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Geographic information — Reference model —

Part 2: Imagery

Information géographique — Modèle de réference —

Partie 2: Imagerie

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics.*

This edition cancels and replaces the first edition (ISO/TS 19101-2:2008) which has been technically revised. In order to promote backward compatibility between different versions of standards, the changes that have been made between this document and the previous version are described in Annex D.

A list of all parts in the ISO 19101 series can be found on the ISO website.

Introduction

This document provides a reference model for processing of geographic imagery which is frequently done in open distributed manners. The motivating themes addressed in this reference model are given below.

In terms of volume, imagery is the dominant form of geographic information.

— Stored geographic imagery volume will grow to the order of an exabyte.

— National imagery archives are multiple petabytes in size; ingesting a terabyte per day.

— Individual application data centers are archiving hundreds of terabytes of imagery.

— Tens of thousands of datasets have been catalogued and can be accessible online.

Large volumes of geographic imagery will not be portrayed directly by humans. Human attention is the scarce resource, and is insufficient to view petabytes of data. Semantic processing will be required: for example, automatic detection of features; data mining based on geographic concepts.

Information technology allows the sharing of geographic information products through processing of geographic imagery. Standards are needed to increase creation of products. A number of existing standards are used for the exchange of geographic imagery.

Examples of technical, legal, and administrative hurdles to moving imagery online include

— technical issues of accessibility – geocoding, geographic access standards,

— maintenance of intellectual property rights,

— maintenance of individual privacy rights as resolution increases, and

— technical issues of compatibility requiring standards.

Governments have been the predominant suppliers of remotely sensed data in the past. This is changing with the commercialization of remotely sensed data acquisition. Geographic imagery is a key input to decision support for policy makers.

The ultimate challenge is to enable the geographic imagery collected from different sources to become an integrated digital representation of the Earth widely accessible for humanity's critical decisions.

Currently a large number of standards exist that describe imagery data. The processing of imagery across multiple organizations and information technologies (IT) is hampered by the lack of a common abstract architecture. The establishment of a common framework will foster convergence at the framework level. In the future, multiple implementation standards are needed for data format and service interoperability to carry out the architecture defined in this document.

The objective of this document is the coordinated development of standards that allow the benefits of distributed geographic image processing to be realized in an environment of heterogeneous IT resources and multiple organizational domains. An underlying assumption is that uncoordinated standardization activities made without a plan cannot be united under the necessary framework.

This document provides a reference model for the processing of geographic imagery which is frequently done in open distributed manners. The basis for defining an information system in this document is the Reference Model for Open Distributed Processing (RM-ODP).[42] A brief description of RM-ODP can be referenced in Annex B. The basis for defining geographic information in this document is the ISO 19100 series of standards.

The RM-ODP[42] viewpoints are used in the following fashion.

— Typical users and their business activities, and policies to carry out those activities, are addressed in the Enterprise Viewpoint.

— Data structures and the progressive addition of value to the resulting products are found in the schemas of the Information Viewpoint.

— Individual processing services and the chaining of services are addressed in the Computational Viewpoint.

Approaches to deploy the components of the Information and Computational viewpoints to distributed physical locations are addressed in the Engineering Viewpoint.

Geographic information — Reference model —

Part 2:
Imagery

1 Scope

This document defines a reference model for standardization in the field of geographic imagery processing. This reference model identifies the scope of the standardization activity being undertaken and the context in which it takes place. The reference model includes gridded data with an emphasis on imagery. Although structured in the context of information technology and information technology standards, this document is independent of any application development method or technology implementation approach.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 19119:2016, *Geographic information — Services*

ISO 19123:2005, *Geographic information — Schema for coverage geometry and functions*

ISO 19130-1:—[1)], *Geographic information — Imagery sensor models for geopositioning*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
band
range of wavelengths of electromagnetic radiation that produce a single response by a sensing device

3.2
calibration
process of quantitatively defining a system's responses to known, controlled signal inputs

[SOURCE: CEOS WGCV]

1) Under preparation. Stage at the time of publication: ISO/DIS 19130-1.

3.3
computational viewpoint
viewpoint (3.42) on an ODP system and its environment that enables distribution through functional decomposition of the system into objects which interact at *interfaces* (3.16)

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.3]

3.4
coverage
feature (3.9) that acts as a function to return values from its range for any direct position within its spatial, temporal or spatiotemporal domain

[SOURCE: ISO 19123:2005, 4.1.7]

3.5
digital elevation model
dataset of elevation values that are assigned algorithmically to 2-dimensional coordinates

3.6
digital number
DN
integer value representing a *measurement* (3.20) as detected by a *sensor* (3.36)

3.7
engineering viewpoint
viewpoint (3.42) on an ODP system and its environment that focuses on the mechanisms and functions required to support distributed interaction between objects in the system

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.4]

3.8
enterprise viewpoint
viewpoint (3.42) on an ODP system and its environment that focuses on the purpose, scope and policies for that system

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.1]

3.9
feature
abstraction of real world phenomena

[SOURCE: ISO 19101-1:2014, 4.1.11]

3.10
geographic feature
representation of real world phenomenon associated with a location relative to the Earth

[SOURCE: ISO 19125-2:2004, 4.2]

3.11
geographic imagery
imagery (3.14) associated with a location relative to the Earth

3.12
geographic imagery scene
geographic imagery (3.11) whose data consists of *measurements* (3.20) or simulated measurements of the natural world produced relative to a specified vantage point and at a specified time

Note 1 to entry: A geographic imagery scene is a representation of an environmental landscape; it may correspond to a remotely sensed view of the natural world or to a computer-generated virtual *scene* (3.35) simulating such a view.

3.13
grid
network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in an algorithmic way

[SOURCE: ISO 19123:2005, 4.1.23]

3.14
imagery
representation of phenomena as images produced by electronic and/or optical techniques

Note 1 to entry: In this document, it is assumed that the phenomena have been sensed or detected by one or more devices such as radar, cameras, photometers, and infrared and multispectral scanners.

3.15
information viewpoint
viewpoint (3.42) on an ODP system and its environment that focuses on the semantics of information and information processing

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.2]

3.16
interface
named set of *operations* (3.24) that characterize the behaviour of an entity

[SOURCE: ISO 19119:2016, 4.1.8]

3.17
interoperability
capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units

[SOURCE: ISO/IEC 2382:2015, 2121317]

3.18
knowledge base
data base of knowledge about a particular subject

Note 1 to entry: The database contains facts, inferences, and procedures needed for problem solution (Webster Computer).

3.19
measurable quantity
attribute of a phenomenon, body or substance that may be distinguished qualitatively and determined quantitatively

[SOURCE: VIM:1993, 1.1]

3.20
measurand
particular quantity subject to *measurement* (3.20)

EXAMPLE Vapour pressure of a given sample of water at 20 °C.

Note 1 to entry: The specification of a measurand may require statements about quantities such as time, temperature and pressure.

[SOURCE: VIM:1993, 2.6]

3.21
measurement
set of *operations* (3.24) having the object of determining the value of a quantity

[SOURCE: VIM:1993, 2.1]

3.22
metadata
information about a resource

[SOURCE: ISO 19115-1:2014, 4.10]

3.23
metric traceability
property of the result of a *measurement* (3.20) or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

[SOURCE: Derived from VIM]

3.24
operation
specification of a transformation or query that an object may be called to execute

Note 1 to entry: An operation has a name and a list of parameters.

[SOURCE: ISO 19119:2016, 4.1.10]

3.25
orthoimage
image in which by orthogonal projection to a reference surface, displacement of image points due to *sensor* (3.36) orientation and terrain relief has been removed

Note 1 to entry: The amount of displacement depends on the resolution and the level of detail of the elevation information and on the software implementation.

3.26
picture original
representation of a two-dimensional hardcopy or softcopy input image in terms of the colour-space coordinates (or an approximation thereof)

Note 1 to entry: Picture originals could be obtained from printed maps, printed pictures of a *geographic imagery scene* (3.12), or drawings of geographic information, etc.

3.27
picture portrayal
representations of image data in terms of the colour-space coordinates that are appropriate for, and tightly coupled to, the characteristics of a specified real or virtual output device and viewing

Note 1 to entry: Picture portrayals are geared for visual display whether in hardcopy or softcopy.

3.28
pixel
smallest element of a digital image to which attributes are assigned

Note 1 to entry: This term originated as a contraction of “picture element”.

Note 2 to entry: Related to the concept of a *grid* (3.13) cell.

3.29
policy
set of rules related to a particular purpose

[SOURCE: ISO/IEC 10746-2]

3.30
radiance
at a point on a surface and in a given direction, the radiant intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction

[SOURCE: ISO 80000-7:2008, 7-15]

3.31
radiant energy
energy emitted, transferred or received as radiation

[SOURCE: ISO 80000-7:2008, 7-6]

3.32
record
finite, named collection of related items (objects or values)

[SOURCE: ISO 19107:2003, 4.62]

3.33
remote sensing
collection and interpretation of information about an object without being in physical contact with the object

3.34
resolution (of a sensor)
smallest difference between indications of a *sensor* (3.36) that can be meaningfully distinguished

Note 1 to entry: For *imagery* (3.14), resolution refers to radiometric, spectral, spatial and temporal resolutions.

3.35
scene
spectral *radiances* (3.30) of a view of the natural world as measured from a specified vantage point in space and at a specified time

Note 1 to entry: A scene may correspond to a remotely sensed view of the natural world or to a computer-generated virtual scene simulating such a view.

[SOURCE: ISO 22028-1:2016, 3.35]

3.36
sensor
element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured

[SOURCE: ISO/IEC GUIDE 99:2007, 3.8]

3.37
sensor model
description of the radiometric and geometric characteristics of a *sensor* (3.36)

3.38
service
distinct part of the functionality that is provided by an entity through *interfaces* (3.16)

3.39
technology viewpoint
viewpoint (3.42) on an ODP system and its environment that focuses on the choice of technology in that system

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.5]

3.40
uncertainty
parameter, associated with the result of *measurement* (3.20), that characterizes the dispersion of values that could reasonably be attributed to the *measurand* (3.21)

Note 1 to entry: The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.

Note 2 to entry: Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. The other components, which can also be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

Note 3 to entry: It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

[SOURCE: ISO 19116:2004, 4.26, modified — Notes 1-3 to entry have been added.]

3.41
validation
process of assessing, by independent means, the quality of the data products derived from the system outputs

[SOURCE: CEOS WGCV]

3.42
viewpoint (on a system)
form of abstraction achieved using a selected set of architectural concepts and structuring rules, in order to focus on particular concerns within a system

[SOURCE: ISO/IEC 10746-2:2009, 3.2.7]

4 Abbreviated terms and symbols

4.1 Abbreviated terms

BeiDou	China BeiDou Navigation Satellite System
BIIF	Basic Image Interchange Format
CEOS	Committee on Earth Observation Satellites
CIE	International Commission on Illumination
CMYK	Nonlinear Cyan, Magenta, Yellow, Black
CRS	Coordinate Reference System
CRT	Cathode Ray Tube
CW	Continuous Wavelength

DCP	Distributed Computing Platform
DEM	Digital Elevation Model
DIAL	Differential Absorption LIDAR
DM	Discrete Multivariate Statistics
DN	Digital Number
DSS	Decision Support Service
EOS	Earth Observation Satellite
EOSDIS	Earth Observing System Data and Information System
FIFO	First In, First Out
FIR	Infrared band
FOV	Field of View
G	Gravity
Galileo	European Union Galileo positioning system
GEO	Geosynchronous Earth Orbit
GEOTIFF	Tagged Image File Format for Geographic Imagery
GFM	General Feature Model
GHz	Gigahertz
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System
GML	Geography Markup Language
GMLJP2	GML in JPEG 2000
GPS	Global Positioning System
GSD	Ground Sample Distance
GSI	Ground Sample Interval
HDF	Hierarchical Data Format
HSB	Hue, Saturation, Brightness
HSV	Hue, Saturation, Value
HTTP	Hypertext Transfer Protocol
IEC	International Electrotechnical Commission
IfSAR	Interferometric Synthetic Aperture Radar
IGFOV	Instantaneous Geometric Field of View

IHO	International Hydrographic Organization
IRNSS	Indian Regional Navigation Satellite System
IR-A	Infrared IR-A band
IR-B	Infrared IR-B band
IR-C	IR-C band
ISAR	Inverse Synthetic Aperture Radar Infrared
ISR	Intelligence, Surveillance, and Reconnaissance
ISPRS	International Society for Photogrammetry and Remote Sensing
IT	Information Technology
ITU-R	International Telecommunication Union Radiocommunication Sector
IUS	Image Understanding System
JPEG	Joint Photographic Experts Group
KML	Keyhole Markup Language
LEO	Low Earth Orbit
LIDAR	Light Detection And Ranging
LIFO	Last In, First Out
MIR	Mid-Infrared band
NASA	National Aeronautical and Space Administration
NATO	North Atlantic Treaty Organization
NCSA	National Center for Supercomputing Applications
NEXRAD	Next Generation Radar
NIIA	NATO ISR Interoperability Architecture
NIR	Near-Infrared band
NSIF	NATO Secondary Imagery Format
NSILI	NATO Standard Image Library Interface
ODP	Open Distributed Processing (see RM-ODP)
OGC	OpenGeospatial® Consortium
OLAP	Online Analytical Processing
OSDDEP	Open Skies Digital Data Exchange Profile
QZSS	Japanese Quasi-Zenith Satellite System
RCS	Radar Cross Section

RGB	Red, Green, Blue
RGBI	Red, Green, Blue, Intensity
RM-ODP	Reference Model for Open Distributed Processing
RMSE	Root Mean Squared Error
RNC	Raster Nautical Chart
SAR	Synthetic Aperture Radar
SI	International System
SPCS	State Plane Coordinate System
SQL	Standard Query Language
STANAG	Standardization Agreement
TIFF	Tagged Image File Format
UML	Unified Modelling Language
UTM	Universal Transverse Mercator
VIM	International Vocabulary of Basic and General Terms in Metrology
WMO	World Meteorological Organization
YCrCb	Luminance and Chrominance

4.2 Symbols

λ	wavelength
$\sigma°$	radar backscatter
η_v	volume backscatter coefficient
σ	radar target reflective strength

5 Conformance

5.1 General

To conform to this document, all of the conditions specified for at least one of the conformance classes described below shall be satisfied.

5.2 Enterprise conformance

Any enterprise that claims conformance to this document shall satisfy all of the conditions specified in the test module in A.1.

5.3 Sensor conformance

Any sensor for which conformance to this document is claimed shall satisfy all of the conditions specified in the test module in A.2.

5.4 Imagery data conformance

Any enterprise for which conformance to this document is claimed shall satisfy all of the conditions specified in the test module in A.3.

5.5 Imagery services conformance

Any enterprise for which conformance to this document is claimed shall satisfy all of the conditions specified in the test module in A.4.

5.6 Image processing system conformance

Any image processing system for which conformance to this document is claimed shall satisfy all of the conditions specified in the test module in A.5.

6 Notation

The conceptual schema specified in this document is described using the Unified Modelling Language (UML), following the guidance of ISO 19103[28]. Several model elements used in this schema are defined in other ISO geographic information standards. Names of UML classes, with the exception of basic data type classes, include a two-letter prefix that identifies the standard and the UML package in which the class is defined. Table 1 lists the other documents and packages in which UML classes used in this document have been defined.

Table 1 — Sources of defined UML classes

Prefix	Standard	Package
CV	ISO 19123	Coverages
FC	ISO 19110	Feature cataloguing
GF	ISO 19109	Rules for Application Schema
IG	ISO 19101-2	Reference model — Imagery
LI	ISO 19115-1	Metadata

7 Enterprise viewpoint – Community objectives and policies

7.1 General

The enterprise viewpoint on a geographic imagery processing system and its environment focuses on the purpose, scope and policies as is done in ODP systems[42]. The purpose is provided as the objective of the geographic imagery community. The scope is defined through a high-level scenario in 7.3 and through use cases in Annex C. Policies are discussed in 7.4 through a set of criteria for developing policies for geographic imagery systems as well as several example international policies relating to geographic imagery. The enterprise viewpoint provides a context for the development of standards in the other viewpoints.

7.2 Geographic imagery community objective

The central concept of the enterprise viewpoint is how the geographic imagery community interacts to enable imagery collected from different sources to become an integrated digital representation of the Earth widely accessible for humanity's critical decisions. The enterprise viewpoint provides the metric traceability between this objective and the system design for distributed geographic imagery processing systems.

The fundamental goal of the geographic imagery community is to advance and protect interests of humanity by development of imaging capabilities, and by sustaining and enhancing the geographic imagery industry. Doing so will also foster economic growth, contribute to environmental stewardship, assist into natural and manmade disaster management from planning to recovery, and enable scientific and technological excellence.

7.3 Geographic imagery scenario

Figure 1 provides an example of a geographic imagery scenario. The context is that a customer requests geographic imagery information to be used with other information, including other geographic information, in support of a decision. The analyst is key in the role of decision support.

The customer's request for geographic imagery information is assessed in the planning step. The customer's desired information may be readily available from an archive or a model, or may be processed from information in an archive or available from a model. In this scenario, a model is a simulation of some portion of the geographic environment able to produce geographic imagery. Some additional processing may be needed on the archive or model outputs in order to meet the customer's request.

The customer's request for geographic imagery may require collection of new imagery. Tasking determines the available sensors and platforms and develops an imagery acquisition request. The sensor is tasked to acquire the raw data and the acquisition is performed. Acquisition of the imagery data is done in accordance with the acquisition policies.

Whether the customer's request is to be satisfied from an archive holding, a model output, or a data acquisition, typically some type of additional processing is needed. This could range from changing the encoding format of the imagery to creating derived imagery or image knowledge products. The resulting imagery information may be applied with additional information to form a response that meets the customer's needs. Distribution of the imagery information response is done in accordance with the distribution policies.

