes the principles for describing the quality for geographic data. It defines components for describing data quality; specifies components and content structure of a register for data quality measures; describes general procedures for evaluating the quality of geographic data; and establishes principles for reporting data quality.

The standard also defines a set of data quality measures for use in evaluating and reporting data quality. It is applicable to data producers providing quality information to describe and assess how well a dataset conforms to its product specification and to data users attempting to determine whether or not specific geographic data are of sufficient quality for their particular application.

The standard does not attempt to define minimum acceptable levels of quality for geographic data.

Implementation benefits

ISO 19157:2013 provides a standard way for describing the quality of geographic data. Such descriptions are useful when a producer has to evaluate how well a dataset meets the criteria described in its product specification. For example, if the producer outsourced the acquisition of the data, ISO 19157:2013 could be used to evaluate and describe the quality of the received data during acceptance testing.

Geographic data are increasingly shared and exchanged. As a result, geographic data are often used for purposes that differ from the purpose for which it was originally captured. Complete descriptions of the quality of a dataset encourage and facilitate the sharing, interchange and use of appropriate datasets.

Another benefit of implementing ISO 19157:2013 is that the quality information could assist a user who has to decide whether a specific dataset is appropriate for an intended use or application. If the user has to decide between two or more datasets, standardized quality descriptions simplify comparing the datasets. If ISO 19157:2013 is implemented, quality reports are expressed in a comparable way and there is a common understanding of the quality measures that have been used. A project to develop an XML of ISO 19157:2013 has begun.

Implementation guidelines

ISO 19157:2013 cancels and replaces ISO/TS 19138:2006, ISO 19114:2003 and ISO 19113:2002. According to ISO 19157:2013, data quality comprises six elements: completeness, thematic accuracy, logical consistency, temporal quality, positional accuracy and usability. Each element is comprised of a number of sub-elements, for example, completeness (commission and omission), logical consistency (conceptual, domain, format, topological), etc. These elements are used to describe data quality, i.e. how well a specific dataset meets the criteria for the different elements set forth in its product specification or user requirements. Evaluation against the criteria is done either quantitatively or subjectively (non-quantitatively). The latter case applies if a detailed data product specification does not exist or if the data product specification lacks quantitative measures and descriptors. Three metaquality elements – confidence, ‘representativity’ and homogeneity – provide quantitative and qualitative statements about the evaluation against the criteria and its result.

Quality information can be provided for different units of data, e.g. a dataset series, a dataset or a subset of a dataset with common characteristics. A data quality unit comprises of a scope and data quality elements. The scope specifies the extent, spatial and/or temporal and/or common characteristic(s) of the unit for which the quality information is provided.

In ISO 19157:2013, quality related information provided by purpose, usage and lineage of geographic data conforms to ISO 19115-1:2014 (described in chapter 11).

ISO 19157:2013 specifies four conformance classes, i.e. the standard can be implemented for four different quality aspects of geo-spatial datasets, each briefly described below.

1. Implementing a data quality evaluation process conforming to ISO 19157:2013

A data quality evaluation process conforming to ISO 19157:2013 comprises of four steps:

- Step 1 - Specify the data quality units to be evaluated. Study the data product specification to identify applicable data quality units and their scope. For each data quality unit, identify the applicable data quality element(s). See example in Table 10.26.
- Step 2 - Specify the data quality measures to be used to describe quality of each data quality element of a data quality unit. The requirements in the data product specification provide guidance on applicable data quality measures. See example in Table 10.27. The data quality measures in the table are from the list of standardized data quality measures in ISO 19157:2013. It is also possible to describe user-defined quality measures, see further below, and to maintain a collection of such measures in a catalogue or register.
- Step 3 - Specify the data quality evaluation procedures, i.e. the evaluation method(s) to be applied. The method can be direct (based on inspection of the items in the dataset) or indirect (based on external knowledge, such as lineage metadata). Direct evaluation is further classified by the source against which the evaluation is done: internal if only the data in the dataset is evaluated or external if there is reference to external data (e.g. satellite imagery or ground truth). ISO 19157:2013 includes guidance on how to sample data for evaluation.
- Step 4 - Determine the output of the data quality evaluation, i.e. perform the data quality evaluation described in Steps 1-3 above. Additional results may be produced by aggregating or by deriving from existing results without carrying out a new evaluation. How to report the results of the data quality evaluation is described elsewhere in this chapter.

Table 10.26 Example: Data quality units

Data quality unit	Scope	Data quality elements
Topographic dataset	All features in the dataset	Completeness (commission and omission), thematic accuracy (correct classification)
Street network	Street features in the entire dataset	Logical inconsistency (topological inconsistency)

Table 10.27 Example: Data quality measures

Data quality unit	Data quality element	Data quality measure	Method
Topographic dataset	Completeness (commission)	Measure 1: Excess item	Direct external
		Measure 2: Number of excess items	Direct external
		Measure 3: Number of duplicate feature instances	Direct internal
Topographic dataset	Completeness (omission)	Measure 1: Missing item	Direct external
		Measure 2: Number of missing items	Direct external
Topographic dataset	Thematic accuracy (correct classification)	Measure 1: Number of incorrectly classified features	Direct external
		Measure 2: Misclassification rate	Direct external
Street network	Logical inconsistency (topological inconsistency)	Measure 1: Number of missing connections due to undershoots	Direct internal
		Measure 2: Number of missing connections due to overshoots	Direct internal
		Measure 3: Number of invalid self-intersect errors	Direct internal
		Measure 4: Number of invalid self-overlap errors	Direct internal

2. Implementing data quality metadata conforming to ISO 19157:2013

Data quality metadata describes the quality of geographic data. ISO 19157:2013 specifies a conceptual model of the different components to be used when describing the quality of geographic data. Figure 10.1 provides and overview of the components and their relationships to each other. A data dictionary, including definitions for all the components, is provided in the standard. Data quality metadata conforming to ISO 19157:2013 conforms to this conceptual model and is reported in conformance with ISO 19115:2003 and ISO 19115-2:2009

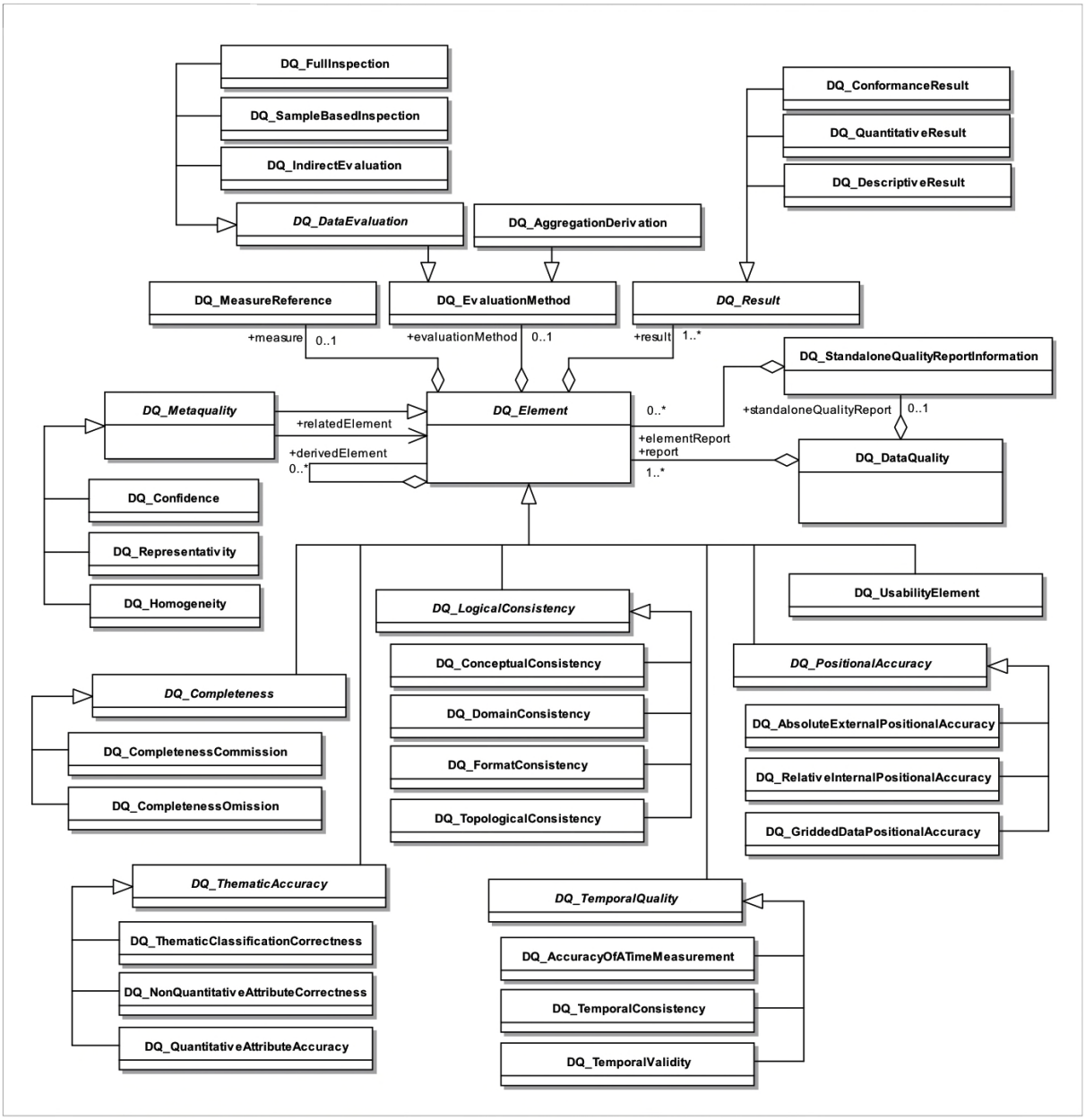

Figure 10.1 Overview of the components to be used to describe data quality (Source: ISO 19157:2013)

3. Implementing data quality reports conforming to ISO 19157:2013

The first (and obvious) requirement is that the quality report comprises quality metadata conforming to ISO 19157:2013 (see 2. above), i.e. it includes sections on all appropriate aspects of

quality and the description of components follow the rules defined in the standard. Additional information can be added to the report, but the structure of the report is not prescribed. Table 10.28 is an example of a section of a data quality report for the quality evaluation process described above.

Table 10.28 Example: Section of a data quality report

Data quality unit	Data quality element	Data quality measure	Result
Topographic dataset	Completeness (commission)	Measure 2: Number of excess items	1,036
		Measure 3: Number of duplicate feature instances	153
Topographic dataset	Completeness (omission)	Measure 2: Number of missing items	697
Topographic dataset	Thematic accuracy (correct classification)	Measure 1: Number of incorrectly classified features	8,774
		Measure 2: Misclassification rate	10%
Street network	Logical inconsistency (topological inconsistency)	Measure 1: Number of missing connections due to undershoots	139
		Measure 2: Number of missing connections due to overshoots	57
		Measure 3: Number of invalid self-intersect errors	11
		Measure 4: Number of invalid self-overlap errors	6

4. Implementing data quality measures conforming to ISO 19157:2013

A data quality measure conforming to ISO 19157:2013 is structurally and semantically well defined and described and modelled as specified in the standard. Such a measure is described by at least an identifier, a name, an element name, definition and a value type. Optional descriptors are an alias, description, a value structure, example, a basic measure and one or more source references and/or parameters. Note that full inspection is most appropriate for small populations or for tests that can be accomplished by automated means. For larger populations, checking a representative part of the data and reporting the quality result as a percentage rate is more appropriate and practical.

10.7.4 Quality assurance of data supply (ISO/TS 19158:2012)

Table 10.29 Overview of ISO/TS 19158:2012

Full name	ISO/TS 19158:2012, Geographic information – Quality assurance of data supply
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:ts:19158:ed-1:v1:en
Type of standard	ISO Technical Specification Application level
Related standard(s)	ISO 19131:2007, Geographic information – Data product specifications ISO 19157:2012, Geographic information – Data quality ISO 9000:2005, Quality management systems – Fundamentals and vocabulary
Application	The standard provides a quality assurance framework for the producer and customer in their production relationship. Methods to manage the quality of production are identified.
Conformance classes	Organisation (i.e. supplier of geographic data)

Scope

ISO 19158:2012 provides a framework for quality assurance specific to geographic information. It is based upon the quality principles and quality evaluation procedures of geographic information identified in ISO 19157 and the general quality management principles defined in ISO 9000.

The framework enables a customer to satisfy itself that its suppliers, both internal and external, are capable of delivering geographic information to the required quality. Fundamental to the framework is the assurance of the supplier's ability to understand and meet the quality requirements. Through the quality assurance framework both the customer and the supplier are able to consider the quality required at the earliest opportunity in the production/update process.

Principles and responsibilities of the relationship between the customer and the supplier that facilitate the framework are provided. The responsibility for the quality assessment procedure is shared between the customer and the supplier.

ISO 19158:2012 is applicable to customers and suppliers of all geographic information where the quality of the product may be impacted upon by the supplier's processes in any of the following scenarios:

- there is an agreement or legislation for the supply of data acquisition services,
- data acquisition services are being tendered for, and
- one or more suppliers exist in the supply chain.

ISO 19158:2012 is not applicable for the supply of legacy datasets or 'off the shelf' products where there is no further data production or update activity to manage.

Implementation benefits

By applying the quality assurance framework in ISO 19158:2012, an organisation can facilitate the production of a product that meets requirements in terms of cost, quantity, quality and timeliness. Applying the framework also provides opportunities for better understanding of requirements by all involved in production and update especially within multiple producer environments; reduced data throughput time; reduced rework; improved data quality; and increased confidence within a mutually beneficial relationship leading to lower costs for both supplier and organisation.

Implementation guidelines

In a typical approach to the production and/or update of geographic information, a customer requests a supplier to produce geographic information according to a data product specification, expecting the supplier to deliver the product on time, within budget and according to the specified data quality requirements. However, the customer has little or no input into the supplier's processes. This approach creates risks, because until the product is delivered, there is limited proof that the supplier has the appropriate capabilities to deliver the required product. These risks are aggravated by complex data, a demand for increased speed to market and outsourcing, i.e. the customer and supplier are in different organisations.

A product is created from the involvement of individuals and teams in several interrelated processes combining outputs to produce a final product. For example, the production of a map of

lookout points in a nature reserve comprises two processes: data collection and map production. The data collection process comprises a first sub-process where a team collects the coordinates of the lookout points using GPS devices. During the second sub-process, an individual at a desktop adds appropriate attributes for each lookout point, e.g. the name, animals likely to be seen and surrounding vegetation types. The map production process can be subdivided into a map preparation sub-process and a printing sub-process. By introducing quality evaluation processes to the outputs from each process, sub-process, team and individual, it is possible to determine how the quality of the final product will be affected. Figure 10.2 provides an overview of the quality assurance framework applied to the example above.

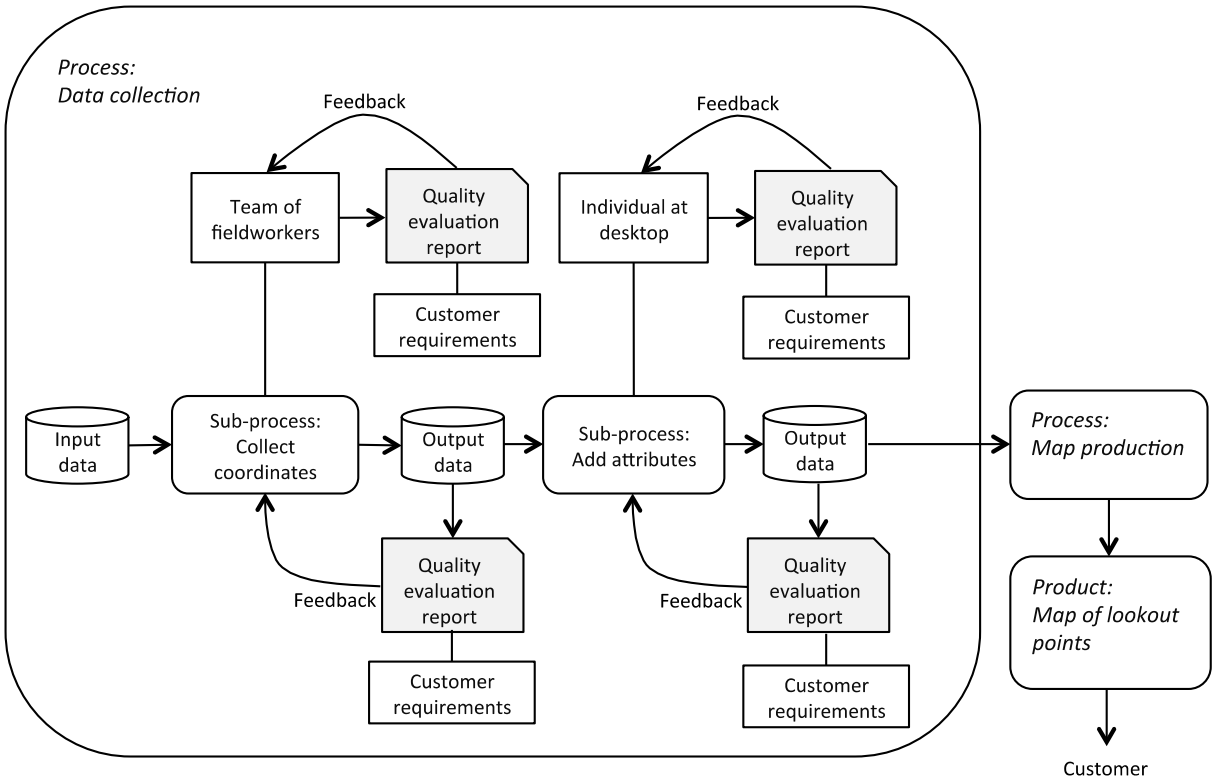

Figure 10.2 Example: Quality assurance framework applied to the production of a map of lookout points

An organisation implementing ISO 19158:2012 ensures that its suppliers of geographic information implement quality assurance and quality assessment procedures conforming to ISO 19158:2012. Quality assurance is a quality management activity focused on providing confidence that quality requirements will be fulfilled (by a supplier), while a quality assessment procedure is a procedure by which a customer assures that a supplier is capable of consistently delivering a product to the required quality.

A supplier of geographic information conforms to ISO 19158:2012 if its quality assurance

- has identified the necessary processes and sub-processes for the production and/or update of the geographic information;
- has identified the geographic data quality requirements for each process and sub-process according to the requirements in ISO 19157;

- has identified the quality requirements for the volume of delivery, schedule of delivery and cost of production and/or update for each process and sub-process; and
- has identified the output quality of the process, sub-process and individuals for data production and/or update.

Three levels of quality assurance with increasing opportunity for risk mitigation are specified in ISO 19158:2012: basic, operational and full. The customer confirms the level of assurance achieved by a production process:

1. Basic quality assurance is achieved if the supplier can demonstrate to the customer that the product specification, the data quality acceptance levels (or limits) and the delivery schedule are understood and that a process is in place to deliver the required volumes and data quality.
2. Operational quality assurance is achieved if the customer has assured that the processes, sub-processes, teams and individuals involved in the production of a product deliver the required quality. The operational quality assessment procedure has to start immediately after confirmation that the basic level of assurance has been achieved and the quality assessment has to be completed within the agreed period.
3. Full quality assurance is achieved if the supplier has sustained operational quality assurance for all sub-processes in the production or update process for a period agreed between the supplier and the customer.

In the example above, basic quality assurance may only assure the customer of the supplier's intent to produce a map, whilst operational quality assurance will assure the customer of the supplier's capability to produce the map in its operating environment. Full quality assurance assures the customer that the supplier has sustained the capability to produce maps over an agreed period of time.

ISO 19158:2012 provides guidance and examples on how to implement the quality assessment framework, as well as the supplier's responsibilities in the quality assurance procedure.

10.7.5 Calibration and validation of remote sensing imagery sensors (ISO 19159-1:2014)

Table 10.30 Overview of ISO/TS 19159-1:2014

Full name	ISO 19159-1:2014, Geographic information – Calibration and validation of remote sensing imagery sensors – Part 1: Optical sensors
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not available yet
Type of standard	ISO Technical Specification Application level
Related standard(s)	ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data ISO/TS 19130:2010, Geographic information – Imagery sensor models for geopositioning ISO 19123, Geographic information – Schema for coverage geometry and functions

Application	The specification defines the service metadata for the calibration procedures of optical remote sensing sensors, as well as the associated data types and code lists. Such information is useful for the evaluation of the quality of images recorded by sensors. Future parts of this specification will specify calibration and validation for other types of sensors.
Conformance classes	Project OpticsSensor: Geometry OpticsSensor: Radiometry OpticsCalibrationFacility: Geometry OpticsCalibrationFacility: Radiometry OpticsValidation Documentation

Scope

ISO/TS 19159-1 defines the calibration and validation of airborne and space borne remote sensing imagery sensors.

The term calibration refers to geometry, radiometry and spectral, and includes the instrument calibration in a laboratory as well as in-situ calibration methods.

The validation methods address validation of the calibration information.

ISO/TS 19159-1 also addresses the associated metadata related to calibration and validation that has not been defined in other ISO geographic information standards.

The specified sensors include optical sensors of the type frame cameras and line cameras (2D CCD scanners).

Implementation benefits

Vast amounts of remotely sensed imaging data are collected through a variety of sensors. The images themselves are used as is, but are also frequently used in the preparation of derived geo-spatial datasets, such as, topographic data and digital elevation models. The quality of these geo-spatial datasets depends, amongst others, on the quality of the measuring instruments that originally sensed the images. The quality of the measuring instruments is determined and documented during calibration.

Calibration can be a costly and time-consuming exercise. Therefore, sometimes strategies are devised to combine longer time intervals between subsequent calibrations with simplified intermediate calibration procedures. The simplified intermediate calibrations save on costs and bridge the time gap, while still ensuring a traceable level of quality. ISO/TS 19159-1:2014 refers to these intermediate calibrations as validations.

The quality of a wide variety of geo-spatial datasets depends on the quality of the measuring instruments used to sense images. Sharing information about the calibration and validation of the quality measuring instruments of sensors facilitates the evaluation of the quality of the images. The different parts of ISO/TS 19159 specify service and data requirements for the calibration of remote sensing imagery sensors and the validation of the calibration information and procedures. They do not, however, address the validation of the data and the derived products. The first part, ISO/TS 19159-1:2014, is concerned with optical sensors, i.e. airborne photogrammetric cameras and space

borne optical sensors. These include digital frame cameras that take 2-dimensional images as a whole, line cameras that apply the pushbroom or whiskbroom principle, as well as sensors that record electromagnetic radiation of the infrared spectrum, such as, thermal, multispectral and hyperspectral cameras.

Implementation guidelines

ISO 19159-1:2014 specifies service and/or data conformance in seven conformance classes:

- Project
- OpticsSensor: Geometry
- OpticsSensor: Radiometry
- OpticsCalibrationFacility: Geometry
- OpticsCalibrationFacility: Radiometry
- OpticsValidation
- Documentation

Service conformance requires the use of an appropriate service interface for the project, sensor, calibration facility and validation respectively. To test conformance, the relevant service interface documentation is verified against the service interface requirements specified in ISO 19159-1:2014.

Data conformance requires an adequate application class for the expression of information about the project, sensor, calibration facility, validation and documentation respectively. To test conformance, the application schema documentation is verified against the requirements specified in ISO 19159-1:2014.

Data and service interface requirements in ISO 19150-1:2014 are specified in a UML model and associated data dictionary. For example, data conformance for a project requires the application class with information about a project to make use of the three codelists illustrated in Figure 10.3, i.e. CA_CalibrationType, CA_TargetEnvironment and CA_IrradianceModel. Note that additional values may be added to a codelist for a specific implementation. As another example, service conformance of the project's service interface requires it to use the interfaces specified in the CA_CalibrationValidation, CA_PhotoFlight, CA_Radiation and CA_Target classes in Figure 10.3.

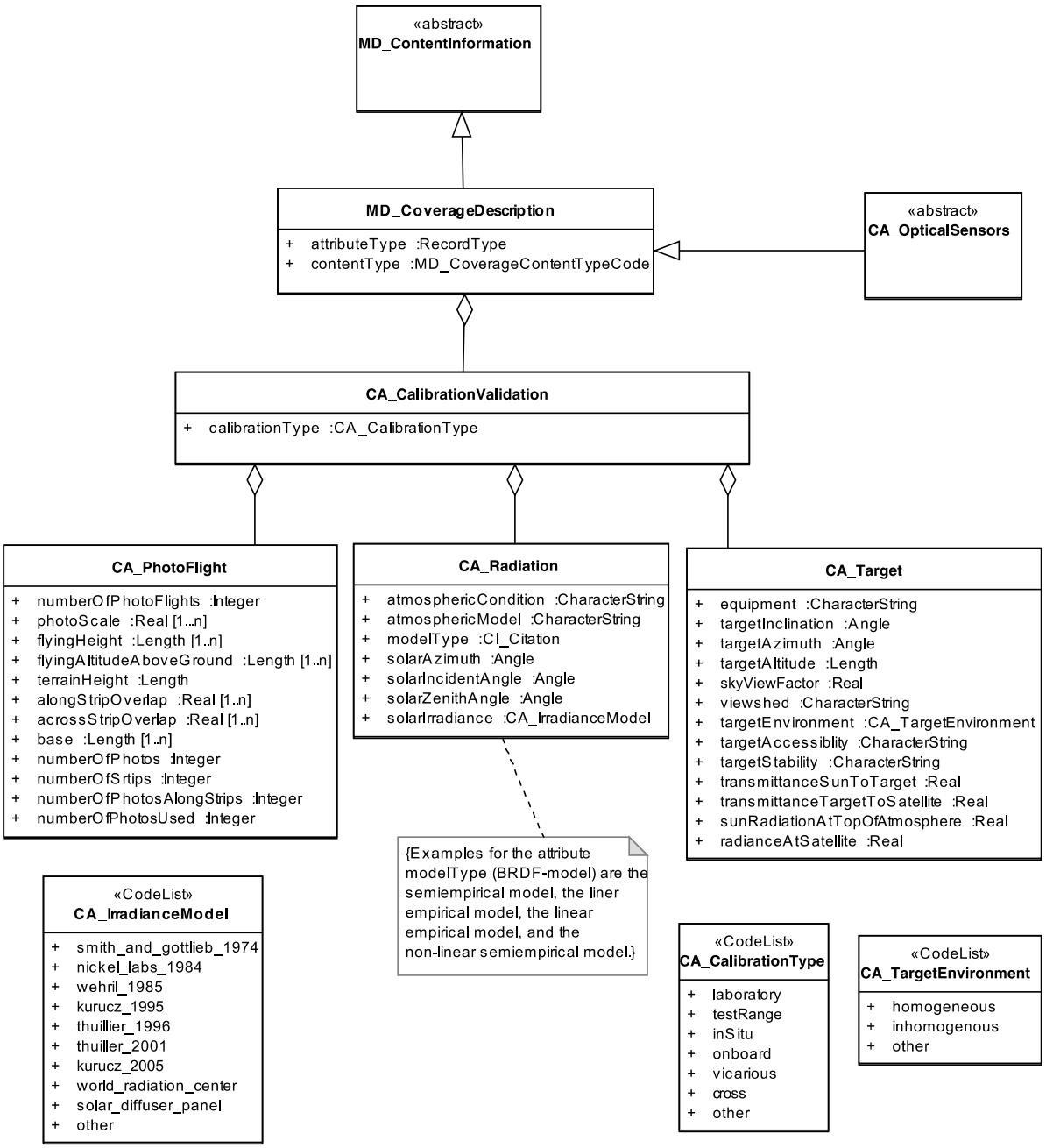

Figure 10.3 Classes with information about calibration and validation (Source ISO/TS 19159-1:2014)

10.7.6 Operational procedures for the organisation and management of S-100 geospatial information registry (S-99)

Table 10.31 Overview of S-99

Full name	S-99, Operational procedures for the organisation and management of S-100 geospatial information registry
Version	Edition 1.1.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English
Online overview	http://iho.int/iho_pubs/standard/S-99/Draft_S-99_Ed1.1.0_Nov12_EN.pdf

Type of standard	IHO International Standard Application level
Related standard(s)	ISO 19135:2005, Geographic information -- Procedures for item registration S-100 IHO Universal Hydrographic Data Model
Application	S-99 defines the roles, responsibilities and procedures for operating and managing the S-100 Geospatial Information Registry and its component registers.
Conformance classes	None specified

Scope

In January 2010 the IHO adopted S-100, a framework geo-spatial standard for hydrographical and related data. S-100 is aligned with the ISO 19100 series of geographic standards – thereby making the use of hydrographical and other geographic data more interoperable than previously using the IHO S-57 data transfer standard. S-100 is underpinned by a Registry and component Registers based on ISO 19135 - Procedures for registration of items of geographic information. IHO owns and manages the Registry. This document describes the roles, responsibilities and procedures for operating and managing the S-100 Geospatial Information Registry and its component Registers.

