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Working Draft 1.3 sf2

Geographic information – Calibration and validation of remote sensing imagery sensors and data

Information géographique

Contents

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

Technical Committee ISO/TC 211, Working Group 6 on Imagery, prepared ISO/TS 19159

Contributions

This section will be removed for the Committee Draft.

Wolfgang Kresse	EuroSDR	kresse@hs-nb.de
Michael Cramer	EuroDAC²	michael.cramer@ifp.uni-stuttgart.de
Emmanuel Devys	IGN France	emmanuel.devys@ign.fr
Takeshi Doihara	Asia Air Survey, Japan	ta.doihara@ajiko.co.jp
Ilse Sebastian	DLR, Germany	ilse.sebastian@dlr.de
Maike Gottschalk	DIN, Germany	maike.gottschalk@din.de
Greg Stensaas	USGS, U.S.A.	gstensaas@usgs.gov
Chris Body	Standards Australia	chris.body@osdm.gov.au

Edited by Wolfgang Kresse, 2011-03-08: Comments from Australia, France, Japan, the U.S. and Germany

Introduction

To be completed later

This International Technical Specification standardizes the calibration of remote sensing imagery sensors and the validation of the calibration information.

All calibration processes should follow the International Standards for documenting uncertainty and traceability.

Geographic information – Calibration and validation of remote sensing imagery sensors and data

1 Scope

This International Specification defines the calibration and validation of identified airborne and space borne remote sensing imagery sensors and data.

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

The validation methods are split into process- and product-validation, and include the prerequisites for installing a validation environment.

This Technical Specification will also cover the associated metadata that has not been defined in other ISO geographic information standards.

The ~~identified~~ specified sensors will include at least frame cameras, pushbroom, and whisk broom type sensors.

Comment [k1]: Comment US/GS4:
USGS –Tom Stone
This appears to be an attempt to establish ISO specifications for calibration and validation of data and
products from airborne and space-based remote sensing instruments. If so, that is an ambitious goal. The CEOS community has vast expertise, and
collectively could establish such a specification quite definitively. But this would require a substantial time commitment, and so there needs to be a compelling reason to get buy-in from the community.

Comment [k2]: Comment BE-1: The title (first page) states that the 'validation' of 'data' is addressed in this document, in addition to other topics. This is confirmed on page 2 (Section 1) where the declared scope of the document is explicated. Section 1 further states that 'The validation methods are split into process- and product-validation'. But later in the document there is no single occurrence of data or product validation, even in Figure 1. Section 7.1 (Validation semantics) addresses only the 'validation of the geometric and radiometric calibration of a … system'. The target of the validation is clearly the calibration, not the data product. This must be clarified, or the validation of data products must be addressed.
BE-Proposal:
Consider extending appropriately the concept of data validation in the whole document, OR adapting the title and the table of content to better reflect the real (current) scope of the document.

Comment [k3]: Comment US/GS6:
CEOS – NASA - Joanne Nightengale – My only suggestion would be that in respect to this document I personally would replace "validation" with "characterization" or "quality assessment"? Validation in this community implies something different than what the scope of this document actually is??? ... [1]

Comment [k4]: Comment DPMqs-1:
What are the "identified" sensors?

Comment [k5]: Comment US/BMS-3:
"validation" is undefined
US/BMS Proposal:
Define it.

2 Conformance

To be completed later

3 Normative references

ISO Guide 31:2000, Reference materials – Contents of certificates and labels

ISO/IEC Guide 98:1995, Guide to the expression of uncertainty in measurement (GUM)

ISO/IEC Guide 99:2007, International vocabulary of metrology – Basic and general concepts and associated terms (VIM)

ISO 9001:2008, Quality management systems – Requirements

ISO/IEC 15775:1999: Information technology – Office machines – Method of specifying image reproduction of colour copying machines by analog test charts – Realisation and application

ISO ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories

ISO 19101:2002, Geographic information – Reference model

ISO 19101-2:2008, Geographic information – Reference model – Part 2: Imagery

ISO/TS 19103:2005, Geographic information – Conceptual schema language

ISO 19108:2002, Geographic information – Temporal schema

ISO 19115:2003, Geographic information – Metadata

ISO 19115-2:2009, Geographic information – Metadata – Part 2: Extensions for imagery and gridded data

ISO 19116:2004, Geographic information – Positioning services

ISO/TS 19130:2010, Geographic information – Imagery sensor models for geopositioning

ISO/TS 19138: Geographic information – Data quality measures

IEC 61391-1:2006, Ultrasonics – Pulse echo scanners – Part 1: Techniques for calibrating spatial measurement systems and measurement of system point-spread function response

IEC 88528-11:2004, Reciprocating internal combustion engine driven alternating current generating sets – Part 11: Rotary uninterruptible power systems – Performance requirements and test methods

4 Terms and definitions

4.1
accessibility
capability to access available data

NOTE Access is the action or process of obtaining or retrieving stored information.

[proposed by CEOS]
(Pascal Lecomte (ESA), Terms and Definitions, ppt-presentation (pdf), 2007)

4.2
accuracy class
class of **measuring instruments** or **measuring systems** that meet stated metrological requirements that are intended to keep **measurement errors** or **instrumental uncertainties** within specified limits under specified operating conditions

NOTE 1 An accuracy class is usually denoted by a number or symbol adopted by convention.

NOTE 2 Accuracy class applies to **material measures**.

[ISO/IEC Guide 99:2007]

4.3
adjustment of a measuring system
adjustment
set of operations carried out on a **measuring system** so that it provides prescribed **indications** corresponding to given **values** of a **quantity** to be measured

NOTE 1 Types of adjustment of a measuring system include **zero adjustment of a measuring system**, offset adjustment, and span adjustment (sometimes called gain adjustment).

NOTE 2 Adjustment of a measuring system should not be confused with **calibration**, which is a prerequisite for adjustment.

NOTE 3 After an adjustment of a measuring system, the measuring system must usually be recalibrated.

[ISO/IEC Guide 99:2007]

4.4
approval
in a <data> context, confirmation, by specified authorities, to indicate compliance with the requirements applicable to the data and an indication that the data meets appropriate guidelines in a <user> context, confirmation, by specified authorities, to indicate compliance with the requirements applicable to the user access

[proposed by CEOS]
(QA4EO-CEOS-GEN-DPK-001 and others)

Comment [k6]: Comment FR4:
This terminology paragraph is huge (even if it is understood that it is going to be simplified by choice of one definition only in most cases where a choice is proposed). After this operation is done, it is suggested to check that only entries used in the document are kept.
FR-Proposal:
Reduce the length of this chapter and minimize it to the necessary entries only.
Action:
A few terms already deleted. Further terms to be deleted by the project team.

Comment [k7]: Comment US/DPMqs-3:
Will these be alphabetized?

Comment [k8]: Comment BE-2:
Although not the general rule, several remote sensing instruments measuring atmospheric composition fall in the category of imagers, thus in the scope of the present document. But this Working Draft 1.1 contains a few definitions and statements which exclude applications to atmospheric imagers and data. Wherever appropriate this document should accommodate somehow the specificity of atmospheric remote sensing and data products.
BE-Proposal:
Most of the changes proposed hereafter

4.5
authorisation
permission from specified authorities to apply data

~~**4.6**~~
~~**availability**~~
~~quality of being at hand when needed~~

~~[proposed by CEOS]~~
~~(Pascal Lecomte (ESA), Terms and Definitions, ppt-presentation (pdf), 2007)~~

4.7
base quantity
quantity in a conventionally chosen subset of a given **system of quantities**, where no subset quantity can be expressed in terms of the others

NOTE 1 The subset mentioned in the definition is termed the "set of base quantities".

NOTE 2 Base quantities are referred to as being mutually independent since a base quantity cannot be expressed as a product of powers of the other base quantities.

NOTE 3 'Number of entities' can be regarded as a base quantity in any system of quantities.

[ISO/IEC Guide 99:2007]

4.8
blooming
overflow of the signal of one pixel to the neighbouring pixel

4.9
calibration
operation that, under specified conditions, in a first step, establishes a relation between the **quantity values** with **measurement uncertainties** provided by **measurement standards** and corresponding **indications** with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a **measurement result** from an **indication**

NOTE 1 A calibration may be expressed by a statement, calibration function, **calibration diagram**, **calibration curve**, or calibration table. In some cases, it may consist of an additive or multiplicative **correction** of the indication with associated measurement uncertainty.

NOTE 2 Calibration should not be confused with **adjustment of a measuring system**, often mistakenly called "self-calibration", nor with **verification** of calibration.

NOTE 3 Often, the first step alone in the above definition is perceived as being calibration.

[ISO/IEC Guide 99:2007]

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

[ISO 19101-2:2008, CEOS WGCV]

Comment [k9]: Comment US/GS10:
Definition needs clarity of one source
To the USGS:
I propose to keep both definitions

(eventually add ISO/IEC Guide definition)

4.10
calibration curve
expression of the relation between **indication** and corresponding **measured quantity value**

NOTE A calibration curve expresses a one-to-one relation that does not supply a **measurement result** as it bears no information about the **measurement uncertainty**.

[ISO/IEC Guide 99:2007]

4.11
calibration diagram
graphical expression of the relation between **indication** and corresponding **measurement result**

NOTE 1 A calibration diagram is the strip of the plane defined by the axis of the indication and the axis of measurement result, that represents the relation between an indication and a set of **measured quantity values**. A one-to-many relation is given, and the width of the strip for a given indication provides the **instrumental measurement uncertainty**.

NOTE 2 Alternative expressions of the relation include a **calibration curve** and associated **measurement uncertainty**, a calibration table, or a set of functions.

NOTE 3 This concept pertains to a **calibration** when the instrumental measurement uncertainty is large in comparison with the measurement uncertainties associated with the **quantity values** of **measurement standards**.

[ISO/IEC Guide 99:2007]

4.12
calibration hierarchy
sequence of **calibrations** from a reference to the final measuring system, where the outcome of each calibration depends on the outcome of the previous calibration

NOTE 1 **Measurement uncertainty** necessarily increases along the sequence of calibrations.

NOTE 2 The elements of a calibration hierarchy are one or more **measurement standards** and measuring systems operated according to **measurement procedures**.

NOTE 3 For this definition, the 'reference' can be a definition of a **measurement unit** through its practical realization, or a measurement procedure, or a measurement standard.

NOTE 4 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the **quantity value** and measurement uncertainty attributed to one of the measurement standards.

[ISO/IEC Guide 99:2007]

4.13
calibrator
measurement standard used in calibration

NOTE The term "calibrator" is only used in certain fields.

[ISO/IEC Guide 99:2007]

4.14
certified reference material
reference material, accompanied by documentation issued by an authoritative body and providing one or more specified property values with associated uncertainties and traceabilities, using valid procedures

EXAMPLE Human serum with assigned **quantity value** for the concentration of cholesterol and associated **measurement uncertainty** stated in an accompanying certificate, used as a **calibrator** or **measurement trueness** control material.

NOTE 1 'Documentation' is given in the form of a 'certificate' (see ISO Guide 30:1992).

NOTE 2 Procedures for the production and certification of certified reference materials are given, e.g. in ISO Guide 34 and ISO Guide 35.

NOTE 3 In this definition, "uncertainty" covers both 'measurement uncertainty' and 'uncertainty associated with the value of a **nominal property**', such as for identity and sequence. "Traceability" covers both '**metrological traceability** of a quantity value' and 'traceability of a nominal property value'.

NOTE 4 Specified quantity values of certified reference materials require metrological traceability with associated measurement uncertainty (Accred. Qual. Assur.:2006).

NOTE 5 ISO/REMCO has an analogous definition (Accred. Qual. Assur.:2006) but uses the modifiers 'metrological' and 'metrologically' to refer to both quantity and nominal property.

[ISO/IEC Guide 99:2007]

4.16
combined standard measurement uncertainty
combined standard uncertainty
standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the **input quantities in a measurement model**

NOTE In case of correlations of input quantities in a measurement model, covariances must also be taken into account when calculating the combined standard measurement uncertainty; see also ISO/IEC Guide 98-3:2008, 2.3.4.

[ISO/IEC Guide 99:2007]

4.18
conventional quantity value
conventional value of quantity
conventional value
quantity value attributed by agreement to a **quantity** for a given purpose

NOTE 1 The term "conventional true quantity value" is sometimes used for this concept, but its use is discouraged.

NOTE 2 Sometimes a conventional quantity value is an estimate of a **true quantity value**.

NOTE 3 A conventional quantity value is generally accepted as being associated with a suitably small **measurement uncertainty**, which might be zero.

[ISO/IEC Guide 99:2007]

4.19
correction
compensation for an estimated systematic effect

NOTE 1 See ISO/IEC Guide 98-3:2008, 3.2.3, for an explanation of 'systematic effect'.

NOTE 2 The compensation can take different forms, such as an addend or a factor, or can be deduced from a table.

[ISO/IEC Guide 99:2007]

4.20
coverage probability
probability that the set of **true quantity values** of a **measurand** is contained within a specified **coverage interval**

NOTE 1 This definition pertains to the Uncertainty Approach as presented in the GUM.

NOTE 2 The coverage probability is also termed "level of confidence" in the GUM.

[ISO/IEC Guide 99:2007]

NOTE 3 The term coverage probability must not be confused with term coverage as it is defined in ISO 19123.

4.21
periodic time
duration of one cycle

[ISO 31-2, ISO 19108]

4.21a
dark current
output current of a photoelectric detector or of its cathode in the absence of incident radiation

[IEC 60050-845]

4.22
dark current noise
noise of current at the output of a detector, when no optical radiation is sensed

4.23
data fusion
formal framework in which are expressed the means and tools for the alliance of data originating from different sources

NOTE It aims at obtaining information of greater quality; the exact definition of 'greater quality' will depend upon the application.

[Wald L., A European proposal for terms of reference in data fusion. International Archives of Photogrammetry and Remote Sensing, Vol. XXXII, Part 7, 651-654, 1998]
(This definition needs to be refined linguistically)

4.24
definitional uncertainty
component of **measurement uncertainty** resulting from the finite amount of detail in the definition of a **measurand**

NOTE 1 Definitional uncertainty is the practical minimum measurement uncertainty achievable in any **measurement** of a given measurand.

NOTE 2 Any change in the descriptive detail leads to another definitional uncertainty.

NOTE 3 In the ISO/IEC Guide 98-3:2008, D.3.4, and in IEC 60359, the concept 'definitional uncertainty' is termed ·intrinsic uncertainty".

[ISO/IEC Guide 99:2007]

4.25
derived quantity
quantity, in a **system of quantities**, defined in terms of the base quantities of that system

[ISO/IEC Guide 99:2007]

4.26
detector (electro-optical)
device that converts electro-magnetic radiation into proportional electrical signal

NOTE Detector elements can be arranged separately or in detector arrays (line or frame).

4.28
geometrical resolution
ability of a sensor system to record signals separately from neighbouring object structures

(non-official translation from German to English)

NOTE In DIN 18740-4 the smallest size of an object structure detectable by the sensor system is meant.

4.30
in-situ measurement
direct measurement of the measurand in its original place

[Latin definition (what does this mean?]

any sub-orbital measurement

Comment [k10]: Comment JP5: http://en.wikipedia.org/wiki/Resolution_(mass_spectrometry) might be some help.

Comment [k11]: Comment FR12: Isn't the term 'spatial resolution' more adequate ?
FR- and BE-Proposal:
Consider the use of 'spatial resolution'
Action:
Pass this question to the project team.
Vote for Fr!!!!!!!!