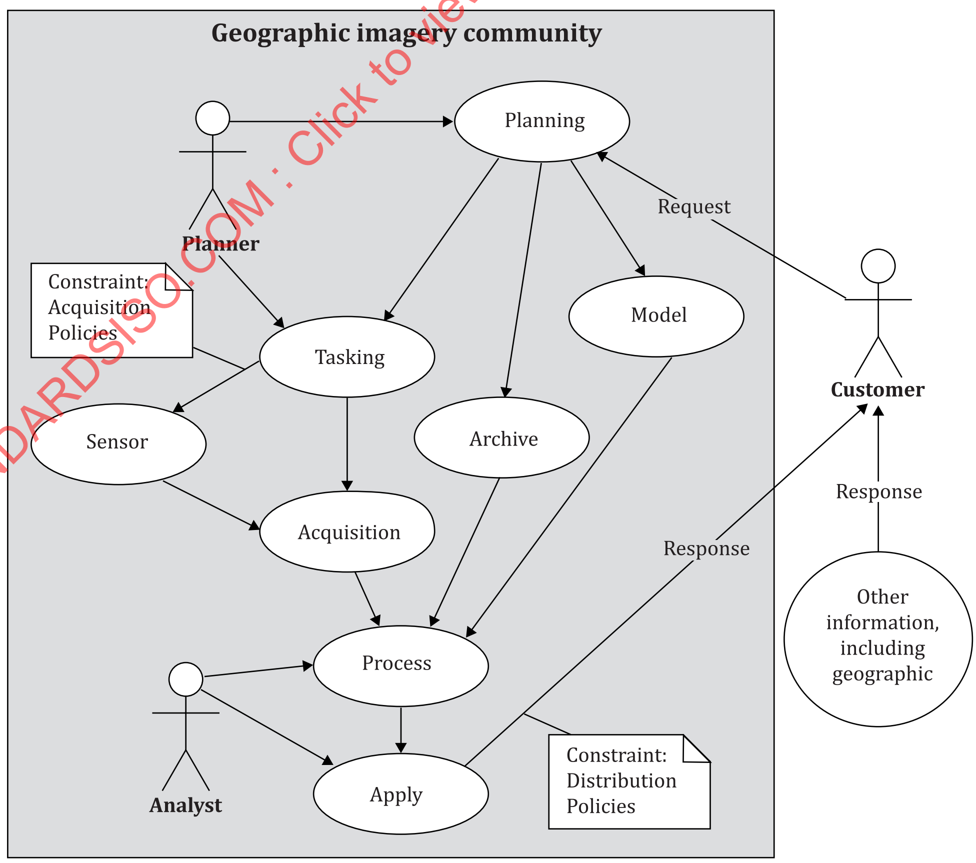


Figure 1 — Geographic imagery scenario

7.4 Geographic imagery policies

7.4.1 Introduction to policies

A policy, as defined in ISO/IEC 10746-2[43], is a set of rules related to a particular purpose. A rule can be expressed as an obligation, a permission or a prohibition. Not every policy is a constraint. Some policies represent an empowerment.

Some geographic imagery policies promulgated by international organizations are included in 7.4.2 and 7.4.3. They may apply to particular geographic imagery systems.

Organizations involved in imagery work should develop policies consistent with the guidelines in Table 2.

7.4.2 Policy development guidelines

Guidelines for development of policies for geographic imagery systems are listed in Table 2. In this document, "policy" refers primarily to issues of ownership i.e. intellectual property, terms and conditions of use i.e. licensing and charging i.e. for fee or open data for geographic imagery.

Table 2 — Policy development guidelines

Stability	Stability of data and services over time is essential so that investment decisions can be made with a correct understanding of the conditions of the future marketplace. Specific policies include continuity in data collection, consistency in format, frequency of observations, and access to comparable data over time.
Simplicity	Access to geographic imagery is subject to many interpretations driven by the variety of people and organizations with informed opinions about the subject. Simple policies that avoid the pitfalls of becoming too deeply entrenched in implementation are necessary.
Fair treatment	Given that much geographic imagery is publicly funded, there is a concern for fair treatment to be applied and to be seen to be applied. This means explicit conditions of access that do not arbitrarily favour one group or penalize another group.
Growth	Growth in the types, extent and volume of geographic imagery is desired. Policies that support growth are critical.
Maximum access	There is widespread interest in maximizing the use of geographic imagery. Image access should follow open standards to allow the integrated use of imagery from multiple sources.
Sustainability	A combination of high investment costs plus a high potential value of the data in the long term means that the value of a sustainable geographic imagery sector should not disappear shortly after applications have been brought to a mature stage.

7.4.3 Policies

7.4.3.1 Imagery acquisition policies

The United Nations resolution "Principles Relating to Remote Sensing of the Earth from Space"[75] was adopted by the United Nations as part of the progression of formulating international rules to enhance opportunities for international cooperation in space.

The International Telecommunication Union – Radiocommunication (ITU-R) has drafted a handbook[21] that identifies radio frequencies that are critical to meteorological measurements and which should not be used for radio transmission as a matter of policy. These measurements would be degraded by radio transmission from non-meteorological sources.

7.4.3.2 Imagery distribution policies

The World Meteorological Organization (WMO) has promulgated a resolution[90] that identifies radio frequencies that are critical to meteorological measurements and their distribution.

7.4.3.3 Enterprise development policies

A policy of standardization for data and interfaces is one of the essential building blocks of the Information Society. There should be particular emphasis on the development and adoption of International Standards. The development and use of open, interoperable, non-discriminatory and demand-driven standards that take into account needs of users and consumers is a basic element for the development and greater diffusion of information and communication technologies and more affordable access to them[92].

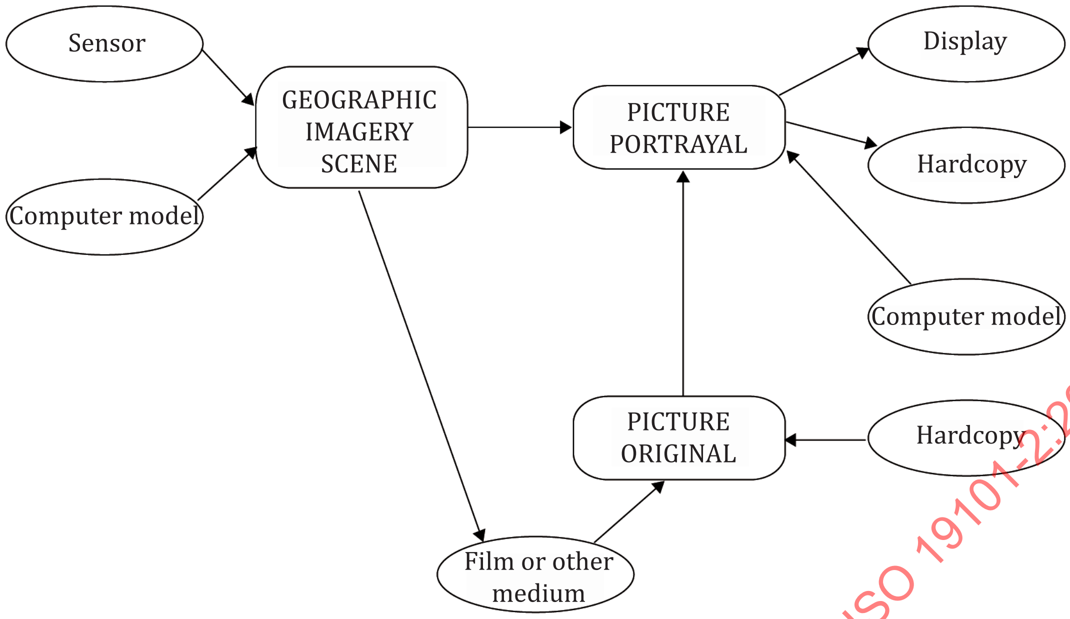
8 Information Viewpoint — Knowledge-based decisions

8.1 Introduction to Information Viewpoint

8.1.1 Introduction to types of geographic imagery

The term "image" is not explicitly defined or addressed in this reference model since there are many meanings of image within various user contexts. Geographic imagery however is defined in this document. Geographic imagery is imagery whose data is associated with a location relative to the Earth. To view geographic imagery, a presentation process is required.

To place geographic imagery in the larger context of imagery, various types of "images" are shown in Figure 2, which is derived from the image state diagram of ISO 22028-1:2016[35]. ISO 22028-1 categorizes image encodings into scene-referred or picture-referred image states. Those image encodings have been refined further within this document in the manner described below.



Key

ENCODED

Source of image

Transformation

EXAMPLE 1 Picture Portrayal: PNG file for visual display.

EXAMPLE 2 Picture Original: TIFF scan of a paper map.

EXAMPLE 3 Geographic Imagery Scene: Multi-spectral scan of environment.

Figure 2 — Image state diagram with modifications for geographic imagery

A scene may correspond to a remotely sensed view of the natural world or to a computer-generated virtual scene simulating such a view. This document applies the approach of feature modelling of the 19100 series of International Standards to “Geographic Imagery Scenes”.

A feature is an abstraction of real world phenomena[27]. A geographic feature has implicit or explicit reference to a location relative to the Earth. A coverage is a feature that acts as a function to return values from its range for any direct position within its spatiotemporal domain. Examples of coverages include an image, a polygon overlay, or a digital elevation matrix. Consistent with the ISO 19100 series approach of feature modelling, a Geographic Imagery Scene (Figure 2) is a type of coverage. A Geographic Imagery Scene is a coverage whose range values quantitatively describe physical phenomena.

This document emphasizes scene-referred imagery, such as derivations of geophysical values based on sensor measurements. This derived imagery is also considered to be a type of Geographic Imagery Scene.

Physical quantities and units as defined in ISO 80000-1[37] should be used in a Geographic Imagery Scene for the quantitative description of physical phenomena as far as possible. Conventional scales may be used in other types of geographic coverages. The physical quantities of a Geographic Imagery Scene may be the result of a measurement by a sensor or from a prediction by a physical model (denoted as ovals labelled “Sensor” and “Computer Model” in Figure 2).

A Geographic Imagery Scene is a representation of an environmental landscape, i.e. a measurement of the natural world at a specified vantage point in space and at a specified time. It may correspond to a remotely sensed view of the natural world or to a computer-generated virtual scene simulating such a view. To accommodate geographic imagery, this document has modified the image state diagram of ISO 22028-1 by changing from “Scene-referred colour encoding” to “Geographic Imagery Scene.” Geographic Imagery Scenes make use of a much broader spectrum than the colours addressed by ISO 22028-1. Also, Geographic Imagery Scenes may be measurements other than radiances, i.e. they may correspond to a computer-generated virtual scene simulating a remotely sensed view of radiances.

“Picture Portrayals” (Figure 2) are representations of image data in terms of the colour-space coordinates that are appropriate for, and tightly coupled to, the characteristics of specified real or virtual output device and viewing. They use colour coding for the representation of pixel values and are geared for visual displays suited for human readability, whether in hardcopy or softcopy (denoted as “Hardcopy” and “Display” ovals in Figure 2). The portrayal of geographic information is addressed in ISO 19117[32].

“Picture Originals” (Figure 2) are representations of a two-dimensional hardcopy or softcopy input image in terms of the colour-space coordinates (or an approximation thereof). For geographic information, Picture Originals could be obtained from printed maps, printed pictures of geographic imagery, drawings of geographic information, etc. (denoted as the oval labelled “Hardcopy” in Figure 2). Although a Picture Original may be a picture of a Geographic Imagery Scene, it is not a Scene as defined in 4.35 because the picture was previously colour-rendered for printing.

Both Picture Portrayals and Picture Originals are colour encodings of any type of geographic information including, but not limited to, geographic imagery. Issues such as false-colour rendering shall be addressed to transform the broader spectrum of geographic imagery into colour imagery.

8.3 to 8.5 present a detailed conceptual schema for geographic imagery scenes.

8.1.2 Creating knowledge from imagery

The Information Viewpoint in this document identifies various types of geographic information characterizing Geographic Imagery Scenes. The Information Viewpoint is structured following an integrated approach to geographic imagery showing relationships of raw sensed data to higher semantic content information and knowledge. As defined in ISO/IEC 10746-1[42] an Information Viewpoint specification of an ODP system focuses on the semantics of information and information processing. The resulting structure of the Information Viewpoint is reflected in the UML packages identified in Figure 3. The contents of these packages are addressed in 8.2 to 8.5 of this Information Viewpoint.

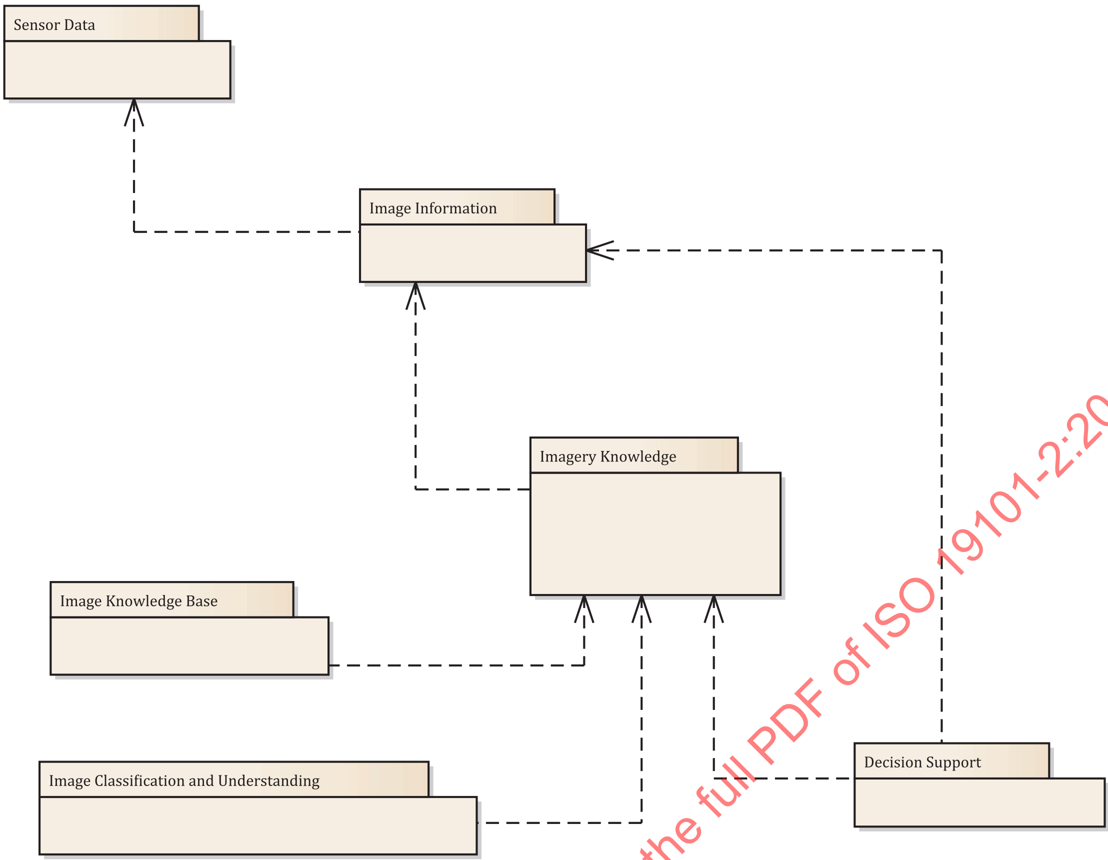


Figure 3 — Information Viewpoint packages

Geographic imagery is used to signify something about the environment. Figure 4 presents the structure for the Information Viewpoint[2].

Decisions	Pragmatic application of knowledge
Knowledge	Integrated model of information
Information	Data with meaning assigned
Data	Representation subject to interpretation

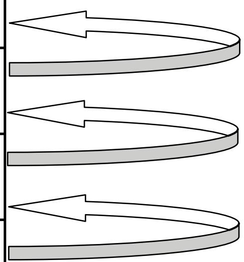


Figure 4 — Structure of the Information Viewpoint

Data (Figure 4, bottom layer) is a reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing[40]. For imagery, data consists of the results of measurement by a sensor.

Meaning is assigned to data by applying conventions or agreed-upon codes so that it becomes information[3]. Structuring the sensor data in a standard syntax allows for transmission of the data to entities in the open distributed processing system.

As information is gathered, observed regularities are generalized and models are developed forming the transition to knowledge. Knowledge is an organized, integrated collection of facts and generalizations.

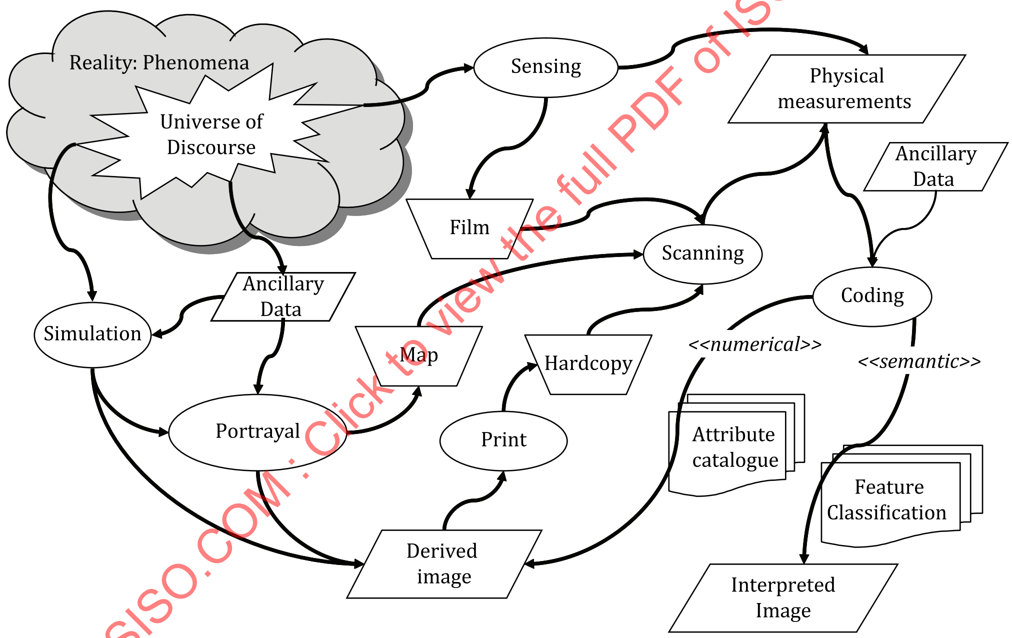
Imagery can be interpreted based on a model of feature types that correspond to a universe of discourse. The resulting feature-based description of a Geographic Imagery Scene is described in 8.1.3.

The knowledge base is used in the formation of pragmatic decisions that address the goals of multiple stakeholders. A key to effective decisions is identifying the context in which the decision applies. The context determines what information is relevant to the decision.