As a result of the practical use of the S-100 Registry by the Registry Manager and other organisations outside the IHO that are using S-100, a number of revisions have been introduced in edition 1.1.0. These revisions concern conceptual rather than substantive changes to the notion of domains and the previous theoretical subdivision of the Registry into main and supplementary registers. The time limit on consideration of proposals has also been extended from 30 days to 60 days in order to allow stakeholders, as represented by the Domain Control Bodies, more time for consideration.

Implementation benefits

S-99 clears up the roles and responsibilities for registers and registries within IHO. This ensures that the process is transparent to avoid mistakes and disagreements, and confirms that the responsibilities are clear to the tasked individual.

Implementation guidelines

Roles and responsibilities for management of the registry and registers are addressed. IHO is the owner of the registry and all registers in the S-100 Geospatial Information Registry. A registry manager shall be appointed to perform the day-to-day operations, maintenance and backup of the database. The registry manager shall ensure that for each register being managed 1) all aspects of the registration process are handled in accordance with good business practices; 2) the content of the register is accurate; and 3) only authorised persons can make changes to the content of the register.

A Domain Control Body (DCB) shall be appointed and be responsible for acting as the spokesperson for their domain, gather opinions on any new proposals, and forward a decision to the register manager within a given time frame. An Executive Control Body (ECB) shall consist of representatives of each of the domains. The ECB shall monitor and advise the register manager(s) and act as the arbiters for any decisions or disputes. Criteria for the eligibility of members to the bodies are provided in S-99.

Proposals for new register items, clarification of existing register items, and suppression or retirement of register items can be submitted by organisations through a register web interface. The proposals will be evaluated and either be accepted, rejected or sent back to the submitting organisation for changes. Appeals are allowed.

10.8 Data models for fundamental geo-spatial datasets

10.8.1 Spatial referencing by geographic identifiers (ISO 19112:2003)

Table 10.32 Overview of ISO 19112:2003

Full name	ISO 19112:2003, Geographic information – Spatial referencing by geographic identifiers
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19112:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19111:2007, Geographic information – Spatial referencing by coordinates ISO 19115:2003, Geographic information – Metadata
Application	A spatial reference system is a system for identifying position in the real world. There are two ways of identifying positions: using coordinates or using geographic identifiers. In a spatial reference system using geographic identifiers, positions are identified by a label or code that identifies a location. The standard can be applied in two ways: firstly, to describe a spatial reference system using geographic identifiers, and secondly, to describe a directory of geographic identifiers, known as a gazetteer.
Conformance classes	Spatial reference system Gazetteer
Fundamental geo-spatial dataset	Category: *Administration and spatial organisation* Data Theme: *Geographic names*

Scope

ISO 19112:2003 defines the conceptual schema for spatial references based on geographic identifiers. It establishes a general model for spatial referencing using geographic identifiers, defines the components of a spatial reference system and defines the essential components of a gazetteer.

Spatial referencing by coordinates is addressed in ISO 19111. However, a mechanism for recording complementary coordinate references is included.

ISO 19112:2003 enables producers of data to define spatial reference systems using geographic identifiers and assists users in understanding the spatial references used in datasets. It enables gazetteers to be constructed in a consistent manner and supports the development of other standards in the field of geographic information.

ISO 19112:2003 is applicable to digital geographic data, and its principles may be extended to other forms of geographic data such as maps, charts and textual documents.

Implementation benefits

Spatial reference systems assist users in understanding the spatial references used in geographic datasets, maps, charts or textual documents. Conforming to ISO 19112:2003 ensures that gazetteers and their location instances are well defined. This facilitates interoperability and exchange of gazetteers. For example, a gazetteer can be used in more than one software product or different gazetteers can be used in the same software. Well-defined gazetteers also support the maintenance (e.g. through versioning) of location instances.

Implementation guidelines

A spatial reference identifies the position of a feature in the real world. The position can be identified either explicitly by using coordinates, or indirectly by using a geographic identifier, i.e. a label or code that uniquely identifies a location on, below or above the earth's surface. In ISO 19112:3003 the location identified by the geographic identifier is regarded as a (feature and) reference for other features.

A spatial reference system using geographic identifiers is comprised of a set of one or more location types, together with their corresponding geographic identifiers. These location types may be related to each other through aggregation or disaggregation, possibly forming a hierarchy. Refer to Table 10.33 for examples of spatial reference systems.

Table 10.33 Examples of spatial reference systems by identifier

Spatial reference system	Location types	Geographic identifiers
Municipalities of South Africa	Province	Province name
	District municipality	District municipality name or identifier
	Metropolitan municipality	Metropolitan municipality name or identifier
	Municipality	Municipality name or identifier
Human settlements in a region	Municipality	Municipality name or identifier
	Village	Village name
Road names	Suburb	Suburb name
	Road	Road name or identifier

A gazetteer is a directory of geographic identifiers for location instances. A location instance is an instance of a specific location type. For example, 'South Africa' is a location instance of the 'country' location type. The gazetteer may include information about the position of each location instance, such as, a coordinate reference or any other descriptive information about the location instance. More than one gazetteer could exist for a location type. For example, for the 'Village' location type Table 10.33, there could be gazetteers for different time periods.

A spatial reference system by identifier conforming to ISO 19112:2003 meets the following requirements (see examples in Table 10.34):

1. The spatial reference system comprises of a set of one or more ISO 19112:2003 conformant location types with a common theme.
2. The spatial reference system is described by at least the following four attributes:
    - name, which serves as identifier;

- theme, which characterises the spatial reference system;
- overall owner, i.e. the authority with overall responsibility for the spatial reference system; and
- domain of validity, i.e. the geographic area within which the reference system occurs.

3. The spatial reference system is versioned as follows:
   - The version information is included in the name attribute.
   - A new version is created whenever a location type is added, removed or replaced by a new version of a location type.

Table 10.34 Example: Descriptions of spatial reference systems by identifier conforming to ISO 19112:2003

Name	Theme	Overall owner	Domain of validity	Location types
Census 2001 geographic area hierarchy structure	Census	StatsSA	South Africa	Province Municipality Main place Sub place Enumeration area
Villages in the Karoo after 1994	Population	Department of Human Settlements	Karoo	Municipality Village
Boreholes in the Kalahari V1.0	Hydrography	Department of Water Affairs	Kalahari desert within Botswana's borders	Water management area Borehole

A location type in a spatial reference system conforms to ISO 19112:2003 if it meets the following requirements (see examples in Table 10.35):

1. The location type is described by at least the following six attributes:
   - name;
   - theme, e.g. 'administration', 'electoral', 'postal';
   - identification, i.e. the method of uniquely identifying location instances;
   - definition, i.e. the way in which location instances are defined;
   - territory of use, i.e. the geographic area within which the location type occurs; and
   - owner, i.e. the name of an organisation or class of organisations with the ability to create and destroy location instances.
2. The location type is versioned; a new version is created whenever one of its attributes is modified. While ISO 19112:2003 does not specify this, it is practical to include version information in the name of the location type.
3. The location type is uniquely identified by means of one or more geographic identifiers.
4. There is at least one gazetteer of location instances for the location type.
5. The location type may be related to parent and child location types, possibly forming a hierarchy.

Table 10.35 Example: Descriptions of location types conforming to ISO 19112:2003

Name	Theme	Identification	Definition	Territory of use	Owner
Municipality	Administrative boundaries	Name assigned by the Municipal Demarcation Board	Municipal boundary demarcated by the Municipal Demarcation Board	South Africa	Municipal Demarcation Board
Village	Settlement patterns	Name used by the village population	A cluster of twenty or more dwellings	Karoo	Department of Human Settlements
Water management area	Water resource management	Alphanumeric identifier assigned by the Department of Water Affairs	Administrative boundary for the management of water resources	Botswana	Department of Water Affairs
Borehole	Water resources	Alphanumeric identifier, which is a combination of the land parcel identifier and a sequence number starting with 1 for each land parcel	A narrow shaft bored into the ground for the extraction of water	Kalahari desert within Botswana's borders	Department of Water Affairs

A gazetteer conforming to ISO 19112:2003 meets the following requirements (see examples in Table 10.36):

1. The gazetteer is described by at least the following four attributes:
   - identifier;
   - territory of use, i.e. the geographic domain covered by the gazetteer;
   - custodian, i.e. the organisation responsible for maintenance of the gazetteer; and
   - the location types for which instances are recorded in the gazetteer.
2. Optionally, the gazetteer may also be described by the following two attributes:
   - scope, i.e. description of the location types in the gazetteer; and
   - coordinate reference system, i.e. name of the coordinate reference system used to describe positions of location instances in the gazetteer.
3. The gazetteer is versioned; a new version is created whenever any location instance is added, removed or replaced with a new version of a location instance. The version information is included in the name attribute.
4. All location instances are recorded in the gazetteer and location instances conform to ISO 19113:2003.

Table 10.36 Example: Gazetteer descriptions conforming to ISO 19112:2003

Name	Census 2001 geographic area hierarchy v2000-03	Karoo villages v2004	Karoo villages v2006
Territory of use	South Africa	Northern Cape province	Northern Cape province
Custodian	StatsSA	Northern Cape Premier's Office	Northern Cape Premier's Office
Scope	Hierarchical structure of geographic areas used for the Census	Villages	Villages

Coordinate reference system	WGS 84 (EPSG::4326)	WGS 84 (EPSG::4326)	WGS 84 (EPSG::4326)

A location instance in a gazetteer conforms to ISO 19112:2003 if it meets the following requirements (see examples Table 10.37):

1. The location instance is associated with a location type.
2. The location instance is described by at least the following three attributes:
   - geographic identifier, i.e. the unique identifier for the location instance;
   - geographic extent, i.e. description of the location instance itself; and
   - administrator, i.e. the organisation responsible for defining the characteristics of the location instance.
3. Optionally, the location instance may also be described by the following three attributes:
   - temporal extent, i.e. the date on which this location instance was created in the gazetteer;
   - alternative geographic identifier (for the same location instance);
   - position, i.e. coordinates of a representative point of the location instance (e.g. centroid of an administrative area). Note that positions shall be recorded if the geographic identified contains insufficient information to identify the location.
4. The location instance is versioned; a new version of a location instance is created whenever any of its attributes is modified, for example, when the boundary of a municipality changes during a demarcation process. The version information is recorded in the temporal extent attribute.
5. The location instance may be related to parent and child location instances.

Table 10.37 Example: Location instances of the 'Karoo villages v2004' gazetteer conforming to ISO 19112:2003

Location type	Municipality	Village	Village
Geographic identifier	Hantam	Buitepos	Bergsig
Geographic extent	<polygon boundary>	<polygon boundary>	<polygon boundary>
Administrator	Municipal Demarcation Board	Department of Human Settlements	Department of Human Settlements
Temporal extent	20010628	20040228	20040301
Alternative geographic identifier	Hantam Local Municipality (NC 065)	-	Mountain view
Position	<coordinates>	<coordinates>	<coordinates>
Parent location instance	-	Hantam	Hantam
Child location instances	Buitepos	-	-
	Bergsig	-	-

Figure 10.4 shows a UML diagram for the representation of spatial reference systems and gazetteers conforming to ISO 19112:2003.

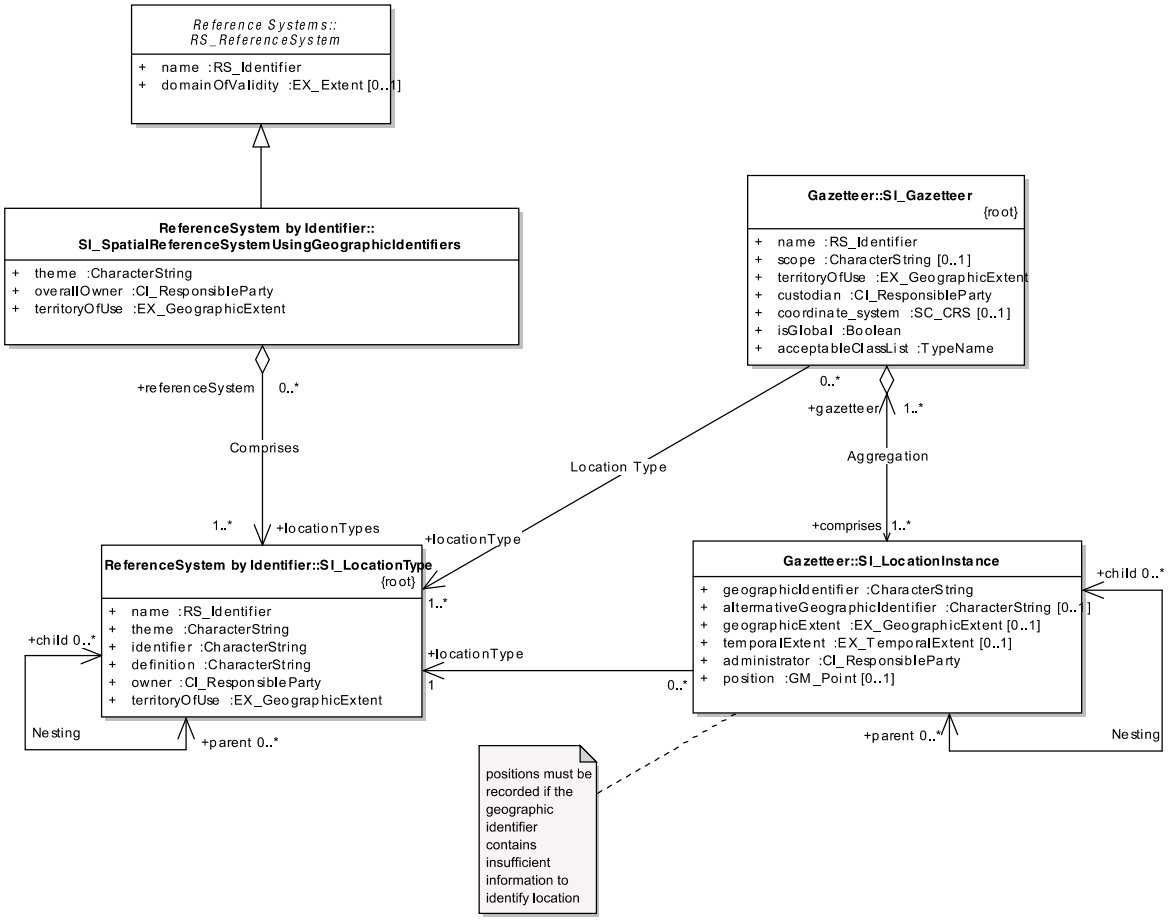

Figure 10.4 UML representation of spatial reference systems and gazetteers (Source ISO 19112:2003)

10.8.2 Schema for coverage geometry and functions (ISO 19123:2005)

Table 10.38 Overview of ISO 19123:2005

Full name	ISO 19123:2005, Geographic information – Schema for coverage geometry and functions
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19123:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19110 ISO 19111:2003, Geographic information – Spatial referencing by coordinates ISO 19115:2003, Geographic information – Metadata ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data ISO 19118:2011, Geographic information – Encoding ISO/TR 19121:2000, Geographic information – Imagery and gridded data ISO 19129:2009, Geographic information – Imagery, gridded and coverage data framework

Application	This standard 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.
Conformance classes	Simple coverage interface Discrete coverage interface Thiessen polygon coverage interface Quadrilateral grid coverage interface Hexagonal grid coverage interface TIN coverage interface Segmented curve coverage interface Discrete coverage interchange Thiessen polygon coverage interchange Quadrilateral grid coverage interchange Hexagonal grid coverage interchange TIN coverage interchange Segmented curve coverage interchange
Fundamental geo-spatial dataset	Category: *Base geography* Data Theme: *Rectified imagery*

Scope

ISO 19123:2005 defines a conceptual schema for the spatial characteristics of coverages. Coverages support mapping from a spatial, temporal or spatiotemporal domain to feature attribute values where feature attribute types are common to all geographic positions within the domain. A coverage domain consists of a collection of direct positions in a coordinate space that may be defined in terms of up to three spatial dimensions as well as a temporal dimension. Examples of coverages include rasters, triangulated irregular networks, point coverages and polygon coverages. Coverages are the prevailing data structures in a number of application areas, such as remote sensing, meteorology and mapping of bathymetry, elevation, soil and vegetation. This International Standard defines the relationship between the domain of a coverage and an associated attribute range. The characteristics of the spatial domain are defined whereas the characteristics of the attribute range are not part of this standard.

Implementation benefits

ISO 19123:2005 provides a comprehensive explanation of coverages and on that basis alone is an excellent reference work for anyone dealing with imagery, gridded, raster or any other type of coverage data. Formally, a **coverage** is a "*feature that acts as a function to return values from its range for any direct position within its spatial, temporal or spatiotemporal domain*". In practice, this means that a coverage includes all the different types of imagery, gridded and raster data. This is because all these types of data have some or all of their **non-spatial attributes** being associated with their **spatial attributes** (i.e. with positions in the coverage), depending on the coverage's function or rules. A coverage could have a regular or irregular distribution of non-spatial attribute values.

The key difference between all these types of coverage data and a vector-type feature is that with a vector-type feature, the spatial and non-spatial attributes are independent of one another. For example, while a non-spatial attribute (say, its official name) might be homogenous for the whole of a vector-type feature, a non-spatial attribute of a coverage (say, the strength of reflectance in a particular radiometric frequency band) might vary throughout the feature, depending on where it is in

the feature. In other words, each pixel (or grid cell or point) in the coverage has both a position and a set of one or more values. Depending on the nature of the coverage, the position of each point is given explicitly (as for a triangulated irregular network), or determined as an offset from the origin of the coverage (as for a regular grid). Similarly, the boundary of the coverage might be its convex hull or might be specified by a clip area.

ISO 19129:2009, Geographic information – Imagery, gridded and coverage data framework, (see Table 10.39) draws heavily on ISO 19123:2005, with the key difference being that ISO 19129:2009 provides a framework for understanding the various formats for encoding coverages and template application schemas for different types of imagery and gridded data.

Implementation guidelines

ISO 19123:2005 is not implemented directly: rather, it is implemented through other standards, such as ISO 19129:2009 (see Table 10.39), or in application schemas. The primary purpose of ISO 19123:2005 is to define the conceptual schema for the spatial characteristics of the different types of coverage data. The standard also describes the domain of a coverage (the direct positions or locations in the coverage), the range of a coverage (the attribute values), interpolation methods and sequential enumeration for various types of coverages. There are two main types of coverage:

- **Discrete**: typically this is a set of polygons with the attributes of each polygon relating to every point within that polygon. Note that the polygons could overlap one another and/or there could be gaps between polygons. A discrete coverage could actually consist of any finite set of geometric objects. A typical example is a classified, geocoded satellite image. The five types of discrete coverage described in ISO 19123:2005 are:
    - **Discrete point coverage**: typically a set of irregularly distributed points used for creating continuous coverage functions, such as the points in a TIN.
    - **Discrete grid coverage**: A finite set of points in a grid.
    - **Discrete curve coverage**: A finite set of curves or lines that are typically elements in a network. Essentially, this is a raster representation of a network.
    - **Discrete surface coverage**: A finite set of surfaces that are typically mutually exclusive and that partition the extent of the coverage exhaustively, that is, they provide continuous coverage but do not overlap one another. A special case of a discrete surface coverage is a typical polygon coverage, which is where the surfaces are flat and parallel with the surface of the Earth.
    - **Discrete solid coverage**: A finite set of solids. An example would be flight paths, air corridors, and other uncontrolled, controlled, restricted and prohibited air spaces modelled as three-dimensional objects (solids).
- **Continuous**: typically these are attribute values that vary across space, as is commonly found in an unclassified image. More formally, it is a coverage containing a set of direct positions, each of which has its own attribute values. Another typical example of a continuous coverage is a dataset that has been interpolated from a set of measurements scattered throughout the area (e.g. kriging from borehole data) or that has been generated

by running models (e.g. weather forecasting). The six types of continuous coverage described in ISO 19123:2005 are described in detail in the standard, but briefly they are:

- **Thiessen polygon coverage:** all the points inside one Thiessen polygon (or Voronoi or Dirichlet polygon or tessellation) are closer to the centre (or seed or generator) of that polygon than to the centre of any other polygon. The boundaries between two neighbouring polygons are then the perpendicular bisector of the line joining their centres. However, it is also possible to have weighted Thiessen polygons, to use distances other than the direct, Euclidian distance between two centres, or to have fuzzy boundaries between polygons.
- **Quadrilateral grid coverage:** a regular tessellation on a square, rectangular, parallelogram or parallelepiped grid. An example of a parallelogram coverage would be an uncorrected image from a push-broom type satellite-based sensor, with each row being offset due to the rotational geometry of the satellite.
- **Hexagonal grid coverage:** a regular tessellation on a hexagonal grid. It can be converted easily into a parallelogram grid.
- **Triangulated irregular network (TIN) coverage:** the structure of the TIN is determined by GM_TIN, which is defined in ISO 19107:2003, Geographic information – Spatial schema. Specifically, GM_TIN specifies the stop lines (questionable local continuity, which a triangle side shall not cross), break lines (local ridges or depressions that shall become triangle sides), maximum length of a triangle side, and the control points (posts or triangle corners).
- **Segmented curve coverage:** lines or curves (typically in a network) along which attribute values vary continuously or discontinuously. An example with a continuously varying attribute would be traffic volume on a road network, while an example of a discontinuously varying attribute would be the posted speed limit on a road network.

As can be gathered, some vector datasets could be represented directly as coverages, for example, representing buildings as a discrete solid coverage or a road network as a discrete curve coverage. Further, some datasets could be represented as a discrete coverage or as a continuous coverage generated from the discrete coverage.

Each coverage has the attributes domainExtent (its extent in space, time or space-time), rangeType (attributes and their data types) and commonPointRule (the method for determining the attribute value along a polygon boundary or between grid points). Each coverage has five operations that specify how to list, select, find, evaluate and evaluate inverse (determine the locations where an attribute value occurs) the attributes of the coverage.

Annex B describes the UML notation used in the ISO/TC 211 standards. Initially, such an annex was common in the ISO/TC 211 standards, but it is now omitted because ISO 19103:2005 (see Table 10.7) describes the conceptual schema language used in the standards. These annexes make the standards more expensive (price is determined by the number of pages). Annex C describes nine

types of interpolation methods, three for segmented curve coverages, namely linear interpolation, quadratic interpolation and cubic interpolation; three for quadrilateral grid coverages, namely bilinear interpolation, biquadratic interpolation and bicubic interpolation; one for Thiessen polygon and hexagonal grid coverages, namely lost area interpolation; one for TIN coverages, namely barycentric interpolation; and one for all types of coverages, namely nearest neighbour interpolation. Annex D describes six types of sequential enumeration: linear scanning, boustrophedonic scanning, Cantor-diagonal (or zigzag) scanning, spiral scanning, Morton order, Hilbert order and interleaving of feature attribute values.

10.8.3 Imagery, gridded and coverage data framework (ISO/TS 19129:2009)

Table 10.39 Overview of ISO/TS 19129:2009

Full name	ISO/TS 19129:2009, Geographic information – Imagery, gridded and coverage data framework
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19129:ed-1:v1:en
Type of standard	ISO Technical Specification Meta-meta level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19115:2003, Geographic information – Metadata ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data ISO 19118:2011, Geographic information – Encoding ISO/TR 19121:2000, Geographic information – Imagery and gridded data ISO 19123:2005, Geographic information – Schema for coverage geometry and functions
Application	This standard provides a framework for applications dealing with imagery, gridded, coverage and/or 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.
Conformance classes	Continuous Quadrilateral Grid Coverage Riemann Hyperspatial Multi-Dimensional Grid Coverage Triangular Irregular Network Coverage Discrete Point Coverage Discrete Grid Coverage
Fundamental geo-spatial dataset	Category: *Base geography* Data Theme: *Rectified imagery*

Scope

ISO 19129:2009 defines the framework for imagery, gridded and coverage data. This framework defines a content model for the content type imagery and for other specific content types that can be represented as coverage data. These content models are represented as a set of generic UML patterns for application schemas.

Implementation benefits

There are many different ways to encode imagery, gridded and coverage data because of structural complexities (e.g. square grids, hexagonal grids, quad trees, TINs or Thiessen polygons), traversal methods for sequencing grid cells (e.g. linear, Morton, spiral or Hilbert), distributing attributes over a space, interpolation, break lines, sensor information, geo-referencing, look-up tables, metadata, compaction and compression. There is also different and even contradicting terminology between specifications, such as the terms 'imagery', 'raster' or 'matrix'. The result is the legacy problem of needing to deal with many old, but still very relevant, datasets in different formats.

ISO/TS 19129:2009 does not attempt to provide a new, universal format to replace the existing ones. Rather, it provides a framework for understanding the critical aspects of these formats and how imagery, gridded and coverage data fit into the general feature model used in the ISO 191xx series of standards. Further, ISO/TS 19129:2009 provides template application schemas for different types of imagery and gridded data.

Implementation guidelines

A **feature** is the fundamental unit of geospatial data and is defined as an "abstraction of real world phenomena", that is, something in a database representing some identifiable thing in the real world (or the imaginary world: as planned, as envisioned, as speculated, as simulated, as fancied, etc.). Traditionally, the concept of a feature might have been applied only to vector data, where a feature had spatial attributes (geometry, possibly with multiple representations), non-spatial attributes (including multimedia), a classification or feature type, topological relationships to other features (intersection, containment, adjacency, etc.), logical relationships to other features (compound features and associations), symbology (suitable graphic representations of the feature) and metadata.