Comment [k12]: Comment US/GS13: Agree with comment on spatial vs. geometric

Comment [k13]: Comment BE-5: Spatial resolution can have different meanings, depending on the field of application. E.g., in the case of meteorological and atmospheric remote sensing of a temperature/constituent profile, the retrieved information is smoothed spatially by scattering phenomena and it originates actually from an air mass that can differ significantly from the field of view of the instrument. The spatial resolution of the data, thus the "horizontal" and "vertical" dimensions of the retrieved information, differs from the geometrical resolution of the data, the latter being associated rather with the on-ground projection of the field of view (the so-called ground pixel).
BE-Proposal:
Avoid the use of 'spatial resolution', that might be too domain dependent.

Comment [k14]: Comment AU1: In-situ in RS usually means ground measurement

Comment [k15]: Compare with INSPIRE.definition

Comment [k16]: Comment FR14: The comment 'any sub-orbital measurement appears too restrictive
FR-Proposal:
Consider suppression of this comment (or indicate it is only one example)
Action:
Find definition for in-situ given by INSPIRE/GMES: Action by pl

Comment [k17]: Comment US/GS15: This need some review and refinement

Comment [k18]: Comment BE-6: 'Any sub-orbital measurement' is too domain dependent and restrictive. There are in situ measurements performed by SATELLITES: e.g., space weather applications used to prevent and mitigate effects of solar storms on electric power plants, make use of satellite observations of the magnetic field vector at satellite altitude, thus 'in its original place'. There are also several types of 'sub-orbital' measurements of remote sensing nature, from the ground and from balloons, providing EO data hundreds of kilometres away from the instrument: stricto sensu they cannot be called 'in situ' as they do not refer to a 'measurement of the measurand in its original place'.
BE-Proposal:
Consider transforming this proposed definition in a NOTE like: In thematic domains dealing with observations of the Earth's surface a ... [2]

[proposed by CEOS]
(Pascal Lecomte (ESA), Terms and Definitions, ppt-presentation (pdf), 2007)

4.31
indicating measuring instrument
measuring instrument providing an output signal carrying information about the **value** of the **quantity** being measured

NOTE 1 An indicating measuring instrument may provide a record of its **indication**.

NOTE 2 An output signal may be presented in visual or acoustic form. It may also be transmitted to one or more other devices.

[ISO/IEC Guide 99:2007]

4.32
indication
quantity value provided by a measuring instrument or a measuring system

NOTE 1 An indication may be presented in visual or acoustic form or may be transferred to another device. An indication is often given by the position of a pointer on the display for analog outputs, a displayed or printed number for digital outputs, a code pattern for code outputs, or an assigned quantity value for **material measures**.

NOTE 2 An indication and a corresponding value of the **quantity** being measured are not necessarily values of quantities of the same **kind**.

[ISO/IEC Guide 99:2007]

4.33
input quantity in a measurement model
input quantity
quantity that must be measured, or a quantity, the value of which can be otherwise obtained, in order to calculate a **measured quantity value** of a **measurand**

NOTE 1 An input quantity in a measurement model is often an output quantity of a **measuring system**.

NOTE 2 **Indications**, **corrections** and **influence quantities** can be input quantities in a measurement model.

[ISO/IEC Guide 99:2007]

4.34
intermediate measurement precision
intermediate precision
intermediate precision under a set of intermediate precision conditions of measurement

NOTE Relevant statistical terms are given in ISO 5725-3:1994.

[ISO/IEC Guide 99:2007]

4.35
intermediate precision condition of measurement
intermediate precision condition
condition of **measurement**, out of a set of conditions that includes the same **measurement procedure**, same location, and replicate measurements on the same or similar objects over an extended period of time, but may include other conditions involving changes

NOTE 1 The changes can include new **calibrations**, **calibrators**, operators, and **measuring systems**.

NOTE 2 A specification for the conditions should contain the conditions changed and unchanged, to the extent practical.

NOTE 3 In chemistry, the term "inter-serial precision condition of measurement" is sometimes used to designate this concept.

[ISO/IEC Guide 99:2007]

4.36
international measurement standard
measurement standard recognized by signatories to an international agreement and intended to serve worldwide

[ISO/IEC Guide 99:2007]

4.37
International System of Quantities
ISQ
system of quantities based on the seven **base quantities**: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity

NOTE 1 This system of quantities is published in the ISO 80000 and IEC 80000 series *Quantities and units.*

NOTE 2 The **International System of Units (SI)** is based on the ISQ.

[ISO/IEC Guide 99:2007]

4.38
irradiance
electromagnetic radiation energy per unit area per unit time

NOTE The SI unit is watts per square meter (W/m^2)

4.38a
spectral irradiance
electromagnetic radiation energy per unit area per unit time per unit frequency interval

NOTE The SI unit is watts per square meter per nanometer($W/m^2/nm$)

4.39
Instantaneous field of view
IFOV
opening angle corresponding to one detector element

(non-official translation from German to English)

4.39a
keystone ring
A compression ring with both sides tapered; it is used in those cas when ring sticking can be expected. Due to its wedge shape, any radial movement of the ring will alter its axial clearance and thus minimize the build-of combustion residues.

[ISO 6621-1]

4.41
kind of quantity
kind
aspect common to mutually comparable **quantities**

NOTE 1 The division of the concept of 'quantity' according to 'kind of quantity' is to some extent arbitrary.

NOTE 2 Quantities of the same kind within a given **system of quantities** have the same **quantity dimension**. However, quantities of the same dimension are not necessarily of the same kind.

NOTE 3 In English, the terms for quantities in the left half of the table in 1.1, Note 1, are often used for the corresponding 'kinds of quantity'. In French, the term "nature" is only used in expressions such as "grandeurs de même nature" (in English, "quantities of the same kind").

[ISO/IEC Guide 99:2007]

4.42a
linearity error
deviation from straight a line of the curve representing the output quantity as a function of the input quantity

[IEC 60050-394:2007-04]
(non-official translation from German to English)

4.43
material measure
measuring instrument reproducing or supplying, in a permanent manner during its use, **quantities** of one or more given **kinds**, each with an assigned **value**

NOTE 1 The **indication** of a material measure is its assigned **quantity value.**

NOTE 2 A material measure can be a **measurement standard**.

[ISO/IEC Guide 99:2007]

Comment [k19]: change sequence: instantaneous …, then IFOV

Comment [k20]: Comment FR13: Is there any ISPRS definition available for IFOV? Action: Find definition for in-situ given by INSPIRE/GMES: Action by pl/editor

Comment [k21]: Was this a typo in the original?

4.44
measurable quantity

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

[ISO/TS 19101-2 with reference to VIM]

4.45
measurand
particular quantity subject to measurement

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

NOTE The specification of a measurand may require statements about quantities such as time, temperature and pressure.

[VIM, ISO 19101-2:2008]

4.46
measure (noun)
value described using a numeric amount with a scale or using a scalar reference system

NOTE When used as a noun, measure is a synonym for physical quantity.

[N 2616, CD Observations and Measurements]

4.47
measured quantity value
measured value of quantity
measured value
quantity value representing a measurement result

NOTE 1 For each **measurement** involving replicate **indications**, each indication can be used to provide a corresponding measured quantity value. This set of individual measured quantity values can be used to calculate a resulting measured quantity value, such as an average or median, usually with a decreased associated **measurement uncertainty**.

NOTE 2 When the range of the **true quantity values** believed to represented the **measurand** is small compared with the measurement uncertainty, a measured quantity value can be considered to be an estimate of an essentially unique true quantity value and is often an average or median of individual measured quantity values obtained through replicate measurements.

NOTE 3 In the case where the range of the true quantity values believed to represent the measurand is not small compared with the measurement uncertainty, a measured value is often an estimate of an average or median of the set of true quantity values.

NOTE 4 In the GUM, the terms "result of measurement" and "estimate of the value of the measurand" or just "estimate of the measurand" are used for 'measured quantity value'.

[ISO/IEC Guide 99:2007]

4.48
measurement
set of operations having the object of determining a value of a quantity

[VIM, ISO 19101-2:2008]

4.49
measurement accuracy
accuracy of measurement
accuracy
closeness of agreement between a measured quantity value and a true quantity value of a measurand

NOTE 1 The concept 'measurement accuracy' is not a **quantity** and is not given a **numerical quantity value**. A **measurement** is said to be more accurate when it offers a smaller **measurement error**.

NOTE 2 The term 'measurement accuracy' should not be used for **measurement trueness** and the term **measurement precision** should not be used for 'measurement accuracy', which, however, is related to both these concepts.

NOTE 3 'Measurement accuracy' is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

[ISO/IEC Guide 99:2007]

4.50
measurement bias
bias
estimate of a systematic measurement error

[ISO/IEC Guide 99:2007]

4.51
measurement error
error of measurement
error
measured quantity value minus a reference quantity value

NOTE 1 The concept of 'measurement error' can be used both

a) when there is a single reference quantity value to refer to, which occurs if a **calibration** is made by means of a **measurement standard** with a **measured quantity value** having a negligible **measurement uncertainty** or if a **conventional quantity value** is given, in which case the measurement error is known, and

b) if a **measurand** is supposed to be represented by a unique **true quantity value** or a set of true quantity values of negligible range, in which case the measurement error is not known.

NOTE 2 Measurement error should not be confused with production error or mistake.

[ISO/IEC Guide 99:2007]

4.52
measurement model
model of measurement model
mathematical relation among all **quantities** known to be involved in a **measurement**

NOTE 1 A general form of a measurement model is the equation $h(Y, X_1, \ldots, X_n) = 0$, where Y, the **output quantity in the measurement model**, is the **measurand**, the **quantity value** of which is to be inferred from information about **input quantities in the measurement model** $X_1, \ldots, X_n$.

NOTE 2 In more complex cases where there are two or more output quantities in a measurement model, the measurement model consists of more than one equation.

[ISO/IEC Guide 99:2007]

4.53
measurement precision
1. Definition according to ISO 19116
measure of the repeatability of a set of measurements

NOTE Precision is usually expressed as a statistical value based upon a set of repeated measurements such as the standard deviation from the sample mean.

[ISO 19116:2004]

2. Definition according to ISO/IEC Guide 99:2007
precision
closeness of agreement between **indications** or **measured quantity values** obtained by replicate **measurements** on the same or similar objects under specified conditions

NOTE 1 Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.

NOTE 2 The 'specified conditions' can be, for example , **repeatability conditions of measurement, intermediate precision conditions of measurement**, or **reproducibility conditions of measurement** (see ISO 5725-3:1994).

NOTE 3 Measurement precision is used to define **measurement repeatability**, **intermediate measurement precision**, and **measurement reproducibility**.

NOTE 4 Sometimes 'measurement precision' is erroneously used to mean **measurement accuracy**.

[ISO/IEC Guide 99:2007]

4.54
measurement procedure
detailed description of a measurement according to one or more measurement principles and to a given measurement method, based on a measurement model and including any calculation to obtain a measurement result

NOTE 1 A measurement procedure is usually documented in sufficient detail to enable an operator to perform a measurement.

NOTE 2 A measurement procedure can include a statement concerning a **target measurement uncertainty**.

NOTE 3 A measurement procedure is sometimes called a standard operating procedure, abbreviated SOP.

[ISO/IEC Guide 99:2007]

4.55
measurement repeatability
repeatability
measurement precision under a set of repeatability conditions of measurement

[ISO/IEC Guide 99:2007]

4.56
measurement reproducibility
reproducibility
measurement precision under reproducibility conditions of measurement

NOTE Relevant statistical terms are given in ISO 5725-1:1994 and ISO 5725-2:1994.

[ISO/IEC Guide 99:2007]

4.57
measurement result
result of measurement
set of **quantity values** being attributed to a **measurand** together with any other available relevant information

NOTE 1 A measurement result generally contains "relevant information" about the set of quantity values, such that some may be more representative of the measurand than others. This may be expressed in the form of a probability density function (PDF).

NOTE 2 A measurement result is generally expressed as a single **measured quantity value** and a **measurement uncertainty**. If the measurement uncertainty is considered to be negligible for some purpose, the measurement result may be expressed as a single measured quantity value. In many fields, this is the common way of expressing a measurement result.

NOTE 3 In the traditional literature and in the previous edition of the VIM, measurement result was defined as a value attributed to a measurand and explained to mean an **indication**, or an uncorrected result, or a corrected result, according to the context.

[ISO/IEC Guide 99:2007]

4.58
measurement standard
etalon
realization of the definition of a given **quantity**, with stated **quantity value** and associated **measurement uncertainty**, used as a reference

NOTE 1 A "realization of the definition of a given quantity" can be provided by a **measuring system**, a **material measure**, or a reference material.

NOTE 2 A measurement standard is frequently used as a reference in establishing **measured quantity values** and associated measurement uncertainties for other quantities of the same **kind**, thereby establishing **metrological traceability** through **calibration** of other measurement standards, **measuring instruments**, or measuring systems.

NOTE 3 The term "realization" is used here in the most general meaning. It denotes three procedures of "realization". The first one consists in the physical realization of the **measurement unit** from its definition and is realization *sensu stricto.* The second, termed "reproduction", consists not in realizing the **measurement unit** from its definition but in setting up a highly reproducible measurement standard based on a physical phenomenon, as it happens, e.g. in case of use of frequency-stabilized lasers to establish a measurement standard for the metre, of the Josephson effect for the volt or of the quantum Hall effect for the ohm. The third procedure consists in adopting a material measure as a measurement standard. It occurs in the case of the measurement standard of 1 kg.

NOTE 4 A standard measurement uncertainty associated with a measurement standard is always a component of the combined standard measurement uncertainty (see ISO/IEC Guide 98-3:2008, 2.3.4) in a measurement result obtained using the measurement standard. Frequently, this component is small compared with other components of the combined standard measurement uncertainty.

NOTE 5 Quantity value and measurement uncertainty must be determined at the time when the measurement standard is used.

NOTE 6 Several quantities of the same kind or of different kinds may be realized in one device which is commonly also called a measurement standard.

NOTE 7 The word "embodiment" is sometimes used in the English language instead of "realization".

NOTE 8 In science and technology, the English word "standard" is used with at least two different meanings: as a specification, technical recommendation, or similar normative document (in French "norme") and as a measurement standard (in French "étalon"). This Vocabulary is concerned solely with the second meaning.

NOTE 9 The term "measurement standard" is sometimes used to denote other metrological tools, e.g. 'software measurement standard' (see ISO 5436-2).

[ISO/IEC Guide 99:2007]

4.59
measurement trueness
trueness of measurement
trueness
closeness of agreement between the average of an infinite number of replicate **measured quantity values** and a **reference quantity value**

NOTE 1 Measurement trueness is not a **quantity** and thus cannot be expressed numerically, but measures for closeness of agreement are given in ISO 5725.

NOTE 2 Measurement trueness is inversely related to **systematic measurement error**, but is not related to **random measurement error**.

NOTE 3 **Measurement accuracy** should not be used for 'measurement trueness' and vice versa.

[ISO/IEC Guide 99:2007]

4.60
measurement uncertainty
uncertainty of measurement
uncertainty
non-negative parameter characterizing the dispersion of the **quantity values** being attributed to a **measurand**, based on the information used

NOTE 1 Measurement uncertainty includes components arising from systematic effects, such as components associated with **corrections** and the assigned quantity values of **measurement standards**, as well as the

definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated

NOTE 2 The parameter may be, for example, a standard deviation called **standard measurement uncertainty** (or a specified multiple of it), or the half-width of an interval, having a stated **coverage probability**.

NOTE 3 Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by **Type A evaluation of measurement uncertainty** from the statistical distribution of the quantity values from series of **measurements** and can be characterized by standard deviations. The other components, which may be evaluated by **Type B evaluation of measurement uncertainty**, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

NOTE 4 In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quality value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

[ISO/IEC Guide 99:2007]

4.61
measurement unit
unit of measurement
unit

real scalar **quantity**, defined and adopted by convention, with which any other quantity of the same **kind** can be compared to express the ratio of the two quantities as a number

NOTE 1 Measurement units are designated by conventionally assigned names and symbols.