8.1.3 General Feature Model

Geographic imagery is a type of geographic information. The ISO 19100 series of International Standards defines a conceptual modelling approach for geographic information. ISO 19101-1[31] defines Conceptual Modelling and the Domain Reference Model that this document extends for geographic imagery. ISO 19109[29] defines the General Feature Model that is used in the ISO 19100 series wherever application schemas are dealt with.

The definitions of the feature types and their properties, as perceived in the context of an application field, are derived from the universe of discourse. A feature catalogue documents the feature types. An application schema defines the logical structure of data and may define operations that can be performed on or with the data.



Key

Catalogue

Physical/Analogue data set

Action

Geospatial DB

Figure 5 — Feature modelling extended to imagery

Figure 5 shows the process of directly sensing or otherwise producing a representation of reality in a data set that can be processed to provide measurements of physical quantities or to be interpreted as a set of discrete features. The physical quantities and their properties, as perceived in the context of an application field, are derived from the universe of discourse. An attribute catalogue documents the physical quantities as attribute types.

Elements in the parallelograms of Figure 5 are defined in this clause. Sensors and the resulting data are described in 8.2, as are the physical quantities in an attribute catalogue. Derived Image is described in 8.3.2. Interpreted Image is described in 8.4.

8.1.4 Topics relevant across data, information, and knowledge

8.1.4.1 Resolution

The resolution of a sensor is distinct from the resolution of an image. The resolution of a sensor is the smallest difference that can be detected by a sensor. Sensor resolution is a measure of the ability of a sensor to detect differences between sensed objects and it may be expressed in many ways depending on the sensor (see 8.2).

For imagery, resolution refers to radiometric, spectral, spatial and temporal resolutions. Radiometric resolution is the amount of energy required to increase a pixel value by one quantization level or “count”. Radiometric resolution measures sensitivity by discriminating between intensity levels.

Spectral resolution measures sensitivity in discriminating between wavelengths. It is proportional to the number of bands recorded in an image and inversely proportional to their width.

The spatial resolution of an image is the minimum separation between two objects that can be distinguished as separate objects in the image. Pixel ground resolution defines the area on the ground represented by each pixel. This is often expressed as the distance between the centers of the areas represented by two adjacent pixels, called Ground Sample Distance (GSD) or Ground Sample Interval (GSI).

Related to the spatial resolution is the Instantaneous Geometric Field of View (IGFOV). IGFOV is the geometric size of the image projected by the detector on the ground through the optical system. IGFOV is also called pixel footprint. The related concept of CV_Footprint shall be defined as described in ISO 19123 A CV_Footprint is the sample space of a grid in an external coordinate reference system, e.g. a geographic CRS or a map projection CRS.

Temporal resolution is an issue when successive images are used for change detection or for tracking moving objects. It is expressed as the frequency with which successive images are obtained or as the interval between successive images.

8.1.4.2 Uncertainty in imagery

Understanding and estimating the uncertainty in image data is important for absolute measurements of phenomena as well as for data integration. Sources of error are found across the many elements of geographic image processing. Table 3 provides examples.

Table 3 — Aspects of imagery within which errors may arise

Acquisition	Geometric aspects Sensor systems Platforms Ground control Geographic Imagery Scene considerations
Data Processing	Geometric rectification Radiometric rectification Data conversion
Data Analysis	Quantitative analysis Classification system Data generalization
Data Conversion	Raster to vector Vector to raster
Aspects of Error Assessment	
Error Assessment	Sampling Spatial autocorrelation Locational accuracy Error Matrix Discrete Multivariate Statistics Reporting standards

8.1.4.3 Imagery fusion

Imagery fusion is the combining of imagery and other sources of geospatial information to improve the understanding of a specific phenomenon. Fusion may be performed at several levels: pixel (8.3.3.6), feature (8.4.4.4) and decision (8.5.5). Standards that enable fusion of measurements from different sensors should be suited to these levels of pixel, feature and decision fusion.

8.2 Sensor data package

8.2.1 General

The concepts that should be modelled in the Sensor Data package appear in Figure 3, and are described in 8.2. Some of these concepts are modelled in ISO 19130-1 and the remainder may be modelled in other standards. Calibration and validation of sensors are described in the ISO 19159[54][55] multipart standard.

8.2.2 Sensors and platforms

The attribute values of an image are numerical representations of the values of a physical parameter. The value for a physical parameter at a given time and place is obtained by conducting a measurement using a sensor. An imaging sensor typically performs multiple measurements to populate a grid of values. The raw imagery data described in 8.2 focuses on sensors, the data they produce [e.g. Digital Numbers (DN) and radiances at the sensor inputs], the methods for creating a grid of values, and the uncertainty of the sensor data.

Most geographic imagery data is obtained by remote sensing which aims to measure attributes of a real world phenomenon without being in mechanical contact with the phenomenon. The main type of remote sensing is radiometry – the measurement of the quantities associated with radiant energy, i.e. electromagnetic radiation.

Electromagnetic radiation is commonly classified as a function of wavelength across the electromagnetic spectrum (Figure 6). Sensors are designed to be sensitive to particular bands of the spectrum, e.g. visible band. A band is a range of wavelengths of electromagnetic radiation that produces a single response from a sensing device. Multispectral radiometers measure radiance in several wavelength bands over a given spectral region. Hyperspectral radiometers detect hundreds of very narrow spectral bands throughout the visible and infrared portions of the electromagnetic spectrum.

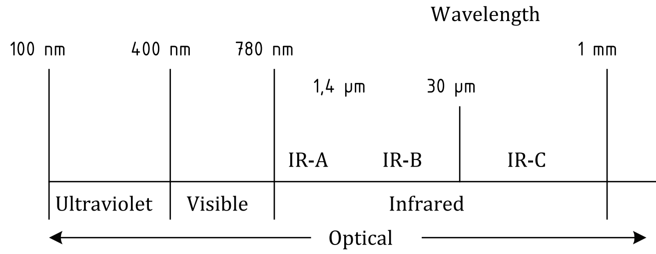


Figure 6 — Portion of the electromagnetic spectrum relevant for geographic imagery

The immediate output of a digital sensor are DNs. Prior to deployment, a sensor is calibrated in a laboratory using standard radiation sources. Using a calibration curve, DNs are mathematically converted to sensor input radiances.

The resolution of a sensor is defined by several quantities. The band structure for a sensor determines its spectral resolution. The radiometric sensitivity of a sensor for a specific band is the radiance increment for a single bit change in the DN. The spatial resolution of the sensor is the solid angle for which the sensor measures radiances.

An interferometer is an apparatus used to produce and measure interference from two or more coherent wave trains from the same source. An interferometer is an instrument used to measure distance. It does so by producing and measuring the interference between two or more coherent wave trains from the same source.

Sensor descriptions are organized by the type of energy sensed by the sensor. Firstly, the electromagnetic energy sensors are described: optical, microwave, and Light Detection And Ranging (LIDAR). Secondly, the various mechanical wave energy sensors are described, such as sonar for example. Passive and active sensors are differentiated as necessary within this document.

Schemas for describing some of these sensors and platforms shall be detailed as described in ISO 19130-1.

8.2.3 Optical sensing

8.2.3.1 General description

Optical radiation is electromagnetic radiation at wavelengths between the region of transition to X-rays ($\lambda \sim 1$ nm) and the region of transition to radio waves ($\lambda \sim 1$ mm)[19]. Optical radiation includes infrared, visible and ultraviolet radiation (Table 4). Table 4 is derived from the International Lighting Vocabulary[19].

Visible radiation is any optical radiation capable of causing a visual sensation directly. There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer. The lower limit is generally taken to be between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

Infrared radiation is optical radiation for which the wavelengths are longer than those for visible radiation.

Ultraviolet radiation is optical radiation for which the wavelengths are shorter than those for visible radiation[19].

Table 4 — Optical sensing wavelengths

Ultraviolet radiation	100 nm to 400 nm
Ultraviolet UV-C band	100 nm to 280 nm
Ultraviolet UV-B band	280 nm to 315 nm
Ultraviolet UV-A band	315 nm to 400 nm
Visible radiation (no precise limits)	Lower limit between 360 nm and 400 nm Upper limit between 760 nm and 830 nm
Infrared radiation (CIE)	780 nm to 1 000 000 nm (780 nm to 1 mm)
Infrared IR-A band	780 nm to 1 400 nm
Infrared IR-B band	1 400 nm to 3 000 nm (1,4 µm to 3 µm)
Infrared IR-C band	3 000 nm to 1 000 000 nm (3 µm to 1 000 µm) (3 µm to 1 mm)
Infrared radiation (ISO 20473)	780 nm to 1 000 000 nm (780 nm to 1 mm)
Near-Infrared band (NIR)	0,78–3 µm
Mid-Infrared band (MIR)	3–50 µm
Far-Infrared band (FIR)	50–1 000 µm

8.2.3.2 Measurements

Optical sensors measure the radiant energy in bands and in differing energy quantities (Table 5).

Table 5 — Optical measurements definitions

Quantity	ISO 80000-7, Quantities and units — Part 7: Light	Name of unit
Radiant energy	Energy emitted, transferred or received as radiation	joule
Radiant flux (power)	Power emitted, transferred or received as radiation	watt
Irradiance	At a point on a surface, the radiant energy flux incident on an element of the surface, divided by the area of that element	watt/m^2
Radiance	At a point on a surface and in a given direction, the radiant intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction	watt/m^2
Radiant intensity	In a given direction from a source, the radiant energy flux leaving the source, or an element of the source, in an element of solid angle containing the given direction, divided by that element of solid angle	watt/steradian

An image is a grid of values from a geographic extent. Different sensors produce values in different manners, e.g. in a single measurement, and scanning or measuring over time[8]. The following are examples of scan geometries:

— frame camera or sensor array;

— scan linear array;

— pushbroom sensor;

— whiskbroom sensor;

— conic scanning sensor.

8.2.3.3 Derivable information

Optical remote sensing makes use of visible and infrared sensors to form images by detecting the radiation reflected or emitted from targets on the ground. Different materials reflect, absorb or emit differently at different wavelengths. Thus, the spectral signatures in the remotely sensed images can differentiate the targets. Optical remote sensing systems are classified into the following types, depending on the number of spectral bands used in the imaging process.

— **Panchromatic imaging system** – The sensor is a single channel detector sensitive to radiation within a broad wavelength range. If the wavelength range coincides with the visible range, then the resulting image resembles a "black-and-white" photograph. The physical quantity being measured is the apparent brightness of the targets. The spectral information or "colour" of the targets is lost.

— **Multispectral imaging system** – The sensor is a multichannel detector with a few spectral bands. Each channel is sensitive to radiation within a narrow wavelength band. The resulting image is a multilayer image that contains both the brightness and spectral (colour) information of the targets being observed (e.g. RGB or RGBI).

— **Hyperspectral imaging system** – A hyperspectral imaging system is also known as an "imaging spectrometer". It acquires images in about a hundred or more contiguous spectral bands. The precise spectral information contained in a hyperspectral image enables better characterization and identification of targets. Hyperspectral images have potential applications in such fields as precision agriculture (e.g. monitoring the types, health, moisture status and maturity of crops), coastal management (e.g. monitoring of phytoplanktons, pollution, and bathymetry changes).

8.2.4 Microwave sensing

8.2.4.1 Passive microwave

8.2.4.1.1 General description

Microwave radiation is electromagnetic radiation in the range 0,3 mm to 300 mm[17].

Vertically and horizontally polarized measurements are taken for all frequencies.

8.2.4.1.2 Measurements

An imaging radiometer maps the brightness temperature distribution over a Field Of View (FOV). An aperture radiometer does it by scanning either electrically or mechanically across the FOV. Brightness temperature is the measurand.

8.2.4.1.3 Derivable information

Passive microwave measurements can be used to derive, for example, the following geophysical quantities: rainfall, sea surface temperature, vertical water vapour, ocean surface wind speed, sea ice parameters, snow water equivalent, and soil surface moisture.

Geophysical quantities derived from microwave measurements enable investigation of atmospheric and surface hydrologic and energy cycles.

Spatial resolution of passive microwave data is currently limited to kilometres due to antenna size.

8.2.4.2 Radar

8.2.4.2.1 General description

Radar is an electromagnetic system for the detection and location of objects that operates by transmitting electromagnetic signals, receiving echoes from objects (targets) within its volume of coverage, and extracting location and other information from the echo signal[17]. Imaging radar systems operate in thirteen frequency bands and they are listed in Table 6[16]. Reflectance of surface materials differs between bands.

Radar is an active radio detection and ranging sensor that provides its own source of electromagnetic energy. A radar sensor emits microwave radiation in a series of pulses from an antenna. When the energy reaches the target, some of the energy is reflected back toward the sensor. This backscattered microwave radiation is detected, measured, and timed. The time required for the energy to travel to the target and return back to the sensor is determined by the distance or range to the target. By recording the range and magnitude of the energy reflected from all targets as the system passes by, an image of the surface can be produced. Because radar provides its own energy source, images can be acquired day or night. Microwave energy is also able to penetrate clouds and most rain.

Table 6 — Radar band designations

Band designation	Nominal frequency range
HF	3 MHz to 30 MHz
VHF	30 MHz to 300 MHz
UHF	300 MHz to 1 000 MHz
L	1 GHz to 2 GHz
S	2 GHz to 4 GHz
C	4 GHz to 8 GHz
X	8 GHz to 12 GHz
Ku	12 GHz to 18 GHz
K	18 GHz to 27 GHz
Ka	27 GHz to 40 GHz
V	40 GHz to 75 GHz
W	75 GHz to 110 GHz
mm	110 GHz to 300 GHz

8.2.4.2.2 Measurements

Radar systems make the following measurements.

— Intensity of microwave radiation at sensor.

— Time taken for the emitted pulse of radiation to travel from the sensor to the ground and back.

— Doppler shift in the frequency of the radiation echo as a result of the relative motion of the sensor and the ground.

— Polarization of the radiation.

The various radar measurement quantities are listed in Table 7[17].

Table 7 — Radar measurements

Quantity	Measurand
Backscatter	Energy reflected or scattered in a direction opposite to that of the incident wave.
Backscatter coefficient	Normalized measure of radar return from a distributed scatterer. — For area targets, backscatter is expressed in decibels and denoted by σ^{0}, which is dimensionless but is sometimes written in units of m^2/m^2 for clarity. — For volume scatter, such as that from rain, chaff, or deep snow cover, it is defined as the average monostatic radar cross-section per unit volume and is expressed in units of m^2/m^3 or m^{-1}. The volume backscatter coefficient is often expressed in decibels and denoted by the symbol η_v.
Radar cross-section (RCS)	Measure of the reflective strength of a radar target; usually represented by the symbol σ and measured in square meters. RCS is defined as $4\sigma^{0}$ times the ratio of the power per unit solid angle scattered in a specified direction of the power unit area in a plane wave incident on the scatterer from a specified direction. More precisely, it is the limit of that ratio as the distance from the scatterer to the point where the scattered power is measured approaches infinity.

Spatial resolution for radar is defined by a resolution cell. A resolution cell is a one-dimensional or multidimensional region related to the ability of radar to resolve multiple targets. For radar, dimensions that involve resolution can include range, angle and radial velocity (Doppler frequency).

8.2.4.2.3 Derivable information

Imaging radar is high-resolution radar and its output is a representation of the radar cross-section with the resolution cell (backscatter coefficient) from the object resolved in two or three spatial dimensions. The radar may use real aperture (such as a sidelooking airborne radar), Synthetic-Aperture Radar (SAR), Inverse Synthetic Aperture Radar (ISAR), Interferometric SAR (IfSAR) or tomographic techniques.

SAR is a coherent radar system that generates a narrow cross range impulse response by signal processing (integrating) the amplitude and phase of the received signal over an angular rotation of the radar line of sight with respect to the object (target) illuminated[17]. Due to the change in line-of-sight direction, a synthetic aperture is produced by the signal processing that has the effect of an antenna with much larger aperture (and hence a much greater angular resolution).

SAR Imaging Modes are as follows.

— **Stripmap** – The antenna pointing is fixed relative to flight line (usually normal to the flight line). The result is a moving antenna footprint that sweeps along a strip of terrain parallel to the path motion.

— **Spotlight** – The sensor steers its antenna beam to continuously illuminate a specific (predetermined) spot or terrain patch while the platform moves in a straight line.

— **ScanSAR** – The sensor steers the antenna beam to illuminate a strip of terrain at any angle to the path of the platform motion.

A radar altimeter uses radar principles for height measurement. Height is determined by measurement of propagation time of a radio signal transmitted from the vehicle and reflected back to the vehicle from the terrain below.

Civilian radar systems have concentrated on radiometric accuracy and investigation of natural targets; the priority of military systems is the detection and recognition of man-made targets (often vehicles) against a clutter background. Ground-based radar measures the rainfall density and line-of-sight velocity, for example, NEXRAD. Ground-penetrating radar may be applied to detection of buried objects and determination of geophysical parameters below the surface.

Among the more recent options for determining digital elevation is IfSAR, a radar technology capable of producing products with vertical accuracies of 30 cm RMSE. Not only that, but IfSAR provides cloud penetration, day/night operation (both because of the inherent properties of radar), wide-area coverage and full digital processing. The technology is quickly proving its worth[18].

8.2.5 LIDAR sensor

8.2.5.1 General description

LIDAR is a light detection and ranging sensor that uses a laser to transmit a light pulse and a receiver with sensitive detectors to measure the backscattered or reflected light. Distance to the object is determined by recording the time between transmitted and backscattered pulses and by using the speed of light to calculate the distance travelled. In addition to mapping of land and water surfaces, LIDAR systems can be used to determine atmospheric profiles of aerosols, clouds and other constituents of the atmosphere.

In general, LIDAR systems used for gathering geographic information can be classified in the following ways:

— measurement techniques;

— target scanning techniques;

— sensed phenomena.

8.2.5.2 Measurement techniques

There are three types of laser sensing systems (Figure 7). They include pulsed and continuous wave (CW) laser ranging systems as well as light-striping/video-profiling systems.

A pulsed laser system transmits laser pulses, senses the light that is scattered back through an optical telescope and amplifies the returned signal using a photomultiplier tube. The time required for the transmitted pulse to travel to the target and back is recorded and used with the speed of light to determine the distance to the object.

On the other hand, the CW laser system transmits a continuous signal. Ranging can be carried out by modulating the light intensity of the laser light. Typically, the modulated signal is sinusoidal. That sinusoidal signal is received with a time delay. The travelling time is directly proportional to the phase difference between the received and transmitted signal.