However, these can all apply to a **coverage**, a "feature that acts as a function to return values from its range for any direct position within its spatial, temporal or spatiotemporal domain". The key difference is that in a vector-type feature, the spatial and non-spatial attributes are independent of one another, while in a coverage, some of its non-spatial attributes are associated with its spatial attributes (i.e. with positions in the coverage), depending on the coverage's function or rules. For example, while a non-spatial attribute (say, its official name) might be homogenous for the whole of a vector-type feature, a non-spatial attribute of a coverage (say, the strength of reflectance in a particular radiometric frequency band) might vary throughout the feature, depending on where it is in the feature.

A coverage could be a raster image, polygon overlay, digital elevation model, Delaunay triangulation, triangulated irregular network, or Lidar point set or cloud, for example. The real benefits of considering both vector-type data and coverages as features is that it facilitates mixing them together in the same datasets, models and databases, and allows for a single application schema.

For the user wanting to understand better the nature of imagery, gridded and coverage data and the formats used for such data, Clauses 5 to 8 inclusive of ISO/TS 19129:2009, and ISO 19123 (see above), will be most useful. They provide details of:

- The value of **separating carrier and content**, as many imagery and gridded data transfer formats 'hardwire' the encoding format into the data model, such as the encoding format

determining the bit lengths of numbers, which means that the transfer format cannot be used for imagery with a higher spectral resolution.

- The **content model** is the 'information view' of an application schema, that is, it describes the semantics of the data, independently of the transfer format or how the data are portrayed. It includes the definitions, types and valid domains of the attribute values (or the coverage function), spatial referencing information, metadata and quality information.
- An explanation of how **coverages are features**, which is outlined above.
- Spatial referencing of imagery, gridded and coverage data are handled differently, depending on the nature of the data. For example, a grid can be referenced as a whole, given the location of its origin, the spacing of cells in the grid, and the orientation of the grid. On the other hand, in a point dataset (such as a Lidar point cloud), each point has its own direct position.

In addition, Clause 7 of ISO/TS 19129:2009 provides the framework for imagery, gridded and coverage data, that is, how they fit in the general feature model. It caters for five patterns or types of coverage, for which template application schemas are provided in Section 10:

- Continuous quadrilateral grid coverage, such as a typical satellite image;
- Quadtree grid coverage (Riemann hyperspatial multidimensional grid coverage), such as a large set of classified satellite imagery that benefits from the compression of quadtrees, because of adjacent cells with the same value;
- TIN coverage, a unique set of non-overlapping triangles, often used for elevation data;
- Discrete point coverage, such as a Lidar point cloud;
- Discrete surface grid coverage, with mutually exclusive polygons that provide continuous coverage, often with irregular boundaries, such as a classified satellite image.

Section 7 includes the diagram in Figure 10.5 to show the packages from the ISO 191xx suite of standards that are applicable to imagery, gridded and coverage data.

Imagery, gridded and coverage data can be described at an abstract level (see ISO 19123), a content model level (application schema, type of coverage, spatial referencing, portrayal and metadata) and an encoding level (such as XML, BIIF or JPEG2000). Data compaction is part of the content model level while data compression is part of the encoding level.

Clause 9 of ISO/TS 19129:2009 then provides the formal components of the imagery, gridded and coverage data structure, which in Clause 10, are assembled into template application schemas for different types of imagery, gridded and coverage data. The components are:

- IF_DataSet, the logical entity, defined by a data product specification (see the section on ISO 19131) and which can be all or part of a collection and can have one or more tiles;
- IF_Transmittal, the entity used for the transfer of the IF_DataSet, including encoding and physical medium;

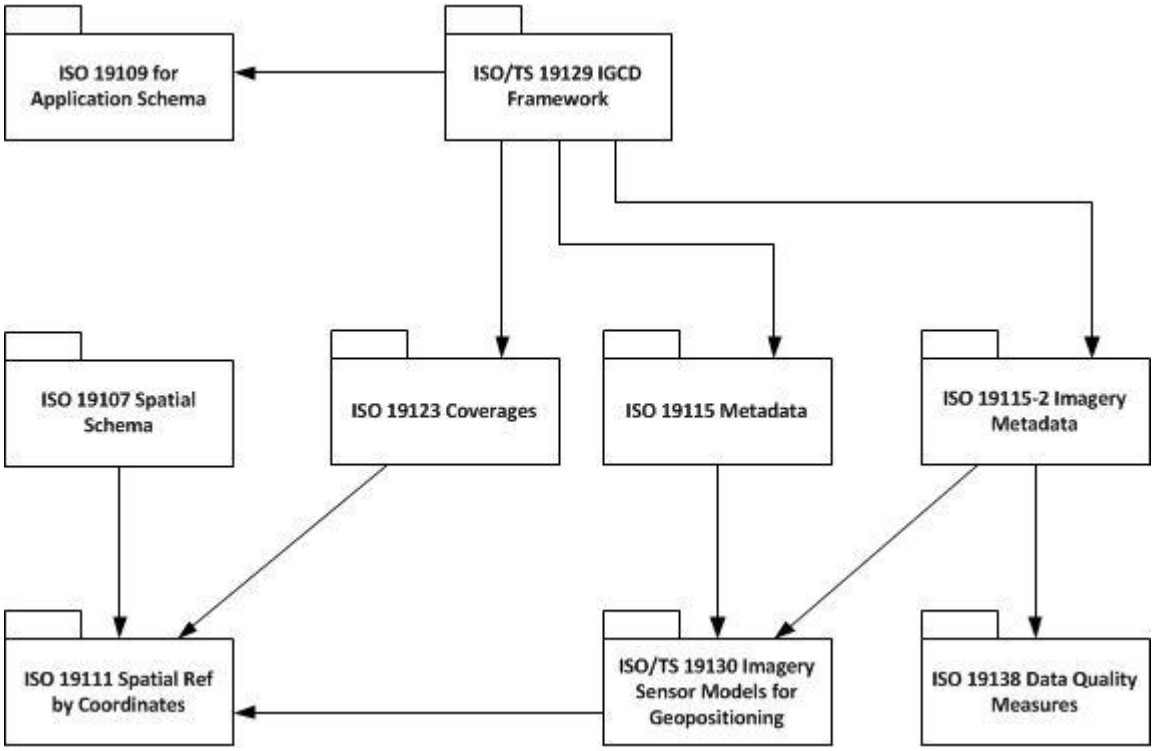

Figure 10.5 Packages applicable to imagery gridded and coverage data (Source ISO/TS 19129:2009)

- IF_DiscoveryMetadata, the core metadata defined in ISO 19115;
- IF_Collection, a set of IF_CoverageData (IF_GridCoverage, IF_TINCoverage, IF_PointSetCoverage and/or IF_DiscreteSurfaceCoverage) and IF_CollectionMetadata;
- IF_CollectionMetadata, the metadata for the IF_Collection as a whole, including the IF_DiscoveryMetadata, IF_StructuralMetadata, IF_AcquisitionMetadata and IF_QualityMetadata;
- IF_StructuralMetadata, the structure of the collection, which is optional, including grid sizes and tiling;
- IF_AcquisitionMetadata, the source(s) of the data, essentially the lineage of the collection, which is optional;
- IF_QualityMetadata, the quality of the data in terms of ISO 19157 or its predecessors, which is also optional;
- IF_GridCoverage (either an IF_QuadGriddedData or an IF_RiemannGridded Data type of grid), IF_TINCoverage, IF_PointSetCoverage and/or IF_DiscreteSurfaceCoverage, which contain the actual data;
- IF_Tiling, which describes the tiling scheme used, outlined briefly in Clause 11 of ISO 19129:2009.

The five templates in Section 10 are all structured similarly and are straightforward to interpret, if one understands the different types of imagery, gridded and coverage data. They cater for aspects

such as interpolation method, sequence type, scan direction, dimensions, axes, break lines (for TINs), domains and ranges.

Annexes B and C are very brief and describe use cases and portrayal.

10.8.4 Imagery sensor models for geopositioning (ISO/TS 19130:2010)

Table 10.40 Overview of ISO/TS 19130:2010

Full name	ISO/TS 19130:2010, Geographic information – Imagery sensor models for geopositioning
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not available yet
Type of standard	ISO Technical Specification Meta level
Related standard(s)	ISO 19115:2003, Geographic information – Metadata ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data ISO 19123:2005, Geographic information – Schema for coverage geometry and functions ISO/TS 19138:2006, Geographic information – Data quality measures, which has been replaced by ISO/TC 19158:2012, Geographic information – Quality assurance of data supply
Application	The technical specification defines sensor models and geopositioning metadata to support interoperability of imaging data between applications and to facilitate exchange of imaging data.
Conformance classes	Correspondence Model Physical Model – Synthetic Aperture Radar Physical Model – Electro-optical True Replacement Model Ground Control Point collection
Fundamental geo-spatial dataset	Category: *Base geography* Data Theme: *Rectified imagery*

Scope

ISO/TS 19130:2010 identifies the information required to determine the relationship between the position of a remotely sensed pixel in image coordinates and its geoposition. It supports exploitation of remotely sensed images. It defines the metadata to be distributed with the image to enable user determination of geographic position from the observations.

ISO/TS 19130:2010 specifies several ways in which information in support of geopositioning may be provided.

1. It may be provided as a sensor description with the associated physical and geometric information necessary to rigorously construct a Physical Sensor Model. For the case where precise geoposition information is needed, ISO/TS 19130:2010 identifies the mathematical formulae for rigorously constructing Physical Sensor Models that relate two-dimensional image space to three-dimensional ground space and the calculation of the associated propagated errors. ISO/TS 19130:2010 provides detailed information for three types of passive electro-optical/infrared (IR) sensors (frame, pushbroom and whiskbroom) and for an

active microwave sensing system [Synthetic Aperture Radar (SAR)]. It provides a framework by which these sensor models can be extended to other sensor types.

2. It may be provided as a True Replacement Model, using functions whose coefficients are based on a Physical Sensor Model so that they provide information for precise geopositioning, including the calculation of errors, as precisely as the Physical Sensor Model they replace.

3. It may be provided as a Correspondence Model that provides a functional fitting based on observed relationships between the geopositions of a set of ground control points and their image coordinates.

4. It may be provided as a set of ground control points that can be used to develop a Correspondence Model or to refine a Physical Sensor Model or True Replacement Model.

ISO/TS 19130:2010 does not specify either how users derive geoposition data or the format or content of the data the users generate.

Implementation benefits

Vast amounts of remotely sensed imaging data are collected through a variety of sensors. In order to use this data in geo-spatial applications it needs to be geopositioned, i.e. image coordinates have to be converted to coordinates relative to the Earth. Due to the diversity in sensor types and the lack of a common sensor model, the metadata required for geopositioning differs from one imaging product to another.

ISO/TS 19130:2010 specifies standardized sensor models and geopositioning metadata to support interoperability of imaging data between applications and to facilitate exchange of imaging data. For example, the standard enables the development of software products for imaging data from multiple data producers and/or a variety of sensors.

Implementation guidelines

Image geopositioning refers to the process of determining the coordinates of a feature relative to the Earth from image coordinates. ISO/TS 19130:2010 specifies the geopositioning information required for three approaches to geopositioning:

1. Physical Sensor Models employ a mathematical representation of the physics and geometry of the image sensing system to determine the Earth coordinates. Firstly, a sensor model for the type of sensor under consideration is constructed mathematically. Secondly, information to relate the sensing event to the ground coordinate reference system is needed to apply the model to a given image. This information can be in one of two forms: 1) accurate data about the position, attitude, and dynamics of the sensor during imaging; or 2) ground control information such as a set of Global Navigation Satellite System (GNSS)-determined ground control points (GCPs).

2. In True Replacement Models the equations to describe the sensor and its relationship to the Earth coordinate reference system are replaced with a set of equations that directly describe the relationship between the image coordinates and the Earth coordinates.

3. In Correspondence Models a set of ground control points (Earth coordinates) and their corresponding image coordinates are identified and used to derive the Earth coordinates of other image coordinates. Correspondence Models are widely used but less rigorous than the other two models.

Geolocating refers to the geopositioning of an object using a Physical Sensor Model or a True Replacement Model. Georeferencing refers to geopositioning through correspondence modelling.

ISO/TS 19130:2010 specifies a conformance class for each method of providing geopositioning information. The requirements for each class are indicated in Table 10.41. Conditional requirements are indicated with a 'C'. For example, the geopositioning metadata for an image conforms to the Correspondence Model if the metadata meets the requirements specified in ISO/TS 19130:2010 for geopositioning information, GCP collection, GCP repository, functional fitting and the Correspondence Model. An overview of the geopositioning metadata requirements is provided in the remainder of this section. Refer to ISO/TS 19130:2010 for UML model diagrams and a data dictionary that describe these requirements in detail. The specification also includes extensive informative text to explain geopositioning and the three different approaches to geopositioning.

Table 10.41 Overview of conformance classes and requirements in ISO/TS 19130:2010

Requirement / **Conformance class**	Geopositioning information	GCPs		Physical Sensor Model					Functional fitting	True Replacement Model	Correspondence Model
		GCP collection	GCP repository	Sensor model completeness	Platform information	Sensor information	Optics	SAR			
Correspondence Model	X	X	X						X		X
Physical Sensor Model – SAR	X			X	X	X		X			
Physical Sensor Model – Electro-optical	X			X	X	X	X				
True Replacement Model	X								X	X	
GCP collection	X	X	X	C	C	C	C	C	C	C	C

Geopositioning information shall consist of sensor model information and a set ground control points, where applicable. Optionally, quality information may be provided together with the set of ground control points to allow the generation of a fitting function in the Correspondence Model.

A GCP collection consists of one or more GCPs and shall have an identifier, a name and an attribute to specify the coordinate reference system of its GCPs. A GCP shall have at least two horizontal coordinates (X, Y) and an optional vertical coordinate (Z). A GCP is specified either in correspondence to image coordinates or as a description that allows a user to identify the GCP in the image. It is possible to specify the GCP collection as a grid (as opposed to a one-dimensional list).

A GCP repository is a library of GCP collections, which may be used to lookup GCP information if such information is not provided with the image itself. Access to the repository may be restricted.

The Physical Sensor Model requirement specifies the content to be included in the description of a Physical Sensor Model, amongst others, internal sensor parameters (e.g. focal length, principal point offset, pixel size, distortion coefficients), external sensor/platform parameters (e.g. sensor location, sensor orientation, collection platform velocity), the ground-to-image function, the reverse image-to-ground function, error propagation and adjustable model parameters. Quality information for Physical Sensor Models shall be provided using the appropriate quality measures specified in ISO/TS 19138:2006 (replaced by ISO 19158:2012).

The functional fitting requirement describes the information to be provided if a functional fit between image and geographic coordinates is used to geoposition the image. The function may be based on a Physical Sensor Model, as in the case of a True Replacement Model, or it may be a simple Correspondence Model based upon ground control points. The function may be a single polynomial applicable to the entire image or it may be a set of polynomials, each applicable to a separate partition. The fit may also be derived by interpolating between points in a grid where both the grid and geographic coordinates are known. A function produced by interpolation cannot be expressed in a simple analytic form over the entire image; its first derivative is discontinuous at grid cell boundaries.

The True Replacement Model requirement specifies the content to be included in the description of a True Replacement Model, amongst others, the region of validity, accuracy, information about the fitting function and geolocation information.

The Correspondence Model requirement specifies the content to be included in the description of a Correspondence Model, amongst others, the GCP collection, the region of validity and information about the fitting function.

10.8.5 Classification systems – Part 2: Land cover meta language (ISO 19144-2:2012),

Table 10.42 Overview of ISO 19144-2:2012

Full name	ISO 19144-2:2012, Geographic information – Classification systems – Part 2: Land cover meta language
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19144-2:ed-1:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19109:2005, Geographic information – Rules for application schema ISO/TS 19103:2005, Geographic information – Conceptual schema language ISO 19144-1:2009 Geographic information – Classification systems – Part 1: Classification system structure ISO 19135:2005, Geographic information – Procedures for item registration
Application	For describing different land cover classification systems consistently according to physiognomy, so that they can be compared and data classified according to different land cover classification systems can be combined.

Conformance classes	Conformance of a land cover classification system Conformance of a register for the extension of the metalanguage Test case for uniqueness of registered metaclass names Test case for backward compatibility Conformance of a comparison process of two Land Cover Classification Systems
Fundamental geo-spatial dataset	Category: *Environmental information* Data Theme: *Natural environment (Land cover)*

Scope

This part of ISO 19144 specifies a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different land cover classification systems to be described based on the physiognomic aspects. This part of ISO 19144 also specifies the detailed structure of a register for the extension of LCML but does not specify the maintenance of the register. This International Standard recognizes that there exist a number of land cover classification systems. It provides a common reference structure for the comparison and integration of data for any generic land cover classification system, but does not intend to replace those classification systems.

Implementation benefits

There are many different land cover classification systems used around the world, which makes it very difficult to obtain land cover data at a global scale. This is particularly important for assessing environmental changes, such as fluctuations in the biomass in forests. A land cover metalanguage allows one to define the various land cover classification systems on a consistent basis, so that one can combine and compare data in the different classification systems.

ISO 19144-1:2009, Geographic information – Classification systems – Part 1: Classification system structure, specifies the structure for a classification system and the mechanism for defining and registering classifiers, with the result of applying a classification system to an area represented as a discrete coverage (i.e. continuous coverage by non-overlapping polygons). ISO 19144-2:2012 is then an implementation of ISO 19144-1:2009, for land cover. However, it does not specify a directly implementable classification system (or a legend or nomenclature), but rather a metalanguage for describing classification systems for land cover, based on the physiognomic aspects of the land cover. There are obviously other ways for determining land cover, such as the spectral radiation of the land cover.

Once the different land cover classification systems (such as CORINE, Anderson or Africover) have been described using LCML (which has already been done for some systems), one can immediately get a better understanding of them and their similarities and differences. This should enable one to combine data from the different land cover classification systems meaningfully – though unfortunately, it might show why it cannot be done. ISO 19144-2:2012 should also help those creating or selecting a new land cover classification system for an application to understand the implications of the options for their classification.

The development of ISO 19144-2:2012 was motivated by the Africover project of the Food and Agriculture Organization of the United Nations (FAO), which evolved into the FAO's Land Cover

Classification System (LCCS). Hence, the concepts of ISO 19144-2 should be familiar to many experts across Africa who are involved in land cover mapping and analysis.

Implementation guidelines

Firstly, ISO 19144-2:2012 should only be used by those with a good understanding of land cover and the principles of classifying on the basis of physiognomy. While Annex C of ISO 19144-2:2012 does contain extensive examples of types of land cover with illustrations, it is not a tutorial or textbook on land cover classification. The standard uses UML class diagrams extensively (as do most standards from ISO/TC 211), but these should be reasonably easy to understand with a crib sheet on UML conventions.

A class in any land cover classification system can be described by a set of independent elements from LCML, which together form a land cover metalanguage object. In ISO 19144-2:2012, the LCML elements are represented by the class LC_Element and its subtypes. The LCML elements are identified by their appearance or physiognomic aspect and layering or strata. Annex D provides an extensive glossary of land cover meta-elements that may be used to describe the classes in one's land cover classification system. However, one does not have to use this glossary, which is why the annex is informative and not normative. Clause 9 of ISO 19144-2:2012 explains how to extend the LCML, if required, and how to establish a registry, in conformance with ISO 19135:2005, *Geographic information – Procedures for item registration*.

LC_Element has two subtypes, LC_VegetationElement (for all surfaces covered by vegetation) and LC_AbioticElement (for all surfaces without vegetation, such as bare soil or artificial structures). The subtypes of LC_VegetationElement are:

- LC_GrowthForm: woody, herbaceous, lichen and moss, and floating and submerged algae; and
- LC_GrowthFormCharacteristic: floristic aspect (dominant or most frequent species), allometric measurement (trunk and crown diameters), growth form age, tree area management practices (evenly aged management, clearcutting, seed tree harvesting and unevenly aged management), grazing (intensity and animal type), mowing, vegetation artificiality (natural or semi-natural, vs. cultivated and managed vegetation), and as percentages of vegetation so affected, burnt status, dead status, water stress, vegetation damage (and the type of damage), and growth form illness (and the type of illness).

The subtypes of LC_AbioticElement are:

- LC_ArtificialSurfaceElement: built-up surfaces (linear, being road, railway and communications and other; and non-linear, being building, other construction and other artificial surface) and non-built-up surfaces (dump site and extraction), and for both, the artificial surface characteristics;
- LC_NaturalSurfaceElement: rocks (bare rocks and hard pan), and soils and deposits (coarse mineral fragments, bare soil, loose and shifting sand and deposits); and
- LC_WaterBodyAndAssociatedSurfaceElement: water body (flowing or standing), snow, ice (moving or standing) and permafrost, and for all four, whether above or below surface, the

water and associated surface characteristics and periodic variation (atmospheric, daily, tidal and seasonal, duration of persistence, and a description).

As can be expected, ISO 19144-2:2012 caters for more detailed subtypes of these elements and further characteristics of them, but it is beyond the scope of this document to describe them all. Characteristics that can refine all the elements are climate, landform, geographic aspects (beach, bay, estuary and shore), topographical aspects (altitude, slope and aspect), rock type, rock age, soil type, erosion type and sedimentation type. Some of the code lists provided in ISO 19144-2:2012 for the characteristics are empty, but the code lists can be expanded or populated through registration.

What makes LCML very powerful for describing land cover classification systems is that basic LCML elements can be combined into layers or strata in any combination required of vegetated and/or abiotic elements, with the proportions of the elements specified as percentages. Further, there is no limit to the number of strata (ordered, from the surface upwards), which caters for complex three-dimensional land cover classes.

10.8.6 Land Administration Domain Model (LADM) (ISO 19152:2012)

Table 10.43 Overview of ISO 19152:2012

Full name	ISO 19152:2012, Geographic information – Land Administration Domain Model (LADM)
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	Not available yet
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO/DIS 19160-1, Addressing – Part 1: Conceptual Model (under development) ISO 14825:2011, Intelligent transport systems — Geographic Data Files (GDF) — GDF5.0
Application	The land administration domain model provides a formal mechanism for describing land administration data, such as cadastral and deeds data. It is implemented by developing an application schema or profile of the LADM model. It provides an extensible basis for the development and refinement of efficient and effective land administration systems, based on a Model Driven Architecture (MDA), and enables involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary (that is, an ontology), implied by the model. The latter is required for the sharing and exchange of data.
Conformance classes	Party – Level 1, Level 2 and Level 3 Administrative – Level 1, Level 2 and Level 3 Spatial Unit – Level 1, Level 2 and Level 3 Surveying and Representation – Level 1, Level 2 and Level 3
Fundamental geo-spatial dataset	Category: *Administration and spatial organisation* Data Theme: *Land management units/areas*

Scope

ISO 19152:2012

- 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);
- provides an abstract, conceptual model with four packages related to parties (people and organisations); basic administrative units, rights, responsibilities, and restrictions (ownership rights); spatial units (parcels, and the legal space of buildings and utility networks); spatial sources (surveying), and spatial representations (geometry and topology);
- provides terminology for land administration, based on various national and international systems, that is as simple as possible in order to be useful in practice. The terminology allows a shared description of different formal or informal practices and procedures in various jurisdictions;
- provides a basis for national and regional profiles; and
- enables the combining of land administration information from different sources in a coherent manner.

Implementation benefits

Land administration systems have in common that they are concerned with the relationships between people and land, and the description of rights (e.g. ownership or use) over the land. Over the past decades there has been a consistent move to digital land administration systems and these systems are widely influenced by developments in information and communication technology (ICT). Two common functions of all land administration systems are to keep the contents of the relationships up-to-date and to provide information from the system.

ISO 19152:2012 facilitates the development of tools that are usable by any land administration system conforming to ISO 19152:2012; for example, software and utilities to capture and update land administration information and web services for query and retrieval of land administration information.

Most countries have developed land administration systems to suit their own specific circumstances. For example, one country may have a deeds registration system, another a title registration system. Some systems are centralised, others decentralised. Some systems are based on a general boundaries approach, others on fixed boundaries. Some systems have a fiscal background, others a legal one. These different approaches and implementations hinder meaningful communication across borders. Implementing ISO 19152:2012 not only facilitates verbal communication and understanding, it also allows one to exchange land administration data or aggregate data from different sources.

Implementation guidelines

Land administration refers to the process of determining, recording and disseminating information about the relationship between people and land. It is a wide field; the focus in ISO

19152:2012 is on land administration concerned with rights, responsibilities and restrictions affecting land (or water), and the geometrical (geo-spatial) components thereof.

Land administration systems are concerned with geo-spatial data (e.g. land parcel boundaries), as well as with non-spatial data, such as information about people and relationships among people. In some jurisdictions, the relationship between people and land, e.g. the ownership right to land, has legal status. Such rights are often registered with the purpose of assigning legal meaning to the registered right.

The land administration domain model (LADM) is a conceptual model. Implementation of LADM requires the development of an application schema, such as a country profile. The LADM is generic, but expandable. It is very likely that additional attributes, operators, associations and classes, are needed for a specific regional or country profile. A variety of profile examples are included in the informative annexes of ISO 19152:2012. Representation of land administration related data, such as address data, taxation data, land use data, land cover data, valuation data, physical utility network data and archive data are not within the scope of the LADM. However, LADM provides guidance on how such data may be represented and linked to the LADM.

The LADM is organised into three packages (Party, Administrative and SpatialUnit) and one sub package (Surveying and Representation). A (sub)package groups related classes into a single unit. The model is represented in UML. Figure 10.6, Figure 10.7, Figure 10.8 and Figure 10.9 provide an overview of the main classes and associations in the four packages.

The *Party* package contains classes representing information about a person or organisation with a relationship to land. This can be a party or a group party. A group party is a number of parties together forming a distinct entity in the context of land administration.

The classes in the *Administrative* package represent the rights, restrictions and responsibilities associated with a basic administrative unit, i.e. one or more spatial units against which a homogeneous right or restriction can be registered or recorded. The administrative source provides the evidence for these rights, restrictions and responsibilities, for example, a document describing the property transaction (deed).