NOTE 2 Measurement units of quantities of the same **quantity dimension** may be designated by the same name and symbol even when the quantities are not of the same kind. For example, joule per kelvin and J/K are respectively the name and symbol of both a measurement unit of heat capacity and a measurement unit of entropy, which are generally not considered to be quantities of the same kind. However, in some cases special measurement unit names are restricted to be used with quantities of a specific kind only. For example, the measurement unit 'second to the power minus one' (1/s) is called hertz (Hz) when used for frequencies and becquerel (Bq) when used for activities of radionuclides.

NOTE 3 Measurement units of **quantities of dimension one** are numbers. In some cases these measurement units are given special names, e.g. radian, steradian, and decibel, or are expressed by quotients such as millimole per mole equal to 10^{-3} and microgram per kilogram equal to 10^{-9}.

NOTE 4 For a given quantity, the short term "unit" is often combined with the quantity name, such as "mass unit" or "unit of mass".

[ISO/IEC Guide 99:2007]

4.62
measuring instrument

device used for making **measurements**, alone or in conjunction with one or more supplementary devices

NOTE 1 A measuring instrument that can be used alone is a **measuring system**.

NOTE 2 A measuring instrument may be an **indicating measuring instrument** or a **material measure**.

[ISO/IEC Guide 99:2007]

4.63
measuring system
set of one or more **measuring instruments** and often other devices, including any reagent and supply, assembled and adapted to give information used to generate **measured quantity values** within specified intervals for **quantities** of specified **kinds**

NOTE A measuring system may consist of only one measuring instrument.

[ISO/IEC Guide 99:2007]

4.64
metadata
data about data

[ISO 19115:2003]

4.66
metric traceability
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

[derived from VIM, ISO 19101-2:2008]

4.67
metrological compatibility of measurement results
metrological compatibility
property of a set of **measurement results** for a specified **measurand**, such that the absolute value of the difference of any pair of **measured quantity values** from two different measurement results is smaller than some chosen multiple of the **standard measurement uncertainty** of that difference

NOTE 1 Metrological compatibility of measurement results replaces the traditional concept of 'staying within the error', as it represents the criterion for deciding whether two measurement results refer to the same measurand or not. If in a set of **measurements** of a measurand, thought to be constant, a measurement result is not compatible with the others, either the measurement was not correct (e.g. its **measurement uncertainty** was assessed as being too small) or the measured **quantity** changed between measurements.

NOTE 2 Correlation between the measurements influences metrological compatibility of measurement results. If the measurements are completely uncorrelated, the standard measurement uncertainty of their difference is equal to the root mean square sum of their standard measurement uncertainties, while it is lower for positive covariance or higher for negative covariance.

[ISO/IEC Guide 99:2007]

4.68
metrological traceability
property of a **measurement result** whereby the result can be related to a reference through a documented unbroken chain of **calibrations**, each contributing to the **measurement uncertainty**

NOTE 1 For this definition, a 'reference' can be a definition of a **measurement unit** through its practical realization, or a **measurement procedure** including the measurement unit for a non-**ordinal quantity**, or a **measurement standard**.

NOTE 2 Metrological traceability requires an established **calibration hierarchy**.

NOTE 3 Specification of the reference must include the time at which this reference was used in establishing the calibration hierarchy, along with any other relevant metrological information about the reference, such as when the first calibration in the calibration hierarchy was performed.

NOTE 4 For **measurements** with more than one input **quantity** in the **measurement model**, each of the input **quantity values** should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input quantity value should be commensurate with its relative contribution to the **measurement result**.

NOTE 5 Metrological traceability of a measurement result does not ensure that the measurement uncertainty is adequate for a given purpose or that there is an absence of mistakes.

NOTE 6 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards.

NOTE 7 The ILAC considers the elements for confirming metrological traceability to be an unbroken **metrological traceability chain** to an **international measurement standard** or a **national measurement standard**, a documented measurement uncertainty, a documented measurement procedure, accredited technical competence, metrological traceability to the SI, and calibration intervals (see ILAC P-10:2002).

NOTE 8 The abbreviated term "traceability" is sometimes used to mean 'metrological traceability' as well as other concepts, such as 'sample traceability' or 'document traceability' or 'instrument traceability' or 'material traceability', where the history ("trace") of an item is meant. Therefore, the full term of "metrological traceability" is preferred if there is any risk of confusion.

[ISO/IEC Guide 99:2007]

4.69
metrological traceability chain
traceability chain
sequence of **measurement standards** and **calibrations** that is used to relate a **measurement result** to a reference

NOTE 1 A metrological traceability chain is defined through a **calibration hierarchy**.

NOTE 2 A metrological traceability chain is used to establish **metrological traceability** of a measurement result.

NOTE 3 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the **quantity value** and **measurement uncertainty** attributed to one of the measurement standards.

[ISO/IEC Guide 99:2007]

4.70
national measurement standard
national standard
measurement standard recognized by national authority to serve in a state or economy as the basis for assigning **quantity values** to other **measurement standards** for the **kind of quantity** concerned

[ISO/IEC Guide 99:2007]

4.70a
noise
a) unwanted signals which may impair fidelity and which occur for periods exceeding 0,2 s

[ISO 6551:1982]
b) unwanted signal which can corrupt the measurement

[ISO 12718:2008]

4.71
nominal property
property of a phenomenon, body, or substance, where the property has no magnitude

NOTE 1 A nominal property has a value, which can be expressed in words, by alphanumerical codes, or by other means.

NOTE 2 'Nominal property value' is not to be confused with **nominal quantity value**.

[ISO/IEC Guide 99:2007]

4.71a
non-linearity
peak deviation of a line expressing the actual relationship between the output signal and the profile depth, and a least-squares, best-fit straight line through the relationship

NOTE Non-linearity is expressed as a percentage of the measuring range

[ISO 13473-2:2002]

4.72
numerical quantity value
numerical value of a quantity
numerical value
number in the expression of a **quantity value**, other than any number serving as the reference

NOTE 1 For **quantities of dimension one**, the reference is a **measurement unit** which is a number and this is not considered as a part of the numerical quantity value.

NOTE 2 For **quantities** that have a measurement unit (i.e. those other than ordinal quantities), the numerical value {*Q*} of a quantity *Q* is frequently denoted {*Q*} = *Q*/[*Q*], where [*Q*] denotes the measurement unit.

[ISO/IEC Guide 99:2007]

4.73
ordinal quantity
quantity, defined by a conventional **measurement procedure**, for which a total ordering relation can be established, according to magnitude, with other quantities of the same **kind**, but for which no algebraic operations among those quantities exist

NOTE 1 Ordinal quantities can enter into empirical relations only and have neither **measurement units** nor **quantity dimensions**. Differences and ratios of ordinal quantities have no physical meaning.

NOTE 2 Ordinal quantities are arranged according to **ordinal quantity-value scales**.

[ISO/IEC Guide 99:2007]

4.74
ordinal quantity-value scale
scale ordinal value scale
quantity-value scale for ordinal quantities

NOTE An ordinal quantity-value scale may be established by **measurements** according to a **measurement procedure**.

[ISO/IEC Guide 99:2007]

4.75
output quantity in a measurement model
output quantity
quantity, the measured value of which is calculated using the values of input quantities in a measurement model

[ISO/IEC Guide 99:2007]

4.76
point-spread function (PSF)
characteristic response of an imaging system to a high-contrast point target

NOTE For an ultrasound system, an individual ultrasound PSF cannot be used as the overall system impulse response, due to changes in the PSF with depth.

[IEC 88528-11:2004]

4.77
positional accuracy
closeness of **coordinate** value to the true or accepted value in a specified reference system

NOTE The phrase 'absolute accuracy' is sometimes used for this concept to distinguish it from relative positional accuracy. Where the true coordinate value may not be perfectly known, accuracy is normally tested by comparison to available values that can best be accepted as true.

[ISO 19116]

4.77a
periodic time
duration of one cycle

[ISO 31-2, ISO 19108]

4.79
quality assurance
part of quality management focussed on providing confidence that quality requirements will be fulfilled

[ISO 9000:2005]

4.80
quality control
part of quality management focussed on fulfilling quality requirements

[ISO 9000:2005]

4.83
quantity
property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

NOTE 1 The generic concept 'quantity' can be divided into several levels of specific concepts, as shown in the following table. The left hand side of the table shows specific concepts under 'quantity'. These are generic concepts for the individual quantities in the right hand column.

length, l	radius, r	radius of circle A, r_A or r(A)
	wavelength, λ	wavelength of the sodium D radiation, λ_D or λ(D; Na)
energy, E	kinetic energy, T	kinetic energy of particle i in a given system, T_i
	heat, Q	heat of vaporization of sample i of water, Q_i
electric charge, Q		electric charge of the proton, e
electric resistance, R		electric resistance of resistor i in a given circuit, R_i
amount-of-substance concentration of entity B, c_B		amount-of-substance concentration of ethanol in wine sample i, $c_i(C_2H_5OH)$
number concentration of entity B, c_B		number concentration of erythrocytes in blood sample i, C(Erys; B_i)
Rockwell C hardness (150 kg load), HRC(150 kg)		Rockwell C hardness of steel sample i, HRC_i(150 kg)

NOTE 2 A reference can be a **measurement unit**, a **measurement procedure**, a **reference material**, or a combination of such.

NOTE 3 Symbols for quantities are given in the ISO 80000 and IEC 80000 series *Quantities and units.* The symbols for quantities are written in italics. A given symbol can indicate different quantities.

NOTE 4 The preferred IUPAC-IFCC format for designations of quantities in laboratory medicine is "System-Component; quantity".

NOTE 5 A quantity as defined here is a scalar. However, a vector or a tensor, the components of which are quantities, is also considered to be a quantity.

NOTE 6 The concept 'quantity' may be generically divided into, e.g. 'physical quantity', 'chemical quantity', and 'biological quantity', or **'base quantity'** and **'derived quantity'**.

[ISO/IEC Guide 99:2007]
(Compare with "measurable quantity".)

4.84
quantity dimension
dimension of a quantity
dimension
expression of the dependence of a quantity on the base quantities of a system of quantities as a product of powers of factors corresponding to the base quantities, omitting any numerical factor

NOTE 1 A power of a factor is the factor raised to an exponent. Each factor is the dimension of a base quantity.

NOTE 2 The conventional symbolic representation of the dimension of a base quantity is a single upper case letter in roman (upright) sans-serif type. The conventional symbolic representation of the dimension of a **derived quantity** is the product of powers of the dimensions of the base quantities according to the definition of the derived quantity. The dimension of a quantity *Q* is denoted by dim *Q*.

NOTE 3 In deriving the dimension of a quantity, no account is taken of its scalar, vector, or tensor character.

NOTE 4 In a given system of quantities.
- quantities of the same kind have the same quantity dimension,
- quantities of different quantity dimensions are always of different kinds, and
- quantities having the same quantity dimension are not necessarily of the same kind.

NOTE 5 Symbols representing the dimensions of the base quantities in the ISQ are:

Base quantity	Symbol for dimension
length	L
mass	M
time	T
electric current	I
thermodynamic temperature	Θ
amount of substance	N
luminous intensity	J

Thus, the dimension of a quantity *Q* is denoted by $\dim Q = L^{\alpha} M^{\beta} T^{\gamma} I^{\delta} \theta^{\varepsilon} N^{\zeta} J^{\eta}$
where the exponents, named dimensional exponents, are positive, negative, or zero.

[ISO/IEC Guide 99:2007]

4.85
quantity of dimension one
dimensionless quantity
quantity for which all the exponents of the factors corresponding to the **base quantities** in its **quantity dimension** are zero

NOTE 1 The term "dimensionless quantity" is commonly used and is kept here for historical reasons. It stems from the fact that all exponents are zero in the symbolic representation of the dimension for such quantities. The term "quantity of dimension one" reflects the convention in which the symbolic representation of the dimension for such quantities is the symbol 1 (see ISO 31-0:1992, 2.2.6).

NOTE 2 The **measurement units** and **values** of quantities of dimension one are numbers, but such quantities convey more information than a number.

NOTE 3 Some quantities of dimension one are defined as the ratios of two quantities of the same **kind**.

NOTE 4 Numbers of entities are quantities of dimension one.

[ISO/IEC Guide 99:2007]

4.86
quantity value
1. Definition according to ISO/TS 19115-2 with reference to ISO/TS 19103:
element of a type **domain**

NOTE 1 A value may consider a possible state of an object within a class or type (domain).

NOTE 2 A data value is an instance of a data type, a value without identity.

[ISO/TS 19103]

2. Definition according to ISO/IEC Guide 99:2007:
value of a quantity
value
number and reference together expressing magnitude of a **quantity**

NOTE 1 According to the type of reference, a quantity value is either
a product of a number and a **measurement unit**; the measurement unit one is generally not indicated for **quantities of dimension one**, or
a number and a reference to a **measurement procedure**, or
a number and a **reference material**.

NOTE 2 The number can be complex.

NOTE 3 A quantity value can be presented in more than one way.

NOTE 4 In the case of vector or tensor quantities, each component has a quantity value.

[ISO/IEC Guide 99:2007]

4.87
quantity value scale
measurement scale
ordered set of **quantity values** of **quantities** of a given **kind of quantity** used in ranking, according to magnitude, quantities of that kind

[ISO/IEC Guide 99:2007]

4.87a
quantum efficiency
ratio of the energy of a single laser photon to the energy of a single pumping photon which causes the inversion in an optically pumped laser

[ISO 11145:2006]

4.88
random measurement error
random error of measurement
random error
component of **measurement error** that in replicate **measurements** varies in an unpredictable manner

NOTE 1 A **reference quantity value** for a random measurement error is the average that would ensue from an infinite number of replicate measurements of the same **measurand**.

NOTE 2 Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance.

NOTE 3 Random measurement error equals measurement error minus **systematic measurement error**.

[ISO/IEC Guide 99:2007]

4.89
reference material
RM
material, sufficiently homogeneous and stable with reference to specified properties, which has been established to be fit for its intended use in **measurement** or in examination of **nominal properties**

NOTE 1 Examination of a nominal property provides a nominal property value and associated uncertainty. This uncertainty is not a **measurement uncertainty**.

NOTE 2 Reference materials with or without assigned quantity values can be used for **measurement precision** control whereas only reference materials with assigned quantity values can be used for **calibration** or **measurement trueness** control.

NOTE 3 'Reference material' comprises materials embodying **quantities** as well as **nominal properties**.

NOTE 4 A reference material is sometimes incorporated into a specially fabricated device.

NOTE 5 Some reference materials have assigned quantity values that are metrologically traceable to a **measurement unit** outside a **system of units**. Such materials include vaccines to which International Units (IU) have been assigned by the World Health Organization.

NOTE 6 In a given **measurement**, a given reference material can only be used for either calibration or quality assurance.

NOTE 7 The specifications of a reference material should include its material traceability, indicating its origin and processing (Accred. Qual. Assur.:2006).

NOTE 8 ISO/REMCO has an analogous definition but uses the term "measurement process" to mean 'examination' (ISO 15189:2007, 3.4), which covers both measurement of a quantity and examination of a nominal property.

[ISO/IEC Guide 99:2007]

4.90
reference measurement procedure
measurement procedure accepted as providing **measurement results** fit for their intended use in assessing **measurement trueness** of **measured quantity values** obtained from other measurement procedures for **quantities** of the same **kind**, in **calibration**, or in characterizing **reference materials**

[ISO/IEC Guide 99:2007]

4.91
reference quantity value
reference value
quantity value used as a basis for comparison with values of **quantities** of the same **kind**

NOTE 1 A reference quantity value can be a **true quantity value** of a **measurand**, in which case it is unknown, or a **conventional quantity value**, in which case it is known.