Currently, the pulsed laser systems are most widely used because they can produce high power output at a very high pulse repetition rate.

There is one type of laser measurement that is based on a combination of a laser light stripe generator and a video camera. It is so-called “non-contact” optical measurement. The laser source is apart from the video camera, which can be digital. The laser light is visible on the target surface as a continuous line. This line is considered as a surface profile. Then, during the movement of a carrying platform, the profiles are registered to a 3D coordinate system by an iterative surface-matching algorithm. The digital image processing is based on a projective transformation between the image plane of the camera and the plane of the laser sheet, and also the direction of the scanning with respect to the plane of the laser sheet. The refinement is obtained through weighted least squares matching of multiple profile maps acquired from different points of view, and registered previously using an approximate calibration.

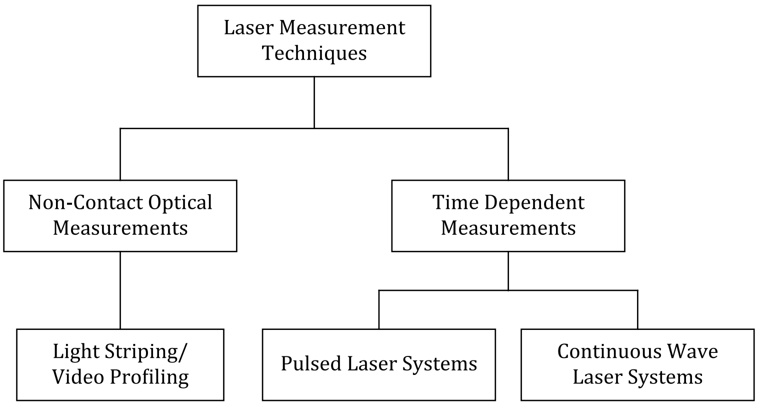


Figure 7 — Basic laser measurement techniques

8.2.5.3 Target scanning techniques

LIDAR systems can be classified on the basis of scanning techniques (Figure 8). Laser scanners are typically cross-track or pushbroom scanners. An airborne laser profiling system is a laser altimeter.

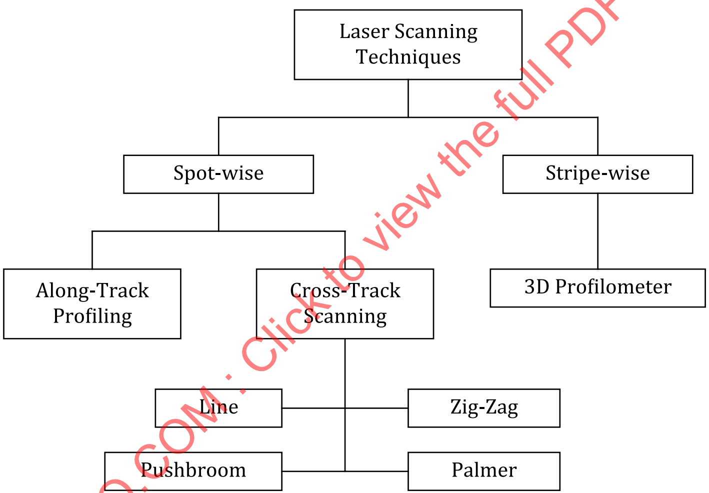


Figure 8 — Laser scanning techniques

8.2.5.4 Sensed phenomena

LIDAR systems can be classified on the basis of the different physical phenomena that they are designed to detect.

— **Aerosol LIDAR** directly measures the optical properties of atmospheric aerosol distributions. Typical parameters measured by an aerosol LIDAR are:

  — scattering ratio and its wavelength dependence;

  — structure and optical depth of the clouds;

  — planetary boundary;

  — multi-layer structure;

  — layer height;

  — averaged integrated backscatter;

  - fractional cover;
  - radiation budget via measurements of surface reflectance and albedo as a function of incidence angle.
- **Coherent Doppler LIDAR** is usually used for remote sensing of the distribution of wind velocity and aerosol backscatter within three-dimensional volumes in the troposphere and lower stratosphere. Coherent LIDAR is considered to be more sensitive and to provide better wind measurements at aerosol levels consistent with the boundary layer and lower troposphere, as well as from atmospheric ice and water clouds.
- **Differential absorption LIDAR (DIAL)** transmits two closely spaced wavelengths. One of these wavelengths coincides with an absorption line of the constituent of interest, and the other is in the wing of this absorption line. During transmission through the atmosphere, the emission that is tuned to the absorption line is attenuated more than the emission in the wing of the absorption line. The concentration of the species can be determined based on the relative optical attenuation.
- **Raman LIDAR** uses the Raman-shifted component that is a transition that involves a change in the vibrational energy level of molecules. Since each type of molecule has unique vibrational and rotational quantum energy levels, each has a unique spectral signature.
- **Rayleigh LIDAR** measures the intensity of the Rayleigh backscatter, which is used to determine a relative density profile. This is used in turn to determine an absolute temperature profile.
- **Resonance LIDAR** uses the resonant scattering that occurs when the energy of an incident photon is equal to the energy of an allowed transition within an atom. As each type of atom and molecule has a unique absorption and fluorescent spectrum, this effect can be used to identify and measure the concentration of a particular species.

8.2.5.5 Typical areas of applications

Typical applications of LIDAR systems include:

- atmospheric monitoring and studies (e.g. aerosol profiling and ozone measurements);
- 3D terrain mapping [e.g. urban areas (3D city modelling), power lines and mining];
- hydrographic measurements (e.g. bathymetry);
- forestry and forest management (e.g. biomass, stem volume, tree heights);
- environmental monitoring (e.g. water quality and phytoplankton);
- pollution detection (e.g. pipeline leak detection like oil or gas);
- mapping organic pollution (e.g. oil and petroleum products on soil or in water);
- measuring industrial structures (e.g. bridges and tanks);
- homeland security.

For many of these applications, LIDAR systems are flown together with other optical sensors such as photogrammetric cameras.

8.2.6 Sonar sensor

8.2.6.1 Sonar measurements

Sonar is a sound transmittal and detection sensor that uses one or more transducers to transmit sound pulses with one or more receivers that measure the reflected sound pulses along with backscatter information (signal to noise ratio). The calculated depth is determined by recording the time interval between transmitted and received sonar pulses. The speed of sound as described in sound velocity profiles is used to calculate the travel distance. Sonar can also determine bottom types (mud, gravel, rock, sand, etc.) by using backscatter as a measure of hardness determined by comparison to classification catalogues.

Multiple pulses transmitted and received by multibeam sonar create 100 % coverage surfaces of the sea bottom. The sonar error footprint is dependent on depth and sound frequency.

Sonar systems make the following measurements.

— Time taken for the emitted pulse of sound to travel from the sensor to the ground and back (milliseconds).

— Backscatter – measure of the reflective intensity of the reflected sonar pulse.

— Sonar footprint – usually represented by measurements in square meters.

8.2.6.2 Derivable information

Information that can be derived from sonar sensor data includes

— depth – time taken for the emitted pulse of sound to travel from the sensor to the ground and back, interpreted in meters,

— sound velocity profiles (m/s),

— digital elevation models,

— tide/current models,

— sea bottom texture maps based on backscatter,

— storm surge models,

— coastal erosion maps,

— free-air gravity maps (fusion of gravity and bathymetric maps),

— coastal flooding models,

— seabed classification,

— sediment thickness, and

— sea level rise.

8.2.7 Digital images from film

While this document is limited to digital information, one source of digital imagery is film. Film cameras remain widely used. Film images have to be scanned before further processing.

Both film negatives and film prints can be scanned to create digital information. The scanning process may be performed using colour-space coordinates or the scanning process may gather more spectral information than can be represented in colour-space coordinates. A scanned image constrained by colour-space coordinates is a Picture Original. A scanned image not constrained by colour-space coordinates is a Geographic Imagery Scene.

8.2.8 Scanned maps

A geographic image can be obtained by scanning a hardcopy map. The resulting image is a Picture Original. Hardcopy maps are constrained to contain the spectrum of the colour coordinates of the printing process and any aging of the print. Also, maps contain portrayed features and annotations as well as Geographic Imagery Scene information. A scanned map can be classified into either georectified or non-georectified, depending on whether the cells are uniformly spaced in reference to geographic map coordinates.

For example, a scanned topographic sheet in the State Plane Coordinate System (SPCS) in the US is georectified because the scanned cells are uniformly spaced along the state plane's X and Y coordinates (assuming no distortion of the map and no position errors during scanning). When a paper map or chart is scanned, often there already exists a printed grid on the map or chart. This grid can be used to provide a set of control points to georectify the scanned map or chart. The intersections of the gridlines printed on the scanned map or chart can relate the cells in which those intersections occur to the coordinate system used on the map.

The projection and reference system printed on a paper chart may not be well referenced, or for the case of older maps, even well known. It is necessary in a scanned map or chart to reference the gridded data cells to the Earth as well as to the map reference grid printed on the chart. Often this is done by generating a second set of control points that relate known points on the map to the Earth. Having two sets of control points for a scanned paper map or chart allows the user to work in the grid coordinates printed on the map or chart and also relate the map or chart to the real world. It is necessary to allow the user to work in the coordinate system printed on the scanned paper map or chart, because that grid is visible to the user.

For example, in a Raster Nautical Chart system (as defined by IHO) that uses a scanned paper chart and which plots ships-own-position as an overlay on the chart, it is necessary for the user to see coordinates in the coordinate system printed on the chart, but also for the symbol representing ships-own-position to be correctly derived from real-world coordinates.

8.2.9 Calibration, validation and metrology

Requirements for calibration and validation recommended by the Committee on Earth Observation Satellites (CEOS)[89] include the following.

— All Earth observation measurement systems should be traceable to SI units for all appropriate measurands.

— Pre-launch calibration should be performed using equipment and techniques that can be demonstrably traceable to, and consistent with, the SI system of units; and metric traceability should be maintained throughout the lifetime of the mission.

These resolutions follow closely those adopted by the 20th General Conference of the International Bureau of Weights and Measures which concluded that: "those responsible for studies of the Earth resources, the environment, human well-being and related issues ensure that measurements made within their programmes are in terms of well-characterized SI units so that they are reliable in the long-term, are comparable world-wide and are linked to other areas of science and technology though the world's measurement systems established and maintained under the Convention du Mètre"[66].

Calibration is not always critical. For small target detection in single-channel data, image calibration is often unnecessary because there is no concern for precise measurements – only the contrast between the target and its background is of interest – so only radiometric resolution (signal-to-noise) and uniformity of response of the sensor are critical. However, as soon as temporal information is required, data from more than one source are compared, or where the data may form a baseline for a long-term study, clear knowledge of uncertainty is essential. Understanding of uncertainty is achieved through metric traceability to recognized primary standards.

Techniques for calibration are based on metrology that establishes general rules for evaluating and expressing uncertainty in measurement. Metrology is mainly concerned with the uncertainty in the measurement of a well-defined physical quantity – the measurand – that can be characterized by an essentially unique value. It also covers the evaluation and expression of uncertainty associated with the experiment design, measurement methods, and complex systems.

Metrology is focused on measurable quantities. A measurable quantity is an attribute of a phenomenon, body or substance that may be distinguished qualitatively and determined quantitatively. A measurement is a set of operations having the object of determining the value of a quantity. A measurand is a particular quantity subject to measurement[37].

Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. The other components, which can also be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

A focus of calibration is to determine the accuracy of measurement. Accuracy is a qualitative concept that describes the closeness of the agreement between the result of a measurement and a true value of the measurand[37]. Quantitatively, the uncertainty of measurement characterizes the dispersion of the values that could reasonably be attributed to the measurand.

It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

— Metric traceability is the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties[37].

— Calibration is the process of quantitatively defining a system's responses to known, controlled signal inputs[82].

— Validation is the process of assessing, by independent means, the quality of the data products derived from the system outputs[82].

For image sensing data requiring calibration, the uncertainty of the sensor shall be measured. For determination of uncertainty of an imaging sensor, metric traceability shall be defined.

8.2.10 Position and attitude determination

Concurrent with attribute value data, the imaging sensor and its associated positioning system shall record location and attitude information. This information may be applied immediately to geolocate the data or may be carried with the data, supporting geolocation at a later time. A positioning system is a system of instrumental and computational components for determining position. Various types of positioning systems are listed in Table 8. Examples of positioning systems are provided in ISO 19116[31], which specifies the data structure and content of an interface that permits communication between position-providing device(s) and position-using device(s) so that the position-using device(s) can obtain and unambiguously interpret position information and determine whether the results meet the requirements of the intended use. ISO 19130-1 addresses the use of positioning information with regard to imagery. Positioning of imagery may involve a series of transformations between relative positions of elements of the sensing system. Photogrammetric techniques are also used for positioning imagery.

Table 8 — Positioning systems

Inertial positioning system	Positioning system employing accelerometers, gyroscopes, and computers as integral components to determine coordinates of points or objects relative to an initial known reference point.
Satellite positioning system	Positioning system based upon receipt of signals broadcast from satellite. In this context, satellite positioning implies the use of radio signals transmitted from "active" artificial objects orbiting the Earth and received by "passive" instruments on or near the Earth's surface to determine position, velocity, and/or attitude of an object. Examples are GPS, GLONASS, IRNSS, QZSS and BeiDou.
Integrated positioning system	Positioning system incorporating two or more positioning technologies. Measurements produced by each positioning technology in an integrated system may be any of position, motion, or attitude. There may be redundant measurements. When combined, a unified position, motion, or attitude is determined.

8.2.11 Image acquisition request

An image acquisition request is a message sent to a sensor system that defines the image desired by a user. The image acquisition request includes elements for data type and quality, observation/visibility requirements, and data for planning and tasking.

8.3 Geographic imagery information — Processed, located, gridded

8.3.1 General

All the UML classes and other information which comprises the Image Information package shown in Figure 3, are described in 8.3.

8.3.2 IG_Scene

8.3.2.1 Introduction to IG_Scene

Geographic imagery is defined as the class IG_Scene in Figure 9. IG_Scene is an information object. IG_Scene is a type of geographic coverage. Within the remainder of this document, the focus will be on gridded coverages.

When the sensor data described in 8.2 is combined with descriptive representation information, an imagery information object is created. Information is a combination of data and representation information[25]. In this document, data is a grid of image values, i.e. sensor data, and the representation information. The metadata shall defined as described in ISO 19115-1 and ISO 19115-2. The manner of how imagery information objects are to be structured is defined in 8.3.2.2 to 8.3.2.5.

A coverage has both a range and domain, and both are included in CV_GridValuesMatrix. IG_GridScene is an instantiation of a gridded coverage with a constraint on the values in the coverage CV_GridValuesMatrix (see Figure 9). The IG_SceneValues shall be sensor data or a derivation of sensor data. The grid of an image may have georeferencing information available that allows for the geolocation of the grid cells, or the grid may be georectified. Table 9 provides examples of IG_GridScene. Table 10 provides operations for IG_GridScene that are appropriate for image processing.

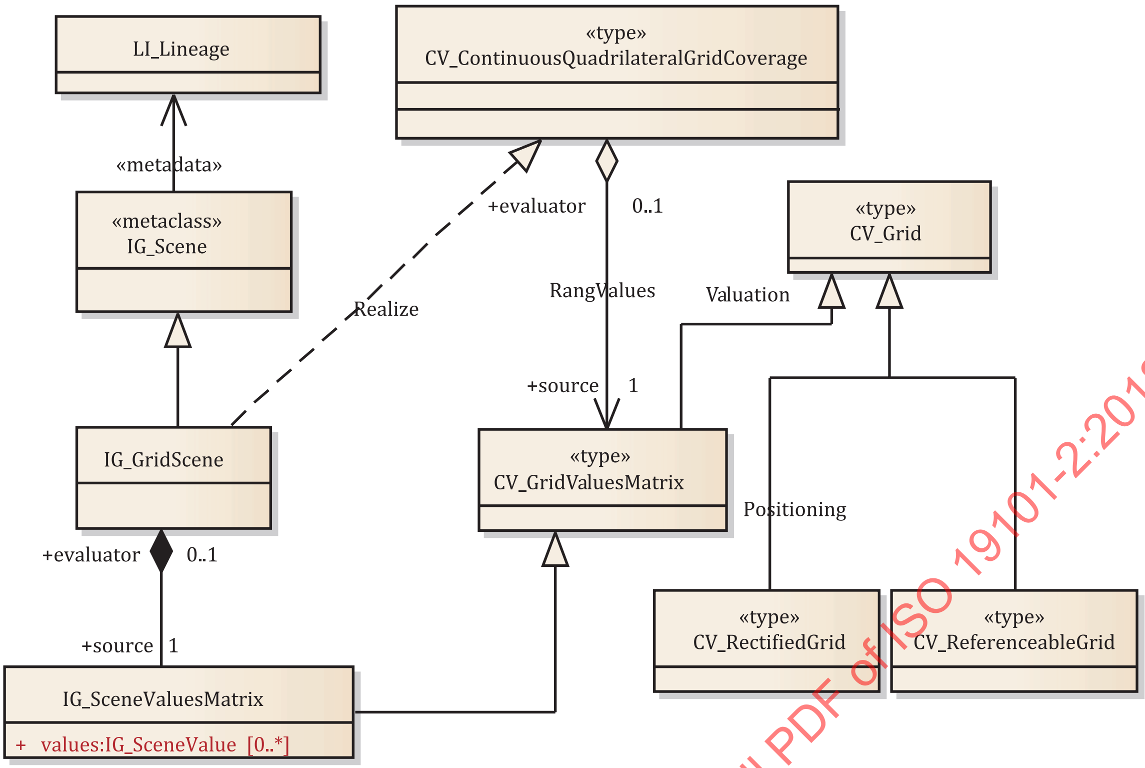


Figure 9 — IG_Scene

Table 9 — IG_SceneValues examples

Spatial\attribute properties	IG_SensorData	IG_DerivedData
CV_ReferenceableGrid	Non-georectified images (e.g. Landsat scene, digital aerial photo, NASA EOS-DIS Swathe, SAR)	Non-georectified derived data (e.g. leaf area index, soil moisture; usually intermediate products only until rectified)
CV_RectifiedGrid	Georectified images (e.g. orthoimages, image maps)	Georectified derived data (e.g. gridded leaf area index, soil moisture)

According to ISO 19109[29], an application schema provides a formal description of the structure and content of the data required by one or more applications. Images are a major component of the data required by many geographic applications. As such, they need to be described in application schemas.