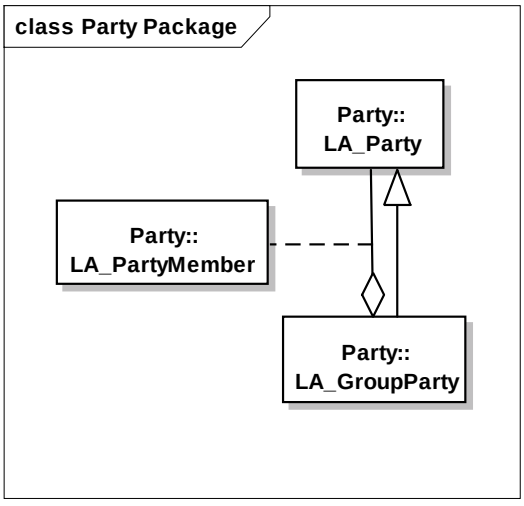

Figure 10.6 Main classes in the Party package (Source ISO 19152:2012)

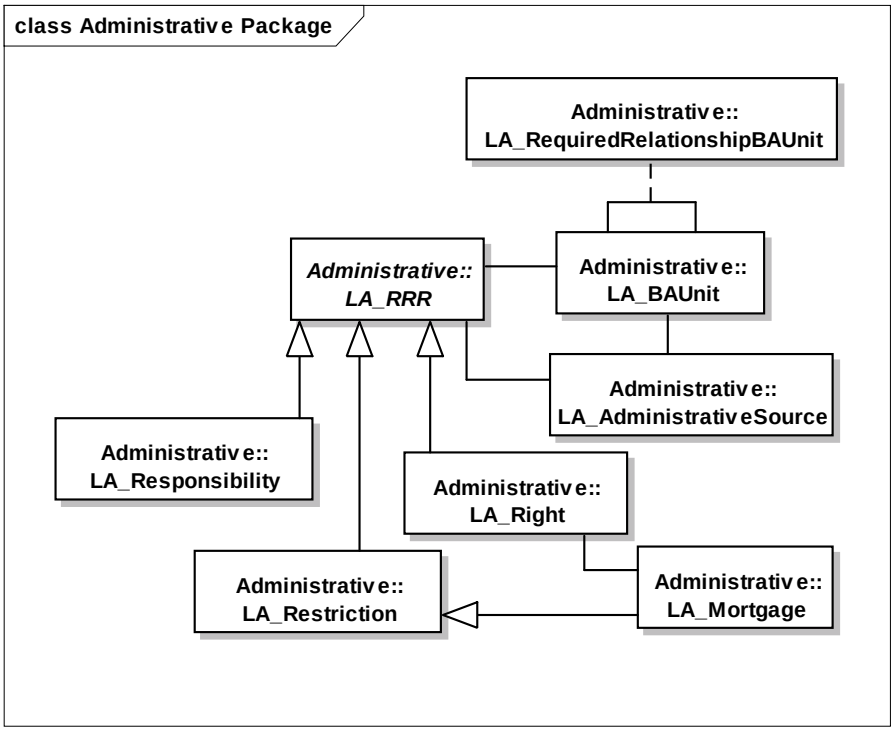

Figure 10.7 Main classes in the Administrative package (Source ISO 19152:2012)

The *Spatial Unit* package contains classes representing an area of land and/or water or a volume of space, as well as the relationships between them. A land parcel is defined as an alias for a spatial unit. Spatial units are structured to support creation and management of basic administrative units. They may be grouped hierarchically in two ways. Firstly, spatial units can be aggregated into spatial unit groups. For example, all land parcels in a municipality could be grouped into a spatial unit group. Secondly, a spatial unit can be an aggregation of sub-units. For example, a land parcel, which is a group of sub parcels created by subdivisions.

The classes in the Surveying and Representation package represent information about surveys and point, line and surface representations of spatial units (LA_Point, LA_BoundaryFaceString, LA_BoundaryFace). A survey is documented with one or more spatial sources, such as a registered survey plan or aerial photograph. Point, line and surface representations can be acquired in the field (e.g. with classical surveys or through the GNSS), or be compiled from other sources, such as field sketches and orthophotos. The representations of spatial data conform to the spatial schema described in ISO 19107:2003, Geographic information – Spatial schema.

An application schema, such as a regional or country profile, may conform to ISO 19152:2012 at one of three levels for one or more of the packages and sub packages. The content of a conformant dataset corresponds to an application schema conforming to ISO 19152:2012 (for the relevant packages and levels).

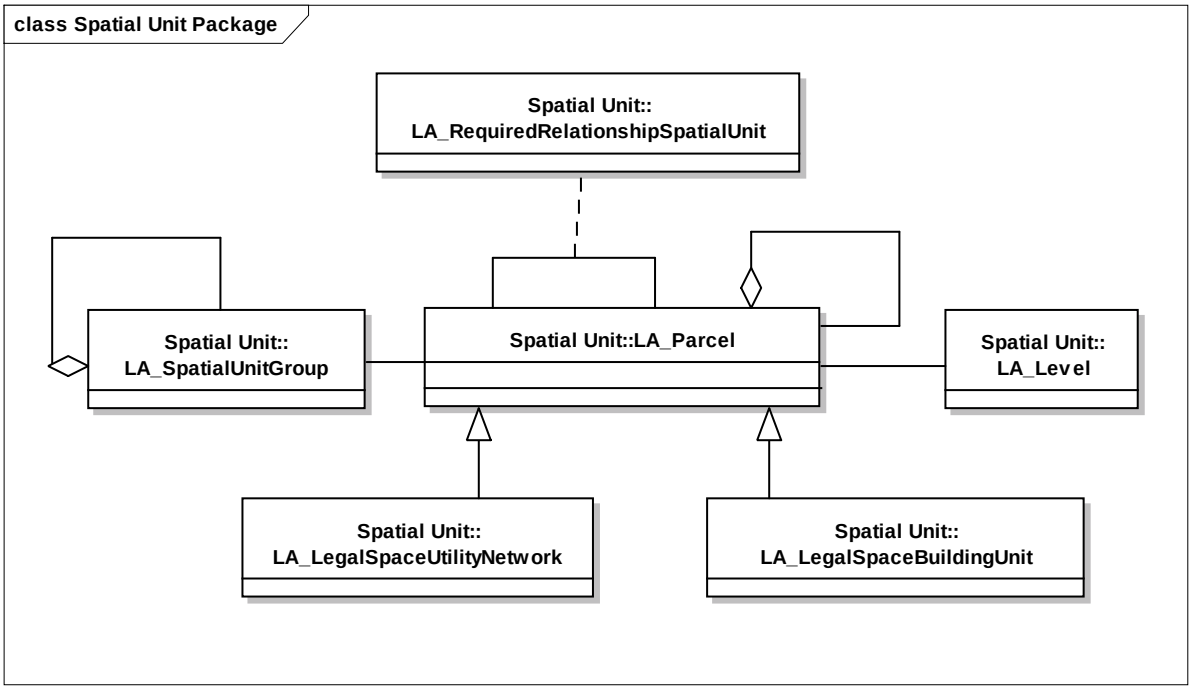

Figure 10.8 Main classes in the Spatial Unit package (Source ISO 19152:2012)

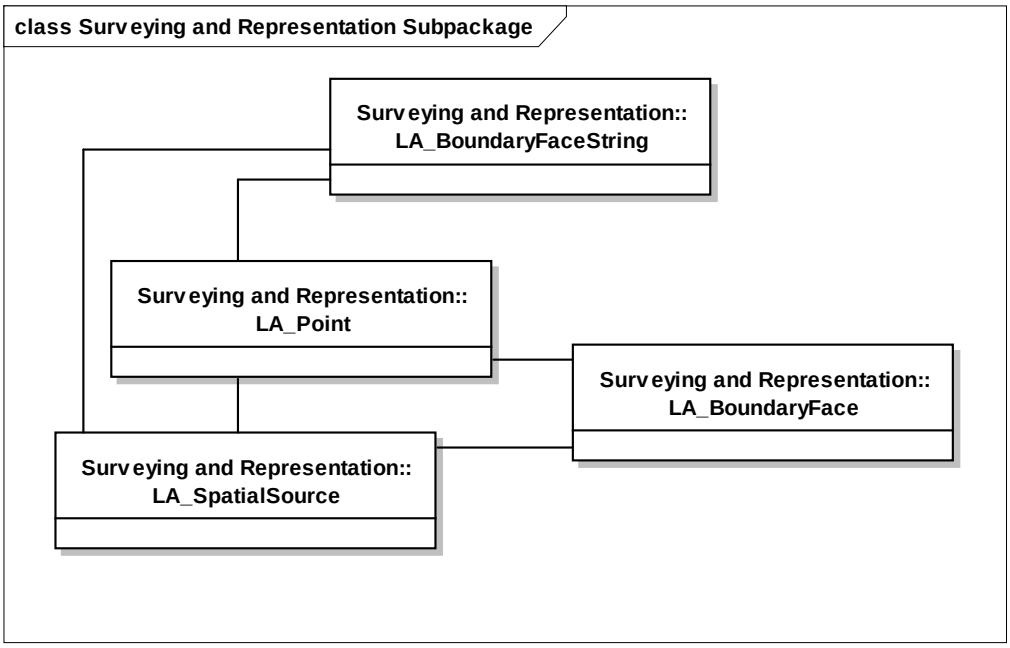

Figure 10.9 Main classes in the Surveying and Representation package (Source ISO 19152:2012)

Level 1, 2 and 3 compliance requires the relevant classes of a package to pass the conformance tests specified for those classes in ISO 19152:2012. For example, Table 10.44 lists the classes indicated as level 1 in the different packages. If the classes in an application schema pass all the tests specified in ISO 19152:2012 for the Party, Administrative and Spatial Unit classes in Table 10.44, the model is said to be Level 1 conformant for the Party, Administrative and Spatial Unit packages. An example of such a conformance test for LA_Party is to ensure that the application schema contains at least one class conforming to the definition of LA_Party and has all mandatory

attributes and association roles of LA_Party specified in ISO 19152:2012. Conformance tests are performed by examining the application schema.

Table 10.44 Classes indicated as level 1 in the LADM

Package	Level 1 classes
-	Versioned Object
-	LA_Source
Party	LA_Party
Administrative	LA_RRR
Administrative	LA_Right
Administrative	LA_BAUnit
Administrative	LA_AdministrativeSource
Spatial Unit	LA_SpatialUnit

10.8.7 Observations and Measurements (ISO 19156:2011)

Table 10.45 Overview of ISO 19156:2011

Full name	ISO 19156:2011, Geographic information – Observations and Measurements
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19156:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19109:2005, Geographic information – Rules for application schema Observations & Measurements (O&M) – XML implementation (published by OGC) OGC® SensorML: Model and XML Encoding Standard 2.0 OGC® Sensor Observation Service Interface Standard 2.0 OGC® Sensor Planning Service Implementation Standard 2.0 OGC® Sensor Planning Service Interface Standard 2.0 Earth Observation Satellite Tasking Extension 2.0 OpenGIS Sensor Model Language (SensorML) 1.0.0 OpenGIS Sensor Observation Service 1.0.0 OpenGIS Sensor Planning Service Application Profile for EO Sensors (0.9.5) OpenGIS® SWE Service Model Implementation Standard 2.0
Application	This standard specifies a schema for observations and measurements, including a schema for sampling features. The schema is useful for the exchange of information describing observation acts and their results, both within and between technical and scientific communities. Examples in the natural environment are water quality, seismic, temperature and other weather observations.
Conformance classes	Generic observation interchange Measurement interchange Specialized observation interchange Coverage observation interchange Temporal coverage observation interchange Sampling feature interchange Spatial sampling feature interchange Sampling point interchange Sampling curve interchange Sampling surface interchange Sampling solid interchange Specimen interchange

Fundamental geo-spatial dataset	Category: *Environmental information* Data Theme: *Natural environment*

Scope

ISO 19156:2011 defines a conceptual schema for observations, and for features involved in sampling when making observations. These provide models for the exchange of information describing observation acts and their results, both within and between different scientific and technical communities.

Observations commonly involve sampling of an ultimate feature-of-interest. ISO 19156:2011 defines a common set of sampling feature types classified primarily by topological dimension, as well as samples for ex-situ observations. The schema includes relationships between sampling features (sub-sampling, derived samples).

ISO 19156:2011 concerns only externally visible interfaces and places no restriction on the underlying implementations other than what is needed to satisfy the interface specifications in the actual situation.

Implementation benefits

ISO 19156:2011 has its origins in the work on Sensor Web Enablement (SWE) undertaken in OGC. SWE is concerned with establishing interfaces and protocols to enable a 'Sensor Web' through which applications and services are able to access sensors of all types, and observations generated by them, over the Web. While ISO 19156:2011 has its origins in a Web initiative, it can equally well be used to facilitate the exchange of observations and measurements through other media.

Implementation guidelines

Observation is the act of observing a property. The goal of an observation is to measure or otherwise determine the value of a property. A value is exact if assigned by some authority (e.g. name or price), while a value determined by the application of an observation procedure is an estimate (e.g. height or classification). The observation result – the value – describes a phenomenon or property of a feature, the feature-of-interest of the observation. Observations are often made by an instrument or a sensor, but may also be made by a process chain, human observer, an algorithm, a computation or a simulator. Observation properties provide context or metadata to support evaluation, interpretation and use of the observation results.

The principal location of interest of an observation is usually associated with the ultimate feature-of-interest, but this location is not always trivial to determine (e.g. complex processing is required to geolocate a remotely sensed image) and sometimes the location is of no interest (e.g. observations on non-located chemical species). Therefore, ISO 19156:2011 is flexible about the inclusion of the observation location in an application schema.

ISO 19156:2011 defines a conceptual schema for observations and measurements that may either be used in application schemas, profiles and implementation specifications or be included in a cross-domain application schema. The conceptual schema is represented in UML.

Any application schema conforming to ISO 19156:2011 has to conform to the general rules for application schema specified in ISO 19109:2005. In addition, ISO 19156:2011 defines 12 conformance classes for application schemas of observations and measurements that support applications with varying requirements:

- Generic observation interchange
- Measurement interchange
- Specialized observation interchange
- Coverage observation interchange
- Temporal coverage observation interchange
- Sampling feature interchange
- Spatial sampling feature interchange
- Sampling point interchange
- Sampling curve interchange
- Sampling surface interchange
- Sampling solid interchange
- Specimen interchange

For example, an application schema conforming to the Generic observation interchange conformance class correctly implements the mandatory attributes, associations and constraints specified for the OM_Observation class in the conceptual schema defined in ISO 19156:2011. See Figure 10.10. Conformance of an application schema is tested by inspecting the schema's documentation.

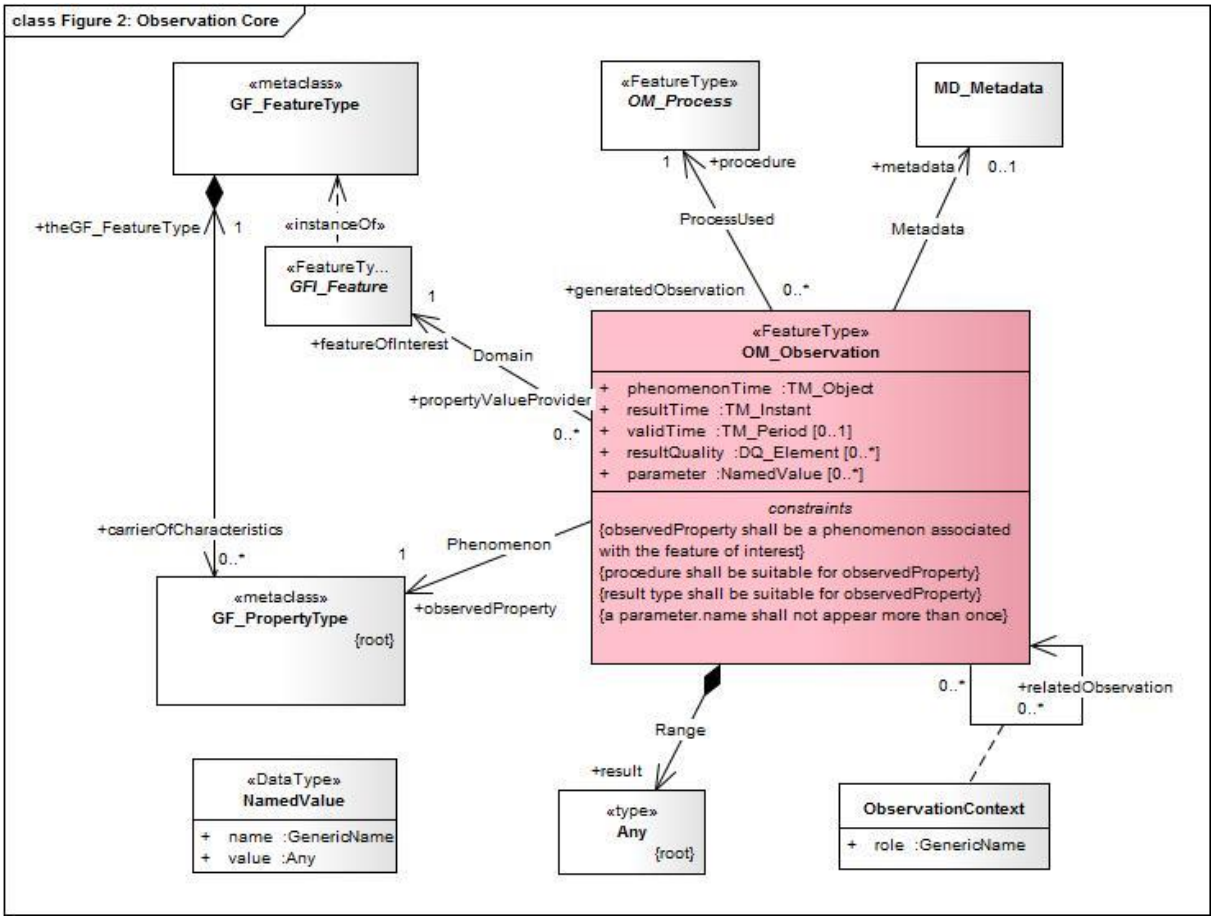

Figure 10.10 UML representation of OM_Observation (Source ISO 19156:2011)

The model for observations in ISO 19156:2011 uses terminology based on current practice in a variety of scientific and technical disciplines. It is designed to apply across disciplines, so the best or 'most neutral' term has been used in naming the classes, attributes and associations in the model. The terminology does not, however, correspond precisely with any single discipline. Therefore the use of alternative names for classes and properties is allowed, provided there is a one-to-one mapping to the classes and properties specified in the UML model of the standard. Annex B in the standard provides a mapping from the model element names to common terminology in application domains, such as Earth observations, metrology and chemistry.

10.8.8 Addressing – Part 1: Conceptual model (ISO/DIS 19160-1)

Table 10.46 Overview of ISO/DIS 19160-1 (under development)

Full name	ISO/DIS 19160-1, Geographic information – Addressing - Part 1: Conceptual model
Version	Draft International Standard (DIS)
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not available yet
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19152:2012, Geographic information – Land administration domain model (LADM)

Application	The standard is implemented by developing a profile of the ISO 19160-1 conceptual model. It facilitates communication about addresses and interoperability between address specifications; for example, in the cross mapping of conceptual models between different address specifications.
Conformance classes	Model – Core Model – Lifecycle Model – Provenance Model – Locale Model – Full conformance Address profile documentation
Fundamental geo-spatial dataset	Category: *Administration and spatial organisation* Data Theme: *Land management units/areas*

Scope

ISO 19160-1 defines a conceptual model for address information (address model), together with the terms and definitions that describe the concepts in the model. Lifecycle, metadata and address aliases are included in the conceptual model. The model is presented in UML.

The model provides a common representation of address information, independent of actual addressing implementations. It is not intended to replace conceptual models proposed in other specifications, but provides a means to cross-map between different conceptual models for address information and enables the conversion of address information between specifications.

The model provides a basis for developing address specifications by individual countries or communities.

Implementation benefits

Addresses are one of the most common ways to unambiguously determine an object for purposes of identification and location. Address reference systems vary from country to country: in many Euro-centric countries reference to a road network in the address is common, while addresses in countries such as Japan and South Korea (though South Korea is moving away from this) comprise a hierarchy of administrative areas without reference to a thoroughfare. Addresses are used for a wide variety of purposes: postal delivery, emergency response, customer relationship management, land administration, utility planning and maintenance, to name a few. ISO 19160-1 provides a formal mechanism to describe conceptual models in addressing. It facilitates communication about addressing with a set of addressing terms defined in the standard.

A variety of address standards and/or specifications are in use around the world, described in the report of the preparatory work for this ISO standard, the Review summary of the ISO 19160 stage zero project (2011). These standards and specifications are well integrated into various operational processes and in some cases legally enforced. At the same time, some countries are rationalising their addressing system or creating a new one. Due to developments in ICT, addresses are increasingly used to reference new geographic objects (e.g. road furniture), while they are also increasingly used in new technology, such as in-vehicle navigation. ISO 19160-1 does not replace any standards and specifications, but rather aims to facilitate interoperability between existing and future address specifications. It facilitates the development of addressing tools, for example, software and

utilities to assign and maintain addresses, and web services for query and retrieval of address information.

Implementation guidelines

An address is structured information that allows the unambiguous determination of an object (the addressed object) for purposes of identification and location. A set of addresses unambiguously determining the same object are called address aliases. Examples are colloquial, lifecycle and locale aliases.

Address components, e.g. address number, thoroughfare name and place name, are combined to form an address. An address reference system defines the rules for combining address components into addresses. A set of addresses that share the same address components, operations, methods, relationships, and semantics are collectively referred to as an address class.

An address component may have alternative values, for example, ‘Jozi’ and ‘Joburg’ are colloquial forms of ‘Johannesburg’. Other alternatives are abbreviations (‘St’ and ‘Street’) or alternatives in different languages (‘Köln’ and ‘Cologne’). The address component may reference (an)other object(s), for example, a thoroughfare name component may reference a set of street centre line segments, a place name component may reference an administrative area boundary or a municipality name may reference an object with non-spatial attributes.

The address model in ISO 19160-1 defines classes and associations for the representation of addressing information. Figure 10.11 provides an overview of the address model. From this a profile for a specific country, region or purpose can be developed. Profiles of ISO 19160-1 will be published at http://standards.iso.org/iso/19160/-1/.

The first five conformance classes in ISO 19160-1 concern the address model:

1. An address model conforming to ‘Model – Core’ appropriately includes the specified classes, attributes and associations.
2. An Address, AddressComponent or AddressableObject class conforming to ‘Model - Lifecycle’ includes the relevant lifecycle attributes and its unique identifier attribute is mandatory.
3. An Address or AddressComponent class conforming to ‘Model - Provenance’ includes the relevant provenance attributes.
4. An Address, AddressComponent or AddressComponentValue class conforming to ‘Model - Locale’ includes the relevant provenance attributes.
5. An address model conforming to ‘Model – Full’ passes the conformance tests specified for the above four conformance classes.

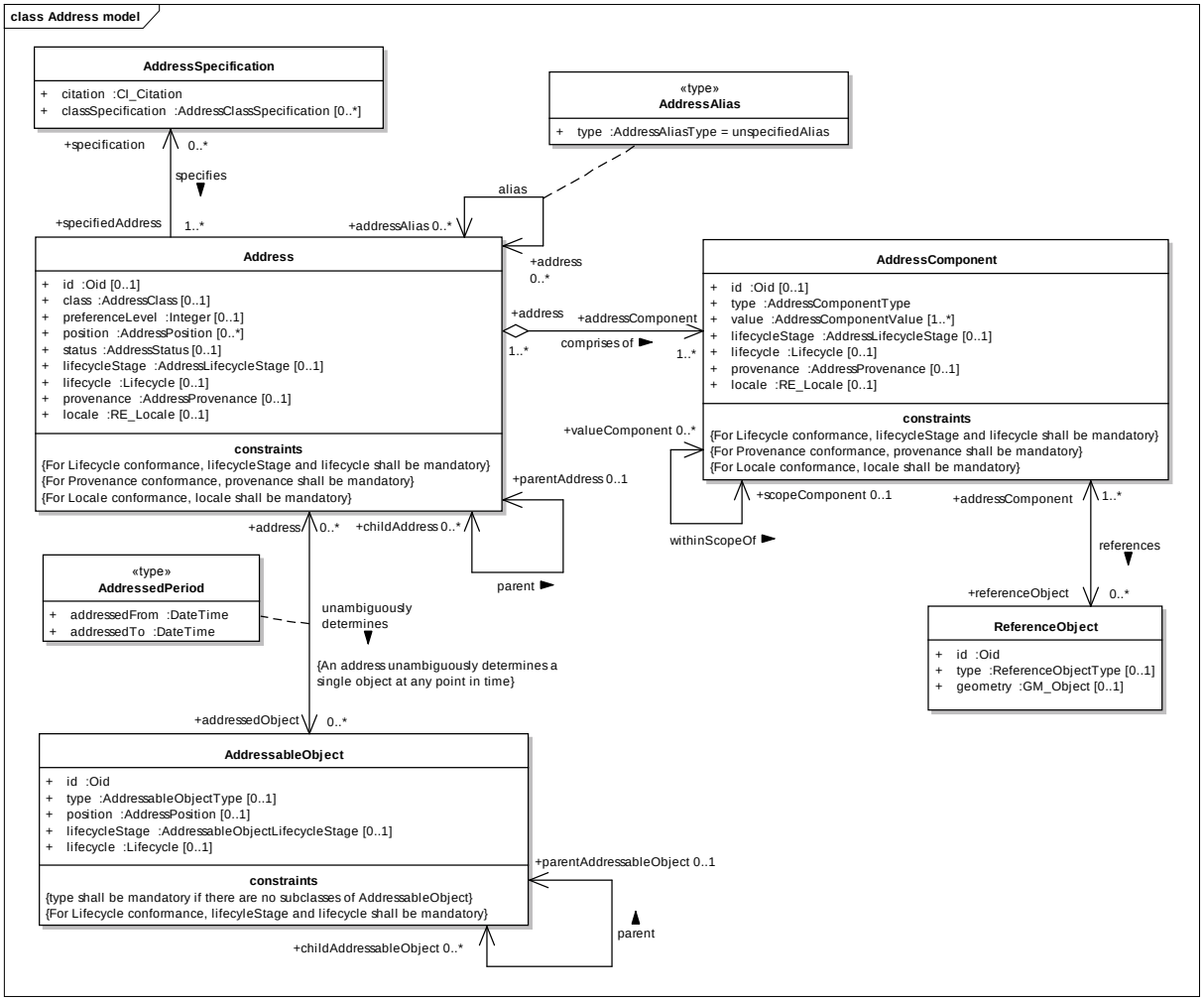

Figure 10.11 Overview of the ISO 19160-1 address model (Source ISO/DIS 19160-1)

A sixth conformance class is specified for the documentation of an address profile. Conformant documentation meets the documentation requirements specified in the standard, amongst others, the documentation includes reference to the address specification represented in the model, diagrams with the relevant classes, types, codelists and associations, a bi-directional mapping between addresses in the address specification and the profile, and diagrams of instance data. Some of the profile examples in the annexes of ISO 19160-1 meet the requirements specified for the 'Address profile documentation' conformance class.

10.8.9 Intelligent transport systems – Geographic Data Files (GDF) (ISO 14825:2011)

Table 10.47 Overview of ISO 14825:2011

Full name	ISO 14825:2011, Intelligent transport systems – Geographic Data Files (GDF) – GDF5.0
Version	Edition 2
Amendments	None
Corrigenda	None
Published by	ISO/TC 204, Intelligent transport systems
Languages	English
Online overview	Not available yet
Type of standard	ISO International Standard Instance level

Related standard(s)	ISO 14813-1:2007, Intelligent transport systems – Reference model architecture(s) for the ITS sector, ITS service domains, service groups and services ISO 17572-1:2008, Intelligent transport systems (ITS) – Location referencing for geographic databases, General requirements and conceptual model ISO 17572-2:2008, Intelligent transport systems (ITS) – Location referencing for geographic databases, Pre-coded location references (pre-coded profile) ISO 19115:2003, Geographic information – Metadata ISO 19132:2007, Geographic information – Location-based services – Reference model ISO/DIS 19147, Geographic information – Transfer nodes
Application	Exchange of data for intelligent transport systems, automotive navigation systems, traffic, fleet and dispatch management, road traffic analysis, automatic vehicle location and other transport applications.
Conformance classes	None specified
Fundamental geo-spatial dataset	Category: *Infrastructure* Data Theme: *Transportation*

Scope

ISO 14825:2011 specifies the conceptual and logical data model and physical encoding formats for geographic databases for Intelligent Transport Systems (ITS) applications and services. It includes a specification of potential contents of such databases (data dictionaries for Features, Attributes and Relationships), a specification of how these contents shall be represented, and of how relevant information about the database itself can be specified (metadata).