NOTE 2 A reference quantity value with associated **measurement uncertainty** is usually provided with reference to

a material, e.g. a **certified reference material**,
a device, e.g. a stabilized laser,
a **reference measurement procedure**.
a comparison of **measurement standards**.

[ISO/IEC Guide 99:2007]

4.92
reference standard
measurement standard designated for the calibration of other measurement standards for quantities of a given kind in a given organization or at a given location

Comment [k22]: Comment US/GS22: What does NPL use for this term?

[proposed by CEOS)
(CEOS, QA4EO-CEOS-GEN-DQK-002 and others)

4.93
repeatability condition of measurement
Repeatability condition
condition of **measurement**, out of a set of conditions that includes the same **measurement procedure**, same operators, same **measuring system**, same operating conditions and same location, and replicate measurements on the same or similar objects over a short period of time

NOTE 1 A condition of measurement is a repeatability condition only with respect to a specified set of repeatability conditions.

NOTE 2 In chemistry, the term 'intra-serial precision condition of measurement' is sometimes used to designate this concept.

[ISO/IEC Guide 99:2007]

4.93a
remote sensing
collection and interpretation of information about an object without being in physical contact with the object

[ISO 19101-2:2008]

4.94
reproducibility conditions of measurement
reproducibility condition
condition of **measurement**, out of a set of conditions that includes different locations, operators, **measuring systems**, and replicate measurements on the same or similar objects

NOTE 1 The different measuring systems may use different **measurement procedures**.

NOTE 2 A specification should give the conditions changed and unchanged, to the extent practical.

[ISO/IEC Guide 99:2007]

4.95
1. Definition according to ISO 19101-2:2008:
resolution
smallest difference between indications of a **sensor** that can be meaningfully distinguished

NOTE For imagery, resolution refers to radiometric, spectral, spatial and temporal resolutions.

[ISO/TS 19101-2:2008]

2. Definition according to ISO/IEC Guide 99:2007:
smallest change in a **quantity** being measured that causes a perceptible change in the corresponding **indication**

NOTE Resolution can depend on, for example, noise (internal or external) or friction. It may also depend on the value of a quantity being measured.

[ISO/IEC Guide 99:2007]

4.96
Ground Sample Distance
GSD
spacing of areas represented by each pixel in a digital photo of the ground from air or space.

NOTE GSD is a measure of one limitation to image resolution, that is, the limitation due to sampling distance on the ground that corresponds to the pixel distances in the image plane.

4.99
sensor ~~(of the remote sensing)~~
element of a measuring instrument or measuring chain that is directly affected by the **measurand**

[VIM, ISO 19101-2:2008]

4.99a
spatial resolution
actual ability of the sensor to resolve details across the image

4.101
spectral resolution
specific wavelength interval within the electromagnetic spectrum

EXAMPLE Band 1 of Landsat TM lies between 0.45 and 0.52 µm in the visible part of the spectrum.

[ISO 19115-2]

4.101a
spectral responsivity
Quotient of the detector output dY[lambda] by the monochromatic detector input dXe [e half index down]([lambda]) = Xe, [lambda] [e, [lambda] has index down}([lambda]) · d[lambda] in the wavelength interval d[lambda] as a function of the wavelength [lambda]; [see formula in the standard]

[IEC 60050-845]

4.101b
spectral sensitivity
light sensitivity as a function of wavelength

[IEC 60050-394:2007-04]

4.102
stability of a measuring instrument
stability
property of a **measuring instrument**, whereby its metrological properties remain constant in time

NOTE Stability may be quantified in several ways.

[ISO/IEC Guide 99:2007]
(other definition provided in CEOS, QA4EO-WGCV-IVO-CLP-001)

Comment [k23]: To the USGS:
"(of the remote sensing)" removed
Definition 93a remote sensing" added.
This might meet the comment AU3.

Comment [k24]: Comment AU3:
This definition doesn't make sense. Sensor in remote sensing usually refers to the instrument being used to capture the data, ie. a Landsat TM, SPOT, AVIRIS, etc.

Comment [k25]: Comment AU4:
I suggest replace with perhaps: Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. (http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter2/04_e.php)

Comment [k26]: Comment BE-11:
'specific wavelength interval within the spectrum' is not the definition of spectral resolution, but rather that of the spectral bandwidth. Spectral resolution is defined appropriately in NIST documents.

BE-Proposal:
Consider NISTIR 7203 definition 'The least difference in the radiation wavelengths of two monochromatic radiators of equal intensity that can be distinguished according to a given criterion.'

4.103
standard measurement uncertainty
standard uncertainty of measurement
standard uncertainty
measurement uncertainty expressed as a standard deviation

[ISO/IEC Guide 99:2007]

4.104
standardization
activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context

Note 1: In particular, the activity consists of the processes of formulating, issuing and implementing standards.
Note 2: Important benefits of standardization are improvement of the suitability of products, processes and services for their intended purposes, prevention of barriers to trade and facilitation of technological cooperation.

[ISO/IEC Guide 2:2004]

4.104a
stray light
light emitted by a lighting installation which falls outside the boundaries of the property for which the lighting installation is designed

[EN 12464-2:2007]

4.105
system of quantities
set of **quantities** together with a set of non-contradictory equations relating those quantities

NOTE Ordinal quantities, such as Rockwell C hardness, are usually not considered to be part of a system of quantities because they are related to other quantities through empirical relations only.

[ISO/IEC Guide 99:2007]

4.106
systematic measurement error
systematic error of measurement
systematic error
component of **measurement error** that in replicate **measurements** remains constant or varies in a predictable manner

NOTE 1 A reference quantity value for a systematic measurement error is a true quantity value, or a measured quantity value of a measurement standard of negligible measurement uncertainty, or a conventional quantity value.

NOTE 2 Systematic measurement error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement error.

NOTE 3 Systematic measurement error equals measurement error minus random measurement error.

[ISO/IEC Guide 99:2007]

4.107
target measurement uncertainty
target uncertainty
measurement uncertainty specified as an upper limit and decided on the basis of the intended use of **measurement results**

[ISO/IEC Guide 99:2007]

4.108
traceability
(CEOS, QA4EO-CEOS-GEN-DQK-001 and others provides a different definition for the slightly different term "metrological traceability".)
(Compare with ISO/IEC Guide 90:2007, term traceability chain)

4.109
true quantity value
true value of a quantity
true value
quantity value consistent with the definition of a **quantity**

NOTE 1 In the Error Approach to describing **measurement**, a true quantity value is considered unique and, in practice, unknowable. The Uncertainty Approach is to recognize that, owing to the inherently incomplete amount of detail in the definition of a quantity, there is not a single true quantity value but rather a set of true quantity values consistent with the definition. However, this set of values is, in principle and in practice, unknowable. Other approaches dispense altogether with the concept of true quantity value and rely on the concept of **metrological compatibility of measurement results** for assessing their validity.

NOTE 2 In the special case of a fundamental constant, the quantity is considered to have a single true quantity value.

NOTE 3 When the **definitional uncertainty** associated with the **measurand** is considered to be negligible compared to the other components of the **measurement uncertainty**, the measurand may be considered to have an "essentially unique" true quantity value. This is the approach taken by the GUM and associated documents, where the word "true" is considered to be redundant.

[ISO/IEC Guide 99:2007]

4.112
uncertainty
parameter, associated with the result of measurement, that characterizes the dispersion of values that could reasonably be attributed to the **measurand**

[ISO 19101-2:2008, ISO 19116:2004]

NOTE 1 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 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 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.

NOTE 4 When the quality of accuracy or precision of measured values, such as coordinates, is to be characterized quantitatively, the quality parameter is an estimate of the uncertainty of the measurement results. Because accuracy is a qualitative concept, one should not use it quantitatively, that is associate numbers with it; numbers should be associated with measures of uncertainty instead.

4.113
validation
process of assessing, by independent means, the quality of the data products derived from the system outputs

[ISO 19101-2:2008, CEOS WGCV]

4.113a
dataset validation
process of assessing the validity of parameters

NOTE With respect to the general definition of validation the “dataset validation” does only refer to a small set of parameters (attribute values) such as the result of a sensor calibration.

Comment [k27]: To the USGS: When reviewing our discussion in Sioux Falls I felt like having a separately defined term for the specific meaning of validation in this TS. I took “dataset validation” as potential alternatives deemed too broad such as “information v.” or “parameter v.”

4.114
value domain
set of accepted **values**

EXAMPLE The range 3-28, all integers, any ASCII character, enumeration of all accepted values (green, blue, white).

[ISO/TS 19103]

4.115
verification
provision of objective evidence that a given item fulfils specified requirements

NOTE 1 When applicable, **measurement uncertainty** should be taken into consideration.

NOTE 2 The item may be, e.g. a process, measurement procedure, material, compound, or measuring system.

NOTE 3 The specified requirements may be, e.g. that a manufacturer's specifications are met.

NOTE 4 Verification in legal metrology, as defined in VIML, and in conformity assessment in general, pertains to the examination and marking and/or issuing of a verification certificate for a measuring system.

NOTE 5 Verification should not be confused with **calibration**. Not every verification is a **validation**.

NOTE 6 In chemistry, verification of the identity of the entity involved, or of activity, requires a description of the structure or properties of that entity or activity.

[ISO/IEC Guide 99:2007]

4.116
vicarious calibration
post-launch calibration of sensors that make use of natural or artificial sites on the surface of the Earth

[proposed by CCRS, Canada]
(Pascal Lecomte (ESA), Terms and Definitions, ppt-presentation (pdf), 2007)
(The definition was linguistically modified to meet the ISO rules.)

Comment [k28]: Comment JP7: http://calvalportal.ceos.org/cvp/c/document_library/get_file?uuid=96d0d8fe-3408-428c-b3fc-0619f5fbfa68&groupId=10136 by Prof.Teillet is also useful.

4.117
zero adjustment of a measuring system
zero adjustment
adjustment of a measuring system so that it provides a null indication corresponding to a zero **value** of a **quantity** to be measured

[ISO/IEC Guide 99:2007]

5 Symbols and abbreviated terms

The details are not yet checked for consistency and relevance.

Comment [k29]: Comment BE-12: AAIA, AAOT, AERONET, ICFA and many other abbreviations do not appear in the document.

Others like CEOS, ESA and WGCV appear only in red and will be probably removed in the final version.
BE-Proposal:
Consider removing abbreviations not found in the document.

Comment [k30]: Comment US/JBC-5: Several terms used with this document are not listed in the abbreviation list.
US/JBC Proposal:
Recommend including the following:
MTF – Modulation Transfer Function

Comment [k31]: Comment US/JBC-4: Numerous abbreviations in the existing version are not germane to this document.
US/JBC Proposal:
Recommend deleting items (see separate sheet)

Comment [k32]: Comment DPMqs-4: Do all acronyms need to be in this section (like CD & SD)?

~~AATSR~~	~~Advanced Along Track Scanning Radiometer~~
~~ACSG~~	~~Atmospheric chemistry subgroup~~
~~AFRL/VSBT~~	~~Air Force Research Lab, Space Vehicles Directorate~~
~~AOT~~	~~Aerosol optical thicknesses~~
~~ARM~~	~~Atmospheric Radiation Measurement~~
~~ARVI~~	~~Atmospheric Resistant Vegetation Index~~
~~ASAR~~	~~Active phased array SAR~~
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer (Japan; NASA, EOS)
~~ATM~~	~~WGCV's Atmospheric Composition Subgroup~~
~~ATSR~~	~~Along-Track Scanning Radiometer (ESA ERS)~~
~~AU~~	~~Astronomic Unit~~
~~AVIRIS~~	~~Airborne Visible/Infrared Imaging Spectrometer~~
~~BIAS~~	~~Basic Infra-red Absorption Spectroscopy~~
~~BOA~~	~~Bottom of the atmosphere~~
BRDF	Bi-directional Reflectance Distribution Function
~~BSST~~	~~bulk sea surface temperature~~
CalVal	Calibration Validation, Calibration and Validation (two versions found!)
~~CE~~	~~Guideline relating to Communication and Education~~
CEOS	Committee on Earth Observation Satellites
CEOS WGCV	Committee on Earth Observation Satellites Working Group Calibration Validation
CIPM	Comité International des Poids et Mesures
CNES	Centre National d'Études Spatiales (France)
~~CZCS~~	~~Coastal Zone Color Scanner system~~
DDV	Dense Dark Vegetation

~~DOAS~~	~~Differential Optical Absorption Spectroscopy~~
~~DP~~	~~Guideline relating to Data Product Policy~~
~~DQ~~	~~Guideline relating to Data Product Quality~~
~~ECMWF~~	~~European Centre for Medium range Weather Forecasting~~
ENVISAT	Environmental Satellite
EO	Earth Observation
ERS	European Remote-Sensing Satellite (ESA)
ESA	European Space Agency
FOV	Field-of-View
~~GEN~~	~~Generic guideline~~
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
~~GLI~~	~~Global Imager (Japan, ADEOS)~~
GMES	Global Monitoring Earth System
~~GOME~~	~~Global Ozone Monitoring Experiment~~
~~GOMOS~~	~~Global Ozone Monitoring by Occultation of Stars~~
GPS	Global Positioning System
GS	Ground Segment
GUM	ISO Guide to the Expression of Uncertainty in Measurement
~~HRV~~	~~Haute Résolution Visible~~
IEEE	Institute of Electrical and Electronics Engineers
~~IOP~~	~~Inherent Optical Property~~
~~IOPA~~	~~IOP of the Aerosols~~
~~IPSL~~	~~Institut Pierre Simon Laplace~~
ISO	International Organisation for Standardisation
IVO	WGCV's Infrared, Visible & Optical Sensors Subgroup
~~IVOS~~	~~Infrared and Visible Optical Sensors subgroup~~
~~K~~	~~Key guideline~~
~~KI~~	~~Knowledge Information~~
~~MEGS~~	~~MERIS Ground Segment~~
~~MERIS~~	~~Medium Resolution Imaging Spectrometer (ESA Envisat)~~
~~MERMAID~~	~~MERis Mach up Insitu Data base~~
~~MOBY~~	~~Marine Optical Buoy~~
MODIS	Moderate-Resolution Imaging Spectroradiometer (NASA EOS)
~~MRA~~	~~Mutual Recognition Arrangement~~
~~MRSR~~	~~Marine Remote Sensing Reflectance~~
MTF	Modulation Transfer Function
MWS	WGCV's Microwave Sensors Subgroup
NIR	Near Infrared (spectral region)
NIST	National Institute for Standards and Technology
~~POLDER~~	~~Polarization and Directionality of the Earth's Reflectances (CNES,~~ ADEOS)
QA	Quality Assurance
QA4EO	Quality Assurance Framework for Earth Observation
~~QI~~	~~Quality Indicator~~
RTC	Radiative Transfer Code
SAA	Solar azimuth angle
~~SAM~~	~~Standard aerosol models~~
SAR	WGCV's Synthetic Aperture Radar Subgroup
~~SBA~~	~~Societal Benefit Areas~~
~~SeaWiFS~~	~~Sea-Viewing Wide Field-of-View Sensor (USA)~~
SZA	Solar zenith angle
TMS	WGCV's Terrain Mapping Subgroup
TOA	Top of the atmosphere

VAA	View azimuth angle
VIM	Vocabulary of International Metrology
VZA	View zenith angle
WGCV	Working Group on Calibration and Validation
WGEdu	CEOS Working Group on Education

Θ_s	solar angle
$E_s(\lambda)$	solar irradiance at top of the atmosphere
hc/λ	photon elementary energy
$T_g(\lambda,\mu_s)$	Gaseous transmittance of the downward path
$T_{atm}(\lambda,\mu)$	Scattering transmittance for the downward path, black ocean and no Fresnel reflection
$S_{atm}(\lambda)$	Spherical albedo
$\rho_w(\lambda)$	Lambertian surface reflectance (water body + foam)

Conventions

Some of the classes and attributes are defined in other standards of the ISO 19100 series. Those classes and attributes are identified by one of the following two-character codes.