The central concept of any geographic application schema is the feature – an abstraction of real world phenomena. An image is a feature abstracted from real world phenomena by an imaging sensor. Thus an image can be modelled in conformance to the General Feature Model[29]. However, an image is modelled as a coverage that has a structure somewhat different from that of other feature types – values of some of the attributes of a coverage (the coverage range) are associated with individual geometric or temporal elements of the feature (the coverage domain) rather than with the feature as a whole.

Typically, an image is represented as a grid providing organization to a set of pixels. Each pixel contains a record of the radiant energy propagated at that point. Each pixel may also contain additional attributes such as the identification of a feature associated with the pixel, so that the pixels corresponding to each feature within the image area are marked as such. A grid values matrix contains a description of the grid structure, a set of records each containing values for a grid point, and a rule for assigning a record of values to each grid point.

8.3.2.2 Domain of IG_GridScene

The data content of IG_GridScene is contained in IG_SceneValuesMatrix, which is a realization of CV_GridValuesMatrix (Figure 9). ISO 19123 specifies that an instance of CV_GridValuesMatrix may be, at the same time, an instance of either CV_RectifiedGrid or an instance of CV_ReferenceableGrid. This is shown by the partitioning of the inheritance relationships of CV_Grid. The difference between CV_RectifiedGrid and CV_ReferenceableGrid is the method used to determine the spatial coordinates of a CV_GridCell based on the cell's grid coordinates.

A rectified grid shall be defined by an origin in an external coordinate reference system, and a set of offset vectors that specify the direction of, and distance between, the grid lines. There is an affine transformation between the grid coordinates and the external coordinate reference system, e.g. a projected coordinate reference system.

An orthoimage is a rectified digital image in which displacement of objects in the image due to sensor orientation and terrain relief has been removed.

A referenceable grid has information that can be used to transform grid coordinates to external coordinates. ISO 19130-1 specifies information that supports transformation of the coordinates of a referenceable grid.

Transformation of gridded data from one grid coordinate system to another usually requires resampling, which is the interpolation of data values at a new set of points from those associated with an original set of points. Resampling affects the quality of the data in ways that depend upon both the characteristics of the data and the interpolation method chosen to accomplish the resampling. Lineage metadata (see ISO 19115-1) for gridded data shall include descriptions of any resampling applied to the data after its initial acquisition.

8.3.2.3 Range of IG_GridScene

The range of a coverage consists of a set of attribute values. ISO 19123 specifies that a coverage shall provide a Record of attribute values for each direct position within the domain of the coverage. The elements of that record are specified by an instance of RecordType, which is a sequence of name: datatype pairs each of which describes a field of the Record. An application schema shall include a specification of the RecordType for any coverage that it specifies.

There are two types of data values relevant for IG_Scene (see Figure 10).

Sensor digital numbers are the integer values produced by an image sensor. The class name IG_SensorDN shall be used to identify values of this data type in specifying a RecordType.

Values of the measurand of a sensor are physical quantities. They are commonly expressed as real numbers. In specifying a RecordType, the class name IG_PhysicalQuantity shall be used to identify values of this kind, with the data type set to Real.

EXAMPLE The physical data for an optical radiation sensor are radiances received at the sensor.

Values for physical quantities are calculated using calibration information determined by laboratory testing or by vicarious calibration.

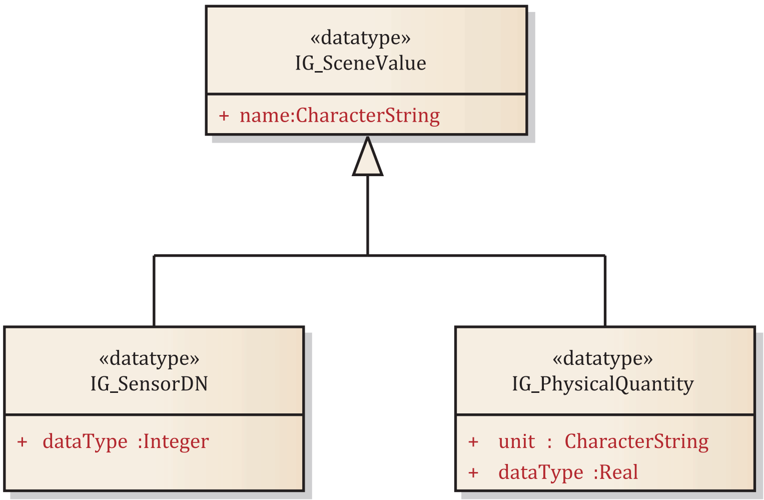


Figure 10 — IG_SceneValues

8.3.2.4 IG_PhysicalQuantity

Physical quantities are used for the quantitative description of physical phenomena. Conventional scales, such as the Beaufort scale, Richter scale and colour intensity scales, and quantities expressed as the results of conventional tests, for example corrosion resistance, are not treated here.

Physical quantities may be grouped together into categories of quantities that are mutually comparable. Lengths, diameters, distances, heights, wavelengths, etc. would constitute such a category. Mutually comparable quantities are called "quantities of the same kind". If a particular example of a quantity from such a category is chosen as a reference quantity called the unit, then any other quantity from this category can be expressed in terms of this unit: as a product of this unit and a number. Further information on this topic can be found in ISO 80000-1:2009, 4.2[37].

8.3.2.5 IG_GridScene operations

IG_GridScene inherits several operations from CV_ContinuousQuadrilateralGridCoverage that are generic operations that can be executed for any type of coverage. Application schemas may specify additional operations to support the application. Table 10 provides examples; many of these represent families of closely related operations. A future standard could specify a set of standardized operations for imagery coverages.

Table 10 — Types of operations applicable to IG_GridScene

Operation	Description
Change CRS	Changes the coordinate reference system for an image associated with a CV_ReferenceableGrid.
Change grid	Resamples an IG_GridScene to produce a set of values associated with the grid points of a different grid.
Change SequenceRule	Changes the *sequencingRule* attribute of the IG_SceneValuesMatrix. This also requires re-ordering of the value elements in IG_SceneValuesMatrix and may require changing the *startSequence* attribute as well.
Statistics	Returns statistical measures for the values contained in IG_SceneValuesMatrix, e.g. minimum, maximum, mean, median, mode and standard deviation from the mean.
Histogram	Returns the relative frequencies of the values contained in IG_SceneValuesMatrix.
Texture	Returns texture characteristics of the values contained in IG_SceneValuesMatrix, e.g. the size of repeating items (coarseness), brightness variations (contrast), and the predominant direction (directionality).

Table 10 *(continued)*

Operation	Description
Correlation	Returns a measure of the correlation between *values* contained in IG_SceneValuesMatrix.
Scatterplot	Returns a scatterplot for the *values* contained in IG_SceneValuesMatrix.
Browse	Returns a reduced-resolution encoded image suitable for portrayal, leaving IG_GridScene unchanged.
Enhance	Changes the *values* contained in IG_SceneValuesMatrix to improve the contrast of values within a small range of data values. Enhancement methods include mathematical operations on individual grid-point values: linear, root, equalization, and infrequency enhancement.
SpatialFilter	Changes IG_SceneValues by filtering that alters the grid values on the basis of the neighbourhood grid values. Filter types include: mean, mode, median, Gaussian, Laplacian-Type filters.
Threshold	Returns an encoded grid with an attribute of Boolean value based on a threshold of an element of the records in IG_SceneValuesMatrix.
BandRatioing	Returns an encoded grid with an attribute formed from the ratio of two elements of the records in IG_SceneValuesMatrix: (value of element 1)/(value of element 2).
DensitySlice	If the number of breakpoints specified is n, then the grid coverage source sample dimension will be classified into $n + 1$ values.
RangeTag	Returns an encoded grid with an attribute value from a list of tags where each tag identifies a defined non-overlapping range of an element of each record in IG_SceneValuesMatrix.

8.3.3 Derived imagery

8.3.3.1 General

Remote sensors indirectly measure physical properties of a remote object. For example, optical and microwave sensors measure electromagnetic flux at the sensor which generally needs to be converted into values such as leaf area and soil moisture on the surface. Deriving the desired values from the sensor data requires addressing issues such as the following.

a) Remote sensing data contains undesired influences. In the optical spectral range the atmosphere strongly influences the measured signal. This shall be eliminated using atmospheric correction schemes. SAR backscatter strongly influences the speckle effect that makes pixel-based land surface parameter retrieval difficult.

b) Sensor viewing angle is variable. Sensor data shall be corrected for variations in sensor viewing geometry, e.g. scan angle, sun angle, off-nadir corrections.

c) Spectral information can be ambiguous. Multiple solutions of an inversion of a radiative transfer model are possible especially if the equation system for the retrieval is underdetermined. Retrieval of surface variables is dependent on the use of ancillary data, which restricts ambiguities in the remote sensed data.

d) Environmental parameters of interest may not be identical to the variables derivable from the remote sensed data. For example, surface soil moisture can be estimated with C-band SAR to a depth of 2 cm, whereas water balance calculations need the soil moisture of the whole root zone that may reach to a depth of 250 cm.

Both a) and b) can be handled through processing images on an individual basis resulting in derived imagery, i.e. IG_DerivedScene. The case of c) is an example where multiple images and a physical process model are required to estimate the parameter of interest. Physical process models for imagery are addressed in 8.4.4.2.

8.3.3.2 IG_DerivedScene

Derived imagery often needs to be created to obtain observations of interest.

This document emphasizes images derived from Geographic Imagery Scenes, such as derivations of geophysical values based on sensor measurements. These derived images are also considered to be Geographic Imagery Scenes. Geographic Imagery Scenes that include information which is more specific to a user's needs are created through processing. In Figure 11, IG_GridScene is the source Geographic Imagery Scene that is processed to become an IG_DerivedScene. The processing needed to create an IG_DerivedScene is described using LI_Lineage. LI_Lineage is metadata describing the source (LI_Source) as well as metadata describing the potentially multiple steps in processing (LI_ProcessingStep) in addition to other lineage data which might be recorded in the earlier data acquisition stage. The processing could also require additional, potentially non-imagery inputs (IG_AncillaryData). The processing steps to create IG_DerivedScene may have various purposes. Several processing approaches are described in 8.3.3.

The values included in the associated IG_SceneValuesMatrix are of type IG_PhysicalQuantity. The UML class IG_DerivedScene is depicted in Figure 11.

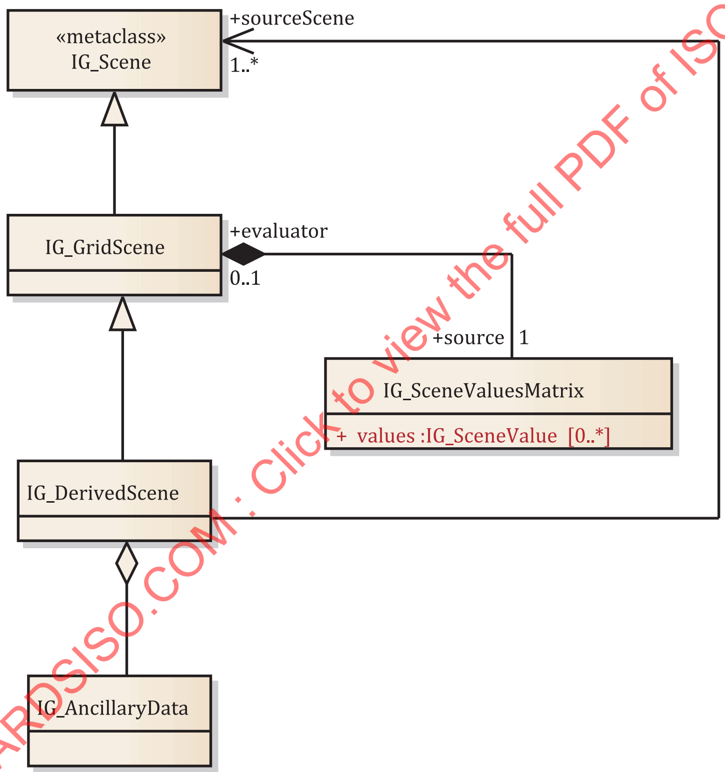


Figure 11 — IG_DerivedScene

8.3.3.3 Derived geophysical values: IG_DerivedScene

Optical and microwave sensors measure electromagnetic flux at the sensor which will be converted into values such as leaf area and soil moisture. Deriving information about the Geographic Imagery Scene can be done in multiple ways. Two approaches are described here: Forward Problem and Inverse Problem.

In the Forward Problem, the properties of the Geographic Imagery Scene along with the incoming radiation (e.g. radar or sunlight) are specified and used to predict the observed measurement.

In the Inverse Problem, the unknown properties of the Geographic Imagery Scene are inferred from the observed measurements. The number of parameters needed to characterize the target exceeds the number of independent measurements available at the sensor. In this case, the dimensionality of the parameter space may be reduced by assuming that some parameters are known or the solution is insensitive to them (these parameters then remain unmeasurable for the observations, but access to the other parameters becomes possible). Even when a proper inversion is possible, measurements have still often failed to confirm the theory, reflecting in some way the failure of the theory to capture the relevant physics of the observation process.

8.3.3.4 Atmospheric correction

The apparent radiance of ground reflection as measured by a remote sensor differs from the intrinsic surface radiance because of the presence of the intervening atmosphere (see Figure 12). The atmosphere can selectively scatter, absorb, re-emit, and refract radiation that traverses through it. The atmosphere has a filtering or distorting function that changes spatially, spectrally, and temporally. Correcting measured radiance data using a model of the atmosphere improves the accuracy of pattern recognition and image interpretation.

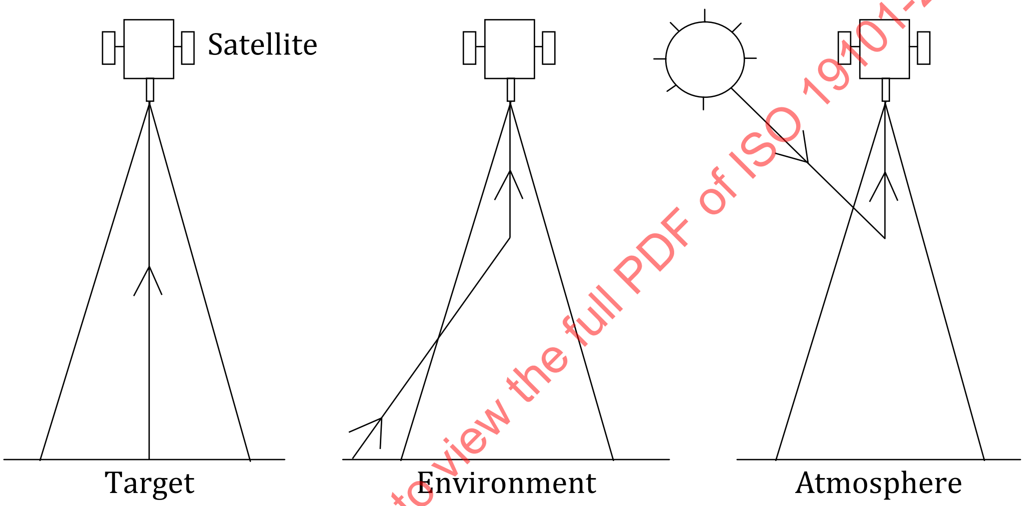


Figure 12 — Effects of atmospheric scattering

Current solutions to atmospheric corrections of imagery involve applying a standard radiative transfer and atmospheric input data to produce a correction. Significant correction improvements can be achieved by accurately representing the dynamic variability of the intrinsic atmospheric optical parameters that serve as input to the radiative transfer model (primarily aerosols and water vapour).

8.3.3.5 Atmospheric sounding

Atmospheric sounding provides a vertical distribution of atmospheric parameters such as temperature, pressure and composition, for example aerosols, using data from a sensor above the atmosphere. The atmospheric profile is a derived image.

8.3.3.6 Pixel fusion

Fusion at the level of individual cells is termed pixel fusion. Pixel fusion techniques combine data from multiple sensors, as well as ancillary sources, to achieve better accuracies and inferences than could be achieved by use of data from a single source. Observational data may be combined, or "fused" at a variety of levels beginning with the raw data, proceeding to the feature level and ending at the decision level.

The fusing of raw sensor data usually requires that the sensors are measuring the same physical phenomena. If the sensor data are dissimilar, then the data shall be fused at the feature level or decision level.

Multisensor image (pixel) fusion commonly uses adaptive neural networks to automatically classify the contents of the Geographic Imagery Scene based on the various inputs. For this type of fusion, accurate co-registration of the multisensor images being used is essential. Accurate geocoding is essential if absolute Earth location is important. Resampling of image data to common pixel spacing and map projection is usually required, but newer methods are capable of dealing with different resolutions.

Standards that enable fusion of measurements at the level of individual cells should be used.

8.3.4 Imagery metadata

Metadata is information about a resource (ISO 19115-1). Metadata is required for describing geographic information and services. It provides information about the identification, extent, quality, spatial and temporal schema, spatial reference, and distribution of digital geographic data.

Some elements required for describing imagery are defined in ISO 19115-1 whereas aspects of Imagery metadata related to acquisition and processing is described in ISO 19115-2.

8.3.5 Encoding rules for imagery

8.3.5.1 General

Most existing imagery exchange standards imply an information model in terms of its representation in an exchange format. The format specification defines data fields and describes the contents and meaning of these data fields. This implicitly defines the information content that can be carried by this exchange format. Some of the existing standards even separate their "information" from the encoding within the description of the standard, but in the end it is the encoding that defines these standards. This document supports the separation of content and carrier, where a common content model allows for a mapping to the structures defined in the encoding standards. The content model includes the spatial structure and the metadata. The encoding structure is separate but related.

A content model describes the information content of a set of geographic data, consisting of the feature identification and spatial schema, where other aspects such as quality and georeferencing are represented in the associated metadata. The content model does not include portrayal, encoding or the organization of the data to accommodate various storage or exchange media. Exchange metadata that contain information about a data interchange are also not defined by the content model.

The encoding structure is separate but related. ISO 19118[33] defines an encoding rule as an identifiable collection of specifications that defines the encoding for a particular data structure. The encoding rule specifies the data types to be converted as well as the syntax, structure and coding schemes used in the resulting data structure. An encoding rule is applied to application-schema-specific data structures to produce system-independent data structures suitable for transport or storage.