The focus of ISO 14825:2011 is on ITS applications and services and it emphasises road and road related information. ITS applications and services, however, also require information in addition to road and road related information.

EXAMPLE 1 ITS applications and services need information about addressing systems in order to specify locations and/or destinations. Consequently, information about the administrative and postal subdivisions of an area is essential.

EXAMPLE 2 Map display is an important component of ITS applications and services. For proper map display, the inclusion of contextual information such as land and water cover is essential.

EXAMPLE 3 Point-of-Interest (POI) or service information is a key feature of traveller information. It adds value to end-user ITS applications and services.

The Conceptual Data Model has a broader focus than ITS applications and services. It is application independent, with observance for harmonization of this International Standard with other geographic database standards.

Implementation benefits

ISO 14825:2011 is widely used for intelligent transport systems (ITS) and related applications, and services, by vehicle manufacturers, electronic components manufacturers, manufacturers of global positioning system receivers, and geospatial data vendors. Note that while the geospatial data might be distributed using GDF, it is typically encoded into proprietary formats for more efficient processing within navigation systems and other components.

ISO 14825:2011 has been harmonised with the relevant ISO/TC 211 standards and includes all the core metadata defined in ISO 19115:2003.

However, it does not appear that GDF is used much for other types of applications.

Implementation guidelines

ISO 14825:2011 is a very large document (over 1200 pages), as in addition to the data format (physical encoding), it includes the conceptual and logical data models, media record specifications, XML schema specifications, SQL encoding specifications, rules for data capture and portrayal, metadata and a comprehensive feature catalogue (classification system) with attributes, relationships and extensive code lists. The standard also includes annexes with extensive examples of how to use GDF, such as for complex time domains and generalizing networks. However, it is not clear why the standard has an annex duplicating ISO 639-2, Codes for the Representation of Names of Languages Part 2: Alpha-3 Code (as it was on 3 March 2009), and ISO 3166-1, Codes for the representation of names of countries and their subdivisions — Part 1: Country codes (as it was on 17 October 2008). Both ISO 639-2 and ISO 3166-1 are updated from time to time and freely available on the ISO website.

While very large, ISO 14825:2011 is probably relatively easy (though rather tedious) to implement, as it has extensive definitions, descriptions and illustrations, and snippets of pseudo-code and XML. However, it is probably only of interest to those implementing intelligent transport systems (ITS) and related transport applications.

10.8.10 Universal hydrographic data model (S-100)

Table 10.48 Overview of S-100

Full name	S-100, IHO Universal hydrographic data model
Version	Edition 1.0.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English
Online overview	http://iho.int/iho_pubs/standard/S-100/S-100_Version_1.0.0.zip
Type of standard	IHO International Standard Meta level
Related standard(s)	ISO/TS 19103:2005, Geographic information – Conceptual schema language ISO 19106:2004, Geographic information – Profiles ISO 19107:2003, Geographic information – Spatial schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19110:2005, Geographic information – Methodology for feature cataloguing ISO 19111:2007, Geographic information – Spatial referencing by coordinates ISO 19115:2005, Geographic information – Metadata ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data ISO 19117:2012, Geographic information – Portrayal ISO 19118:2011, Geographic information – Encoding ISO 19123:2005, Geographic information – Schema for coverage geometry and functions ISO 19126:2009, Geographic Information – Feature concept dictionaries and registers ISO/TS 19129:2009, Geographic information – Imagery, Gridded and Coverage Data Framework ISO 19130:2012, Geographic information – Sensor and data models for imagery and

	gridded data ISO 19135:2005, Geographic Information – Procedures for registration of items of geographic information ISO 19157:2013, Geographic information – Data quality OMG Unified Modeling Language (OMG UML), Superstructure, V2.1.2 ISO 8601:2004, Data elements and interchange formats - Information interchange – Representation of dates and times ISO/IEC 8211:1994, Specification for a data descriptive file for information interchange Structure implementations ISO/IEC 12087-5:1998 - Computer graphics and image processing -- Image Processing and Interchange (IPI) - Functional Specification - Basic Image Interchange Format (BIIF) ISO/IEC 15444-1:2004 - Information Technology -- JPEG 2000 image coding system S-57 Cumulative Maintenance Document N°8 S-52 Specifications for Chart Content and Display Aspects of ECDIS S-61 Product Specification for Raster Navigational Charts (RNC) American National Standard T1.523-2001 - Telecommunications Glossary 2000
Application	S-100 specify the methods and tools for data management, processing, analysing, accessing, presenting and transferring of hydrographical or related data.
Conformance classes	None specified

Scope

S-100 – IHO Hydrographic Geospatial Standard for Marine Data and Information comprises twelve related parts that give the user the appropriate tools and framework to develop and maintain hydrographical related data, products and registers. These standards specify, for hydrographical and related information, methods and tools for data management, processing, analysing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. By following this set of geo-spatial hydrographical standards users will be able to build constituent parts of an S-100 compliant product specification.

S-100 conforms as far as is reasonably possible to the ISO TC 211 series of geographic information standards, and where necessary has been tailored to suit hydrographical requirements.

S-100 details the standard to be used for the exchange of hydrographical and related geo-spatial data between national hydrographical offices as well as between other organisations and for its distribution to manufacturers, mariners and other data users.

S-100 comprises multiple parts that profile standards developed by the ISO Technical Committee 211. ISO TC 211 is responsible for the ISO series of standards for geographic information. The objective is that, together, the standards will form a framework for the development of sector specific applications that use geographic information. S-100 is an example of such an application.

This standard specifies the procedures to be followed for:

1. establishing and maintaining registers of hydrographical and related information;
2. creating product specifications, feature catalogues and a definition of the general feature model;
3. using spatial, imagery and gridded data, and metadata specifically aimed at fulfilling hydrographical requirements.

Implementation benefits

S-100 covers a wide range of activities with the hope of harmonizing them for hydrographical data and ensuring interoperability. The profiles define a subset of requirements that are specific for hydrographical data, but ensure interoperability with other data sources. Each profile would have its own implementation benefits, for example, the metadata profile defines a metadata schema for hydrographical data and extends the ISO 19115 for this application to ensure that all the aspects of hydrographical data are covered in the profile.

Implementation guidelines

S-100 was developed to align and exploit ISO/TC 211 standards to support a variety of data formats, products and customers. The data model will allow the development of new applications that leverage the new technologies and reaches beyond the traditional scope of hydrographical applications. S-100 encapsulates the use of best practice methods and procedures by including guidelines on implementing efficient production methods, optimizing the quality of products and services, and enabling interoperability through common interfaces.

S-100 specifies a framework of components that can be used by interested communities to develop their own maritime geo-spatial products and services. S-100 consists of eleven profiles of ISO/TC 211 standards:

1. Conceptual Schema Language

   The first part of S-100 specifies a CSL and basic types that shall be used within the IHO community. The CSL is defined as a combination of UML and a set of basic data type definitions for specification of geographic information. Guidelines on the use of UML to create standardized geographic information and service models are also provided. Basic knowledge of the Object Management Group (OMG) UML is required to understand and implement the CSL profile.

2. Management of IHO Geospatial Information Registries

   The management of IHO geo-spatial information registries profile specifies the procedures that shall be followed when maintaining and publishing registers of unique, unambiguous and permanent identifiers assigned to items of geographic, hydrographical and metadata information. The roles and responsibilities for management of a registry and its registers are defined and described.

   This part also specifies a feature concept dictionary registers. A FCD specifies hydrographical definitions that may be used to describe geographic information. Such a register will improve the IHO's ability to manage and extend multiple products based on S-100.

3. General Feature Model and Rules for Application Schema

   The General Feature Model defines a conceptual model of features, their characteristics and associations, and the rules for developing an application schema. This part further deals with conceptual modelling of features and their properties, conceptual modelling of information

types and associated attributes, and the development of application schemas and the related rules for such a schema.

4. Metadata

   The S-100 metadata profile described is divided into three parts and provides specifications for describing, validating and exchanging metadata of data produced by hydrographical organisations. This profile is based on ISO 19115:2003, ISO 19115-2:2006, and ISO 19139:2007. The primary intent of this profile is to describe digital geo-spatial data. However, it can also be used for other products, such as charts, maps, images, textual documents and non-geographic resources. The profile is not limited to ISO 19115 since it can be extended to include additional resources.

5. Feature Catalogue

   The feature catalogue specifies a framework for organisation and reporting the classification of real world phenomena as geographic data. It defines the methodology for classification of the feature types and specifies how they are organised in a feature catalogue and presented to the users of a set of geographic data. A feature catalogue shall be defined for each product specification. This profile is for defining geographic features at the type level.

6. Coordinate Reference Systems

   The location of an object shall be defined by means of coordinates, which relate to the feature's position. This profile describes the elements required to define the referencing by means of coordinate systems and datums. A conceptual schema for describing spatial referencing by coordinates and the minimum requirements for multi-dimensional spatial coordinate references are defined.

7. Spatial Schemas

   S-100 spatial schema requirements are less comprehensive than ISO 19107, which contains all the information necessary for describing and manipulating the spatial characteristics of geographic features. This part is only a profile of ISO 19107 and contains thus only a subset of the classes. The profile added additional constraints (omitted optional elements or constrained cardinalities) for hydrographical data.

8. Imagery and Gridded data

   Imagery and gridded data have become common forms of geographic data and there exist many external standards designed to handle such data. S-100 shall not preclude compatibility with external sources of data. This profile aligns with the ISO/TC 211 standards on imagery and gridded data in order to support multiple sources of data and uses the common information structures. This allows the data to be combined with various other data types. This part defines specific grid organisations to be used for hydrographical data and images associated with hydrographical data. Both simple grids and complex multidimensional grids are defined, as well as point sets and TINs.

9. Portrayal

Portrayal is not included in this version of S-100 and will be developed at a later date.

10. Encoding Formats

    S-100 does not mandate particular encoding formats. The developer of a product specification can decide on suitable encoding standards and shall then document their chosen format. Encoding is complicated because numerous encoding standards are available. The parts provide guidelines on the selection and documentation of an encoding format.

11. Product Specification

    A data product specification defines a geo-spatial data product, and describes all the features, attributes and relationships of a given application and their mapping to a dataset. This part describes data product specifications for hydrographical requirements for geographic data products. Its aim is to provide a clear and similar structure for any data product specification to be written.

10.8.11 IHO Standards for Hydrographic Surveys (S-44)

Table 10.49 Overview of S-44

Version	Edition 5
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English, French, Spanish, Portuguese
Online overview	http://iho.int/iho_pubs/standard/S-44_5E.pdf
Type of standard	IHO International Standard Application level
Related standard(s)	ISO 19115:2003, Geographic information – Metadata S-100 IHO Universal Hydrographic Data Model S-44 IHO Standards for Hydrographic Surveys (previous editions) ISO/IEC 98:1995 Guide to the expression of uncertainty in measurement ISO/IEC 99:2007 International Vocabulary of Metrology – Basic and general concepts and associated terms (VIM)
Application	S-44 sets the minimum requirements for surveys conducted for the safety of surface navigation.
Conformance classes	None specified

Scope

This publication is designed to provide a set of standards for the execution of hydrographical surveys for the collection of data, which will primarily be used to compile navigational charts to be used for the safety of surface navigation and the protection of the marine environment.

It must be realised that this publication only provides the minimum standards that are to be achieved. Where the bathymetry and expected shipping use requires it, hydrographical offices / organisations wishing to gather data may need to define more stringent standards. Also, this publication does not contain procedures for setting up the necessary equipment, for conducting the survey or for processing the resultant data. These procedures (which are a fundamental part of the complete survey system) must be developed by the hydrographical office/organisation wishing to

gather data that is compliant with these Standards. Consideration must be made of the order of survey they wish to achieve, the equipment they have at their disposal and the type of topography that they intend to survey. Annexes A and B provide guidelines for Quality control and Data Processing and it is intended that these will be moved to the Manual on Hydrography (IHO Publication M-13) which provides further guidance on how to perform hydrographical surveys.

There is nothing to stop users adopting these Standards for other uses. Indeed, such a broadening of the use of these Standards is welcomed. However, users who wish to adopt these for other means must bear in mind the reason why they were written and therefore accept that not all parts may be suitable for their specific needs.

To be compliant with an S-44 Order a survey must be compliant with ALL specifications for that order included in these Standards.

It is also important to note that the adequacy of a survey is the end product of the entire survey system and processes used during its collection. The uncertainties quoted in the following chapters reflect the total propagated uncertainties of all parts of the system. Simply using a piece of equipment that is theoretically capable of meeting the required uncertainty is not necessarily sufficient to meet the requirements of these Standards. How the equipment is set up, used and how it interacts with the other components in the complete survey system must all be taken into consideration.

All components and their combination must be capable of providing data to the required standard. The hydrographical office / organisation needs to satisfy itself that this is so by, for example, conducting appropriate trials with the equipment to be used and by ensuring that adequate calibrations are performed prior to, as well as during and, if appropriate, after the survey being carried out. The surveyor is an essential component of the survey process and must possess sufficient knowledge and experience to be able to operate the system to the required standard. Measuring this can be difficult although surveying qualifications (e.g. having passed an IHO Cat A/B recognised hydrographical surveying course) may be of considerable benefit in making this assessment.

It should be noted that the issue of this new edition to the standard does not invalidate surveys, or the charts and nautical publications based on them, conducted in accordance with previous editions, but rather sets the standards for future data collection to better respond to user needs.

It should also be noted that where the sea floor is dynamic (e.g. sand waves), surveys conducted to any of the Orders in these Standards would quickly become out-dated. Such areas need to be resurveyed at regular intervals to ensure that the survey data remains valid. The intervals between these resurveys, which will depend on the local conditions, should be determined by national authorities.

Implementation benefits

The requirements set out in S-44 are of great importance to improve the safety of navigation. The data captured by hydrographical surveys are used to compile navigational charts. These navigational charts are used for surface navigation and the protection of the marine environment. S-44 defines four types of order of surveys and the measurements and observations required to ensure that navigational charts of the highest quality and standardized worldwide.

Implementation guidelines

First to be addressed by the IHO standards for hydrographical surveys (S-44) is the Classification of surveys. This chapter specifies the orders of survey that are acceptable to allow hydrographical offices or organisations to produce navigational products. The navigational products will allow the expected shipping to navigate safely across the area surveyed. Due to varying requirements four types of orders of survey are defined:

1. Special Order is the most rigorous and is only intended for areas where under-keel clearance is critical. Its type of order requires the full sea floor to be searched and the size of feature to be detected is kept small.
2. Order 1a is intended for areas where the sea is sufficiently shallow to allow natural or man-made features on the seabed to be of concern to the type of surface shipping expected to transit. Under-keel clearance is not as critical. Order 1a also requires a full sea floor search, however the size of the feature to be detected are larger than for Special Order. Order 1a surveys may be limited to water shallower than 100 metres.
3. Order 1b is meant for areas shallower than 100 metres where the general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area. Some features may be missed, since a full sea floor search is not required. This order of survey is only recommended where under-keel clearance is not required.
4. Order 2 is intended for areas where the water depth is such that a general depiction of the seabed is considered adequate. A full sea floor search is not required. This order of survey is recommended for water deeper than 100 metres.

Positions should be referenced to a geocentric reference frame based on the International Terrestrial Reference System (ITRS), for example WGS84. Uncertainty of a position is the uncertainty at the position of the sounding or feature within the geodetic reference frame. S-44 further sets out the requirements for the horizontal uncertainty of features significant to navigation, the coastline and topographic features.

The navigation of vessels requires accurate knowledge of the water depth in order to exploit safely the maximum cargo carrying capacity, and the maximum available water for safe navigation. The measured depths and drying heights shall be referenced to a vertical datum that is compatible with the products to be made or updated from the survey. S-44 specifies the requirements for the following depth measurements: vertical uncertainty, water-level observations, depth measurement, feature detection, and sounding density.

Other measurements standardized by S-44 are seabed sampling, chart and land survey vertical datum connection, and tidal prediction. These measurements are not required for all order of surveys.

S-44 recommends the use of S-100 IHO Universal Hydrographic Data Model to perform a comprehensive assessment of the quality of the data. If a Bathymetric Model is required, the metadata should include the following: model resolution, computational model, underlying data density, uncertainty estimate, and a description of the underlying data. The Report of Survey shall provide a clear and comprehensive account of how the survey was performed, the results, the difficulties

encountered, and the shortcomings. The report is the means by which the Surveyor in charge approves the survey record.

To improve the safety of navigation, it is desirable to eliminate doubtful data. This is achieved through carefully defining the area to be searched and subsequently surveying that area according to the standards outlined in S-44.

10.9 Standards for products used in the acquisition and maintenance of fundamental geo-spatial datasets

This section provides a tabular overview of standards implemented in products and tools for the acquisition and maintenance of fundamental geo-spatial datasets.

Table 10.50 Spatial schema (ISO 19107:2003)

Full name	ISO 19107:2003, Geographic information – Spatial schema
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19107:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19108:2002, Geographic information – Temporal schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19137:2007, Geographic information – Core profile of the spatial schema
Application	ISO 19107 provides conceptual schemas for describing and manipulating spatial characteristics of geographic features. The associated set of operators is also described.
Conformance classes	Geometric primitives Geometric complexes Topological complexes Topological complexes with geometric realisations Boolean operators
Implementation benefits	ISO 19107 describes the geometry and topology of vector features, as well as three-dimensional features. The geometry described in ISO 19107 provides a means of quantitative description of features, for example, using coordinates or mathematical functions. The taxonomy of operators includes a formal definition and thus allows for harmonious implementations.
Products	The concepts from ISO 19107 are implemented in applications such as Esri ArcGIS and QuantumGIS. ISO 19107 is also the basis for GML (refer to Table 10.16).

Table 10.51 Temporal schema (ISO 19108:2002)

Full name	ISO 19108:2002, Geographic information – Temporal schema
Version	Edition 1
Amendments	None
Corrigenda	Corrigenda 1
Published by	ISO/TC 211
Languages	English

Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19108:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19137:2007, Geographic information – Core profile of the spatial schema
Application	ISO 19108 defines the concepts for describing temporal characteristics of geographic features.
Conformance classes	Application schemas for data transfer Application schemas for data with operations Feature catalogues Metadata element specifications Metadata for datasets
Implementation benefits	A conceptual schema for temporal characteristics of geographic features allows the development and use of geographic information in applications, such as predictive modelling. ISO 19108 provides the basis for defining the temporal feature attributes, feature operations, and feature associations, and for defining the temporal aspects of metadata about geographic information.
Products	ISO 19108 is implemented in numerous applications, mainly for metadata purposes or for handling time-aware data. Libraries such as GeoTools, implement ISO 19108 to handle all temporal events.

Table 10.52 Rules for application schema (ISO 19109:2005)

Full name	ISO 19109:2005, Geographic information – Rules for application schema
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19109:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19108:2002, Geographic information – Temporal schema ISO 19137:2007, Geographic information – Core profile of the spatial schema
Application	ISO 19109 defines the rules for creating and documenting application schemas, including principles for the definition of features.
Conformance classes	Feature types in an application schema Defining features Creating application schemas in UML
Implementation benefits	ISO 19109 describes a metamodel framework for the definition of features and application schemas. An application schema defines a formal description of the data structure and specifies the associated operators for manipulating and processing data by an application. Application schemas are important for data and application interoperability. ISO 19109 also defines the General Feature Model (GFM), which is a model of the concepts required to classify a view of the real world. The main concepts of GFM are: name, description, feature type, feature attribute, feature associated roles characterizing the feature type, and the defined behaviours of the feature type.
Products	A popular product of ISO 19109 is GML (refer Table 10.16).

Table 10.53 Spatial referencing by coordinates (ISO 19111:2007)

Full name	ISO 19111:2007, Geographic information – Spatial referencing by coordinates
Version	Edition 2

Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19111:ed-2:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19108:2002, Geographic information – Temporal schema ISO/IEC 18026:2009 Information technology -- Spatial Reference Model (SRM)
Application	ISO 19111 defines the conceptual schema for the description of 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.
Conformance classes	Coordinate reference systems Coordinate operations between two coordinate reference systems
Implementation benefits	Coordinates are vague until the system to which they relate is fully defined. ISO 19111 defines a conceptual schema for describing coordinate reference systems. The schema allows interoperability of the coordinate reference system. It also assists in the development of applications that allow the transformation of coordinates.
Products	The concepts from ISO 19111 are implemented commonly in GIS software packages.

Table 10.54 ISO 19125-1:2004, Geographic information – Simple feature access – Part 1: Common access

Full name	ISO 19125-1:2004, Geographic information – Simple feature access – Part 1: Common access
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19125:-1:ed-1:v2:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19109:2005, Geographic information – Rules for application schema ISO 19125-2:2004, Geographic information – Simple feature access – Part 2: SQL option
Application	This part of ISO 19125 describes the common architecture for simple feature geometry.
Conformance classes	Geometry model Correspondence – Geometry type Correspondence – “Atomic” subtype of the Geometry type Correspondence – Collection subtypes of the Geometry type
Implementation benefits	ISO 19125-1 specifies a class Geometry with the following subclasses: Point, Curve, Surface and GeometryCollection. Each geometric object is associated with a Spatial Reference System that describes the coordinate space in which the geometric object is defined. ISO 19125-1 also specifies attributes, methods, and assertions with the geometries. However, ISO 19125-1 does not support topology. ISO 19125-1 allows geometric features to be defined that are interoperable and ‘integratable’ with other objects created using the requirements set out in this standard.
Products	ISO 19125-1 is popular in web applications where the feature needs to be simple and when topology is not a requirement. GeoJSON and GML are examples of implementations of ISO 19125-1.

Table 10.55 Simple feature access – Part 2: SQL option (ISO 19125-2:2004)

Full name	ISO 19125-2:2004, Geographic information – Simple feature access – Part 2: SQL option
Version	Edition 1

Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19125:-2:ed-1:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19125-1:2004, Geographic information – Simple feature access – Part 1: Common access ISO 19107:2003, Geographic information – Spatial schema
Application	Part two of ISO 19125 specifies an SQL schema that supports storage, retrieval, query and update of simple geo-spatial feature collections.
Conformance classes	SQL SQL with Geometry Types
Implementation benefits	ISO 19125-2 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 very simple to use. This extension of SQL is a very effective method of querying a database or performing complex analysis.
Products	Two popular implementations of ISO 19125-2 are PostGIS (an extension of PostgreSQL) and Oracle Spatial.

Table 10.56 Core profile of the spatial schema (ISO 19137:2007)

Full name	ISO 19137:2007, Geographic information – Core profile of the spatial schema
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19137:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19107:2003, Geographic information – Spatial schema ISO 19108:2002, Geographic information – Temporal schema ISO 19109:2005, Geographic information – Rules for application schema ISO 19111:2007, Geographic information -- Spatial referencing by coordinates ISO 19118:2011, Geographic information – Encoding ISO 19136:2007, Geographic information -- Geography Markup Language (GML)
Application	ISO 19137 defines a set of profiles of the spatial schema to provide a minimal set of geometric elements necessary for an efficient creation of application schemata. These profiles include components from ISO 19107, ISO 19108, ISO 19109 and ISO 19111.
Conformance classes	Data types for 0-dimensional geometry Data types for 1-dimensional geometry Data types for 2-dimensional geometry
Implementation benefits	The intent of ISO 19137 is to provide a smaller subset of the numerous classes available in ISO 19107 in order to simplify some applications of spatial schemas. ISO 19137 supports many of the spatial data formats and description languages already developed and in broad use within several nations or liaison organisations. ISO 19137 also clarifies the corresponding encoding rules in ISO 19118.
Products	The concepts from ISO 19137 drive the development of applications, such as Esri ArcGIS and Quantum GIS.

Table 10.57 S-58 IHO Recommended ENC validation checks (draft)

Version	Edition 5.0.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English
Online overview	http://iho.int/iho_pubs/draft_pubs/S-58_e5.0.0/Draft_S-58_ENC_Validation_Checks_e5.0.0.pdf
Type of standard	IHO Recommendation Instance level
Related standard(s)	S-57 IHO transfer standard for digital hydrographic data
Application	S-57 recommends the validation checks which producers of validation tools for Electronic Navigational Charts (ENC) should implement in their software. S-58 replaces S-57 IHO transfer standard for digital hydrographic data Edition 3.1.0.
Conformance classes	None specified
Implementation benefits	ENC software validates that data are conformant with the IHO S-57 ENC product specification. Conformance violations are labelled as either an error or as a warning. This is important to ensure that the correct ENC is produced and that the software is implemented according to the same standard.
Products	S-58 should be implemented by all ENC applications.

11. STANDARDS FOR DISSEMINATION OF FUNDAMENTAL GEO-SPATIAL DATASETS

11.1 Introduction

The first and second parts of this chapter provide implementation guidelines for metadata and feature catalogue standards used in the dissemination of geo-spatial data. The third part covers map standards and the fourth part provides a tabular overview of standards used in the dissemination of geo-spatial data over the Web.

11.2 Metadata standards for disseminating fundamental geo-spatial datasets

11.2.1 The Dublin Core metadata element set (ISO 15836:2009)

Table 11.1 Overview of ISO 15836:2009

Full name	ISO 15836:2009, Information and documentation – The Dublin Core metadata element set
Version	Edition 2
Amendments	None
Corrigenda	None
Published by	ISO/TC 46/SC 4
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:15836:ed-2:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19115:2003, Geographic information -- Metadata
Application	This standard specifies how to document metadata for a wide variety of resources.
Conformance classes	None

Scope

ISO 15836:2009 establishes a standard for cross-domain resource description, known as the Dublin Core Metadata Element Set. Like RFC 3986, this International Standard does not limit what might be a resource.

ISO 15836:2009 defines the elements typically used in the context of an application profile, which constrains or specifies their use in accordance with local or community-based requirements and policies. However, it does not define implementation detail, which is outside the scope of ISO 15836:2009.

Implementation benefits

Because ISO 15836 is so popular, it is probably useful for providing high-level metadata of the likes of a dataset series (e.g. a national medium scale mapping series), so that it can be documented with other resources within the organisation. However, because it uses free text and is at a high level, it is difficult to use effectively any such metadata describing an individual geo-spatial dataset, never mind describing individual features within the dataset.

Implementation guidelines

ISO 15836:2009 is very short (only 13 pages) and hence easy to understand. It is widely used for describing documents and other resources, not only within the library community (where it originated). It specifies 15 metadata elements (properties) for describing a resource, which are documented using free text: title, creator, subject, description, publisher, contributor, date, type, format, identifier, source, language, relation, coverage and rights. This makes it easy to write Dublin Core metadata (any text will conform to the standard), but very difficult to automate metadata operations.

However, ISO 15836:2009 is essentially only the high-level framework for metadata (the 15 metadata elements listed in the previous paragraph) and the Dublin Core Metadata Initiative (DCMI) has developed many other resources built on it, such as more-detailed metadata vocabularies, encodings, resource classes, profiles and tools. DCMI has also done much work on embedding Dublin Core metadata into the work of the World Wide Web Consortium (W3C), particularly implementing Dublin Core in RDF (Resource Description Framework) for supporting linked data. For more details and resources, see: http://dublincore.org/.