MD = ISO 19115 "Metadata"
MI = ISO 19115-2 "Metadata – Part 2: Extension for imagery and gridded data"
SD = ISO/TS 19130 "Imagery data models for geopositioning"

6 Calibration

6.1 Semantics

The Technical Specification ISO/TS 19159 standardizes the calibration of remote sensing imagery sensors and the validation of the calibration information. This Technical Specification is split into more than one part, each of them addressing a specific sensor type. The ISO/TS 19159-1 “Calibration and validation of remote sensing imagery sensors and data – Part 1: Optical Sensors” addresses optical sensors i.e. airborne and space borne cameras. They include digital frame cameras that take a 2-dimensional image as a whole, line cameras which apply the pushbroom or whiskbroom principle as well as sensors that are capable of recording electromagnetic radiation of the infrared spectrum such as thermal, multispectral, and hyperspectral cameras.

The figure 1 depicts a high-level package diagram that shows all intended parts of the ISO/TS 19159 as of the time when the ISO/TS 19159-1 was developed.

Comment [k33]: Comment JP9: Concepts of calibration should be described. In case of optical sensors on board satellite platform, we need the section of both of pre- and post-launch calibration. Post-launch calibration should include onboard, vicarious, and corss-calibration.

Comment [k34]: Comment US/JBC-3: The breaking down of Calibration/Validation into only two areas - geometry and radiometry – is better expanded to four areas to better describe the areas needed characterization, calibration, and validation.
US/JBC Proposal:
Recommend changing architecture from two basic areas for each Cal & Val (Geometry & Radiometry) to four basic areas: Geometry, Radiometry, Spectral, and Spatial. Will involve subsequent rearranging fo some portions of geometry and significant portions of radiometry

Comment [k35]: Comment US/JBC-6: Although paragraph 4 clearly states that “validation” is used in this document to refer only to the validation of the applied calibration, it may help to enhance this with statements as to what validation does NOT mean in this document; i.e. validation of higher-order products, etc.
US/JBC Proposal:
Augment paragraph with appropriate sentence or two to emphasize how validation is and is not used within this document.

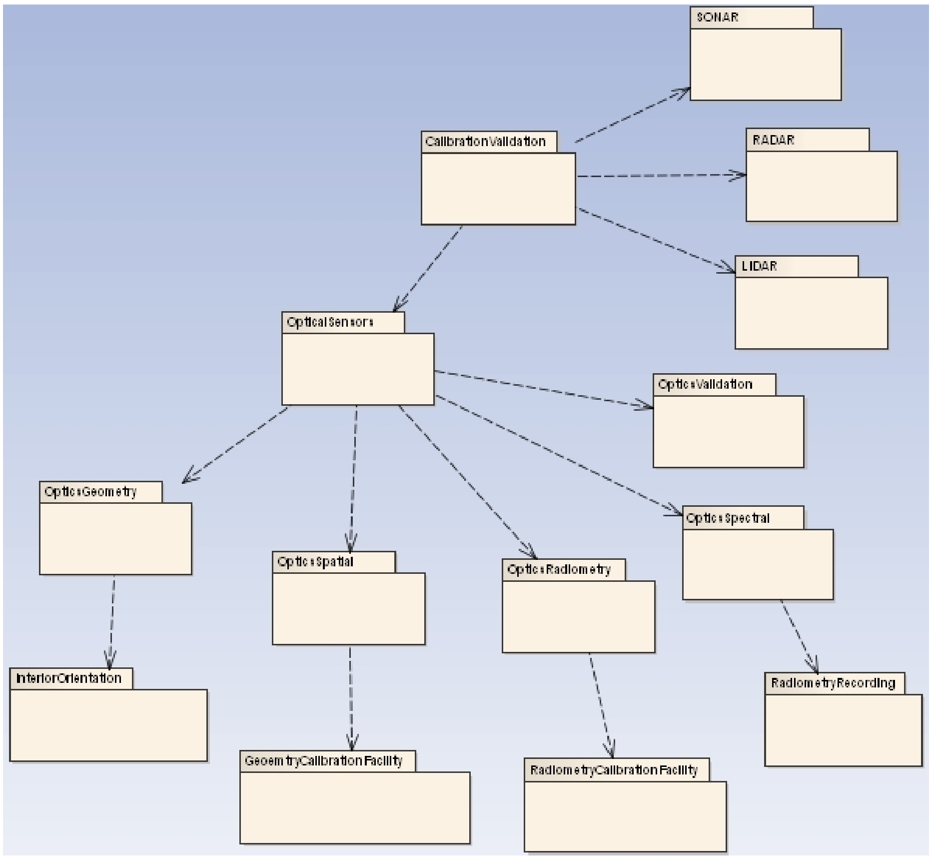


Figure 1: Package diagram of the package CA_CalibrationValidation

The figure 2 depicts the top-level class diagram of the ISO/TS 19159 standards. The specialization for CA_OpticalSensors is shown in figure 3.

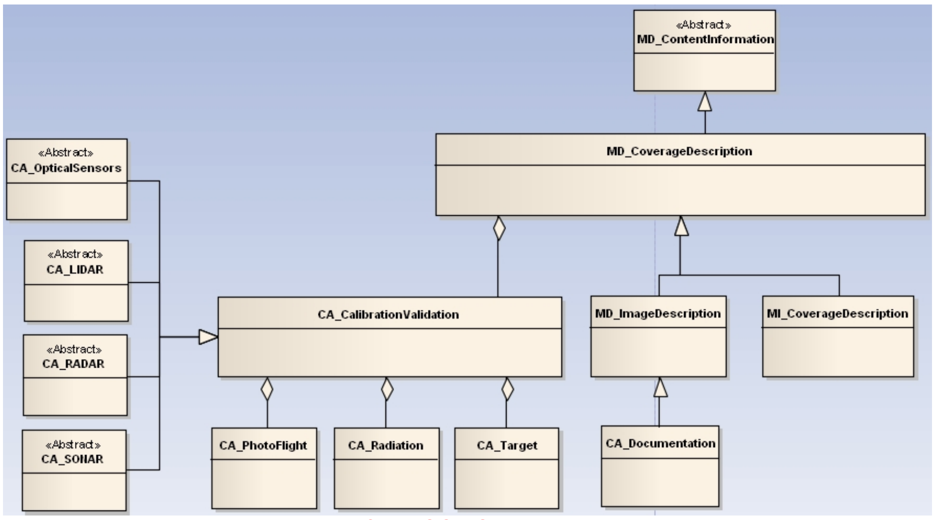
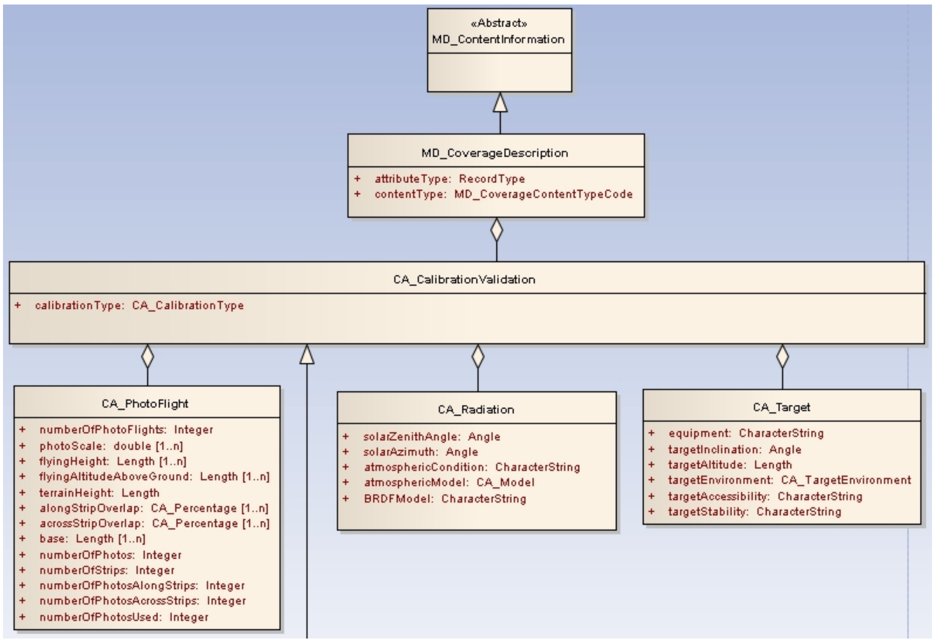


Figure 2: Top-level class diagram of the ISO/TS 19159 standards

The figure 3 depicts the top-level class diagram for the calibration of optical sensors (ISO/TS 19159, part 1). Further details about the geometry are shown in figure 4 and about radiometry in figure 13.



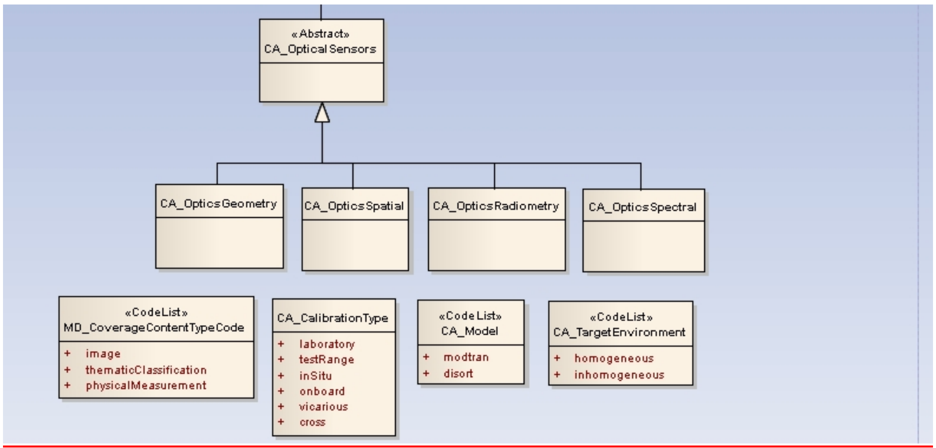


Figure 3 Top-level ~~class~~ class diagram of the package ~~CA_CalibrationValidation~~OpticalSensors.
The data type CA_Percentage is shown in figure 16.

The ten packages shown in figure 1 cover the whole field of calibration and validation of remote sensing imagery sensors and data. The package CalibrationValidation represents the top level with only a little additional information.

The package GeometryCalibration and its two dependent packages cover the aspects of geometric calibration. The first of the dependent packages is GeometryCalibrationFacility which contains all data related to calibration laboratories and their equipment and test fields. Those test fields may be installed as a part of a laboratory or outside. The package InteriorOrientation covers all parameters that describe the geometry of a sensor. A sensor may be optical like cameras designed to record visible and infrared light, LIDAR (light detection and ranging), and microwave. This International Technical Specification provides a broad approach to distortion models.

The package RadiometryCalibration and its two dependent packages contain the aspects of radiometric calibration. The first package of those is RadiometryCalibrationFacility which contains all data related to laboratory equipment and test field installations. The second dependent package named RadiometryRecording covers all sensor-related parameters which characterize the radiometric performance of the sensor and which are essential for a controlled transfer from recorded Digital Numbers (DN) to at-aperture radiances and if the atmosphere is sufficiently known to object radiances.

The package GeometryValidation covers the parameters for ~~validating~~ performing a dataset validation of a geometric sensor calibration while the package RadiometryValidation contains the parameters for ~~validating~~ performing a dataset validaton of a radiometric sensor calibration.

The package Documentation contains all classes for the documentation of the calibration results. This package may be used as a starting point for a certification procedure which is however out of scope of this International Technical Specification.

6.1.1 CA_CalibrationValidation

6.1.2 CA_PhotoFlight

The class CA_PhotoFlight has all information about the photo flight that was made to derive the calibration results from.

The attributes consist of

- photoScale,
- height information such as flyingHeight, flyingAltitudeAboveGround, and terrainHeight,
- the block geometry like alongStripOverlap and sideStripOverlap
- the base, and
- quantites of photos and strips, like numberOfPhotos, numberOfStrips, numberOfPhotosInStrip, and numberOfPhotosUsed.

6.1.3 CA_Radiation

The class CA_Radiation has all information that is necessary to describe the radiative environment during the calibration process.

The attribute solarZenithAngle defines the angle from the zenith towards the sun.

The attribute solarAzimuth defines the horizontal angle to the sun counted counterclockwise from North.

The attributes atmosphericCondition and equipment allow for a general description of the two aspects.

The attribute atmosphericModel states the atmospheric model that is applied in the calibration process.

The attribute BRDFModel states the BRDF (Bidirectional Reflectance Distribution Function) model that is applied in the calibration process.

6.1.4 CA_Target

The class CA_Target has all information necessary to describe the targets used during the calibration process.

The attribute equipment is a character string that allows describing additional equipment, for example measurement instruments.

The attribute targetInclination defines the inclination (slope) of the ground target.

The attribute targetAltitude defines the ground elevation of the target.

The attribute targetEnvironment characterizes the environment of target, namely homogeneous or inhomogeneous.

The attribute targetAccessibility describes the accessibility of the target primarily regarding road condition and eventual seasonal changes.

The attribute targetStability describes the mechanical stability of the target depending on weather conditions like humidity, heat, and wind.

6.1.5 CA_CalibrationType

The class CA_CalibrationType is a code list that specifies six types of calibration: laboratory, testRange, inSitu, onboard, vicarious, and cross. This code list is a data type of the class CA_CalibrationValidation.

6.1.6 CA_Model

The class CA_Model is a code list that has the codes modtran and disort. Both are atmospheric correction models.

Comment [k36]: Comment FR46:
For a given codelist value, it should probably be noticed that the inputs must be the same (same solar irradiance table)
FR-Proposal:
Consider adding some additional guidance.
Action:
Extend codelist and provide additional guidance: To be done by the project team.

Comment [wk37]: Eventually expand this list.

6.1.7 CA_TargetEnvironemnt

The class CA_Model is a code list that has the codes homogeneous and inhomogeneous.

6.2 Package: OpticalSensors

The package OpticalSensors addresses all sensors that record the sensed data as an image which is projected at a detector where it is recorded. This package includes aerial and space borne cameras, multispectral and thermal cameras, as well as hyperspectral sensors.

6.3 Package: OpticsGeometry

The figure 4 depicts the top-level class diagram for the package OpticsGeometry. Further details about the class interior orientation are shown in figures 5 and 6, about the calibration facility in figures 9 and 10, and about the class MI_Instrument in figure 14.

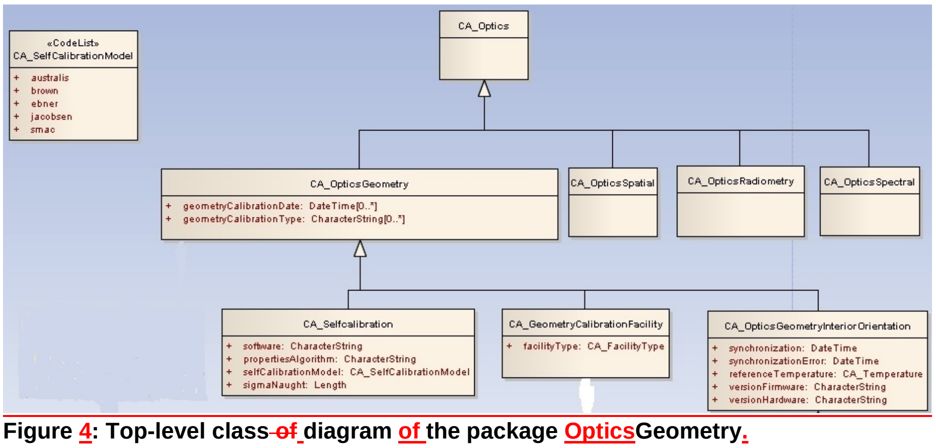


Figure 4: Top-level class ~~of~~ diagram of the package OpticsGeometry.