Compression and compaction are related to the concept of encoding structures. Data compaction removes information based upon its semantic content, while data compression removes information based upon the bit structure, independent of the meaning. An example of data compaction is the removal of information that is known by the application to be unnecessary. Data compaction is applicable for areas over which there is no data as well as unneeded bits of numeric data for lower precision numbers. Data compression removes redundant information that occurs randomly. For example, run length encoding replaces long runs of identical bits with a shorter code. Both data compaction and data compression may be applied to a dataset, but data compaction is specified in the content model, whereas data compression is specified as part of the encoding structure.

Some of the encoding formats of particular relevance for geographic imagery are included in 8.3.5.2 to 8.3.5.5.

Additional discussion on encoding rules for Imagery, Gridded and Coverage data are included in ISO/TS 19129[52] and ISO/TS 19163-1[57].

8.3.5.2 Basic Image Interchange Format (BIIF)

ISO/IEC 12087-5[45] specifies the Basic Image Interchange Format (BIIF). It provides a detailed description of the overall structure of the format as well as a specification of the valid data content and format for all defined fields. BIIF conforms to the architectural and data object specifications of ISO/IEC 12087-1[45]. ISO/IEC 12087-5[46] also provides a data format container for image, symbol and text, along with a mechanism for including image-related support data. BIIF

— provides a means whereby diverse applications can share imagery and associated information,

— allows an application to exchange comprehensive information with users with diverse needs or capabilities, allowing each user to select only those data items that correspond to their needs and capabilities,

— minimizes pre-processing and post-processing of data,

— minimizes formatting overhead, particularly for those applications exchanging only a small amount of data, and for bandwidth-limited systems, and

— provides extensibility to accommodate future data, including objects.

ISO/IEC 12087-5 supports the use of International Standardized Profiles to define and organize domain applications of the standard, and specifies a mechanism for registering such profiles compliant with ISO/IEC 9973[41]. Examples include the NATO Secondary Image Format[82] and the Open Skies Digital Data Exchange Profile which is provided as an informative example in E.3 of ISO/IEC 12087-5:1998.

8.3.5.3 Hierarchical Data Format (HDF)

The Hierarchical Data Format (HDF) is the standard data format for all NASA Earth Observing System (HDF-EOS) data products[14][88]. HDF is a multi-object file format developed at the national center for supercomputing applications (NCSA) at the University of Illinois. NCSA developed HDF to assist users in the transfer and manipulation of scientific data across diverse operating systems and computer platforms, using FORTRAN and C calling interfaces and utilities. HDF supports a variety of data types: *n*-dimensional scientific data arrays, tables, text annotations, several types of raster images and their associated colour palettes, and metadata. The HDF library contains interfaces for storing and retrieving these data types in either compressed or uncompressed formats.

Because many Earth science data structures need to be geolocated, NASA developed the HDF-EOS format with additional conventions and data types for HDF files. HDF-EOS supports the grid, point, and swath geospatial data types, providing uniform access to diverse data types in a geospatial context. The HDF-EOS software library allows a user to query or subset the contents of a file by Earth coordinates and time (if there is a spatial dimension in the data). Tools that process standard HDF files will also read HDF-EOS files. However, standard HDF library calls cannot access geolocation data, time data and product metadata as easily as with HDF-EOS library calls.

8.3.5.4 GeoTIFF

The Tagged Image File Format (TIFF)[84] is a public domain format originally developed by Aldus Corporation. It defines tags to identify several different types of coding and allows “private” tags for extension.

The GeoTIFF[10] data interchange standard for raster geographic images is an extension of the TIFF format that specifies the content and structure of a group of tag sets for the management of georeferenced or geocoded raster imagery. The aim of GeoTIFF is to support a geodetically sound raster data georeferencing capability for tying a raster image to a known model space or map projection, and for describing those projections. The geographic content supported in GeoTIFF tag structure includes its cartographic projection, datum, ground pixel dimension, and other geographic variables. The GeoTIFF format is popular because the image it contains can be viewed in a non-georeferenced fashion using widely available TIFF software.

8.3.5.5 GMLJP2

The GML in JPEG 2000 (GMLJP2) for Geographic Imagery Encoding Standard defines the means by which the Geography Markup Language (GML) Standard is used within JPEG 2000 compressed images for geo-enabled imagery.

The standard provides a GML Coverage application schema to support the encoding of images within JPEG 2000 data files and also a packaging mechanism for including image annotations and GML or KML annotations within JPEG 2000 data files.

Two versions of GMLJP2 are available.

— Version 1.0.0 (2005), based on GML 3.1: OGC # 05-047r3 which is limited to georeferenced imagery in geographic/cartographic coordinate system.

— Version 2.0.1 (2016), based on GML 3.2 (ISO 19136:2007) and CIS 1.0 (emergent ISO 19123-2[2]) equivalent to OGC standard GMLCOV – OGC #09.146r2): GML in JPEG 2000 (GMLJP2) Encoding Standard Part 1: Core: OGC # 08-085r5. This specification is a multi-part specification, for which two extensions/additional parts are under finalization in OGC: extension for annotations and referenceable extension for imagery (in sensor/image reference system) associated with its sensor model.

GMLJP2 is based on the JPEG2000 for compression of still imagery, according to two modes lossless or visually lossless (refer to 8.3.6), allowing fast exchange and access/display of geospatial imagery, together with annotations or vector layers and metadata.

8.3.6 Imagery compression

Imagery can be compressed using various techniques and processes. Major classes of imagery compression are processes such as discrete cosine transformations, wavelet imagery compression, run-length encoding, arithmetic encoding, fractal compression, vector quantization, JPEG[86], and JPEG 2000[49]. There are other techniques for imagery compression but all use the same basic major classes of processing. It is necessary to remember when describing or "marking" data as to the imagery compression technique used that the parameters/attributes used by the algorithm are of equal importance. Refer to the standards listed in the reference section for details concerning the various imagery compression techniques.

Notably, ISO/IEC 15444-1:2016[49] defines the JPEG 2000 compression technique. It specifies a set of lossless (bit-preserving) and lossy compression methods for coding bi-level, continuous-tone gray-scale, palette colour, or continuous-tone colour digital still images. Additionally it

— specifies decoding processes for converting compressed image data to reconstructed image data,

— specifies a code stream syntax containing information for interpreting the compressed image data,

— specifies a file format,

— provides guidance on encoding processes for converting source image data to compressed image data, and

— provides guidance on how to implement these processes in practice.

The following relevant image compression standards are currently used:

— U.S. MIL-STD-188-199, Vector Quantization (VQ) Decompression for the National Imagery Transmission Format Standard, 27 June 1994, including Notice 1[87];

— N106-97, National Imagery Transmission Format Standard Bandwidth Compression Standards and Guidelines Document, 25 August 1998[66];

2) Under preparation. Stage at the time of publication: ISO/FDIS 19123-2.

— ISO/IEC 15444-1:2016, Information Technology — JPEG 2000 image coding system: Core coding system[49];

— ISO/IEC 15444-4:2004, Information Technology — JPEG 2000 image coding system: Image coding system: Conformance testing[50];

— BPJ2K01.00, Information Technology — Computer Graphics and image processing — registered graphical item — Class: BIIF Profile — BIIF Profile for JPEG 2000 Version 01.00 (Latest Version)[5].

8.4 Geographic imagery knowledge — Inference and interpretation

8.4.1 General

All the UML classes and other information which comprises the Imagery Knowledge package shown in Figure 3, are described in 8.4.

8.4.2 Knowledge from imagery

Knowledge is an organized, integrated collection of facts and generalizations. Imagery-based knowledge is accumulated by systematic study and organized by general principles. One aspect of moving from information to knowledge is the identification of redundancies. Knowledge differs from data or information in that new knowledge may be created from existing knowledge using logical inference.

Knowledge is more than a static encoding of facts; it also includes the ability to use those facts in interaction with the world.

Image Knowledge Base is a component of the Imagery Knowledge package shown in Figure 3. Image understanding and classification (see 8.4.3) is also another component of the Imagery Knowledge package which is shown in Figure 3. The basis for separating these concepts is that an image knowledge base assumes a ready archive of imagery whereas image classification processes individual images.

8.4.3 Image understanding and classification

Sensors provide partial information about phenomena occurring in the environment. From this source of information, regions in an image can be aggregated under a single concept, i.e. a named feature. The process moves raw sensed data to higher semantic content information, e.g. polygonal coverages. This process may also be called image understanding: knowledge-based interpretation of visual Geographic Imagery Scenes by computers.

A primary objective of image understanding systems (IUSs) is to construct a symbolic description of the Geographic Imagery Scene depicted in an IG_Scene. Contrast this with image processing that transforms one IG_Scene into another. IUSs analyse an image or images to interpret the Geographic Imagery Scene in terms of the feature models given to the IUSs as knowledge about the world. Here interpretation refers to the correspondence between the description of the Geographic Imagery Scene and the structure of the image. It associates features (e.g. houses, roads) with geometric objects identified in the image (e.g. points, lines, regions).

Most Geographic Imagery Scenes are composed of features of various kinds related to each other through their functions. Thus, to understand the Geographic Imagery Scene, knowledge about (spatial) relations between features as well as knowledge about their intrinsic properties is needed. Using knowledge about feature relations and properties, IUSs conduct reasoning about the structure of the Geographic Imagery Scene. For features with a semantic basis, a set of named feature types is required.

Classes that can be derived from IG_Scene are shown in Figure 13. IG_Feature is a feature interpreted from an image. As such, it is an instance of a feature type, which shall be specified in an application schema (ISO 19109) and described in a feature catalogue (ISO 19110). It has two attributes: featureID is an Integer that shall uniquely identify the feature within the context of the image from which it was extracted; featureType shall contain the typeName from the feature catalogue in which the type of the feature is described.

Instances of IG_ClassifiedImage and IG_SegmentedImage may be created as intermediate products during the process of extracting instances of IG_Feature from an image.

The pixels in an IG_ClassifiedImage have been attributed with labels as a result of human interpretation or an automated classification process that identifies pixels with similar attribute values. The labels may identify feature types or attribute listedValues specified in a feature catalogue.

EXAMPLE 1 An automated classification process might assign the label "water" – a listedValue of a "surfaceType" attribute – to all grid cells in a near infrared image that have an intensity below some threshold value.

An IG_SegmentedImage is the result of applying a pattern-recognition process such as clustering or edge detection to an image. The pixels of the image are assigned to discrete groups. Each group is an instance of IG_SegmentedFeature, so its members shall be labelled with a feature identifier and a feature type. The geometry of the feature is described by a list of grid coordinates that identify the pixels in the group.

EXAMPLE 2 A clustering process applied to the classified image in Example 1 might produce clusters of pixels that could be identified as individual rivers, ponds and lakes.

Both IG_ClassifiedImage and IG_SegmentedImage are realizations of CV_DiscreteCoverage in which the surface elements are grid cells.

The clusters of pixels in a segmented image can be further described in terms of vector geometry as points, curves or surfaces. The resulting collection of instances of GM_Object makes up an IG_FeatureCoverage.

The UML classes for image classification and understanding are listed in Table 11.

Table 11 — Image classification and understanding classes

Feature type	Attribution	Geometric realization	Lineage
IG_ClassifiedImage	Labels on grid cells, e.g. attribute listedValue or feature type code	Discrete Grid Cell Coverage	Supervised classification or human interpretation of an IG_GridScene
IG_SegmentedImage	Labels on grid cells, e.g. feature ID	Discrete Grid Cell Coverage	Clustering or edge detection of an IG_GridScene
IG_FeatureCoverage	Attribute values associated with a feature ID	Discrete Coverage	Conversion of pixel clusters into points, curves, or surfaces
IG_Feature	Attribute values associated with a feature ID	See below	Identification of discrete features in an IG_GridScene
IG_SegmentedFeature	Attribute values associated with a feature ID	Set of grid cells	Segmentation of an image
IG_VectorFeature	Attribute values associated with a feature ID	GM_Object	Identification of discrete features in an IG_GridScene

NOTE The terminology in this document is consistent with the ISO 19100 series of International Standards. Terminology from the field of image understanding is different. A **feature** in the ISO 19100 series is an "object" in image understanding terminology. A **geometric object** identified in an image in the ISO 19100 series is a "feature" in image understanding terminology.

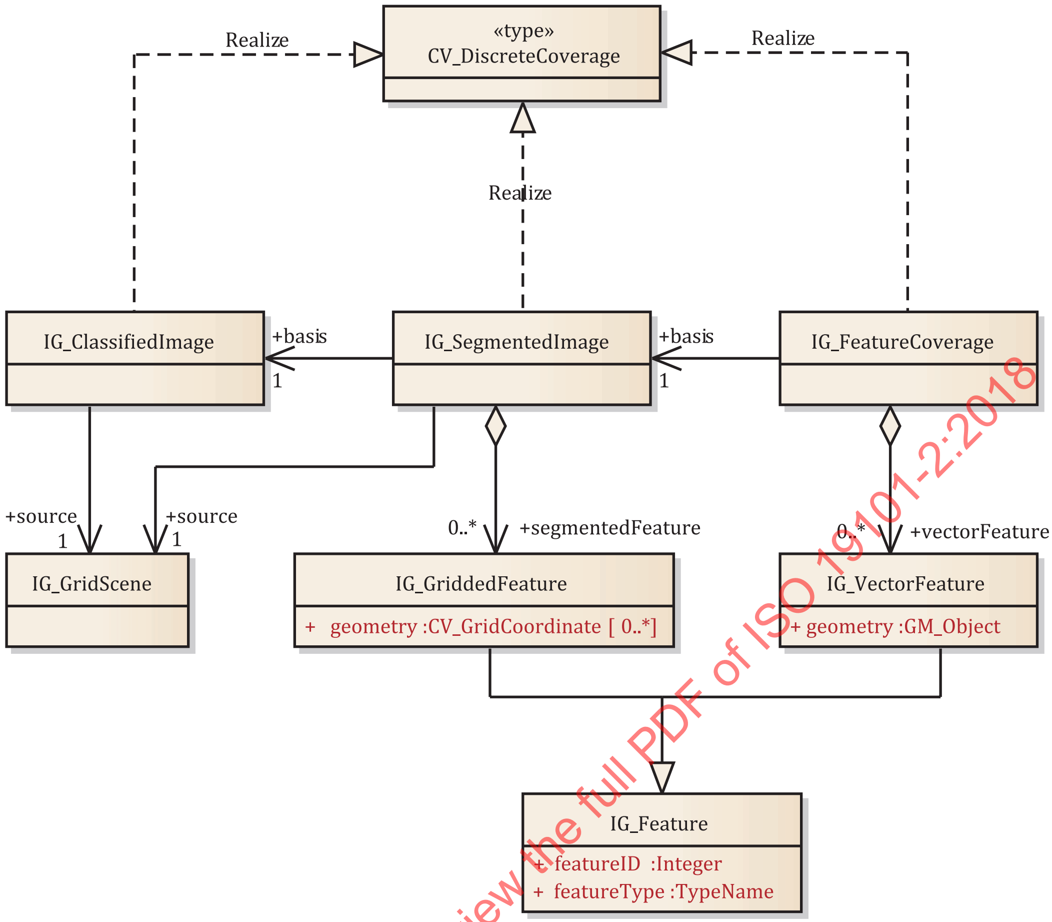


Figure 13 — Image classification and understanding class diagram

8.4.4 IG_KnowledgeBase

8.4.4.1 General

IG_KnowledgeBase (Figure 14) is a collection of information extracted from a set of instances of IG_GridScene. IG_KnowledgeBase provides a basis for the reasoning involved in drawing a conclusion or making a logical judgment on the basis of imagery and ancillary data. Ancillary data is information about scene objects that is not derived from the image.

Different IG_KnowledgeBases use different inference methods to draw conclusions. These are identified by the codelist IG_OrganizingPrinciple as data fusion, data mining or physical modelling.

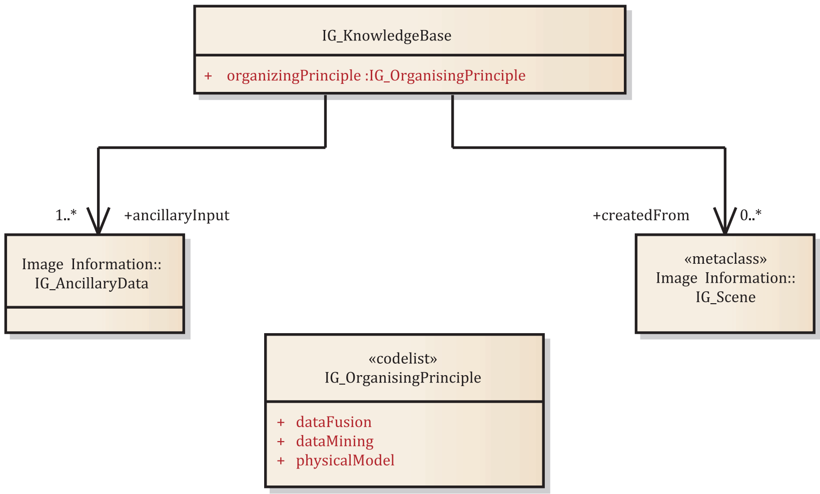


Figure 14 — IG_KnowledgeBase

8.4.4.2 Physical modelling

Physical process models are computer-based mathematical models that realistically simulate spatially distributed, time-dependent environmental processes in nature. The term *model* reflects that any natural phenomena can only be described to a certain degree of accuracy and correctness. It is important to seek the simplest and most general description that still describes the observations with minimum deviations. It is the power and beauty of the basic laws of physics that even complex phenomena can be understood and described quantitatively on the basis of a few simple and general principles. Standards for physical modelling are the domain of standards setting organizations within specific application areas.

EXAMPLE The World Meteorological Organization validates models in the areas of climatology, hydrology, and meteorology.

Data assimilation, a type of modelling, is the melding of observations with model simulations to provide accurate estimation of the state of the atmosphere, oceans, and land surface, etc.

Output of a model may be an IG_GridScene or other type of geographic information. ISO/IEC 18023-3[51] deals with environmental representation including the representation of the results of physical modelling.

8.4.4.3 Data mining

Data mining, also known as knowledge discovery from databases, is the higher-level process of obtaining information through distilling information into knowledge (ideas and beliefs about the mini-world) through interpretation of information and integration with existing knowledge. Data mining is concerned with investigators formulating new predictions and hypotheses from data as opposed to testing deductions from theories through a sub-process of induction from a scientific database. ISO/IEC 13249-6[48] provides an example of data mining using SQL techniques.