11.2.2 Metadata (ISO 19115:2003)

Table 11.2 Overview of ISO 19115:2003

Full name	ISO 19115:2003, Geographic information – Metadata
Version	Edition 1 (withdrawn)
Amendments	None
Corrigenda	ISO 19115:2003/Cor 1 2006, Geographic information – Metadata – Corrigendum 1
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19115:-2:ed-1:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19115-2:2009, Geographic information — Metadata — Part 2: Extensions for imagery and gridded data ISO 19115-3, Geographic information – Metadata – Part 3: XML schema implementation of metadata fundamentals ISO 19131:2007, Geographic information – Data product specifications ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation ISO/TS 19139-2:2012, Geographic information -- Metadata -- XML Schema Implementation -- Part 2: Extensions for imagery and gridded data ISO 15836:2009, Information and documentation – The Dublin Core metadata element set
Application	The standard specifies how to document metadata, which includes information on data quality, lineage, etc.
Conformance classes	Maximum occurrence Short name Data type Domain Schema User-defined extension metadata Exclusiveness Definition Standard metadata Metadata profiles

Scope

ISO 19115:2003 defines the schema required for describing geographic information and services. It provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.

ISO 19115:2003 is applicable to:

- the cataloguing of datasets, clearinghouse activities, and the full description of datasets;
- geographic datasets, dataset series, and individual geographic features and feature properties.

ISO 19115:2003 defines:

- mandatory and conditional metadata sections, metadata entities, and metadata elements;
- the minimum set of metadata required to serve the full range of metadata applications (data discovery, determining data fitness for use, data access, data transfer, and use of digital data);
- optional metadata elements – to allow for a more extensive standard description of geographic data, if required;
- a method for extending metadata to fit specialized needs.

Though ISO 19115:2003 is applicable to digital data, its principles can be extended to many other forms of geographic data such as maps, charts, and textual documents as well as non-geographic data.

NOTE Certain mandatory metadata elements may not apply to these other forms of data.

Implementation benefits

Unfortunately, there is a perception that metadata are difficult and tedious to capture, and of no real value. Indeed, some suggest that with the power of search engines, metadata are actually unnecessary – which betrays a poor understanding of what metadata are. The claim is that the search engines are so good that they can find everything, but metadata often includes information that would otherwise not be available – even to a search engine.

ISO 19115-1:2014 is a revision of ISO 19115:2003 and hence will replace it. ISO 19115:2003 will probably remain available through ISO (as withdrawn rather than deleted), because of the masses of legacy metadata already in the ISO 19115:2003 format. If one uses geospatial data from other organisations, then one will probably have to implement ISO 19115:2003 to be able to read and process the metadata of such geospatial datasets. However, ISO 19115:2003 has been implemented directly in many GISs, both proprietary and open source, so it is likely that one's system already supports ISO 19115:2003. Nevertheless, it is still necessary to understand the standard to be able to interpret the metadata.

On the other hand, if one is starting from scratch with the capturing of metadata for geospatial datasets that one is producing, then it would be best to start with ISO 19115-1:2014, which has now been published and is summarised below.

Implementation guidelines

ISO 19115 is used widely and has been implemented directly in many different GISs, both proprietary and open source. There are also stand-alone and/or web-based metadata editors available that support ISO 19115. To varying extents, these GISs and editors can automate the capture of metadata.

These GISs and editors also typically support Content Standard for Digital Geospatial Metadata (CSDGM) from the Federal Geographic Data Committee (FGDC) of the U.S. and other metadata standards, so care must be taken to select the correct standard before capturing metadata. CSDGM is largely similar to ISO 19115 and there is a crosswalk between the two standards. Because ISO 19115 is generally encoded and ISO 15836 (Dublin Core) is primarily free text, it is relatively easy to convert from ISO 19115 to ISO 15836, but not the other way around.

Similar standards are:

- ISO 19115-1:2014, Geographic information – Metadata – Part 1: Fundamentals
- ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data
- ISO 19119:2005/Amd 1:2008, Extensions of the service metadata model
- CSDGM, a predecessor of ISO 19115 (also known as FGDC, the committee responsible for it)

While ISO 19115:2003 was published in May 2003, a substantial corrigendum (of 33 pages) for ISO 19115:2003 was published in July 2006. When one purchases ISO 19115:2003, the corrigendum should be included at the beginning of the document.

ISO 19115:2003 allows metadata to be defined 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 includes a comprehensive dataset metadata profile with hundreds of metadata elements. There are 14 packages of metadata:

1. Metadata entity set information, MD_Metadata
2. Identification information, MD_Identification
3. Constraint information, MD_Constraints
4. Data quality information, DQ_DataQuality
5. Maintenance information, MD_MaintenanceInformation
6. Spatial representation information, MD_SpatialRepresentation
7. Reference system information, MD_ReferenceSystem
8. Content information, MD_ContentInformation
9. Portrayal catalogue information, MD_PortrayalCatalogueReference
10. Distribution information, MD_Distribution

11. Metadata extension information, MD_MetadataExtensionInformation

12. Application schema information, MD_ApplicationSchemaInformation

13. Extent information, EX_Extent

14. Citation and responsible party information, CI_Citation & CI_ResponsibleParty

ISO 19115:2003 defined a core metadata profile, primarily for cataloguing purposes, but it is what most users are likely to have implemented, possibly with a few additions. Nominally, this core profile has only 22 metadata elements, as shown in Table 11.3, but in practice this expands into many more metadata elements. The draft African profile of ISO 19115:2003 followed this approach. It was compiled in 2007 for the CODIST-Geo Working Group on Standards: CODIST is the Committee on Development Information, Science and Technology, established to inform the United Nations Economic Commission for Africa (UN ECA) on development challenges, and CODIST-Geo is the CODIST Sub-committee for Geo-information. Unfortunately, funding was not available to complete and publish the African profile of ISO 19115:2003.

Table 11.3 ISO 19115:2003 Core profile

Metadata	Metadata element
Dataset title (M)	(MD_Metadata > MD_DataIdentification.citation > CI_Citation.title)
Dataset reference date (M)	(MD_Metadata > MD_DataIdentification.citation > CI_Citation.date)
Dataset responsible party (O)	(MD_Metadata > MD_DataIdentification.pointOfContact > CI_ResponsibleParty)
Geographic location of the dataset (by four coordinates or by geographic identifier) (C)	(MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_GeographicExtent > EX_GeographicBoundingBox or EX_GeographicDescription)
Dataset language (M)	(MD_Metadata > MD_DataIdentification.language)
Dataset character set (C)	(MD_Metadata > MD_DataIdentification.characterSet)
Dataset topic category (M)	(MD_Metadata > MD_DataIdentification.topicCategory)
Spatial resolution of the dataset (O)	(MD_Metadata > MD_DataIdentification.spatialResolution > MD_Resolution.equivalentScale or MD_Resolution.distance)
Abstract describing the dataset (M)	(MD_Metadata > MD_DataIdentification.abstract)
Distribution format (O)	(MD_Metadata > MD_Distribution > MD_Format.name and MD_Format.version)
Additional extent information for the dataset (vertical and temporal) (O)	(MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_TemporalExtent or EX_VerticalExtent)
Spatial representation type (O)	(MD_Metadata > MD_DataIdentification.spatialRepresentationType)
Reference system (O)	(MD_Metadata > MD_ReferenceSystem)
Lineage (O)	(MD_Metadata > DQ_DataQuality.lineage > LI_Lineage)
On-line resource (O)	(MD_Metadata > MD_Distribution > MD_DigitalTransferOption.onLine > CI_OnlineResource)
Metadata file identifier (O)	(MD_Metadata.fileIdentifier)
Metadata standard name (O)	(MD_Metadata.metadataStandardName)
Metadata standard version (O)	(MD_Metadata.metadataStandardVersion)
Metadata language (C)	(MD_Metadata.language)
Metadata character set (C)	(MD_Metadata.characterSet)

Metadata point of contact (M)	(MD_Metadata.contact > CI_ResponsibleParty)
Metadata date stamp (M)	(MD_Metadata.dateStamp)

NOTE: in the left-hand column, (M) is Mandatory, i.e. this element shall always be included in the metadata to conform to the profile; (C) is Conditional, i.e. this element shall be included in the metadata, only if a certain condition has been met; and (O) is Optional, i.e. this element may be included, at the discretion of the person or organisation compiling the metadata.

ISO19115:2003 provides in Clause 6, an overview of the metadata catered for by the standard. The detailed metadata are described in Annex A using UML diagrams and in Annex B using a data dictionary, that is, a table with detailed text descriptions of the metadata elements, the metadata entities (logical groups of metadata elements) and the code lists. The tables in Annex B are formatted according to ISO/IEC 11179, Information technology – Metadata registries (MDR). The data dictionary is probably easier for most users to read, but the UML diagrams show how all the metadata packages, entities and elements are structured.

Annex C of ISO 19115:2003 provides rules for how extensions to, and profiles of, the standard may be created and Annex F describes a recommended methodology for creating metadata extensions. Annex E provides the comprehensive dataset metadata application profile, which is not simply everything defined in Annexes A and B. It consists of the classes, attributes and relationships needed for the metadata for a general purpose dataset, excluding the service-related classes, for example. Annexes G and H present guidelines on implementing the standard and Annex I contains some examples of metadata conforming to the standard. Finally, Annex J describes how ISO 19115:2003 provides multilingual support for free text metadata elements, which allows for text in multiple languages and character sets to be included in the same metadata file. With the variety of languages used across Africa, this is clearly an advantage for using ISO 19115:2003 in Africa.

11.2.3 Metadata – Part 1: Fundamentals (ISO 19115-1:2014)

Table 11.4 Overview of ISO 19115-1

Full name	ISO 19115-1:2014, Geographic information – Metadata – Part 1: Fundamentals
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19115:-1:ed-1:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19115-2:2009, Geographic information — Metadata — Part 2: Extensions for imagery and gridded data ISO 19115-3, Geographic information – Metadata – Part 3: XML schema implementation of metadata fundamentals ISO 19131:2007, Geographic information – Data product specifications ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation ISO/TS 19139-2:2012, Geographic information -- Metadata -- XML Schema Implementation -- Part 2 : Extensions for imagery and gridded data ISO 19157:2013, Geographic information – Data quality ISO 15836:2009, Information and documentation – The Dublin Core metadata element set

Application	The standard specifies how to document metadata, which includes information on data quality, lineage, etc.
Conformance classes	Completeness test Maximum occurrence test Data type test Domain test Schema test Exclusiveness test Definition test Standard metadata test Metadata profiles

Scope

This part of ISO 19115 defines the schema required for describing geographic information and services by means of metadata. It provides information about the identification, the extent, the quality, the spatial and temporal aspects, the content, the spatial reference, the portrayal, distribution, and other properties of digital geographic data and services.

This part of ISO 19115 is applicable to:

- the cataloguing of all types of resources, clearinghouse activities, and the full description of datasets and services;
- geographic services, geographic datasets, dataset series, and individual geographic features and feature properties.

This part of ISO 19115 defines:

- mandatory and conditional metadata sections, metadata entities, and metadata elements;
- the minimum set of metadata required to serve most metadata applications (data discovery, determining data fitness for use, data access, data transfer, and use of digital data and services);
- optional metadata elements – to allow for a more extensive standard description of resources, if required;
- a method for extending metadata to fit specialized needs.

Though this part of ISO 19115 is applicable to digital data and services, its principles can be extended to many other types of resources such as maps, charts, and textual documents as well as non-geographic data. Certain conditional metadata elements might not apply to these other forms of data.

Implementation benefits

ISO 19115-1:2014 is a revision of ISO 19115:2003 (with its corrigendum) and hence replaces it, but because of the sheer volume of legacy metadata already in the latter format, ISO 19115:2003 will probably remain available through ISO (as withdrawn rather than deleted). Hence, while one will probably need to support ISO 19115 for all the legacy metadata one will use, it will be better to

implement ISO 19115-1:2014 for all new metadata captured. Many proprietary and open source GISs already support ISO 19115:2003 and they should soon support ISO 19115-1:2014. Nevertheless, it is still necessary to understand the standard to be able to interpret the metadata.

Implementation guidelines

ISO 19115-1:2014 is structured similarly to ISO 19115:2003, but all the UML diagrams have been included together in Clause 6, rather than split between the main text and an annex. The abstract test suite is now in Annex A (as is usual for the standards of ISO/TC 211), the data dictionary is still in Annex B, and the rules for extensions and profiles are still in Annex C. The annex with the comprehensive dataset metadata application profile has been removed. The informative annexes have been consolidated into two: Annex D has implementation examples and Annex E covers metadata implementation. There is also a new, normative Annex F, which provides the discovery metadata for geographic resources – effectively, it is the minimum metadata to be implemented for inclusion in a catalogue of products and/or services. Referring to the last sentence of the scope, an example of a conditional metadata element that does not apply to other forms of data is the element 'defaultLocale', which is only relevant for digital data.

Most importantly for migrating from ISO 19115:2003 to ISO 19115-1:2014, Annex G provides the details of the changes made in the revision, which are also summarised in the Introduction. Most of the changes were adding new attributes (but not new mandatory ones) and extending code lists to improve the functionality of the standard, such as catering better for online services and repositories. The major changes were:

- Removing the data quality information package, which is now part of ISO 19157:2013, Geographic information – Data quality.
- Including the service metadata from ISO 19119:2005, Geographic information – Services, and ISO 19119:2005/Amd 1:2008.
- Removing the concept of "core metadata".
- Making clear that the scope of ISO 19115-1:2014 is not limited only to describing conventional, structured geospatial datasets, but is also for describing services, unstructured datasets with geospatial references, initiatives, repositories, analogue maps and other analogue resources, such as specimens and other artefacts.
- The UML packages, classes, and elements in ISO 19115-1:2014 have different identifiers from those in ISO 19115:2003, because they are independent standards and to ensure that there is no confusion caused by a mixed environment of metadata to be discovered and interpreted.
- Where elements were changed, the old one was deleted and replaced with a new one with a different name.
- Some definitions were broadened.
- The "Short name" and "Domain code" are no longer used, as they are now redundant. This removes one column from the data dictionary tables in Annex B.

The abstract class DS_Resource has been added to the high-level metadata application diagram (Figure 1 in ISO 19115:2014) to make clear that ISO 19115-1:2014 metadata applies to resources and aggregations of resources other than just geospatial datasets, such as services.

11.2.4 Metadata – Part 2: Extensions for imagery and gridded data (ISO 19115-2:2009)

Table 11.5 Overview of ISO 19115-2:2009

Full name	ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19115:-2:ed-1:v1:en
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19115:2003, Geographic information – Metadata ISO 19139:2007, Geographic information – Metadata – XML schema implementation ISO/TS 19139-2:2012, Geographic information – Metadata – XML schema implementation – Part 2: Extensions for imagery and gridded data
Application	The standard specifies how to document metadata for imagery and gridded data, which includes information on data quality, lineage, etc.
Conformance classes	Completeness Maximum occurrence Short name Data type Domain Schema Exclusiveness Definition Standard metadata Metadata profiles

Scope

This part of ISO 19115 extends the existing geographic metadata standard by defining the schema required for describing imagery and gridded data. It provides information about the properties of the measuring equipment used to acquire the data, the geometry of the measuring process employed by the equipment, and the production process used to digitize the raw data. This extension deals with metadata needed to describe the derivation of geographic information from raw data, including the properties of the measuring system, and the numerical methods and computational procedures used in the derivation. The metadata required to address coverage data in general is addressed sufficiently in the general part of ISO 19115.

Implementation benefits

ISO 19115-2:2009 is an extension of ISO 19115:2003, *Geographic information – Metadata*, defining metadata for imagery and gridded data. As such, it needs to be used in conjunction with ISO 19115:2003, as the latter defines the metadata for the dataset in general and for coverages in general. ISO 19115-2:2009 defines the metadata for the measuring equipment used to acquire the data (such

as a satellite-borne sensor), the geometry of the acquisition and the production processes to produce the dataset.

As the revision of ISO 19115:2003, namely ISO 19115-1:2014, Geographic information – Metadata – Part 1: Fundamentals, has now been published, ISO 19115-2:2009 will need to be revised to benefit from ISO 19115-1:2014. The current version of ISO 19115-2:2009 will be deprecated when its revision is published, but will still be available because of the masses of legacy metadata conforming to ISO 19115-2:2009.

Implementation guidelines

Implementing ISO 19115-2:2009 is essentially the same as implementing ISO 19115:2003 and it is also supported by a wide variety of proprietary and open-source GISs and stand-alone and web-based metadata editors. Note that ISO 19115-2:2009 refers to quality elements defined in ISO 19115:2003 and when ISO 19115-2:2009 is revised, these will refer to the quality elements now in ISO 19157:2013. To the metadata packages, entities and elements defined in ISO 19115:2003, ISO 19115-2:2009 adds the following:

- **Metadata entity set – Imagery**: the package MI_Metadata are for the acquisition information for the imagery or gridded data.
- **Data quality information**: imagery, coverage result, lineage and usability. For the imagery coverage result, QE_CoverageResult consists of the spatial representation, coverage description and data format, which are all defined in ISO 19115:2003. This is necessary because the actual spatial representation of the imagery or gridded data might differ from that of its related coverage (e.g. if the coverage is computed from a subset of the whole dataset). This is coupled with MX_DataFile, which is defined in ISO 19139:2007, Geographic information – Metadata – XML schema implementation, and is a description of the transfer dataset in XML. For usability, QE_Useability specifies the degree of adherence of the dataset to a specific set of user requirements. For the extensions to lineage, there are six new classes specified: LE_Source (input and output datasets), LE_ProcessStep (the event or transformation of the process step from one version of the dataset to the next), LE_ProcessStepReport (the report produced by the process step), LE_Processing (the procedures, processes and algorithms applied during the process step), LE_Algorithm (methodology for obtaining geospatial data from the instrument readings) and LE_NominalResolution (scanning and ground resolution).
- **Spatial representation information – Imagery**: extension to georectified and georeferenceable classes, and ground control point quality. MI_GCP specifies a ground control point, which can have its data quality specified using the data quality elements in ISO 19115:2003. MI_GCPCollection is then a designated set of GCPs, which MI_GeolocationInformation uses to determine geographic location corresponding to image location. MI_Georeferenceable uses MI_GeolocationInformation to allow the geographic or map locations of the raster points to be located. MI_Georectified uses MI_GCP to provide checkpoints.

- **Content information – Imagery**: further details of the coverage, imagery, band, polarisation, transfer function and range element. MI_Band provides details of the wavelength band, its boundaries, nominal spatial resolution, transfer function for scaling, and transmitted and detected polarization. MI_CoverageDescription and MI_ImageDescription describe the specific range elements of the coverage and image respectively, using MI_RangeElementDescription, which names and describes the range elements (the range of a sensor is across its track, so the elements in the range should be the same for each sweep of the sensor).

Acquisition information – Imagery: further details of the platform, plan, instrument, operation, environmental record, objective and requirement. MI_EnvironmentalRecord documents the air temperature, relative humidity, maximum altitude and other meteorological conditions for photo flights. MI_Event documents the trigger, context, sequence and time of a significant collection point for an objective and pass of an instrument. MI_Instrument documents a particular instrument. MI_Objective documents the priority, type, function, spatial and temporal extents, and events of a target for a pass of an instrument. MI_Operation documents the status, type and other details of the plan and platform for an operation, including its relationships with possible child and parent operations. MI_Plan documents the type, status and authority of a plan, the activities that satisfy the plan and the requirement satisfied by the plan. MI_Platform documents a platform, including its sensors and sponsor. MI_PlatformPass documents the collection coverage of a pass. MI_RequestedDate documents the preferred and latest date and time for a desired collection. MI_Requirement documents the requirements to be satisfied by the planned data acquisition, including the requestor, recipient, priority and dates.

11.2.5 Metadata – Part 3: XML implementation of fundamentals (ISO/TS 19115-3)

Table 11.6 Overview of ISO 19115-3

Full name	ISO/TS 19115-3, Geographic information – Metadata – Part 3: XML implementation of fundamentals
Version	Draft Technical Specification (DTS)
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not yet available
Type of standard	ISO International Standard Application level
Related standard(s)	ISO 19118:2011, Geographic information – Encoding ISO 19136:2007, Geographic information – Geography Markup Language (GML) ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation
Application	XML implementation of ISO 19115-1, *Geographic information – Metadata – Part 1: Fundamentals*
Conformance classes	As this standard is an XML implementation, it specifies many conformance classes for the XML schema implementation that can be tested automatically by a validation tool that implements the full W3C XML Schema.

Scope

ISO/TS 19115-3 defines five artefacts to support the use of ISO 19115-1 compliant metadata and migration from ISO19115 to ISO19115-1. These include

1) an XML Schema that implements ISO 19115-1 using encoding rules from ISO 19118 Annex A and ISO 19139 for XML metadata encoding;

2) a set of ISO/IEC 19757-3 (Schematron) rules that implement validation constraints included in the ISO 19115-1 UML Model that are not specified by the XML schema;

2a) a set of ISO/IEC 19757-3 (Schematron) rules that identify content in documents encoded using the XML schema defined in ISO 19115-1 (this Technical Specification) that will not translate to ISO 19115 metadata encoded using the ISO 19139 XML schema;

3) an Extensible Stylesheet Language Transformation (XSLT) for transforming XML-encoded ISO 19115 metadata using the ISO 19139 XML schema into an equivalent document encoded using the XML schema defined in ISO 19115-3 (this Technical Specification); and

3a) an Extensible Stylesheet Language Transformation (XSLT) for transforming metadata encoded using the XML schema defined in ISO 19115-3 (this Technical Specification) into an XML-encoded ISO 19115 metadata document using the ISO 19139 XML schema (this transform will not include all content in the 19115-1 document).

Implementation benefits

This standard specifies the implementation of ISO 19115-1:2014, Geographic information – Metadata – Part 1: Fundamentals, in XML, using parts of the GML, which is defined in ISO 19136:2007, Geographic information – Geography Markup Language (GML). While this standard is still a draft and hence likely to change, it should not change significantly as ISO 19115-1:2014 has already been published. The benefit of implementing ISO 19115-3 will be to access all the metadata encoded using it, and to promote one's products and services by providing one's metadata to clearinghouses using ISO 19115-3 for disseminating metadata.

However, this does not mean that the only way to implement ISO 19115-1:2014 is through XML, as defined in ISO 19115-3. ISO 19115-1 can be implemented in databases and GISs, and encoded using other markup languages such as JSON or GeoJSON, interchange formats such as ISO/IEC 8211 or ASN.1, or even as comma-separated values (CSV).

In the same way that ISO 19115-1:2014 replaces ISO 19115:2003, while leaving a legacy of much metadata conforming to ISO 19115:2003, ISO 19115-3 will replace ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation (the XML implementation of ISO 19115:2003) as the preferred XML schema implementation, but will not invalidate all the metadata already generated that conforms to ISO 19139:2007. ISO 19115-3 also specifies the XSLT (Extensible Stylesheet Language Transformation) for converting metadata from ISO 19139:2007 to ISO 19115-3 and vice versa, though converting from ISO 19115-3 to ISO 19139:2007 will obviously lose that content not defined in ISO 19139:2007. ISO 19139:2007 also defines some general rules and is being revised to cater for them, and not the XML schema implementation of metadata.

Implementation guidelines

ISO 19115-3 implements the entire UML model from ISO 19115-1:2014, through a collection of XML schema that conform to ISO 19118:2011, Geographic information – Encoding, and ISO 19139:2007. The XML schemas are derived algorithmically from the UML. Unsurprisingly, the standard requires a sound knowledge of XML to understand it.

Clause 6.1 provides an overview of the XML schema for geospatial metadata. Clause 5.2 specifies the namespaces used in this standard, clause 5.4 the UML model stereotypes, clause 6.2 the multi-lingual adaptability and polymorphism, and clauses 6.3, 6.4, 6.5 and 6.6 the requirements classes. Clause 6.7 shows in a diagram, the dependencies between encoding requirements classes.

Clause 7 provides the model extensions defined in ISO 19139:2007. Clause 8 provides the encoding rules, which are also described in ISO 19139:2007. Annex D provides encoding descriptions and Annex E provides some implementation examples.

The actual XML will probably be provided in an online repository, rather than just printed out in the standard.

11.2.6 Metadata – XML schema implementation (ISO/TS 19139:2007)

Table 11.7 Overview of ISO/TS 19139:2007

Full name	ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not yet available
Type of standard	ISO Technical Specification Application level
Related standard(s)	ISO 19109:2005, Geographic information - Rules for application schema ISO 19115:2003, Geographic information – Metadata ISO/TS 19115-3, Geographic information – Metadata – Part 3: XML implementation of fundamentals ISO 19118:2011, Geographic information – Encoding ISO 19136:2007, Geographic information – Geography Markup Language (GML) ISO/TS 19139-2:2012, Geographic information – Metadata – XML schema implementation – Part 2: Extensions for imagery and gridded data
Application	XML implementation of ISO 19115:2003, *Geographic information – Metadata*
Conformance classes	Constraints by-value or by-reference or gco:nilReason Co-constraints Extensions Restrictions

Scope

ISO/TS 19139:2007 defines Geographic MetaData XML (gmd) encoding, an XML schema implementation derived from ISO 19115.

Implementation benefits

This standard specifies the implementation of ISO 19115:2003, Geographic information – Metadata, in XML, using parts of GML, which is defined in ISO 19136:2007, Geographic information – Geography Markup Language (GML). In the same way that ISO 19115-1:2014 replaces ISO 19115:2003, while leaving a legacy of much metadata conforming to ISO 19115:2003, ISO/TS 19115-3, Geographic information – Metadata – Part 3: XML implementation of fundamentals (the XML implementation of ISO 19115-1:2014), will replace ISO 19139:2007 as the preferred XML schema implementation, but will not invalidate all the metadata already generated that conforms to ISO 19139:2007. ISO 19139:2007 also defines some general rules and is being revised to cater for them, and not the XML schema implementation of metadata.

The benefit of implementing ISO 19139:2007 will be to access all the metadata encoded using it, and until ISO 19115-3 has been published and implemented, to promote one's products and services by providing one's metadata to clearinghouses using ISO 19139:2007 for disseminating metadata.

However, this does not mean that the only way to implement ISO 19115:2003 is through XML, as defined in ISO 19139:2007. ISO 19115:2003 can be implemented in databases and GISs, and encoded using other markup languages such as JSON or GeoJSON, interchange formats such as ISO/IEC 8211 or ASN.1, or even as comma-separated values.

Implementation guidelines

ISO 19139:2007 implements the metadata defined in ISO 19115:2003 through a collection of XML schema that conform to ISO 19118:2011, Geographic information – Encoding. Unsurprisingly, the standard requires a sound knowledge of XML to understand it. The reader also needs to understand ISO 19118.