The data type CA_Temperature is shown in figure 6. The data type CA_FacilityType is shown in figure 9.

6.1.16.3.1 Semantics

The package OpticsGeometryCalibration contains all components that are related to the geometric calibration of remote sensing imagery sensors. It splits into the specialized packages GeometryCalibrationFacility and InteriorOrientation.

6.1.26.3.2 CA_OpticsGeometry

The class CA_Geometry contains all information that is valid for the entire geometric calibration.

The attribute geometryCalibrationDate defines the time when the calibration was performed.

The attribute geometryCalibrationType characterizes the type of the calibration.

6.3.3 CA_Selfcalibration

The class CA_Selfcalibration has all information related to the triangulation software that was applied to compute the calibration result. The method of deriving geometric calibration parameters of sensor systems based on the triangulation of an image block is called self-calibration.

The attribute software defines the applied software product.

The attribute propertiesAlgorithm defines the specific properties of the adjustment algorithm apart from the standard least-square-model.

The attribute selfCalibrationModel defines the applied model.

The attribute sigmaNaught characterized the block's accuracy.

6.3.4 CA_SelfCalibrationModel

The class CA_SelfCalibrationModel is a code list with the codes australis, brown, ebner, jacobsen, and smac.

The attribute australis refers to an approach named Australis and published by Fraser [1]. The attribute brown refers to the parameter set published by Brown [2]. The attribute ebner refers to the parameter set published by Ebner [3]. The attribute jacobsen refers to a parameter set published by Jacobsen [4]. The attribute smac (SMAC) is an abbreviation of "Simultaneous Multiframe Analytical Calibration". SMAC is a procedure for compensation of aerial camera lens distortion applied by the United States Geological Survey [5].

6.26.4 Package: InteriorOrientation

The figure 5 provides an overview over the classes related to the interior orientation. Further details about the interior orientation are shown in figure 6 and about the optics in figure 7.

Comment [k38]: Comment FR37:
Agreement with the comment from Wolfgang.
The definition need some clarification / expansion
FR-Proposal:
Consider to clarify the definition
Action:
To be clarified by the USGS and the project team.

Comment [k39]: Comment US/DPMqs-5:
Should least-square-model be least-squares-model?

Comment [wk40]: Verify the references to Fraser and Jacobsen.

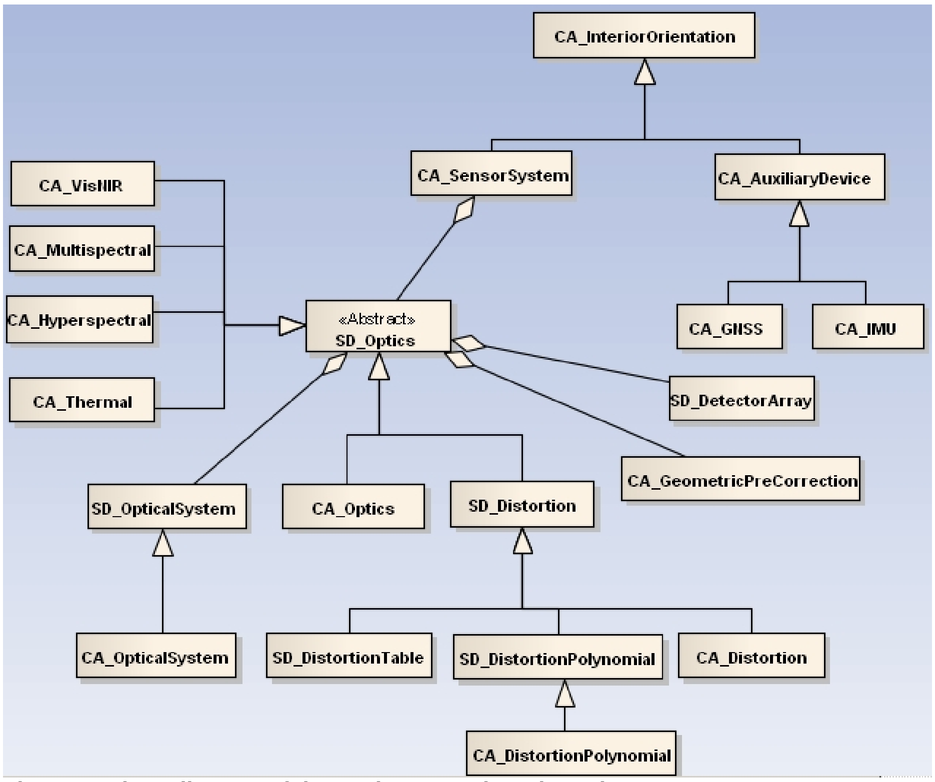


Figure 5: Class diagram of the package InteriorOrientation

~~6.2.1~~6.4.1 Semantics

The package InteriorOrientation defines the details of the geometry of the sensor system relevant for a geometric calibration of this system. The package has two parts, the sensor system and auxiliary devices, which are the Global Navigation Satellite System (GNSS) and Inertial Measurement Unit (IMU). The part sensor system splits into the subparts optics which stands for optical cameras, LIDAR (Light Detection and Ranging), and Microwave, which refers to imaging radar systems.

The definition of metadata for distortion is partly done in the ISO/TS 19130 "Imagery sensor models for geopositioning" and partly in this Technical Specification. The ISO/TS 19159 provides a full reference to the definitions made in the ISO/TS 19130.

The figure 6 provides the details of the classes related to the interior orientation.

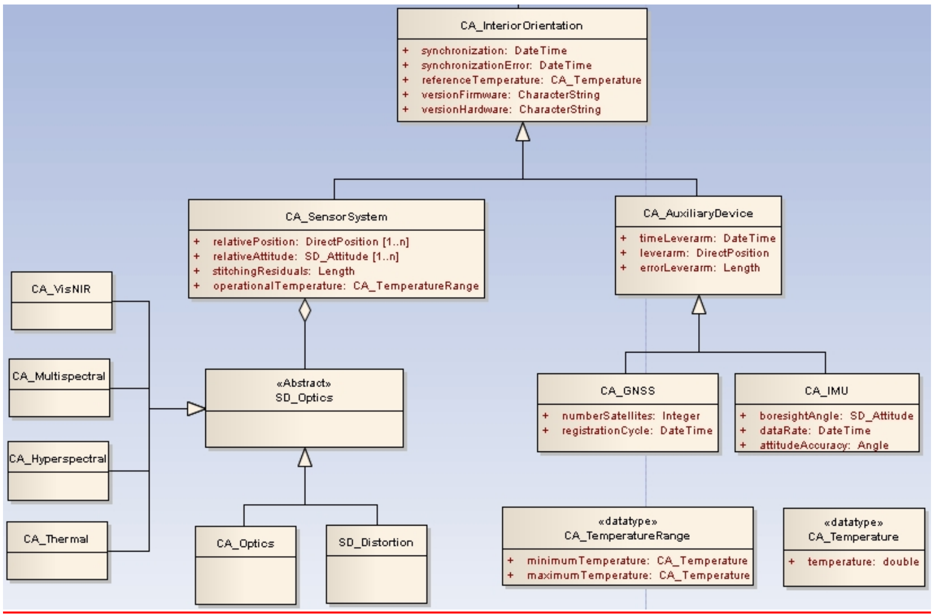


Figure 6: Top-levelDetails of the classes related to CA_ diagram of the package InteriorOrientation

6.2.26.4.2 CA_InteriorOrientation

The class CA_InteriorOrientation has all information that is valid for the sensor systems and the auxiliary devices alike.

The attribute synchronization defines the time between two pulses for the synchronization of the work of the attached components.

The attribute synchronizationError defines the error of the attribute synchronization.

The attribute referenceTemperature defines the temperature for which the calibration is validperformed.

The attributes versionFirmware and versionHardware are reserved for notes about the versions.

6.2.36.4.3 CA_SensorSystem

The class CA_SensorSystem is the superclass for the classes SD_Optics, CA_LIDAR, and SD_Microwave. Those three classes cover those types of remote sensing sensors that are addressed in this Technical Specification: Cameras (optics) for visible light and infrared light, LIDAR, and RADAR (microwave).defines the details of a multihead sensors system.

The attribute relativePosition holds the position of the origin of the coordinate system of a camera head in relation to the coordinate system of the sensor system.

The attribute relativeAttitude holds the rotation of the coordinate system of a camera head in relation to the coordinate system of the sensor system.

The attribute stitchingResiduals holds the geometric error remaining after stitching the multi camera-head images to one large image.

The attribute operationalTemperature hold the temperature range for which the calibration is valid.

The figure 7 provides the details related to the class SD_Optics which is defined in the ISO/TS 19130:2010.

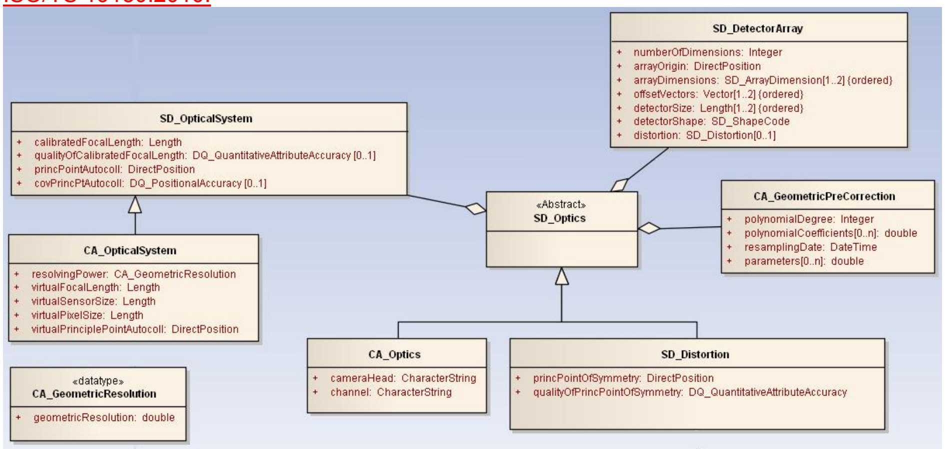


Figure 7: Class diagram of class SD_Optics. The data types SD_ArrayDimension, SD_ShapeCode, and SD_Distortion are defined in figure 8.

~~6.2.4~~6.4.4 SD_Optics

The class SD_Optics is defined in the ISO/TS 19130:2010 "Imagery sensor models for geopositioning" and functions as the superclass of four other classes that provide details about the cameras for visible and infrared light, multispectral sensors, hyperspectral sensors, and thermal cameras.

~~6.2.5~~6.4.5 CA_VisNIR

The class CA_VisNIR has all information relevant for the geometric calibration of an optical camera.

~~6.2.6~~6.4.6 CA_Multispectral

The class CA_Multispectral has all information relevant for the geometric calibration of a multispectral sensor.

~~6.2.7~~6.4.7 CA_Hyperspectral

The class CA_Hyperspectral has all information relevant for the geometric calibration of a hyperspectral sensor.

6.2.86.4.8 CA_Thermal

The class CA_Thermal has all information relevant for the geometric calibration of a thermal camera.

The figure 8 provides the details related to the class SD_Distortion which is defined in the ISO/TS 19130:2010.

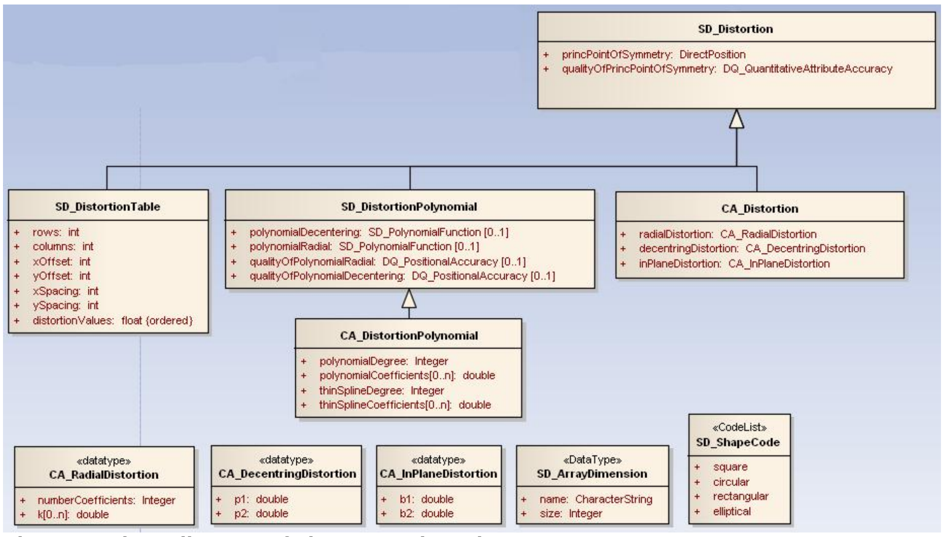


Figure 8: Class diagram of class SD_Distortion

6.2.96.4.9 SD_Distortion

The class SD_Distortion defined in the ISO/TS 19130:2010 is the superclass of the classes SD_DistortionTable, SD_DistortionPolynomial, and CA_Distortion, and has information about the principle point of symmetry (attribute princPointOfSymmetry) and the positional quality (attribute qualityOfPrincPointOfSymmetry).

6.2.106.4.10 SD_DistortionTable

The class SD_DistortionTable provides distortion information in a tabular form and has been defined in the ISO/TS 19130.

The attributes rows and columns define the rows and columns of the distortion table.

The attributes xOffset and yOffset define the image column number and row number corresponding to the first cell in the table.

The attributes xSpacing and ySpacing define the number of columns and the number of rows in the image corresponding to an interval of one table column respective of one of the table rows.

The attribute distortionValues is an array of values describing image distortion.

~~6.2.11~~6.4.11 SD_DistortionPolynomial

The class SD_DistortionPolynomial defines the distortion described using a polynomial.

The attribute polynomialDecentring defines a polynomial that describes decentring distortion.

The attribute polynomialRadial defines a polynomial that describes radially symmetrical distortion.

The attribute qualityOfPolynomialRadial defines the covariance of the polynomial coefficients for radial distortion.

The attribute qualityOfPolynomialDecentring defines the covariance of the polynomial coefficients for decentring distortion.

~~6.2.12~~6.4.12 CA_DistortionPolynomial

The class CA_DistortionPolynomial has all information about the polynomial distortion model that is not defined in the class SD_DistortionPolynomial of the ISO/TS 19130.

The attribute polynomialDegree defines the polynomial degree (u) and the attribute polynomialCoefficients[0..n] defines the coefficients of this polynomial.

The relation between u and n is
n = (u+1)(u+2), e.g. if u=2 then n=12

The attribute thinSplineDegree defines the thin spline degree (u) and the attribute thinSplineCoefficients[0..n] defines the coefficients of this thin spline [xxx].

~~6.2.13~~6.4.13 CA_Distortion

The class CA_Distortion has all distortion information necessary for the geometric calibration of an optical camera that is not covered by the ISO/TS 19130.