During the last decades, imaging satellite sensors have acquired huge quantities of data. Optical, SAR, and other sensors have delivered several millions of Scenes that have been systematically collected, processed, and stored. The state-of-the-art systems for exploiting remote sensing data and images allow queries by geographical coordinates, time of acquisition, and sensor type. This information is often less relevant than the content of the Scene, e.g. structures, patterns, objects, or scattering properties. Thus, only a few of the acquired images can actually be used. In the future, exploitation of image archives will become more difficult due to the enormous data quantity acquired by a new generation of high-resolution satellite sensors. As a consequence, new technologies are needed to easily and selectively extract the information content of image archives and finally to increase the actual exploitation of satellite observations[9].

Data mining uses an IG_KnowledgeBase as a repository that integrates instances of IG_GridScene from one or more sources. Good IG_KnowledgeBase design maximizes the efficiency of analytical data processing or data examination for decision making. An IG_KnowledgeBase often supports online analytical processing (OLAP) tools. OLAP tools provide multidimensional summary views of the IG_KnowledgeBase, e.g. roll-up (increasing the level of aggregation), drill-down (decreasing the level of aggregation), slice and dice (selection and projection) and pivot (re-orientation of the multidimensional data view). Geospatial specifics are utilized for specialized data mining. Examples include geographic measurement frameworks (geometry and topology), spatial dependency and heterogeneity, complexity of spatiotemporal objects and rules, and diverse data types for geographic imagery.

As new automated data mining technologies develop, metadata standards may need to be modified in order to describe the tools, their application and results.

8.4.4.4 Feature fusion

Feature fusion, is the process of combining remote sensing data with other sources of geospatial information to improve the understanding of specific phenomena.

In feature-level data fusion, representative features are first extracted from multiple sensor observations and then combined into a single concatenated feature vector. Feature extraction from the individual images may depend on the environment (extent, shape, neighbourhood) as well as the sensor characteristics. Similar objects from multiple sources are then fused for further assessment using statistical approaches or adaptive neural networks.

Metadata standards could need to be modified to describe the lineage of fused features.

8.5 Geographic imagery decision support — Context-specific applications

8.5.1 General

All the information which comprises the Decision Support package shown in Figure 3, are described in 8.5.

8.5.2 Decision support services

A Decision Support Service (DSS) consists of interactive computer programs that utilize analytical methods, such as decision analysis, optimization algorithms, program scheduling routines, and so on, for developing models to help decision makers formulate alternatives, analyse their impacts, and interpret and select appropriate options for implementation[1]. A DSS permits planners and policy makers to:

1) integrate large quantities of existing geospatial data;

2) use these data as inputs to forecasting models for predicting the results of alternative policy choices;

3) display the model results in easily understood ways.

The output of a DSS is advice to a human decision maker, be it a policy maker, scientist or member of the public. This advice may be a single prediction or recommendation, or it may be a set of discrete pieces of advice to be evaluated and combined with other data and information in the decision process. Outputs of a DSS may include text, graphs and imagery.

As depicted in Figure 15, a DSS may draw on both information extracted directly from imagery as well as distilled information in the form of knowledge residing in an imagery knowledge base. Figure 3 shows the relationship in the context of Information Viewpoint packages.

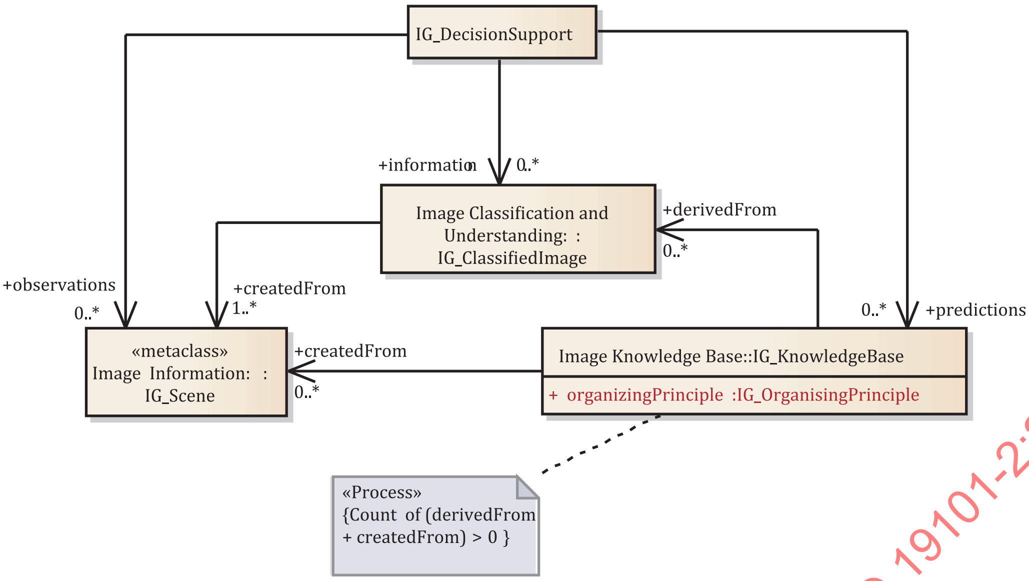


Figure 15 — Imagery for decision support

8.5.3 Geographic portrayal

8.5.3.1 Images of geographic information

8.5.3.1.1 General

In order to portray images of geographic information appropriately for effective decision support, the colour system and attribute colour portrayal scheme used, as well as the manner of visibly displaying those images, are all critical. Each of these considerations is addressed below.

8.5.3.1.2 Portrayals

The visible display or portrayal of geographic information is key to the use of geographic information by humans for decision support. The portrayal of geographic information in general is addressed in ISO 19117[32]. ISO 19117 defines portrayal as the presentation of information to humans. A Picture Portrayal as defined in this document is geographic information directly suited to display to humans using hardcopy or visual display means. The information in a Picture Portrayal may be a colour-space rendering of a Geographic Imagery Scene or any other type of geographic information.

Picture Portrayals use colour coding for the representation of pixel values. Use of colour coordinates can produce significant advantages in reducing the amount of data that needs to be communicated. If only a very few colours are used in a printed product, then only that number of colour map entries are required, and subsequently only a few bits are required per pixel to address entries in the colour map.

EXAMPLE If a chart used only seven inks when it was originally printed, and if it is possible to distinguish these as seven distinct colours, then a colour map could be constructed which specifies each of these seven colours in terms of their exact colour values. Only three bits per pixel would be required to be indexed in the colour map.

8.5.3.1.3 Colour systems

The human eye has three kinds of receptor cells sensitive to different parts of the visible spectrum, conventionally identified as red, green and blue. A mixture of light from these three bands is perceived as a single colour which varies as a function of the relative intensity of the three primary colours.

The Commission Internationale de l'Éclairage has defined a basic system (CIE XYZ)[7] for describing specific colours in terms of three tristimulus values. The tristimulus values represent the quantity of light from each band contained in a mixture of the three that is perceived as having the same colour as a particular wavelength in the visible spectrum. Colours may also be described in terms of three trichromatic coefficients, computed by dividing each of the three tristimulus values by their sum. Since the sum of the trichromatic coefficients is one, the quality (chromaticity) of any colour may be described by two of its trichromatic coefficients, usually the red and green coefficients. As a result, the range of visible colours may be represented independently of brightness on a two-dimensional graph. All colours, even those that cannot be represented on paper or on a CRT, can be described using the CIE System. The CIE System is commonly used to specify colours of printing inks and the phosphorous colours of CRT monitors.

Several colour coding systems are used for imagery and are detailed below:

a) RGB (red, green, blue);

b) CMYK (cyan, yellow, magenta, key);

c) HSV (hue, saturation, value);

d) Luminance/Chrominance.

RGB – The RGB system is based on the physiological characteristics of the eye. Red, green and blue are the additive primary colours; appropriate mixtures of light of these three colours can produce any other perceptible colour. A combination of equal amounts of all three colours produces white, while the absence of all three results in black. Colours are recorded in the RGB system as the total intensity of illumination in each of the bands.

The RGB system is widely used for digital image storage, manipulation and interchange[34][7][23][35][36]. Multispectral remote sensing devices typically operate in the three primary bands. RGB is also the most common system used for computer monitors.

CMYK – The CMYK system[22][26] is based on the combination of intensities of the subtractive primary colours cyan, yellow and magenta. These are also called absorptive primaries; the colour that is perceived as a result of their reflection of white light is that of the light which is not absorbed. A mixture of equal and sufficient amounts of the three subtractive primaries is seen as black. The CMYK system is optimized to support process colour printing. Black ink is added to the mix for several reasons including the fact that the inks of the primary colours are not spectrally pure so the mix of primary colour inks does not produce a true black. In addition, slight mis-registration of the three primary colour plates causes blurring of detail such as text, so text and graphic detail are usually printed in black. The black plate is therefore referred to as the Key plate and by the K in the abbreviated identifier of this system.

HSV – The HSV system separates a colour into its hue, saturation and value. Hue is the colour type expressed as an angular position on a standard colour wheel. It is equivalent to the dominant wavelength of the colour, except for the non-spectral colours (purple and related colours). Saturation is the colourfulness of an area judged in proportion to its brightness. Saturation runs from neutral gray through pastel to saturated colours. Value is the same as brightness, a measure of the flow of power over some interval of the electromagnetic spectrum. HSV is also called HSB (hue, saturation, brightness).

HSV is a non-linear transformation of RGB that scales colours in a way similar to the response of the human eye. It is often used in applications that require a user to select a colour to be applied to some element of a display (8.5.3.1.4) because it supports a linear progression of perceived colour differences. It is used for differentiating cartographic area symbols (8.5.3.1.4) for the same reason.

NOTE The receptor cells of the eye respond logarithmically to the intensity of light.

Luminance/chrominance – Several related systems describe colours in terms of one luminance and two chrominance components. All of these are transformations from RGB. All were developed for colour video broadcasting and recording because the luminance value by itself supports monochrome displays. Luminance (Y) is the overall brightness of a pixel, computed as a weighted sum of the three RGB values. It is equivalent to the value of the HSV system. Chrominance is calculated as the difference between a colour and a reference white at the same luminance. Because the eye is less sensitive to differences in chrominance than to differences in luminance, the chrominance data can be compressed to a greater degree with less loss of perceived image quality. Three variants of the luminance/chrominance system are used in the three regional standards for analogue video[59]. YCrCb is the standard colour system for all digital video[60]. Y is the total luminance across all three colour bands. Cr is the red chrominance, a measure of the difference between the red band intensity and total luminance. Whole Cb is the blue chrominance, a measure of the difference between the blue band intensity and total luminance.

8.5.3.1.4 Attribute colour portrayal

Colour Ramps – Colour Ramps are continuous colour spectra ranging from a specified start to a specified end point. They can cover the complete visible spectrum or a limited component of it. A Colour Ramp can be in grayscale as well. Although theoretically continuous, the application of a Colour Ramp necessitates that the portrayal be a discrete representation of the given spectrum. Large or small ranges of data can be compressed or stretched in the process of ramping the attribute values. Start and end points can be selected on a given spectrum to aid in the best portrayal of data with limited dynamic range.

Colour Banding – Colour Banding is also referred to as Colour Tables. It is a list or table containing discrete colour values and attribute value ranges. For every range of an attribute's value (e.g. 10 to 20) a specific colour is assigned (e.g. red, or R=255, G=0, B=0). Most often the series of colour assignments follows a progressive path which discretely mimics a ramped colour spectrum, but it is not necessary – there is no need for any progressive pattern. Colour Tables can be chosen or designed to best portray certain types of data or to highlight specific aspects.

Feature Colouring – Colour can also be assigned by feature or feature type. In this manner, boulders (the feature "boulder") could be assigned the colour green,

EXAMPLE 1 R = 0, G = 255, B = 0.

while bridge features could be assigned some other colour.

EXAMPLE 2 R = 123, G = 55, B = 234.

This is similar to the Colour Table approach except that colours are assigned to individual features and not an attribute value or range. Several attributes can be used to define a given feature and thus colouring is based indirectly on multiple attributes.

Within a given visualization, data can be portrayed using any of these approaches. Combinations can be used as well.

EXAMPLE 3 Bathymetric depth data could be coloured using a Colour Ramp of the blue spectrum, while boulder features are assigned a feature colour and portrayed as yellow (R = 0, G = 255, B = 255).

8.5.3.2 Human observers

Interpreting a geographic image is an open-ended task. It is not known in advance what pattern is going to appear in an image. Determining features from an image is a context-dependent task. The job of a human interpreter is to make this link between the image and the features. With the increasing volumes of geographic imagery, emphasis has been on automated feature detection. However, pattern recognition and automatic image processing techniques remain inadequate for some applications. For many applications, a "human-in-the-loop" is required.

The interpreter's knowledge, skill and experience is critical in the interpretation of geographic imagery.

8.5.4 Fitness for use context

Imagery is useful to a specific application context if the geometric and attribute values are appropriate to the context. For example, the spatial resolution needs to be appropriate to the mapping scale in the application (see Figure 16). Meeting a user's cognitive requirements means presenting to that user an image/map at a scale that corresponds to an operational scale of process shaping the features of a user's interest[77]. Table 12 lists the spatial resolutions appropriate to the mapping scale in urban applications. See ISO 19115-1 and 19115-2 for information concerning metadata appropriate to determine fitness for use.

An example of a sound application context for imagery for use as a base map is the case in which the imagery has a set of natural colours, is directly interpretable by untrained users, and has uniform radiometry.

For appropriate use as an information source, a satellite image would need to:

— be available as a value added product allowing an update at least annually, and be available “on hand” according to a very flexible limit and at reasonable cost;

— cover large territories in order to lay out the most uniform possible radiometry and thus overcome one of the problems encountered in orthoimages.

NOTE See Figure 16 and Table 12.

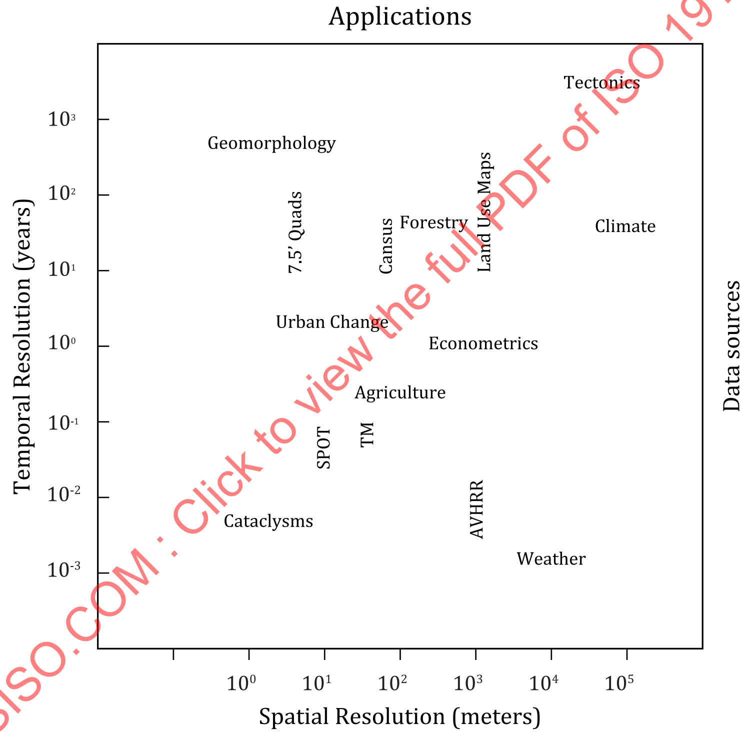


Figure 16 — Applications based on resolution

Table 12 — Examples of applications and spatial resolution

Scales of applications in urban areas		Image data used for these applications	
Applications	**Scale**	**Image source**	**Resolution**
Facility management	1:200 to 1:500	Aerial photo/LIDAR	<20 cm
Basic mapping	1:1 000 to 1:2 000	Aerial photo/LIDAR	20 cm to 50 cm
Urban planning	1:5 000 to 1:10 000	High-resolution satellite/ Aerial photo	50 cm to 10 m
Overview	1:10 000 to 1:1 000 000	Satellite	10 m to 30 m

Table 13 provides a categorization of geographic application areas.

Table 13 — Application area categorization

Societal surveillance	Defence and intelligence Law enforcement History or archaeology research
Societal infrastructure	Electric and gas utilities Telecommunications Transportation (including aviation and aerospace)
Societal commerce	Business site determination Architecture Engineering and construction
Natural resource stewardship	Earth, ocean, or atmospheric research Health care Ecology and conservation Pollution monitoring and control
Natural resource exploitation	Agriculture Mining and petroleum Forestry and lumber Fisheries and marine resource use Water distribution and resources Waste disposal and management
Societal impact reduction	Emergency management Property insurance
Education	Elementary education University education Museums
Public consumers	Tourism Real estate Entertainment Journalism Employment services

8.5.5 Decision fusion

Remote sensing data can be combined with other sources of geospatial information to improve the understanding of specific phenomena.

Fusion at the decision level involves fusion of extracted sensor information. All relevant information is extracted from each sensor, such as a preliminary determination of some metadata such as an object's location, velocity and attributes, and then fused using methods such as voting and inference. Often ancillary data, such as a Digital Elevation Model (DEM) or prior knowledge about Geographic Imagery Scene objects, is incorporated into decision (or information) fusion.

If the characteristics of the input data are not well known it is possible that fusion of multisensor data produces worse results than could be obtained from the most appropriate single sensor. For this reason quantitative evaluation of the accuracy and reproducibility of automated fusion systems is essential.

See ISO 19115-1, ISO 19115-2, and ISO 19130-1 for relevant metadata.

9 Computational viewpoint — Services for imagery

9.1 Task-oriented computation

The computational viewpoint provides a transition from the Information Viewpoint to the distributed deployment represented in the Engineering Viewpoint. The Computational Viewpoint provides a perspective for describing distribution through functional decomposition of the system into objects that interact at interfaces. For geographic imagery systems, the Computational Viewpoint identifies abstract objects necessary for the process flow for acquiring, storing, processing and viewing imagery.

The key objective of the Computational Viewpoint is to enable interoperability. Interoperability is the capability to communicate, execute programs or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units. Two models for developing interoperable components are defined in 9.2.

Robust computational models are needed for the re-use of remote sensing information and services by a wider community. Elements of this model are re-usable service interaction patterns, e.g. service chaining and methods to aid analyst selection of services, e.g. taxonomy of service types.