Clause 5.2 specifies the namespaces used in this standard and clause 5.4 the UML model stereotypes. Clauses 6.1 to 6.8 provide brief overviews of the gmd namespace (geographic metadata extensible markup language), rule-based encoding, quality, web implementations, incorporating other existing XML schemas, multi-lingual support, polymorphism (supporting both multiple languages in the metadata and more detailed versions of metadata elements), and explaining how ISO 19139 conforms to ISO 19109:2005, Geographic information - Rules for application schema. Clause 7 describes how to implement extensions to the UML models, not so much for extensions to the metadata defined in ISO 19115:2003, but particularly for extending the CharacterString class to cater better for XML, including hyperlinks, URIs (uniform resource identifier) and file types; implementing multi-lingual free text and locales (language, country and character set) for text, which are not catered for in plain XML; transferring and aggregating datasets; and catalogues of coordinate reference systems, units of measure and code lists. Clause 8 provides details of how the encoding rules of ISO 19118:2001 have been implemented in ISO 19139:2007, particularly as ISO 19118 allows for multiple ways of transforming UML into XML. It covers the default XML Class Type encoding (a class is made up of one or more properties, such as attributes, associations, aggregations and compositions), XML Class Global Element encoding, XML Class Property Type encoding, special case encodings (abstract classes, inheritance, subclasses, enumerations, code lists, unions, metaclasses and externally

identified implementations), XML namespace package encoding, and XML schema package encoding. Clause 9 provides the encoding descriptions, the relationships between the various namespaces used (gmx, gmd, gts, gss, gsr, gco), the organisation of the namespaces and their many XML Schema Definitions (XSDs) for all the metadata and other relevant packages, entities and elements defined in ISO 19115:2003 and other standards.

Annex B provides a data dictionary for extensions defined in clause 7, for web environment extensions, cultural and linguistic adaptability extensions, interchange or transfer, and code lists and enumerations. Annex C provides a brief summary of geographic metadata XML resources, specifically their URIs. Annex D provides implementation examples in XML. The actual XML defined in ISO 19139:2007 is provided in an online repository, rather than just printed out in the standard. The repository is maintained by ISO itself and caters for standards from a variety of ISO Technical Committees. See http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/ and http://standards.iso.org/iso/19139/.

11.2.7 Metadata – XML schema implementation – Part 2: Extensions for imagery and gridded data (ISO/TS 19139-2:2012)

Table 11.8 Overview of ISO/TS 19139-2:2012

Full name	ISO/TS 19139-2:2012, Geographic information – Metadata – XML schema implementation – Part 2: Extensions for imagery and gridded data
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English
Online overview	Not yet available
Type of standard	ISO Technical Specification Application level
Related standard(s)	ISO 19109:2005, Geographic information - Rules for application schema ISO 19115:2003, Geographic information – Metadata ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data, ISO 19118:2011, Geographic information – Encoding ISO 19136:2007, Geographic information – Geography Markup Language (GML) ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation
Application	XML implementation of ISO 19115-2:2009, *Geographic information – Metadata – Part 2: Extensions for imagery and gridded data*
Conformance classes	XML Schema implementation XML document

Scope

This Technical Specification defines Geographic Metadata for imagery and gridded data (gmi) encoding. This is an XML Schema implementation derived from ISO 19115-2, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data.

Implementation benefits

This standard specifies the implementation of ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data, in XML. It uses and extends ISO

19139:2007, Geographic information – Metadata – XML schema implementation, which uses parts of GML, which is defined in ISO 19136:2007, Geographic information – Geography Markup Language (GML).

As the revision of ISO 19115:2003, Geographic information – Metadata, namely ISO 19115-1:2014, Geographic information – Metadata – Part 1: Fundamentals, has now been published, ISO 19115-2:2009 and ISO 19139-2:2012 will both need to be revised to benefit from ISO 19115-1:2014. As with the revision of ISO 19115:2003, the current versions of ISO 19115-2:2009 and ISO 19139-2:2012 will then be deprecated when their revisions are published, but will still be available because of the masses of legacy metadata conforming to ISO 19115-2:2009 and ISO 19139:2012.

The benefit of implementing ISO 19139-2:2012 will be to access all the metadata encoded using it and to promote one's products and services by providing one's metadata to clearinghouses using ISO 19139-2:2012 for disseminating metadata.

However, this does not mean that the only way to implement ISO 19115-2:2009 is through XML, as defined in ISO 19139-2:2012. ISO 19115-2:2009 can be implemented in databases and GISs, and encoded using other markup languages such as JSON or GeoJSON, interchange formats such as ISO/IEC 8211 or ASN.1, or even as comma-separated values.

Implementation guidelines

ISO 19139-2:2012 is an extension to ISO 19139:2007 and implements the metadata defined in ISO 19115-2:2009 through a collection of XML schema that conform to ISO 19118:2011, Geographic information – Encoding. Unsurprisingly, the standard requires a sound knowledge of XML to understand it. The reader also needs to understand ISO 19118.

Clause 5.2 specifies the UML model stereotypes used in this standard. Clause 6 describes the XML namespaces used in this standard, namely gmi, gco, gmd, gml, gmx, gss, gsr and gts. With the exception of gmi (Geographic Metadata for imagery and gridded data), these are the same namespaces used in ISO 19139:2007. Clause 6 also provides the XML Schema Definitions (XSDs) for gmi. Clause 7 briefly describes the XML document requirements.

Annex B briefly describes the XML resources related to geographic metadata for imagery and gridded data and Annex C provides some implementation examples. The actual XML defined in ISO 19139-2:2012 is provided in an online repository, rather than just printed out in the standard. This is not the ISO repository used for ISO 19139:2007, but rather an ISO/TC 211 repository that is also used for ISO 19139:2007 and other standards from ISO/TC 211. See http://www.isotc211.org/2005/.

11.3 Feature catalogue standards for disseminating fundamental geo-spatial datasets

11.3.1 Methodology for feature cataloguing (ISO 19110:2005)

Table 11.9 Overview of ISO 19110:2005

Full name	ISO 19110:2005, Geographic information – Methodology for feature cataloguing
Version	Edition 1
Amendments	ISO 19110:2005/Amd 1:2011
Corrigenda	None
Published by	ISO/TC 211

Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19110:ed-1:v1:en
Type of standard	ISO International Standard Meta and application level
Related standard(s)	ISO/TS 19103:2005, Geographic information – Conceptual schema language ISO 19109:2005, Geographic information – Rules for application schema ISO 19115:2003, Geographic information – Metadata ISO 19117:2012, Geographic information – Portrayal ISO 19126:2009, Geographic information – Feature concept dictionaries and registries ISO 19135:2005, Geographic information — Procedures for item registration ISO/TS 19139:2007, Geographic information — Metadata — XML schema implementation
Application	This standard does not define a feature catalogue (or feature classification system, as many would understand it), but specifies the methodology for cataloguing feature types (or feature classes, as many would understand it) to compile a feature catalogue. However, it does not specify how to decide what the feature types should be (their collection criteria).
Conformance classes	Catalogue with single-use feature attributes Catalogue with single-use feature attributes and association roles Catalogue with single-use feature attributes, association roles and operations Catalogue with multiple-use feature attributes, associations and operations Catalogue with single-use feature attributes and inheritance Catalogue with single-use feature attributes and association roles with inheritance Catalogue with single-use feature attributes, association roles and operations with inheritance

Scope

ISO 19110:2005 defines the methodology for cataloguing feature types. This International Standard specifies how feature types can be organised into a feature catalogue and presented to the users of a set of geographic data. ISO 19110:2005 is applicable to creating catalogues of feature types in previously uncatalogued domains and to revising existing feature catalogues to comply with standard practice. ISO 19110:2005 applies to the cataloguing of feature types that are represented in digital form. Its principles can be extended to the cataloguing of other forms of geographic data. Feature catalogues are independent of feature concept dictionaries defined in ISO 19126 and can be specified without having to use or create a feature concept dictionary.

ISO 19110:2005 is applicable to the definition of geographic features at the type level. ISO 19110:2005 is not applicable to the representation of individual instances of each type. ISO 19110:2005 excludes portrayal schemas as specified in ISO 19117.

ISO 19110:2005 can be used as a basis for defining the universe of discourse being modelled in a particular application, or to standardize general aspects of real world features being modelled in more than one application.

Implementation benefits

ISO 19110:2005 provides a rigorous methodology for cataloguing feature types (feature classes) to compile a feature catalogue (also known as a classification system) and for publishing the catalogue in a registry (a formal online repository). Closely related to ISO 19110:2005 is ISO 19126:2009, Geographic information – Feature concept dictionaries and registries (see 11.3.2), which specifies how to set up a concept dictionary of the abstract feature concepts that can be specified in

detail in creating a feature catalogue. However, ISO 19110:2005 does not actually define a feature catalogue and it does not specify how to decide what the feature types should be (their collection criteria), which is actually a poorly understood problem.

Implementation guidelines

ISO 19110:2005 and ISO 19126:2009 probably have a more sophisticated approach to classifying features in a geospatial dataset than most users are accustomed to, which probably makes them a bit challenging. The amendment to ISO 19110:2005 was published in 2011 and makes significant changes to the standard – the amendment is almost as long as the original standard itself. It also makes it more difficult to understand the standard, unfortunately, as the amendment is published separately and not merged into the original standard. Further, the amendment uses UML classes from ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation, without expanding them in the tables, so it can appear that some things were deleted by the amendment, when they were not. The main changes introduced by the amendment are to improve harmonization with other ISO/TC 211 standards, cater for XML, facilitate using ISO 19110:2005 to create geographic feature catalogues, ensure consistent descriptions of the feature types of an application schema, and enable registering feature catalogues and their feature types. This discussion is of ISO 19110:2005 as amended in 2011.

ISO 19110:2005 is also currently being revised and as it received 100% support in February 2014 in the DIS ballot, it is likely that the revised standard will be published before the end of 2014.

A feature occurs on two levels, as an instance, which is the actual thing in the real or imaginary world being modelled (a discrete phenomenon associated with its geographic and temporal coordinates that may be portrayed by a particular graphic symbol), or as a type, which is a grouping of instances into a class with common characteristics. Recognising and selecting the relevant characteristics (and hence the classification itself) is subjective and depends upon the needs of particular applications.

Clause 5.2 describes the XML namespaces used in this standard, namely gco, gfc, gmd and gmx. Clause 6 of ISO 19110:2005 provides an overview of the general requirements for a feature catalogue: the form of names and definitions; the requirements for feature types, feature attributes and feature attribute values; and the requirements for the complex relationships between feature types, namely:

- **Feature operation**: an action or query that can be performed on a feature, such as upgrading or downgrading an attribute (e.g. the category for an Important Bird Area), or checking the water level at a weir. A feature operation may have attributes that trigger it, that provide inputs for it or that are affected by it.
- **Feature association**: a relationship linking one feature to another, such as between a river and its catchment, or between a bridge and what it carries and what it spans.
- **Association roles**: the function or undertaking of each feature type or instance in the association. An association role can be navigable, meaning that it can be used to find the

target feature from the source feature. An association role can also be bound to a particular feature type.

Annex B provides the feature catalogue template, which has tables similar to the data dictionary in ISO 19115:2003, Geographic information – Metadata (see 11.2.2), and UML diagrams.

Essentially, each feature catalogue is required to have a name, scope, version number, version date, producer and a set of feature types. It may have an identifier, language, character set, locale, described field of application and a set of definition sources (unfortunately, not linked to the definitions taken from each of them), inheritance relationships, global properties, and if its feature types have feature operations, it may have a functional language for defining them.

A feature type then has a name, a definition, links to the feature catalogues that contain it, and an indicator of whether or not it is abstract (i.e. a superclass with no instances in practice). It may also have a code, aliases, superclasses (from which it inherits operations, associations and properties), subclasses (which inherit operations, associations and properties from it), properties, constraints, and a definition reference. Note that a class (feature type) may have more than one parent, meaning that a feature catalogue is not restricted to a pure hierarchy, but could also be a partially ordered set (poset).

Annex C provides feature cataloguing examples and Annex D provides more detailed descriptions of the feature cataloguing concepts, namely feature operations, feature attributes, feature relationships (particularly generalization and aggregation), and synonyms and included terms (aliases or alternative names), and also provides some examples. The amendment adds two normative annexes, Annex E, which provides the XML encoding description, and Annex F, which specifies the management of feature catalogue registers. The amendment also adds Annex G, which contains XML implementation examples.

11.3.2 Feature concept dictionaries and registries (ISO 19126:2009)

Table 11.10 Overview of ISO 19126:2009

Full name	ISO 19126:2009, Geographic information – Feature concept dictionaries and registries
Version	Edition 1
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19126:ed-1:v1:en
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO/TS 19103:2005, Geographic information – Conceptual schema language ISO 19110:2005, Geographic information – Methodology for feature cataloguing ISO 19115:2003, Geographic information – Metadata ISO 19131:2007, Geographic information -- Data product specifications ISO 19135:2005, Geographic information – Procedures for item registration
Application	The main function of this standard is for creating an online register of abstract feature concepts in a dictionary that can then be specified in detail as feature types and in feature catalogues.
Conformance classes	General conformance to ISO 19135 Conformance to ISO 19135 as a hierarchical register Feature concept dictionary Register of feature concept dictionaries and/or feature catalogues

Scope

ISO 19126:2009 specifies a schema for feature concept dictionaries to be established and managed as registers. It does not specify schemas for feature catalogues or for the management of feature catalogues as registers. However, because feature catalogues are often derived from feature concept dictionaries, this International Standard does specify a schema for a hierarchical register of feature concept dictionaries and feature catalogues. These registers are in accordance with ISO 19135.

Implementation benefits

The main function of ISO 19126:2009 is to specify how to create an online register for a feature concept dictionary, that contains abstract feature concepts, which may then be specified in detail as feature types or in feature catalogues, using ISO 19110:2005, Geographic information – Methodology for feature catalogues, or in data product specifications, using ISO 19131:2007, Geographic information -- Data product specifications.

Superficially, this might appear that ISO 19126:2009 is too abstract or too theoretical for most users. However, the power of ISO 19126:2009 is that it allows different scientific and other disciplines to define and maintain concepts relevant to their field in online registers. Any community of interest can then use these registers in defining their feature types and constructing their feature catalogues appropriately. This is similar to the meta-languages or domain models used in ISO 19144-2:2012, Geographic information – Classification systems – Part 2: Land Cover Meta Language (LCML), and ISO 19152, Geographic information – Land Administration Domain Model (LADM), which are described elsewhere in this document.

Implementation guidelines

Clause 5 of ISO 19126:2009 is primarily about establishing a register, according to ISO 19135:2005, Geographic information – Procedures for item registration. A register is defined as a “set of files containing identifiers assigned to items with descriptions of the associated items”, and is maintained in an information system known as a registry. Each register has a register owner (the organisation that establishes the register), a register manager (to whom responsibility for running the register has been delegated by the register owner), a control body (the group of technical experts that makes the decisions about the contents of the register) and users.

Clause 6 specifies the feature concept dictionary schema, which may include definitions of feature concepts, feature attribute concepts, feature association concepts, feature operation concepts feature role concepts (link between an association and an attribute or operation) and nominal value concepts (category, class, kind or type that may be identified as an element of an enumeration or code list). Each feature concept dictionary has a scope, a possible field of application and possible themes.

Clause 7 specifies procedures for the management of feature concept dictionaries as registers, which are taken largely from ISO 19135:2005. Clause 8 describes a register of feature concept dictionaries and feature catalogues, again drawing largely on ISO 19135:2005.

Annex A provides an overview of how feature concepts in dictionaries, catalogues and application schemas relate to one another. Annex C describes the information to be included in registration proposals. Annex D provides an example implementation of the feature concept dictionary schema as a register. Annex E describes the UML notation used.

11.3.3 Guidance for the preparation and maintenance of international chart schemes and catalogue of international charts (S-11)

Table 11.11 Overview of S-11

Full name	S-11, Guidance for the preparation and maintenance of international chart schemes and catalogue of international charts (formerly M-11)
Version	Edition 2.0.5 of May 2012
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English, French
Online overview	http://iho.int/iho_pubs/standard/S-11/S-11.htm
Type of standard	IHO Guide and Catalogue Application level
Related standard(s)	S-4, Regulations for International (INT) Charts and Chart Specifications of the IHO
Application	A guideline for preparing and maintaining international nautical charts for printing on paper.
Conformance classes	None

Implementation benefits

S-11 is currently only for **paper** nautical charts, and only for **international charts**, which have less detail than **national charts**, to limit updates to items essential for international shipping. It is relevant to those wanting to produce charts of coastal areas and possibly also charts of large inland water bodies, particularly where they include international boundaries, such as the Great Lakes in eastern Africa.

Implementation guidelines

This guideline should only be used by those who have been trained to produce nautical charts and who are familiar with all the relevant IHO standards, including S-4, *Regulations for International (INT) Charts and Chart Specifications of the IHO*, because of the dangers associated with incorrect, incomplete or inaccurate charts. Section 3 provides guidelines on what features and their attributes to include in the international chart, covering port selection, shipping routes, comparison of catalogues, scale (for berthing, harbours, approaches, coastal navigation, general charts and overviews), projections, dimensions of the chart, limits, overlaps, chart numbering, draft schemes and consultation on them, allocation of producers, and review of the charts.

Annex A lists the potential printer nations (which are available for printing one's international chart), which in Africa are Algeria, Morocco, South Africa and Tunisia. Note that most countries will only print maps covering certain areas. Annex B indicates whether or not the potential printer nations can print on A0 paper, and all four African countries can. Annex C provides the terms of reference for the International Charting Coordination Working Groups (ICCWG).

Part B of S-11 is a catalogue of available international charts by region, which gets updated frequently. Note that Africa's coasts fall into the International Charting Regions F (Mediterranean), G (Eastern Atlantic), H (SE Atlantic and SW Indian Oceans) and J (North Indian Ocean).

11.4 Map standards

11.4.1 Portrayal (ISO 19117:2012)

Table 11.12 Overview of ISO 19117:2012

Full name	ISO 19117:2012, Geographic information -- Portrayal
Version	Edition 2
Amendments	None
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	Not available yet
Type of standard	ISO International Standard Meta level
Related standard(s)	OpenGIS Styled Layer Descriptor Profile of the Web Map Service Implementation Specification OpenGIS Symbology Encoding Implementation Specification
Application	ISO 19117 specifies a conceptual schema for describing symbols, portrayal functions that map geo-spatial features to symbols, and the collection of symbols and portrayal functions into portrayal catalogues.
Conformance classes	Portrayal core (general) Portrayal core – symbol Portrayal core – portrayal function Portrayal core – portrayal catalogue Portrayal core plus condition function extension Portrayal core plus context extension Portrayal core plus symbol parameter extension Portrayal core plus compound symbol extension Portrayal core plus complex symbol extension Portrayal core plus reusable symbol component extension Portrayal core plus symbol parameter extension

Scope

This International Standard specifies a conceptual schema for describing symbols, portrayal functions that map geo-spatial features to symbols, and the collection of symbols and portrayal functions into portrayal catalogues. This conceptual schema can be used in the design of portrayal systems. It allows feature data to be separate from portrayal data, permitting data to be portrayed in a dataset independent manner.

This International Standard does not address the following:

- standard symbol collection (e.g. International Chart 1 – IHO);
- a standard for symbol graphics (e.g. scalable vector graphics [SVG]);
- portrayal services (e.g. web map service);
- capability for non-visual portrayal (e.g. aural symbology);
- dynamic rendering (e.g. on the fly contouring of tides);

- portrayal finishing rules (e.g. generalization, resolve overprinting, displacement rules);
- 3D symbolization (e.g. simulation modelling).

Implementation benefits

The conceptual schema defined by ISO 19117 allows the development of a portrayal for a specific application field. This schema can be exchanged and implemented in different applications. One of the main benefits of ISO 19117 is that it will allow datasets to be displayed according to some specification without changing or manipulating the original dataset. Portrayal allows the client to create a unique representation for features to communicate an explicit meaning. ISO 19117 can be applied to a variety of products, such as hard copy maps, digital maps, and online representations in a web browser.

Implementation guidelines

Portrayal is the process of presenting information to humans. The portrayal mechanism (as shown in Figure 11.1) makes it possible to portray a single dataset in multiple ways without altering the dataset. Each feature will point to a rule that is applied when the feature is generated on a map, for example.

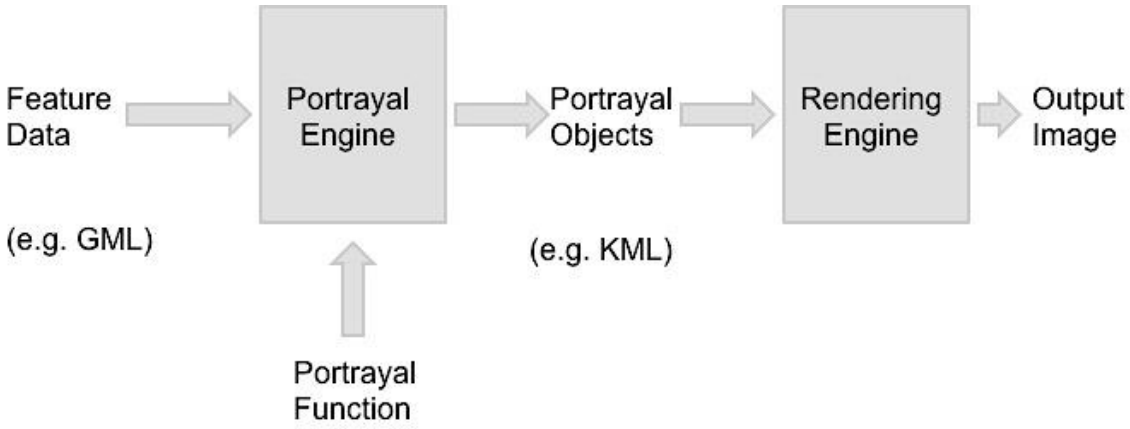

Figure 11.1 Illustration of the portrayal mechanism (Source ISO 19117:2012)

The conceptual schema described in ISO 19117 is based on UML and follows the guidelines set out in ISO/TS 19103. The schema contains a series of UML packages, defining the portrayal core, and extensions for conditional functions, context, compound symbols, reusable components, parameterised symbols and the portrayal functions that use parameterised symbols. Fundamental to the concept of portrayal is that the symbols and portrayal functions shall be not be part of the dataset.

The portrayal core package is divided into three sub packages:

1. Portrayal Function package

   This package is used to define mapping functions. The information to be portrayed shall be defined in an application schema, and all mandatory and conditional (if required) portrayal function elements shall be present in the functions. This package also ensures that elements, which are not being portrayed, are mapped to symbols with no components.

2. Symbol package

   Symbol package is used to define symbols. For the symbol package a default symbol needs to be assigned, and all the mandatory and conditional (if required) symbol elements that shall be present. The core symbol class supports basic symbols, however, one can extend it, for example, with hatch fills or reusable symbols.

3. Portrayal Catalogue package

   The portrayal catalogue package is used to define portrayal catalogues. The portrayal information, such as the feature portrayal functions and applicable symbols shall be present in the portrayal.

11.4.2 Regulations of the IHO for international (INT) charts and chart specifications of the IHO (S-4)

Table 11.13 Overview of S-4

Full name	S-4, Regulations of the IHO for international (INT) charts and chart specifications of the IHO
Version	Edition 4.4.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English, French
Online overview	http://iho.int/iho_pubs/standard/S-4/S-4_e4.4.0_EN_Sep13.pdf
Type of standard	IHO Regulations Application level
Related standard(s)	S-11 Guidance for the preparation and maintenance of international chart schemes and catalogue of international charts S-57 IHO transfer standard for digital hydrographic data S-52 Specifications for chart content and display aspects of ECDIS S-65 ENCs: Production, maintenance and distribution guidance
Application	S-4 specifies regulations of the IHO for International (INT) charts and chart specifications of the IHO. It specifically looks at regulations of the IHO for International (INT) charts, chart specifications of the IHO for medium- and large-scale National and International (INT) charts, and chart specifications of the IHO for small-scale International (INT) charts.
Conformance classes	None specified

Scope

The publication S-4 (previously M-4) 'Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO', includes:

- Part A: 'Regulations of the IHO for International (INT) Charts'
- Part B: 'Chart Specifications of the IHO for Medium- and Large-scale National and International (INT) Charts'
- Part C: 'Chart Specifications of the IHO for Small-Scale International (INT) Charts'

The three parts of S-4 are further subdivided into Sections dealing with specific topics. Regulations and Specifications relating to particular topics may be found either by their subject matter in the Contents page at the beginning of each Section, or by reference to column 5 of INT 1 for Part B

and the index for Part C. Cross referencing draws attention to related Regulations, Technical Resolutions and Specifications. This publication was developed and maintained by the IHO's Chart Standardization Committee to 2003. Its maintenance is now the responsibility of the Chart Standardization and Paper Chart Working Group, to which comments and corrections should be advised.

Implementation benefits

The regulations set out in S-4 are very detailed and provide guidelines for every aspect of a chart from design through production to dissemination. It is important that charts are designed and produced according to these regulations and guidelines to ensure safety for navigation. The intended users need to be able to read and understand charts produced by any country at any scale; this can only be ensured through rigorous regulations.

Implementation guidelines

When S-4 was originally prepared, the term chart referred to a paper chart. Since then, electronic charts have become widely used. Digital charts require additional regulations, which are set out in S-52, S-57 and S-61. S-4 provides regulations for three types of charts:

1. International Charts

   There are two types of international charts: marine navigation and information source. Marine navigation charts are produced by national hydrographical offices to cover international waters. The main aim of these charts is to assist in the safe navigation of coastal waters. Information sources are large-scale chart publications showing the detailed configuration of the seabed offshore. The information about the seabed shape is required by various users, for example, for navigation and construction purposes.

2. Medium- and Large-scale Charts

   Medium- and large-scale charts are charts with a scale of 1:2 000 000 and larger.

3. Small-Scale Charts

   Small-scale charts are charts with a scale smaller than 1:2 000 000. These charts provide a complete and comprehensive small-scale coverage, usable by all nations, for the world's oceans.

S-4 specifies regulations for the following aspects of international charts: general, schemas of International charts, specifications for International charts, maintenance of international charts, exchange of reproduction material, and financial aspects.

For medium- and large-scale charts the regulations are more detailed. The regulations cover topics such as the terms and conventions used, translations of terms, symbology, geographic units, text styles, and use of colour.

Lastly, the regulations for small scale charts look at the chart in general, the format of the chart, topography, hydrography and aids to navigation, geographic names, and style sheets.

11.4.3 Specifications for chart content and display aspects of ECDIS (S-52)

Table 11.14 Overview of S-52

Full name	S-52, Specifications for chart content and display aspects of ECDIS
Version	Edition 6.0.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English
Online overview	http://iho.int/iho_pubs/standard/S-52/S-52_e6.0_EN.pdf
Type of standard	IHO International Standard Application level
Related standard(s)	IMO Performance Standards for ECDIS, 1995 edition S-57 IHO Transfer Standard for Digital Hydrographic Data IHO INT 1 Symbols, Abbreviations, Terms used on Charts IEC 62288 Presentation of navigation related information - General requirements, methods of test and required test results IEC 61174 ECDIS - Operational and performance requirements, methods of testing and required test results IEC 60945 Maritime Navigation and Radio Communication Equipment and Systems – General Requirements – Methods of Testing and Required Test Results IHO S-32 Appendix 1: Hydrographic Dictionary - Glossary of ECDIS-related terms IHO S-60 User´s Handbook on Datum Transformations involving WGS-84
Application	S-52 defines the specifications for Chart Content and Display Aspects of Electronic Chart Display and Information Systems (ECDIS), which are intended to contribute to the safe operation of ECDIS.
Conformance classes	None specified

Scope

These Specifications for Chart Content and Display Aspects of ECDIS are intended to contribute to the safe operation of ECDIS by:

- ensuring a base and supplementary levels of display for ENC data; standards of symbols, colours and their standardized assignment to features; scale limitations of data presentation; and appropriate compatibility with paper chart symbols as standardized in the Chart Specifications of the IHO.
- ensuring the display is clear and unambiguous,
- ensuring that there is no uncertainty over the meaning of colours and symbols on the display,
- establishing an accepted pattern for ECDIS presentation that becomes familiar to mariners and so can be recognized instantly without confusion.