This International Technical Specification covers the ten-parameter physical model reported by Fraser [7]. The calibrated focal length (attribute calibratedFocalLength) and the principle point offset (principle point of ~~autocollimation~~symmetry, attribute ~~princPointAutocoll~~princPointOfSymmetry) are defined in the class SD_~~OpticalSystem~~Distortion of the ISO/TS 19130:2010. The other seven parameters comprise the radial distortion (3), the decentring distortion (2), and the in-plane distortion (2):

$$\Delta x' = \Delta x'_r + \Delta x'_d + \Delta x'_f$$
$$\Delta y' = \Delta y'_r + \Delta y'_d + \Delta y'_f$$

where the subscript r is for radial distortion, d for decentring distortion and f for in-plane image distortion

The attribute radialDistortion defines the radial distortion.

$$\Delta r = K_1 r^3 + K_2 r^5 + K_3 r^7$$

Comment [wk41]: Reference to thin spline needed.

Comment [k42]: Comment US/DPM-12: The only model documented in this section is for Australis. What about the other models identified in section 6.3.19?

where the K_i terms are the coefficients of radial distortion and r is the radial distance from the principle point:

$$r^2 = \bar{x}^2 + \bar{y}^2 = (x' - x'_0)^2 + (y' - y'_0)^2$$

The necessary corrections to the x', y' image coordinates follow as

$\Delta x'_r = \bar{x}\Delta r / r$ and $\Delta y'_r = \bar{y}\Delta r / r$

The attribute decentringDistortion defines the decentring distortion. This is caused by a lack of centering of lens elements along the optical axis.

$$\Delta x_d = P_1(r^2 + 2\bar{x}^2) + 2P_2\overline{xy}$$
$$\Delta y_d = 2P_1\overline{xy} + P_2(r^2 + 2\bar{y}^2)$$

P_1 and P_2 are defined by this attribute. The definition of the other parameters is done above.

The attribute inPlaneDistortion defines distortion that is caused by two effects:

- the differential scaling between x and y image coordinates due to differences between the frequency of the 'analog' CCD pixel shift clock and the sampling frequency of the A/D converter within the framegrabber, and
- the image axis non-orthogonality.

$$\Delta x_f = b_1\bar{x} + b_2\bar{y}$$

where b_1 is the affinity-term and b_2 is the shear-term. The other parameters are defined above.

~~6.2.14~~6.4.14 SD_OpticalSystem

The class SD_OpticalSystem is defined in the ISO/TS 19130:2010 and has information about the calibrated focal length (attribute calibratedFocalLength), the principle point of autocollimation (attribute princPointAutocoll), and their positional quality (attributes qualityOfCalibratedFocalLength and covPrincPtAutocoll).

~~6.2.15~~6.4.15 CA_OpticalSystem

The class CA_OpticalSystem has all information of an optical sensor system that is necessary for the geometric calibration and that is not defined in the ISO/TS 19130.

The attribute resolvingPower defines the resolving power of the optical system.

The attribute virtualFocalLength defines the computed focal length of a camera system with two or more camera heads.

The attribute virtualSensorSize defines the computed full sensor size of a camera system with two or more camera heads.

The attribute virtualPixelSize defines the computed pixel size of a camera system with two or more camera heads.

The attribute virtualPrinciplePointAutocoll defines the computed principle point of autocollimation of a camera system with two or more camera heads.

6.2.166.4.16 SD_DetectorArray

The class SD_DetectorArray is defined in the ISO/TS 19130 and has information about the detector array.

The attribute numberOfDimensions defines the number of dimensions of the detector array.

The attribute arrayOrigin defines position of the origin of the detector array coordinate system in external coordinate system.

The attribute arrayDimensions defines the names and sizes of the dimensions of the detector array.

The attribute offsetVectors[1..2] defines displacement between origin of the detector array coordinate system and the location of the first detector in the detector array.

The attribute detectorSize[1..2] defines size of a detector in a detector array dimension specified by detectorDimensionName.

The attribute detectorShape defines the shape of a detector.

The attribute distortion defines the distortion of the detector array.

6.2.176.4.17 SD_GeometricPreCorrection

The class SD_GeometricPreCorrection has all information about the geometric modification of the image data during the processing from the status raw-data to the status first original.

The attribute polynomialDegree defines the polynomial degree (u).

The attribute polynomialCoefficients[0..n] defines the coefficients of the polynomial.

The attribute resamplingDate defines the time of processing.

The attribute parameters[0..n] defines all other involved parameters.

~~6.4.18CA_LIDAR~~

~~The class CA_LIDAR has all information relevant for the calibration of a LIDAR system.~~

~~The attribute scale defines ???~~

~~6.4.19SD_Microwave~~

~~The class SD_Microwave is defined in the ISO/TS 19130 "Imagery sensor models for geopositioning" and has all information relevant for the calibration of a RADAR system.~~

6.2.206.4.18 CA_AuxiliaryDevice

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Comment [wk43]: What does "scale" define? Proposed by Ayman Habib, U of Calgary.

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The class CA_AuxiliaryDevice is the superclass for CA_GNSS and CA_IMU. GNSS and IMU are auxiliary devices for the measurement of position and attitude of moving platforms, e.g. airplanes.

The attribute timeLeverarm defines the time when the leverarm was calibrated.

The attribute leverarm defines the position-vector from the GNSS-reference point to the reference point of the sensor system, e.g. the projection center of the camera, in the Coordinate Reference System of the platform. The unit of the leverarm is DirectPosition.

The attribute errorLeverarm defines the error of the leverarm.

~~6.2.21~~6.4.19 CA_GNSS

The class CA_GNSS has all information about the satellite navigation that is relevant for the calibration. A GNSS provides 3D position information based on electronic distance measurements to four and more satellites.

The attributes numberSatellites defines the minimum number of satellites that is necessary for performing a calibration measurement.

The attribute registrationCycle defines the longest allowed temporal interval between two position measurements made by the GNSS.

~~6.2.22~~6.4.20 CA_IMU

The class CA_IMU has all information about the Inertial Measurement Unit (IMU) that is relevant for the calibration. An IMU provides the three attitude angles of a body relative to an initial orientation in space.

NOTE The angles are updated in intervals of a millisecond and less.

The attribute boresightAngle defines the three angles between the coordinate reference system of the sensor system, e.g. the camera, and the coordinate reference system of the IMU.

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = R_b \begin{pmatrix} x_{imu} \\ y_{imu} \\ z_{imu} \end{pmatrix}$$

with

$$R_b = \begin{pmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{pmatrix}$$

$r_{11} = \cos\varphi * \cos\kappa$
$r_{12} = -\cos\varphi * \sin\kappa$
$r_{13} = \sin\varphi$
$r_{21} = \cos\omega * \sin\kappa + \sin\omega * \sin\varphi * \cos\kappa$
$r_{22} = \cos\omega * \cos\kappa - \sin\omega * \sin\varphi * \sin\kappa$
$r_{23} = -\sin\omega * \cos\varphi$

r_{31} = sinω * sinκ - cosω * sinφ * cosκ
r_{32} = sinω * cosκ + cosω * sinφ * sinκ
r_{33} = cosω * cosφ

where

x', y', z'	Point vector in the coordinate reference system of the sensor system
R_b	Rotation matrix from the IMU to the sensor system
x_{imu}, y_{imu}, z_{imu}	Point vector in the coordinate reference system of the IMU
ω, φ, κ	Attitude angles

The attribute dataRate defines the temporal interval between two registrations.

The attribute attitudeAccuracy defines the quality of an angular measurement.

NOTE The attitude accuracy decreases over time.

~~6.2.23~~6.4.21 CA_TemperatureRange

The class CA_TemperatureRange is a datatype. It has the attributes minimumTemperature and maximumTemperature.

~~6.2.24~~6.4.22 CA_Temperature

The class CA_Temperature is a datatype that defines a temperature.

~~6.2.25~~6.4.23 CA_ GeometricResolution

The class CA_ GeometricResolution is a datatype that defines the geometric resolution counted in line-pairs per length-unit [1/Length].

~~6.2.26~~6.4.24 SD_ShapeCode

The class SD_ShapeCode is a code list that has the codes square, circular, rectangular, and elliptical. Those codes are used to describe the shape of the detector elements of a detector array.

~~6.2.27~~6.4.25 SD_ArrayDimension

The class SD_ArrayDimension is a datatype that names and defines the dimension of a detector array. The attributes are termed name and size.

~~6.2.28~~6.4.26 CA_RadialDistortion

The class SD_RadialDistortion is a datatype that has the two attributes numberCoefficients and k[0..n].

~~6.2.29~~6.4.27 CA_DecentringDistortion

The class SD_DecentringDistortion is a datatype that has the two attributes p1 and p2.

~~6.2.30~~6.4.28 CA_InPlaneDistortion

The class SD_InPlanelDistortion is a datatype that has the two attributes b1 and b2.

6.36.5 Package: OpticsSpatial

6.46.6 Package: GeometryCalibrationFacility

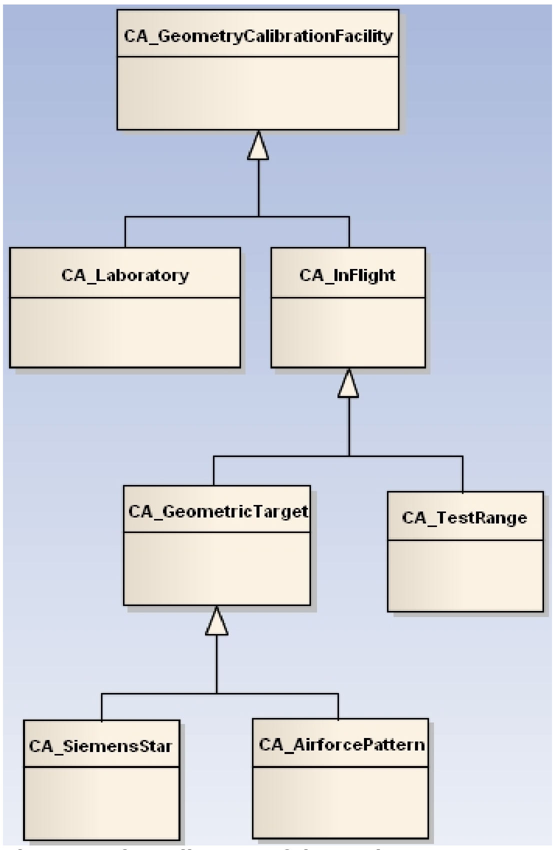

Figure 9: Class diagram of the package GeometryCalibrationFacility

6.4.16.6.1 Semantics

The package GeometricCalibrationFacility is designed to contain information that is related to a calibration laboratory and to an in-flight calibration. Calibration instruments and test fields may be applied in a laboratory calibration while only test fields are common during in-flight calibrations. The package provides detailed information about the test field targets, the calibration photo flight, and the bundle-adjustment-based determination of the calibration results, termed self calibration.

Comment [k44]: Comment FR35:
An exhaustive specification of this package appears as an uneasy task, as in some cases, it is proprietary, if not secret. The required focus should be on standardized quality indicators for the Geometry calibration. Additional elements should be indicated as optional elements that may be provided, and are specified in this specification as examples (but not exhaustive)
FR-Proposal:
Consider re-organizing and re-wording this part under these principles.
Action:
To be done soon: Action by pl

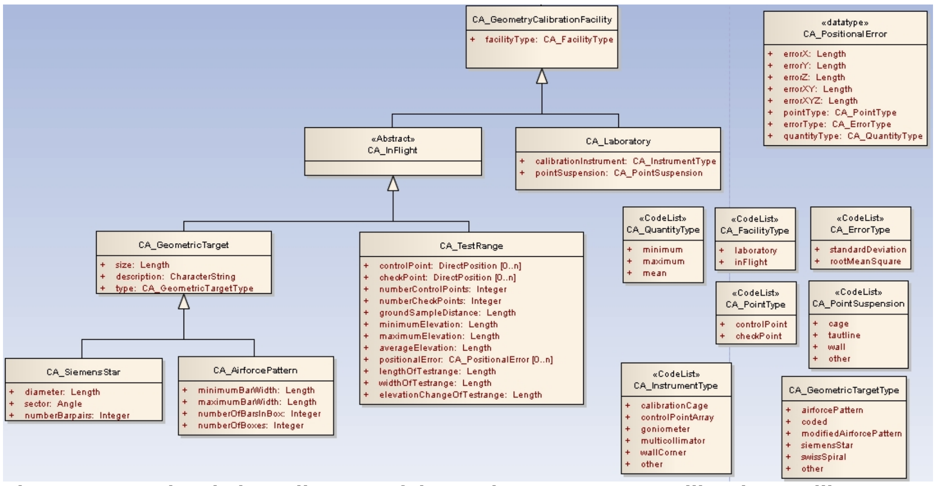

Figure 10: Top-level class diagram of the package GeometryCalibrationFacility

~~6.4.2~~6.6.2 CA_GeometryCalibrationFacility

The class CA_GeometryCalibrationFacility is the superclass of the package GeometryCalibrationFacility. This class has the attribute facilityType which may be coded with laboratory and inFlight.

~~6.4.3~~6.6.3 CA_~~CalibrationInstrument~~Laboratory

The class CA_CalibrationInstrument has ~~all~~ information related to the instruments ~~applied~~ utilised during the calibration.

The attribute calibrationI~~i~~nstrument~~Type~~ ~~may only~~ can be coded ~~with goniometer~~according to the code list CA_InstrumentType.

The attribute pointSuspension defines the method of attaching control points and check points to a fundament. This attribute allows for the distinction between a target attached to a cage, a wall, and a target attached to a tautline which are is mostly stretched between the floor and the ceiling, and other.

~~6.4.4~~6.6.4 CA_InFlight

The class CA_InFlight is the superclass of the classes CA_GeometricTarget and CA_TestRange, and has the stereotype abstract because it has no attributes.

~~6.4.5~~6.6.5 CA_Test~~field~~Range

The class CA_~~Testfield~~ TestRange has all information that is valid for the entire ~~testfield~~test range.

The attibutes controlPoint[0..n] and checkpoint[0..n] define the control points and the check points respectively.

The attributes numberControlPoints and numberCheckPoints define their quantity in the test field.

The attribute groundSampleingDistance defines the smallest Ground Sampling Sample Distance that can sensibly be applied for a sensor calibration on this testfieldtest range. The targets have a given size. Therefore they may not be small enough to be used for a calibration process with a smaller GSD than stated in the attribute groundSamplingDistance groundSampleDistance .

The attributes minimumElevation, maximumElevation, and averageElevation define elevation range of the test field and its average height.

The attribute positionalError characterizes the geometric accuracy of the test fieldrange.

The attributes dimensionTestfield lengthOfTestrange, widthOfTestrange, and elevationChangeOfTestrange describe the three tells the dimensionalal extentity of the testfield test rangeand may be set to 2 or 3.

Figure 7: Class diagram of class CA_Testfield and its subclasses

6.4.66.6.6 CA_GeometricTarget

The class CA_GeometricTarget has all information about the targets.

The attribute size defines the width of the 2-dimensional bounding box around thea square or the diameter of a round target.

The attribute shape description may have the codes round or squareallows for a free text description of the target. An example is “Painted Target” or “White squares 0.5m on each side”.

The attribute type defines the type of the target according to the code list set in the class CA_GeometricTargetType.

6.4.76.6.7 CA_SiemensstarSiemensStar

The class CA_Siemensstar SiemensStar has all information about a target of type SiemensstarSiemens star.

The attribute radius diameter defines the radius diameter of the Siemens star.

The attribute sector defines the sector in which the Siemens star is drawn. Example: If the attribute value is 180°, then the Siemens star is only drawn as a semicircle. In this case an attribute value of numberBarpairs=20 would lead to only 10 white and 10 black sections.

The attribute numberBarpairs defines the partitioning of the full circle. A bar-pair is a white section and a black section. Example: If the attribute value is "20", then the Siemens star has 20 white and 20 black sections with a width of 9° each.

Comment [wk45]: This attribute is proposed by the USGS. Does the definition need expansion?