To ensure that the science of remote sensing yields the greatest value to society and to business, it is critical that data analysis becomes accessible to the lay person who could have access to the data and the analytical ability to interpret results, but not necessarily the mathematical background to delve into algorithmic minutiae.

Knowledge can result in decisions through the integration of the goals of multiple stakeholders. The application of knowledge and information to address the goals of multiple stakeholders results in decisions for applications.

9.2 Computational patterns

Two approaches may be used to define an interoperable Computational Viewpoint based on the Information Viewpoint.

1) Interaction between deployed components is performed through invocation of operations on the classes defined in the Information Viewpoint. In this case, Information Viewpoint interfaces generally match Computational Viewpoint interfaces. The object factory computational pattern typifies this approach (Table 14).

2) Interaction between deployed components is performed by invocation of interfaces on services defined using the semantics of the Information Viewpoint. In this services model the Computational Viewpoint interfaces generally do not match Information Viewpoint interfaces. The message-oriented computational pattern typifies this approach (Table 15).

The Computational Viewpoint addresses services in an abstract approach, i.e. independent of hardware computing hosts and networks. Approaches to deployment of services, including issues of distribution, are addressed in 10.2.

As defined in ISO/IEC 10746-1[42], the objects in the Computational Viewpoint can be application objects, service support objects or infrastructure objects.

Table 14 — Object factory computational pattern

Element of a pattern	Description of element
Name	Factory. Variations: Abstract Factory, Independent Objects.
Problem	Provide an interface for creating related objects without specifying their concrete classes. Provides flexibility in configuring implementations; an implementation of an object may be located separately from where it was created.
Context	Interfaces are defined using object-oriented techniques. Clients manipulate instances through their abstract interfaces. Because a factory creates a complete family of product-specific implementation objects, product specifics are isolated to the factory.
Forces	Dependent upon use of a distributed-object computing platform. Concentrating implementation specifics in the factory object means any extensions are done to the factory interface, which may be difficult. Design considerations are critical to keep the factory object from becoming a bottleneck.
Structure	Client invokes a Create (IG_GridScene:data) operation on the Factory Object. The factory object instantiates an object with the IG_GridScene interface to data as identified in the Create operation and returns a handle to the Client. Subsequent operation invocations by the Client are done using the object handle and the IG_GridScene operations.

Table 15 — Message-oriented computational pattern

Element of a pattern	Description of element
Name	Messaging. Variations: Message Oriented Middleware, Message Exchange Pattern.
Problem	Decoupling the interaction between agents and services by defining a message exchange pattern that lacks any semantic significance of the content of the messages. However, the pattern does focus on the structure of messages, on the relationship between message senders and receivers and how messages are transmitted. The pattern includes normal and abnormal termination of any message exchange.
Context	Some DCPs natively support certain messaging, e.g. HTTP natively supports request-response messaging. The pattern is used in Service-oriented architectures. The message-oriented pattern focuses on those aspects of the architecture that relate to messages and message processing. The pattern shall be applied to specific applications.
Forces	While the pattern is defined to be semantically neutral, in practice domain semantics are typically added to the pattern resulting in message exchange operations typed by inclusion in an interface defined by a domain community, e.g. imagery request interface. Deployed services conform to the abstract message-oriented interfaces.
Structure	Services are defined to accomplish a domain-relevant computation, e.g. image processing. Interfaces composed of message-oriented operations are bound to the service. A client, acting on behalf of an agent, invokes the operation.

9.3 Geographic imagery services

Geographic imagery services shall be specified as extensions of the broader geographic services defined in ISO 19119 and listed in Table 16. The method is to subtype a general service taxonomy to identify services specific to geographic imagery. The purpose of this method is to guide the standardization of geographic information in order to enable the interoperability of a GIS in Distributed Computing Environments (DCP).

Table 16 — Geographic services categorization

Geographic human interaction services	— Services for management of user interfaces, graphics, multimedia, and for presentation of compound documents.
Geographic model/information management services	— Services for management of the development, manipulation, and storage of metadata, conceptual schemas, and data sets.
Geographic workflow/task management services	— Services for support of specific tasks or work-related activities conducted by humans. These services support use of resources and development of products involving a sequence of activities or steps that may be conducted by different persons.
Geographic processing services Geographic processing services – spatial Geographic processing services – thematic Geographic processing services – temporal Geographic processing services – metadata	— Services that perform large-scale computations involving substantial amounts of data. A processing service does not include capabilities for providing persistent storage of data or transfer of data over networks. — Geographic processing services are subtyped by the geographic attribute that the processing modifies. Attribute types are defined in the General Feature Model.
Geographic communication services	— Services for the encoding and transfer of data across communications networks.

Multiple classification schemes may be provided for a given system. Three types of taxonomies are defined here: semantic capability, service interface and service binding[72] (see Figure 17).

A service is defined by more than an interface: instances of the same service type may differ in some non-computational, behavioural, and/or non-functional aspects (such as the cost of using the service). Even if the interface signature is identical, the semantics may be very different (e.g. a LIFO Stack versus a FIFO Queue).

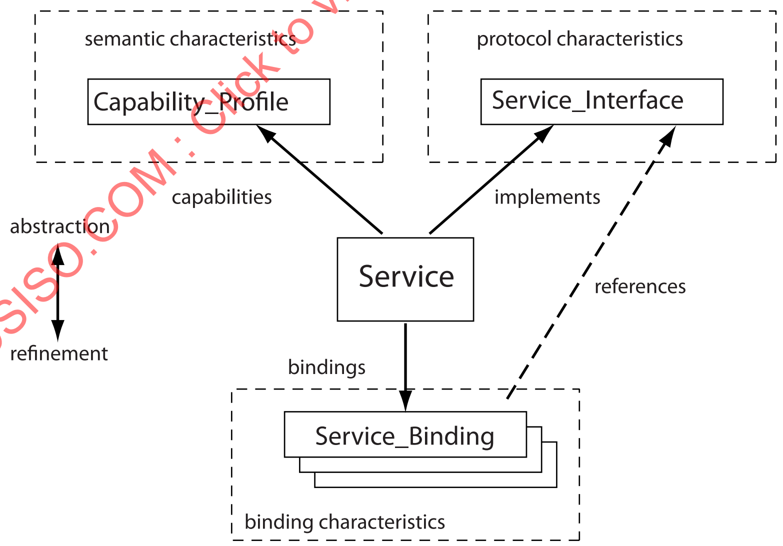


Figure 17 — Types of service description

ISO 19119 defines a geographic services taxonomy based on the semantic characteristics of services, and provides examples. The taxonomy consists of the titles of the categories and the definitions for the categories.

ISO 19119 and OGC Image Exploitation Services[68] provide more detail concerning the geographic imagery services for:

— human interaction;

— model/information management;

— workflow/task management;

— processing for spatial, thematic and temporal data, and metadata;

— communication.

9.4 Service chaining for imagery

Image processing typically involves multiple steps. Some steps can be resource intensive. ISO 19119 defines a computational model for combining services in a dependent series to achieve larger tasks. ISO 19119 addresses the syntactic issues of service chaining, e.g. data structure of a chain; as well as the semantic issues associated with service chaining.

ISO 19119 enables users to combine data and services in ways that are not predefined by the data or service providers. This capability is enabled by the infrastructure of the larger domain of IT.

The quality of a service chain operating on imagery depends upon several issues, e.g. order of the individual services and compatibility of the individual services. See ISO 19119 for a further discussion of service chaining quality.

9.5 Service metadata

For cataloguing purposes, geographic imagery services shall be described using the service metadata specified in ISO 19119. Service metadata records can be managed and searched using a catalogue service as is done for dataset metadata. In order to provide a catalogue for discovering services, a schema for describing a service is needed. ISO 19119 defines a metadata model for service instances.

10 Engineering Viewpoint — Deployment approaches

10.1 General

The Engineering viewpoint on an ODP system and its environment focuses on the mechanisms and functions required to support distributed interaction between objects in the system[37]. Key concepts for the Engineering Viewpoint are node and channel.

An Engineering Viewpoint node, according to ISO/IEC 10746-1[42] is a configuration of engineering objects forming a single unit for the purpose of location in space, and which embodies a set of processing, storage and communication functions. In this document, Engineering Viewpoint nodes will be modelled as UML nodes showing the allocation of Information and Computational Viewpoints to specific nodes.

An Engineering Viewpoint channel, according to ISO/IEC 10746-1, is a configuration of stubs, binders, protocol objects and interceptors providing a binding between a set of interfaces to basic engineering objects, through which interaction can occur. This document will not use the specific list of ISO/IEC 10746-1 channel items, but rather will discuss channels in terms of networks and distributed computing platforms.

Requirements for consistency between Computational and Engineering Viewpoints are as follows.

— Computational interfaces shall correspond to engineering interfaces[42].

— Basic engineering objects correspond to computational objects[42].

— Engineering Viewpoint adds code packaging and operating systems[42].

— Computational interactions correspond to chain of engineering interactions[44].

10.2 Distributed system for geographic imagery

This document defines a distributed system for geographic image processing (Figure 18) which is comprised of five node types, connected by a set of channels.

The deployment diagram of Figure 18 reflects the following requirements.

— Imagery Collection Nodes which collect imagery may be located on a variety of platforms: mobile/fixed, airborne/satellite.

— Imagery Collection Nodes shall be controlled by Imagery Processing Nodes.

— Data from an Imagery Collection Node may be distributed to multiple Sensor Processing Nodes.

— Imagery Archive Nodes may be replicated and federated.

— Each Imagery Archive Node shall contain metadata that describes each of the images it contains.

— Value Added Processing Nodes may process data from multiple Sensor Processing Nodes.

— Value Added Processing Nodes may provide information to Decision Support Nodes.

— Decision Support Nodes may be mobile or fixed.

— Decision Support Nodes may be hosted on a range of computation hardware: from handheld device to a situation room with multiple screens and computing hosts.

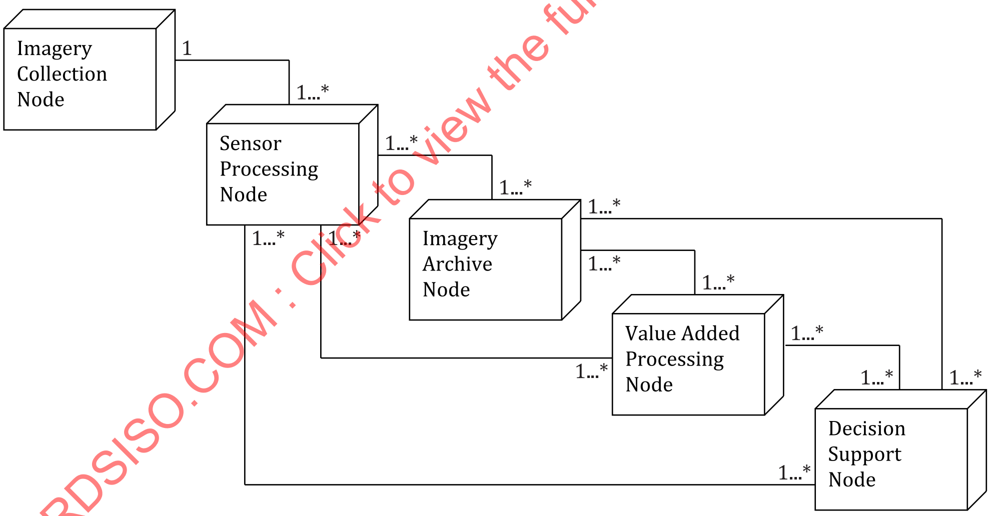


Figure 18 — Geographic imagery system deployment diagram

Deployment of geographic imagery systems compliant with this document shall be specified using the model shown in Figure 18.

Nodes shall be as defined according to 10.3 to 10.7. Computational and Information Viewpoint artifacts shall be as allocated to the various nodes. A system needs not implement every artifact allocated to the node and may add artifacts as needed. It is required that if a system provides a node named in 10.3 to 10.7, the node shall use the interfaces as defined therein.

Multiple nodes of various types may be located in the same physical locations.

Node deployment diagrams in 10.3 to 10.7 are shown with both Information Viewpoint interfaces and Computational Viewpoint services. The various patterns defined in the computational pattern are not constrained in the Engineering Viewpoint. Nodes may be developed with the distributed object pattern or with the messaging pattern. Internal to a node this decision can be made without coordination. A channel between nodes shall agree on computational pattern approaches.

Nodes involved in development of a new image sensor may evolve as development proceeds. Initial development will have a tight coupling of the Image Collection Node and the Sensor Processing Node. This is to assure proper analysis and extraction of the information from the sensor data. As the development proceeds towards operational deployment, one instrument will serve many users, i.e. multiple Sensor Processing Nodes will process the data from an Image Collection Node.

Many tasks require data input from many sources (e.g. many data collection passes, data from multiple sensors, maps, point data.) This places a burden on the system and on analysis to ensure that various data are made compatible. As secondary users begin to combine sensor data with information derived by others, the understanding of separately developed information becomes more important to obtain correct results.

10.3 Imagery Collection Node

An Imagery Collection Node typically contains an imaging sensor, platform, a mount coupling the sensor to the platform, position/attitude sensors and a time sensor.

An Imagery Collection Node may be able to georectify the collected data.

Figure 19 identifies some of the services of the Imagery Collection Node.

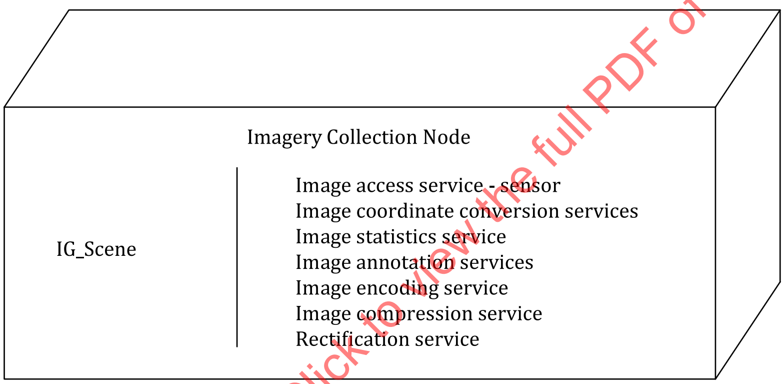


Figure 19 — Imagery Collection Node

Imagery Collection Nodes may be located on a variety of platforms. One platform is an Earth orbiting satellite, which may be government- or commercially-owned. Different satellites have different orbits, e.g. Low Earth Orbit (LEO), Geosynchronous Earth Orbit (GEO). Orbital dynamics and sensor capabilities affect the frequency at which a spot on the Earth can be seen, i.e. the revisit time. Satellite-based instruments may be pointable or have a fixed pointing with respect to platform attitude. Distribution of data from a satellite may be directly to the ground or through other satellites. Once data is received by a ground-located sensor processing facility, the data may be forwarded by network or media, or may remain in place at the ground station with only the metadata being forwarded to a central archive.

Imagery Collection Nodes may also be located on an airborne platform: airplane, helicopter, balloon/blimp, long-duration flyers, etc. The airborne platform may be human-occupied or unoccupied. Acquisition planning for an airborne platform includes definition of a flight plan. Relevant considerations for airborne-platform flight planning include light conditions including solar altitude and cloud cover; flight path considerations include forward overlap and side overlap. Data distribution from an airborne Imagery Collection Node may occur as an in-flight or post-flight transmission. Recent advances in airborne geographic imagery acquisition provide for on-board processing of the imagery based on concurrent position and attitude determination, allowing for rectification of the imagery on-board.

Some examples of Imagery Collection Nodes are provided in Table 17.

Table 17 — Imagery Collection Node examples

Mobility	Measures	
	In situ sensor	Remote sensing
Fixed Platform	Stationary Video Camera	Doppler Radar station
Mobile Platform	"Diving" Salinity probe	Airborne LIDAR

10.4 Sensor Processing Node

A Sensor Processing Node is affiliated with an Imagery Collection Node. A Sensor Processing Node provides imagery containing sensor data as well as derived imagery as standard products from the sensor.

A Sensor Processing Node instance provides command and control for an Imagery Collection Node.

Figure 20 shows the objects and services associated with the Sensor Processing Node.

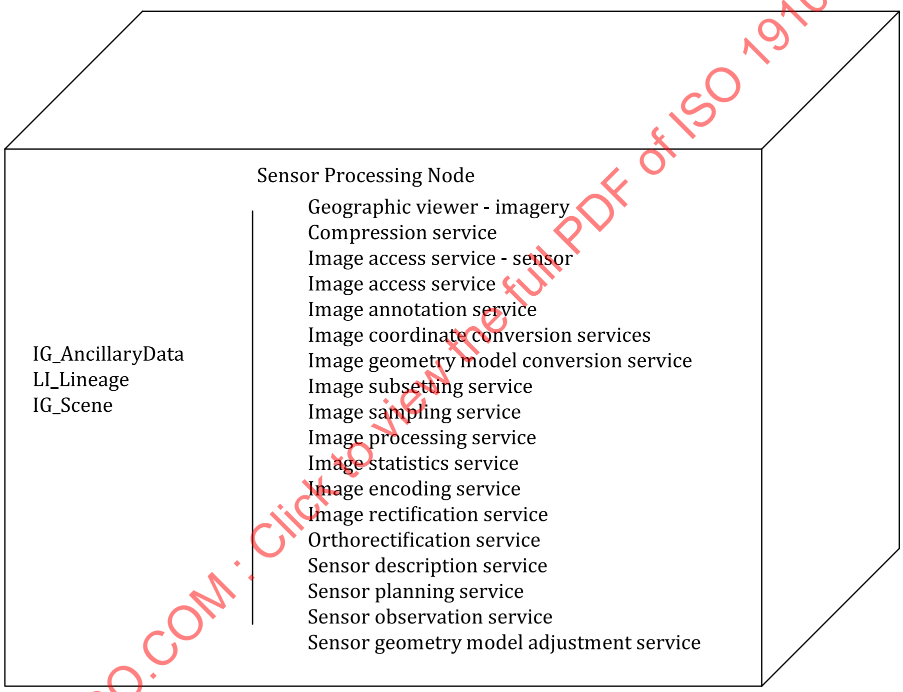


Figure 20 — Sensor Processing Node

10.5 Imagery Archive Node

An Imagery Archive Node preserves imagery information for access and use by a designated community.

Imagery Archive functions as defined in ISO 14721[25] are: ingest, archival storage, data management, preservation planning and access.

Figure 21 shows the objects and services associated with the Imagery Archive Node.