Implementation benefits

S-52 was developed to ensure safety and efficiency of navigation by satisfying the requirements set out in the performance standards for ECDIS. The colours and symbols defined in S-52 are based on common symbology of conventional paper charts. However, due to the special conditions of the ECDIS chart display as a computer generated image, the ECDIS presentation of ENC data does not

match the appearance of a conventional paper chart closely. The specification of symbols and colours ensures that the charts can be used and understood by individuals from different regions.

Implementation guidelines

ECDIS have become popular with the widespread use of computer systems. S-52 provides specifications to ensure that these ECDIS are developed and used optimally. S-52 consists of the following components:

1. Considerations – organising the display

   The design considerations go into great detail about the display and the different aspects of the data to be displayed. They provide detailed guidelines for the design process.

2. Symbol specifications for areas, lines and points, and for text

   The symbol set for ECDIS is described in this specification and illustrations can be obtained in the ECDIS Chart 1 (in the Presentation Library).

3. Specifications for colours

   EDCIS manufacturers can use any technology to develop their display as long as it meets the requirements set out in this specification. The requirements for the colours are described in detail and an accompanying file can be downloaded from the Presentation Library.

4. Specifications for the display screen

   The physical display requirements specify a minimum screen size of 270mm X 270mm, a resolution greater than 864 lines per mm, and the use of 64 colours. The calibration of the display should be performed according to the guidelines in Annex 1 of S-52.

There are also two annexes on the procedure for initial calibration of colour displays and the maintenance thereof.

11.4.4 ENCs: Production, maintenance and distribution guidance (S-65)

Table 11.15 Overview of S-65 ENCs

Full name	S-65 ENCs: Production, maintenance and distribution guidance
Version	Edition 2.0.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English, French
Online overview	http://iho.int/iho_pubs/standard/S-65/S-65_ed2.0.0_Apr12.pdf
Type of standard	IHO International Standard Application level
Related standard(s)	S-57 IHO transfer standard for digital hydrographic data S-52 Specifications for chart content and display aspects of ECDIS
Application	S-65 provides guidelines for the production, maintenance and distribution of Electronic Navigational Charts (ENCs).
Conformance classes	None specified

Scope

This document provides a high level guide to the production, maintenance and distribution of Electronic Navigational Charts (ENCs). It offers a framework to inform hydrographical offices of the processes and requirements necessary to produce, maintain and distribute ENCs. It provides references to documentation, which can support each stage of the process. It is not intended to serve as a technical reference manual but to enable hydrographical offices to gain an overview of ENC production processes, and the requirements and procedures that need to be in place to set up an ENC production facility.

Implementation benefits

S-65 enables Hydrographic Offices to gain an overview of ENC production processes, and the requirements and procedures that need to be in place to set up an ENC production facility. The process promotes accuracy and consistency across borders, provides up-to-date information in a timely manner, and satisfies user needs for safety in navigation.

Implementation guidelines

ENCs consist of digitized data conforming to the specification set out in S-57 which record the relevant charted features necessary for safe navigation, such as coastlines, bathymetry, buoys and lights. The basic unit of geographic coverage for ENC is called a cell. S-65 describes the entire ENC process from production to distribution, and provides guidelines to hydrographical offices on the process and requirements. The following stages form part of this process:

1. Design production process

   This stage consists of two steps: production method and quality system. During the production method, decisions on the source material are made. These depend on factors such as the quality and format of existing survey data, availability of accurately transformed data, and the facilities to produce rectified raster images. After the decisions on the source materials have been made, the production process is designed and a Quality Management System (QMS) is developed. Procedures should be in place at all the stages of the production process to ensure accuracy and consistency. Quality control and quality assurance are important during the production of ENCs.

2. Define ENC production requirements

   The following steps are recommended to each Regional Hydrographic Commission (RHC): identify key shipping routes and ports within the region, identify charts covering these routes and ports to be captured as ENCs, identify producer nations for ENCs, and arrange for their production. The national production plan shall define which geographic areas are to be captured, which navigational purposes are to be populated for each area, how the areas are to be divided into cells for each navigational purpose, and the order of capture. This plan depends on factors, such as the liaisons with bordering countries and priority traffic routes, to name a few.

3. Acquire production system

The production system should depend on the production plan and the extent of data capturing that will be contracted out. Dependencies should be specified in the statement of requirements. There are two main types of production systems. The first type populates and maintain a database of ENC objects, attributes and attribute values in a format that is conformant with S-57. The second type creates individual flat files for each single ENC cell.

4. Obtain and train staff

   Staffing levels shall depend on the amount of in-house work. It is recommended that a skills analysis and training-needs analysis be employed to determine the required skills for the positions. These analyses will also be used to identity the training needs.

5. Prepare specification for data capture

   The data should be structured and follow other requirements as set out in S-57. The content of the ENC, limits of the cells and cell navigation purpose are not covered in S-57 and should be decided upon.

6. Capture data for new cells

   Data can be captured in-house or contracted out. The United Kingdom Hydrographic Office (UKHO) data capture specifications and quality procedures are recommended.

7. Edge match data

   It is important that the borders of cells with the same navigational purpose match, and accuracy should always be kept in mind. The cells should also match between countries and the hydrographical offices should collaborate to achieve this.

8. Verify and validate data

   Verification and validation are important to ensure that the ENC cell content is accurate and consistent. Cells need to be checked for content and capture accuracy. Validation checks as specified in S-58 should be performed.

9. Maintain ENCs

   After the ENC cell has been produced and distributed to the end users, the data should be maintained. The overall Quality Management System should include a mechanism for updating the cell design to meet the user needs. The processes for updating paper charts and ENCs should be synchronised. When an update is performed or a new edition is available, a Notice to Mariners is published.

10. Distribute ENC data

    The distribution mechanism shall provide users with up-to-date ENC data in a timely manner to ensure safe navigation. The distribution system shall also ensure data integrity and data protection. The system should allow automatic updates of ENC data.

11.4.5 Facts about electronic charts and carriage requirements (S-66)

Table 11.16 Overview of S-66 Facts

Full name	S-66, Facts about electronic charts and carriage requirements
Version	Edition 1.0.0
Amendments	None
Corrigenda	None
Published by	IHO
Languages	English, Spanish, Portuguese, Japanese
Online overview	http://iho.int/iho_pubs/standard/S-66/S-66_e1.0.0_EN.pdf
Type of standard	n/a
Related standard(s)	S-57 IHO transfer standard for digital hydrographic data S-52 Specifications for chart content and display aspects of ECDIS S-65 ENCs: Production, maintenance and distribution guidance
Application	S-66 was developed to avoid uncertainty regarding terminology, to provide rules for professional marine navigation, and to describe the types of electronic charts that are available.
Conformance classes	None specified

Scope

The International Convention on the Safety of Life at Sea (SOLAS) includes a requirement for all ships to carry to up-to-date nautical charts and publications for the intended voyage. Progressively from 2012, the chart carriage requirement for certain classes of vessels is to be satisfied by electronic means using an Electronic Chart Display and Information System (ECDIS).

Feedback from those involved in the use of charts and electronic charting systems including manufacturers, distributors, users, ship owners, regulatory authorities, pilots, harbour authorities and others indicates a requirement to provide guidance on the regulations and the status of equipment that is available in the market today. In particular the differences between the various types of equipment and the differences between the various types of chart data offered to the users are unclear with respect to the regulations in place.

This document has been produced to help clarify some of the uncertainties. It is not intended to replace or amend national or international rules and regulations. Readers should always refer to the relevant national administration or Flag State for the latest detailed information.

This document consists of a number of interrelated sections. This first section contains information on various aspects of electronic charts and electronic chart display systems in the form of questions and answers. The main emphasis is on what can be used to satisfy the SOLAS carriage requirements for charts.

- Section 1: Overview of electronic charting and regulations
- Section 2: A list of points of contact for detailed information on Flag State Implementation of ECDIS
- Section 3: ECDIS Training
- Section 4: Technical aspects of electronic charts

- Section 5: Appendix: References, glossary, further reading

Implementation benefits

S-66 is very beneficial to any person working with ENC or ECDIS. It provides a detailed introduction and general information on the field, and also useful information such as links to online resources, and a list of abbreviations.

Implementation guidelines

S-66 is for information purposes and cannot be implemented. It provides detailed information on ENC, ECGIS, flag authorities, training objectives for ECDIS training, and technical details of electronic charts.

11.5 Standards for products used in Web dissemination

11.5.1 Standard web services for accessing geo-spatial data

This section provides a tabular overview of standards required for accessing geo-spatial datasets through the internet. Services provide users (and applications) to access geo-spatial data in a variety of formats ranging from a JPEG map image to a GeoJSON file containing the geometry and attribute data. The services described provide a standard interface that can be deployed in various geo-spatial applications, as well as in spatial data infrastructures (SDIs). The standard interface allows the services to be interchangeable and chained to create more sophisticated services. The services outlined in this section are only some of the basic and well-known geo-spatial services used for accessing geo-spatial data.

Table 11.17 Services (ISO 19119:2005)

Full name	ISO 19119:2005, Geographic information – Services
Version	Edition 1
Amendments	Amendment 1
Corrigenda	None
Published by	ISO/TC 211
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19119:ed-1:v1:en:1
Type of standard	ISO International Standard Meta level
Related standard(s)	ISO 19128:2005, Geographic information – Web Map Server interface ISO 19142:2010, Geographic information – Web Feature Service
Application	ISO 19119 is a high-level standard that describes service architectural patterns, presents a taxonomy for geographic services, and provides guidelines for the selection of services. OGC Web Service Common Implementation Specification is a similar standard.
Conformance classes	Service architecture test module Service specification test module
Implementation benefits	The taxonomy provides standard terms that can be used to describe services in a standard way. ISO 19119 provides details on chaining patterns that assist developers when implementing a service chain. Furthermore, the standard defines the basic concepts required when developing or implementing services to ensure integration and interoperability of the services.
Products	Standards such as Web Map Server and Web Feature Service are based on the concepts described in ISO 19119.

Table 11.18 Web Map Server interface (ISO 19128:2005)

Full name	ISO 19128:2005, Geographic information – Web Map Server interface (also published as OpenGIS Web Map Service Implementation Specification)
Version	ISO: Edition 1 OGC: V1.3.0
Amendments	None
Corrigenda	None
Published by	ISO/TC 211 and OGC
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19128:ed-1:v1:en
Type of standard	ISO International Standard and OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19119:2005, Geographic information – Services ISO 19142:2010, Geographic information – Web Feature Service OpenGIS Catalogue Services Specification
Application	ISO 19128 describes the interface for a Web Map Server (WMS). WMS allows a client to request a map image, for example, a JPEG file, from a web service. OpenGIS Web Map Tile Service Implementation Specification is a similar standard.
Conformance classes	Basic WMS Queryable WMS
Implementation benefits	Through implementing a WMS interface, data can be exposed in a standardized way so that any client familiar with the WMS interface can request a map image of available data. The client specifies parameters, such as the data source, bounding box, and symbology, for the map, through the interface. WMS does not generate map elements, such as a legend. The service can be reused by different clients and is more cost effective than developing a custom service.
Products	deegree 3.3 is an example of an OGC compliant open source implementation of the WMS interface. GeoServer 2.5.2 is an example of an open source implementation of the WMS interface. These implementations are generally easy to use, and libraries, such as OpenLayers, have integrated support for WMS calls.

Table 11.19 Web Map Tile Service

Full name	OpenGIS Web Map Tile Service Implementation Standard
Version	V1.0.0
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/wmts
Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19119:2005, Geographic information – Services ISO 19142:2010, Geographic information – Web Feature Service OpenGIS Catalogue Services Specification
Application	The OGC WMTS provides a complementary approach to the Web Map Service (WMS) for tiling maps. WMS focuses on rendering custom maps and is an ideal solution for dynamic data or custom styled maps (combined with the OGC Style Layer Descriptor (SLD) standard). WMTS trades the flexibility of custom map rendering for the scalability possible by serving of static data (base maps) where the bounding box and scales have been constrained to discrete tiles. The fixed set of tiles allows for the implementation of a WMTS service using a web server that simply returns existing files. The fixed set of tiles also enables the use of standard network mechanisms for scalability such as distributed cache systems.
Conformance classes	Client test module Server test module
Implementation	With WMS (ISO 19128) custom maps can be rendered for dynamic data or custom styled

benefits	data. OGC WMTS trades the flexibility of custom maps for the scalability possible by serving static data (base maps) more efficiently. The main benefit of using WMTS is that tiles can be rendered server-side and then cached client-side. This reduces waiting time and bandwidth limitations. OGC WMTS is used to accelerate and optimize map image rendering and delivery.
Products	GeoWebCache 1.5.3 is one example of an implementation of OGC WMTS.

Table 11.20 Web Feature Service (ISO 19142:2010)

Full name	ISO 19142:2010, Geographic information – Web Feature Service (also published as OpenGIS Web Feature Service Implementation Specification)
Version	ISO: Edition 2 OGC: V2.0.0
Amendments	None
Corrigenda	None
Published by	ISO/TC 211 and OGC
Languages	English, French
Online overview	http://www.opengeospatial.org/standards/wfs
Type of standard	ISO International Standard and OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19119:2005, Geographic information – Services ISO 19128:2005, Geographic information – Web Map Server interface OpenGIS Web Map Tile Service Implementation Standard OpenGIS Catalogue Services Specification
Application	ISO 19142 describes the interface for a Web Feature Service (WFS). WFS allow a client to access and perform transactions on geographic features independent of the underlying data store. These WFS implementations allow clients to edit geographic features online and store the changes to the underlying data store.
Conformance classes	Simple WFS Basic WFS Transactional WFS Locking WFS
Implementation benefits	WFS allow a client to retrieve features or values of features (attribute data) from an underlying data store, and also to access the features to modify or delete features. With WFS the data can be stored in any database or as a shapefile on a server, for example, and the same operations can be performed on the data. This allows the user to query and edit data without having to consider the format of the data.
Products	deegree 3.3 is an example of an OGC compliant open source implementation of the WFS interface.

Table 11.21 Filter encoding (ISO 19143:2010)

Full name	ISO 19143:2010, Geographic information – Filter encoding (also published as OpenGIS Filter Encoding 2.0 Encoding Standard)
Version	ISO: Edition 1 OGC: V2.0.0
Amendments	None
Corrigenda	None
Published by	ISO/TC 211 and OGC
Languages	English, French
Online overview	https://www.iso.org/obp/ui/#iso:std:iso:19143:ed-1:v1:en
Type of standard	ISO International Standard and OpenGIS Implementation Specification Application level

Related standard(s)	ISO 19117:2012, Geographic information -- Portrayal ISO 19119:2005, Geographic information – Services ISO 19128:2005, Geographic information – Web Map Server interface ISO 19142:2010, Geographic information – Web Feature Service OpenGIS Styled Layer Descriptor Profile of the Web Map Service Implementation Specification OpenGIS Symbology Encoding Implementation Specification
Application	ISO 19143 describes XML and Key-Value Pairs (KVP) encodings of a system-neutral syntax for expressing projections, selections and sorting clauses, collectively called a query expression.
Conformance classes	Query Ad-hoc Query Functions Resource Identification Minimum Standard Filter Standard Filter Minimum Spatial Filter Spatial Filter Minimum Temporal Filter Temporal Filter Version navigation Sorting Extended Operators Minimum XPath Schema Element Function
Implementation benefits	Filter Encoding (FE) describes XML and KVP encodings for expressing filters for spatial queries to select a subset of features based on specific attributes. FE is used in conjunction with other standards and thus allows a client to, for example, create a map using a WMS that only shows residential areas.
Products	FE is implemented in conjunction with other services, such as WMS or WFS. An open source examples of an implementation of FE is OpenGeo Suite 4.1.1.

Table 11.22 Catalogue Service

Full name	OpenGIS Catalogue Service Implementation Specification
Version	V2.0.2
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/cat
Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19115:2003, Geographic information – Metadata ISO 19119:2005, Geographic information – Services ISO 19128:2005, Geographic information – Web Map Server interface ISO 19136:2007, Geographic information -- Geography Markup Language (GML) ISO 19142:2010, Geographic information – Web Feature Service OpenGIS Web Map Tile Service Implementation Standard OpenGIS
Application	Catalogue services support the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects. The OGC Catalogue Services Specification defines the requirements for the interface and bindings to realise these functionalities. This specification includes an HTTP protocol binding, called the Catalogue Services for the Web (CSW).
Conformance classes	None specified

Implementation benefits	Catalogue services are an important aspect of most spatial data infrastructures (SDI). It allows the client to search and discover data and associated services. The catalogue service relies on metadata of the data and service.
Products	The geoportal of an SDI is commonly an example of a catalogue service. A proprietary catalogue service implementation is the Esri Geoportal Server 1.2.5.

Table 11.23 Sensor Observation Service (SOS)

Full name	OpenGIS Sensor Observation Service Interface Standard
Version	V 2.0
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/sos
Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19156:2011, Geographic information – Observations and Measurements OGC Sensor Planning Service Implementation Standard Service OGC SensorML: Model and XML Encoding Standard
Application	OpenGIS Sensor Observation Service Interface Standard defines a standardized interface for managing and retrieving metadata and observations from heterogeneous sensor systems.
Conformance classes	Main Requirements class Transactional Extension Result Handling Extension Enhanced Operations Extension Spatial Filtering Profile Binding Extension
Implementation benefits	Sensors are currently the largest contributor of data in the geo-spatial system. The OGC Sensor Observation Service (SOS) allows the aggregation of readings from live, in-situ and remote sensors. OGC SOS provides the client with the capability to discover or bind with individual sensors, sensor platforms, or networked constellations of sensors.
Products	An open source implementation of the SOS service interface is available from 52° North, 52N Sensor Observation Service (SOS) 4.0.

11.5.2 Standards for styling geo-spatial data

This section provides a tabular overview of standards required for styling geo-spatial data on the web. The standards outlined in this section are rarely implemented without one another. Styled layer descriptor (SLD) and symbol encoding (SE) are also mainly implemented with WMS that supports specifying a style for rendering geo-spatial data allow the user more freedom in their design decisions when requesting a map.

Table 11.24 Styled Layer Descriptor (SLD)

Full name	OpenGIS Styled Layer Descriptor Profile of the Web Map Service Implementation Specification
Version	V1.1
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/sld

Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19117:2012, Geographic information -- Portrayal ISO 19119:2005, Geographic information – Services ISO 19128:2005, Geographic information – Web Map Server interface ISO 19143:2010, Geographic information – Filter encoding OpenGIS Symbology Encoding Implementation Specification
Application	SLD is an XML schema that defines the structure of a layer style. SLD defines styles that can be used for publishing raster and vector data available through a WMS. Basically, SLD is what makes the map more colourful and user-friendly and it is responsible for telling the server how to render the map.
Conformance classes	Integrated SLD-WMS Component SLD-WMS Feature Portrayal Service Coverage Portrayal Service
Implementation benefits	SLD allows users to define their own styles. With SLD users can develop style sheets that can be used for specific maps, such as topographic maps. This provides consistency and is an effective method for generating maps. The SLD style sheets are reusable and interoperable.
Products	Commonly, SLD is implemented in conjunction with a WMS. A number of these implementations also provide extensions on the standard SLD. An example of an SLD implementation is GeoServer 2.5.2.

Table 11.25 Symbology Encoding (SE)

Full name	OpenGIS Symbology Encoding Implementation Specification
Version	V1.1.0
Amendments	None
Corrigenda	None
Published by	OGC
Languages	English
Online overview	http://www.opengeospatial.org/standards/se
Type of standard	OpenGIS Implementation Specification Application level
Related standard(s)	ISO 19117:2012, Geographic information -- Portrayal ISO 19119:2005, Geographic information – Services ISO 19128:2005, Geographic information – Web Map Server interface ISO 19143:2010, Geographic information – Filter encoding OpenGIS Styled Layer Descriptor Profile of the Web Map Service Implementation Specification
Application	The OGC Symbology Encoding (SE) standard has initially been a part of the Styled Layer Descriptor (SLD) 1.0 standard. OGC SE describes the actual syntax for the description of styles.
Conformance classes	Basic Schema conformance Basic Feature Styling Functionality Basic Coverage Styling Functionality Full Feature Styling Functionality Full Coverage Styling Functionality
Implementation benefits	OGC SE defines a language for specifying the style of a map. This language can be used to portray the output of WMS, WFS and CSW.
Products	SE is implemented in conjunction with a SLD. An example of an SE implementation is GeoServer 2.5.2.

STANDARDS INFORMATION AVAILABLE ON THE WEB

International Hydrographic Organization (IHO), www.iho.int

International Organization for Standardization (ISO), www.iso.org

ISO online browsing platform, www.iso.org/obp

ISO concept database, cdb.iso.org

ISO/TC 211, Geographic information/Geomatics, www.isotc211.org

Open Geospatial Consortium (OGC), www.opengeospatial.org

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ACRONYMS

2D	two-dimensional
3D	three-dimensional
ARSO	African Regional Organisation for Standardization
ASN.1	Abstract Syntax Notation One
ATS	abstract test suite
BIIF	Basic Image Interchange Format
C	conditional
CCD	Charge Coupled Device
CD	Committee draft
CD-ROM	Compact Disc, read-only-memory
CEN	European Committee for Standardization
CODIST	Committee on Development Information, Science and Technology
CORINE	Coordination of Information on the Environment
CRS	coordinate reference system
CSDGM	Content Standard for Digital Geospatial Metadata
CSI	Committee for Spatial Information
CSL	Conceptual Schema Language
CSV	comma-separated values
CSW	Catalogue Service for the Web
DCB	Domain Control Body
DCMI	Dublin Core Metadata Initiative
DIS	Enquiry draft
DWG	Domain Working Group
DXF	Drawing Exchange
ECB	Executive Control Body
ECDIS	Electronic Chart Display and Information System
ECGIS	European Commission on Geographic Information Systems
ENC	Electronic Navigational Chart
EO	Earth Observation
EPSG	European Petroleum Survey Group
FAO	Food and Agriculture Organization of the United Nations
FCD	feature concept dictionary
FDIS	Final draft international standard
FE	filter encoding
FGDC	Federal Geographic Data Committee
GCP	ground control point
gco	Geographic COmmon extensible markup language
GDF	Geographic Data File
GeoJSON	Geographical JavaScript Object Notation
GeoTIFF	Geographical Tagged Image File Format
GFM	general feature model
GIS	geographic information system
gmd	Geographic MetaData XML
gmx	Geographic Metadata XML Schema
GML	Geographic Markup Language
GNSS	Global Navigation Satellite System

GOM	Group on Ontology Management
GPS	Global Positioning System
gROADS	Global Roads Open Access Data Set
GSDI	Global Spatial Data Infrastructure Association
gsr	Geographic Spatial Referencing extensible markup language
gss	Geographic Spatial Schema extensible markup language
gts	Geographic Temporal Schema extensible markup language
HDF	Hierarchical Data Format
HMMG	Harmonized Model Maintenance Group
HSSC	IHO Hydrographic Services and Standards Committee
IANORQ	Instituto Angolano de Normalização e Qualidade
ICCWG	International Charting Coordination Working Groups
ICSU	International Council for Science
ICT	information and communication technology
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
IGCD	International Geologic Correlation Database
IHC	International Hydrographic Conference
IHO	International Hydrographic Organization
IMO	International Maritime Organization
INT	International
INSPIRE	Infrastructure for Spatial Information in the European Community
IPI	Image Processing and Interchange
IR	infrared
IS	International Standard
ISO	International Organization for Standardization
IT	Information Technology
ITA	Industry Technical Agreement
ITRS	International Terrestrial Reference System
ITS	intelligent transport systems
JPEG	Joint Photographic Experts Group
JSON	JavaScript Object Notation
JTC	Joint Technical Committee
KML	formerly Keyhole Markup Language
KVP	Key-Value Pair
LADM	Land Administration Domain Model
LCCS	Land Cover Classification System
LCML	Land Cover Meta Language
M	mandatory
MDA	Model Driven Architecture
MDR	Metadata registries
NASA	National Aeronautics and Space Administration
NetCDF	OGC Network Common Data Form
NGO	Non-Governmental Organisation
NWIP	New work item proposal
O	optional
O&M	Observations & Measurements
OGC	Open Geospatial Consortium

OGP	International Association of Oil and Gas Producers
OMG	Object Management Group
ORM	OGC Reference Model
OWL	Web Ontology Language
PAS	Publicly Available Specification
PMG	Program Maintenance Group
POI	Point-of-Interest
PWI	Preliminary work item
QMS	Quality Management System
RAND-RF	Reasonable and non-discriminatory terms Royalty Free
RDF	Resource Description Framework
RFC	Request for Comments
RHC	Regional Hydrographic Commission
RNC	Raster Navigational Chart
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SADCSTAN	SADC Cooperation in Standardization
SANS	South African National Standard
SAR	Synthetic Aperture Radar
SB	Standards Baseline
SDI	spatial data infrastructure
SE	symbol encoding
SensorML	Sensor Model Language
SHP	shapefile
SLD	styled layer descriptor
SOLAS	Safety of Life at Sea
SOS	sensor observation service
SQL	Structured Query Language
SRM	Spatial Reference Model
StatsSA	Statistics South Africa
SVG	scalable vector graphics
SWE	Sensor Web Enablement
SWG	Standards Working Group
TC	technical committee
THU	total horizontal uncertainty
TIFF	Tagged Image File Format
TIN	triangulated irregular network
TMB	Technical Management Board
TMG	Terminology Maintenance Group
TPU	total propagated uncertainty
TR	Technical Report
TS	Technical Specification
TUV	total vertical uncertainty
UKHO	United Kingdom Hydrographic Office
UML	Unified Modeling Language
UN ECA	United Nations Economic Commission for Africa
UN-GAID e-SDDC	UN Global Alliance on ICT for Development Open Access to and Application of Scientific Data in Developing Countries
UN-GGIM	United Nations Committee of Experts on Global Geospatial Information Management

UNJLC	United Nations Joint Logistics Center
UNSDI-T	United Nations Spatial Data Infrastructure for Transport
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
US	United States
UTM	Universal Transverse Mercator
VIM	International Vocabulary of Metrology
W3C	World Wide Web Consortium
WD	Working draft
WFS	Web feature service
WG	Working Group
WGS 84	World Geodetic System 1984
WKB	Well known binary
WKT	Well known text
WMS	Web Map Server or Web Map Service
WMTS	Web Map Tile Service
XMG	XML Maintenance Group
XML	Extensible Markup Language
XPath	XML Path Language
XSD	XML Schema Definition
XSLT	Extensible Stylesheet Language Transformation

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