Comment [k46]: Comment US/GS1:
ASPRS - Robert Ryan - 1. Spatial Resolution (Section 6.3.7) (I think geometry should be separated, they are related but different)
a. Edge targets are not included (RER and MTF not fully discussed in relation) Contrast Targets are shown
b. Section 6.6.8 the size of a target depends on the GSD and the PSF Also the BRDF of the target needs to be considered (Lambertian is preferable)

Comment [k47]: Comment US/DPM-4:
To get uniform results from one Siemens star to another, should detailed paint/material types or reflective properties be specified?

Figure 11: Siemens star on a roof

6.4.86.6.8 CA_AirforcePattern

The class CA_AirforcePattern has all information about the target of type airforce pattern.

The attributes minimumBarWidth and maximumBarWidth define the minimum and maximum width of the target-bars.

The sections of the airforce pattern are called boxes. The attribute numberOfBarsInBox define the quantity of bars in one box. The attribute numberOfBoxes defines the quantity of all boxes.

Comment [k48]: Comment US/DPM-6: To get uniform results from one Airforce pattern to another, should specific paint/material types or reflective properties be specified?

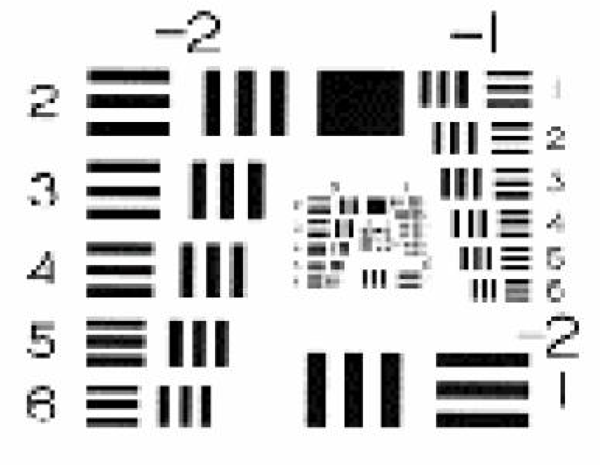

Figure 12: Airforce pattern

~~6.4.9~~6.6.9 CA_FacilityType

The class CA_FacilityType is a code list with the codes laboratory and inFlight. These codes are used to distinguish between different calibration methods.

~~**6.3.11CA_InstrumentType**~~

~~The class CA_InstrumentType is a codelist with the only code goniometer.~~

~~6.4.11~~6.6.10 CA_PositionalError

The class CA_PositionalError is a datatype that specified the positional error of a point. One group of attributes define the dimension of the error such as errorXYZ for the 3-dimensional case.

Three other attributes are named pointType to distinguish between control points and check points, errorType to distinguish between standard deviation and root mean square error, quantityType to inform what the error represents (minimum, maximum, and mean).

NOTE The different quality measures are defined in the ISO~~/TS 19138~~ 19157 "Data quality~~ measures~~".

~~6.4.12~~6.6.11 CA_PointType

The class CA_PointType is a code list with the codes controlPoint and checkPoint.

~~6.4.13~~6.6.12 CA_ErrorType

The class CA_ ErrorType is a code list with the codes standardDeviation and rootMeanSquare.

The standard deviation is defined in the xxx as

Comment [wk49]: Figure needs to be redrawn for the final version.

Comment [k50]: Comment FR41:
Photoflight and Laboratory are not the only 2 values. Why not in-situ (e.g in a street)
FR-Proposal:
Consider providing additional values.
Another solution is to broaden the scope of PhotoFlight, e.g Calibration Survey …
Action:
Add further facility types:
To be done by the project team.

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Comment [k51]: Comment US/DPM-9:
Should standard deviation be standard error?

The root mean square error (RMSE) is defined in the ISO 19157 “Data quality” as

$$\sigma_z = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Z_{mi} - z_t)^2}$$

where

σ_z root mean square error (RMSE)

Z observable

z_t true value of the observable Z

6.4.146.6.13 CA_QuantityType

The class CA_ QuantityType is a code list with the codes minimum, maximum, and mean.

The quantity type is an attribute which defines whether the positional error is the maximum, a mean, or the minimum of a set of errors.

6.4.156.6.14 CA_PointSuspension

The class CA_PointSuspension is a code list with the codes cage, wall, and tautline, and other.

6.4.15CA_DimensionTestfield

The class CA_DimensionTestfield is a codelist with the codes 2 and 3.

6.4.15CA_GeometricTargetShape

The class CA_GeometricTargetShape is a codelist with the codes round and square.

6.4.186.6.15 CA_InstrumentType

The class CA_InstrumentType is a code list with the entries calibrationCage, controlPointArray, goniometer, multicollimator, wallCorner, and other.

6.4.196.6.16 CA_GeometricTargetType

The class CA_GeometricTargetType is a code list with the entries airforcePattern, coded, modifiedAirforcePattern, siemensStar, swissSpiral, and other.

6.7 Package: OpticsRadiometry

The figure 13 provides the top-level class diagram of the radiometric calibration of optical sensors. An overview over the radiometry calibration facility is shown in figure 15 and over the radiometry recording in figure 17. Details about the class CA_RadiometryInFlight are shown in figure 16 and about the class CA_RadiometryRecording in figure 19.

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Comment [k52]: Comment US/JBC-16: Currently only lists round and square. Should be expanded. General question: Is this needed? US/JBC Proposal: Add “coded, “modified Air Force” and others.

Formatted: Bullets and Numbering

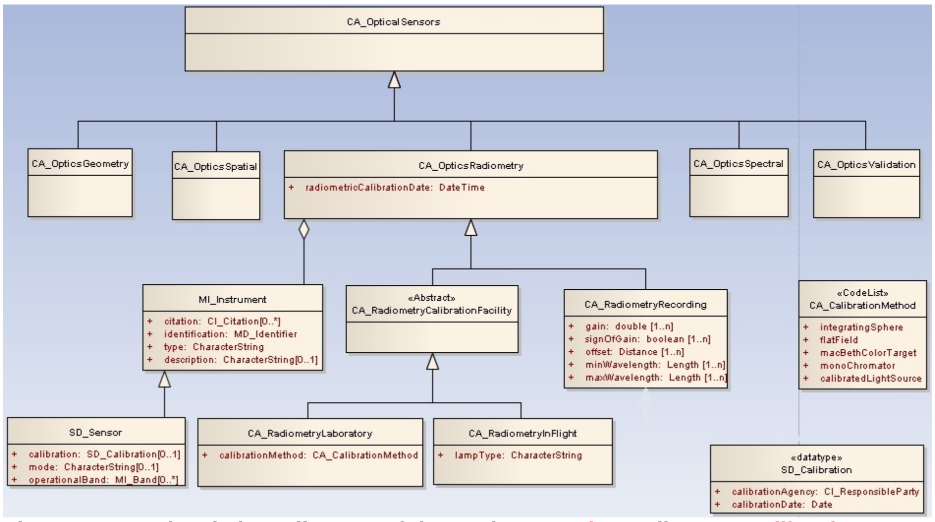

Figure 13: Top-level class diagram of the package OpticsRadiometryCalibration

6.4.206.7.1 Semantics

The package RadiometryCalibration covers the packages RadiometryCalibrationFacility and RadiometryRecording and thus addresses all aspects that are related to the radiometric calibration of remote sensing imagery sensors. The package addresses standardized test fields and targets, properties of the sensor system, and environmental conditions.

6.4.216.7.2 CA_OpticsRadiometry

The class CA_Radiometry defines all information that is valid for the entire radiometric calibration.

The attribute radiometricCalibrationDate defines the date and time when the calibration was performed.

6.7.3 CA_RadiometryLaboratory

The class CA_Laboratory has all information regarding the radiometric calibration in a laboratory.

The attribute calibrationMethod defines the method applied for the calibration.

6.7.4 CA_CalibrationMethod

The class CA_CalibrationMethod is a code list with the codes integratingSphere, flatField, macBethColorTarget, monoChromator, and calibratedLightSource. Those codes are used for characterizing a laboratory calibration.

6.7.5 MI_Instrument

Comment [k53]: Comment FR43:
Is it here Radiometric calibration? Any indication on reference methods (codelist ?)
Action:
Add codelist for reference methods: To be done by the project team.

The class MI_Instrument is defined in the ISO 19115-2 "Metadata – Part 2: Extension for imagery and gridded data" and contains instrument-specific parameters.

The attribute citation[0..*] sets a complete citation of the instrument.

The attribute identifier defines a unique identification of the instrument.

The attribute type is a name of the type of instrument.

Examples: framing, line-scan, push-broom, pan-frame, whiskbroom

The attribute description[0..1] sets a textual description of the instrument.

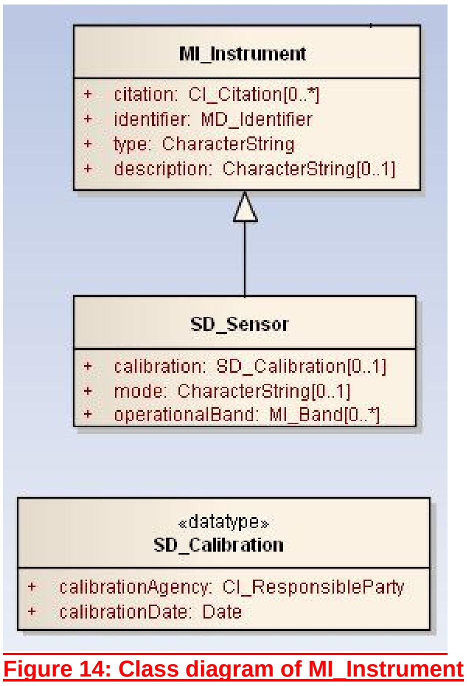

Figure 14: Class diagram of MI_Instrument

6.7.6 SD_Sensor

The class SD_Sensor is defined in the ISO/TS 19130 "Imagery sensor models for geopositioning" and contains the characteristics of the sensor.

The attribute calibration contains information about determination of the relation between instrument readings and physical parameters.

The attribute mode defines the type of observation being made by the sensor.

The attribute operationalBand defines the wavelengths of the electromagnetic spectrum being observed by the sensor.

6.7.7 SD_Calibration

Comment [k54]: Comment US/JBC-7: US/JBC Proposal:

The class SD_Calibration is a datatype defined in the ISO/TS 19130:2010 and contains the circumstances of determination of relation between instrument readings and physical parameters.

The attribute calibrationAgency defines the authority under which calibration took place

The attribute calibrationDate defines the date when the calibration was carried out.

~~6.5~~6.8 Package: RadiometryCalibrationFacility

The figure 15 provides an overview over the classes with in the package RadiometryCalibrationFacility.

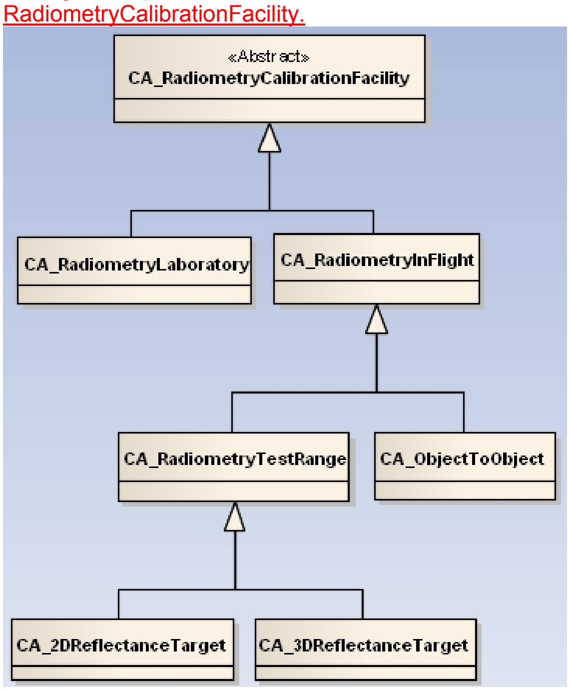

Figure 15: Overview ~~C~~class diagram of the package RadiometryCalibrationFacility

~~6.5.1~~6.8.1 Semantics

The package RadiometryCalibrationFacility contains all information that is related to the calibration equipment including the laboratory and the in-flight environment.

The figure 16 provides the details of the classes related to CA_RadiometryInFlight.

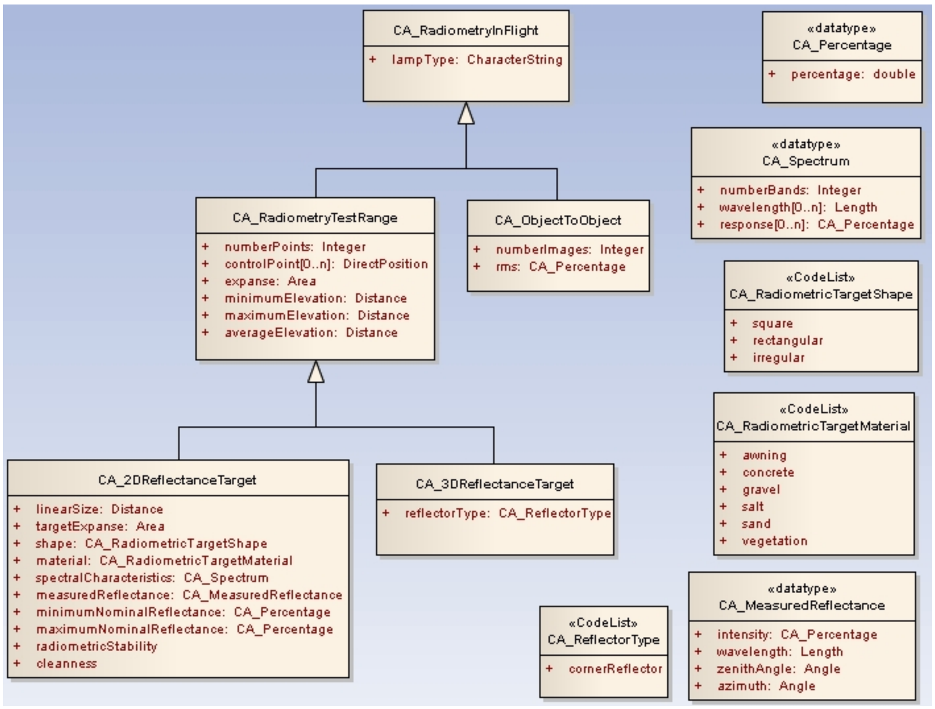

Figure 16: ~~Top-level~~Details of the class CA_RadiometryInFlight and its subclasses ~~class diagram of the package RadiometryCalibrationFacility~~

~~6.5.2~~6.8.2 CA_RadiometryCalibrationFacility

The class CA_RadiometryCalibrationFacility is the superclass of the classes CA_Laboratory and CA_InFlight, and has the stereotype abstract because it has no attributes (figure 13).

~~6.5.3~~6.8.3 CA_RadiometryInFlight

The class CA_InFlight is the superclass of the classes CA_~~Active~~ RadiometryTestRange and CA_~~Passive~~ObjectToObject. ~~Those two classes and their subclasses have all information about active and passive targets in testfields respectively~~

The attribute lampType defines the type of illumination used.~~.~~

Comment [k55]: Comment FR44:
For class CA_InFlight and the 2 subclasses CA_Active and CA_Passive, what about information about slope, altitude, target and environment (homogeneous, or not), accessibility (period of the year for ex), stability…?
Action:
Accepted and attributes added. Project team to check and eventually extend list.

~~6.5.4~~6.8.4 CA_Radiometry~~TestField~~TestRange

The class CA_~~TestField~~ RadiometryTestRange is the superclass of the classes CA_2DReflectanceTarget and CA_3DReflectanceTarget, and has all information about the ~~testfields~~ test ranges used in the radiometric calibration.

The attribute numberPoints defines the number of targets in the ~~testfield~~test range.

The attribute controlPoint[0..n] defines the position of the control points.