INTERNATIONAL STANDARD

ISO 19116

Second edition
2019-12

Geographic information — Positioning services

Information géographique — Services de positionnement

Reference number
ISO 19116:2019(E)

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Published in Switzerland

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Foreword

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

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

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

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

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

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

This second edition cancels and replaces the first edition (ISO 19116:2004), which has been technically revised.

The main changes compared to the previous edition are as follows.

— Device specific definitions have been removed from the model and normative body of the document. These have been clarified and reformatted in Annex D.

— Constructs from withdrawn standards ISO 19113, ISO 19114, and ISO 19115 have been updated where necessary to ISO 19115-1 and ISO 19157. References to these new standards are carried out using approved methods.

— Terminology entries from the first edition were updated and harmonized with other current standards in ISO/TC 211. As per ISO/IEC Directives, Part 2, 2018, unused terms have been removed from this edition.

— Constructs from ISO 19111 have been updated. References to the revised ISO 19111:2019 document are carried out using approved methods.

— A new, convenient yet unobtrusive, set of constructs for determining the reliability of a positioning result have been added to the model, in Clause 8.

— Based on the concepts related to the model, conformance with the other standards, and separation of the technology specific content from the abstract model, all UML models have been updated.

— Original requirements "drafted as normative *shall* statements" were rechecked for consistency with the model. Where necessary the requirements were revised or retained as regular text.

— Significant editorial revisions have been carried out, clarifying the structure of the document, correction of errors, and following current ISO/IEC Directives, Part 2 for drafting specifications.

In accordance with the ISO/IEC Directives, Part 2, 2018, *Rules for the structure and drafting of International Standards*, in International Standards the decimal sign is a comma on the line. However, the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) at its meeting in 2003 passed unanimously the following resolution:

"The decimal marker shall be either a point on the line or a comma on the line."

In practice, the choice between these alternatives depends on customary use in the language concerned. In the technical areas of geodesy and geographic information it is customary for the decimal point always to be used, for all languages. That practice is used throughout this document.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Positioning services are among the processing services identified in ISO 19119:2016. Processing services include services that are computationally oriented and operate upon the elements from the model domain, rather than being directly integrated in the model domain itself. This document defines and describes the positioning service.

Positioning services employ a wide variety of technologies that provide position and related information to a similarly wide variety of applications, as depicted in Figure 1. Although these technologies differ in many respects, there are important items of information that are common among them and serve the needs of these application areas, such as the position data, time of observation and its accuracy. Also, there are items of information that apply only to specific technologies and are sometimes required in order to make correct use of the positioning results, such as signal strength, geometry factors, and raw measurements. Therefore, this document includes both general data elements that are applicable to a wide variety of positioning services and technology specific elements that are relevant to particular technologies.

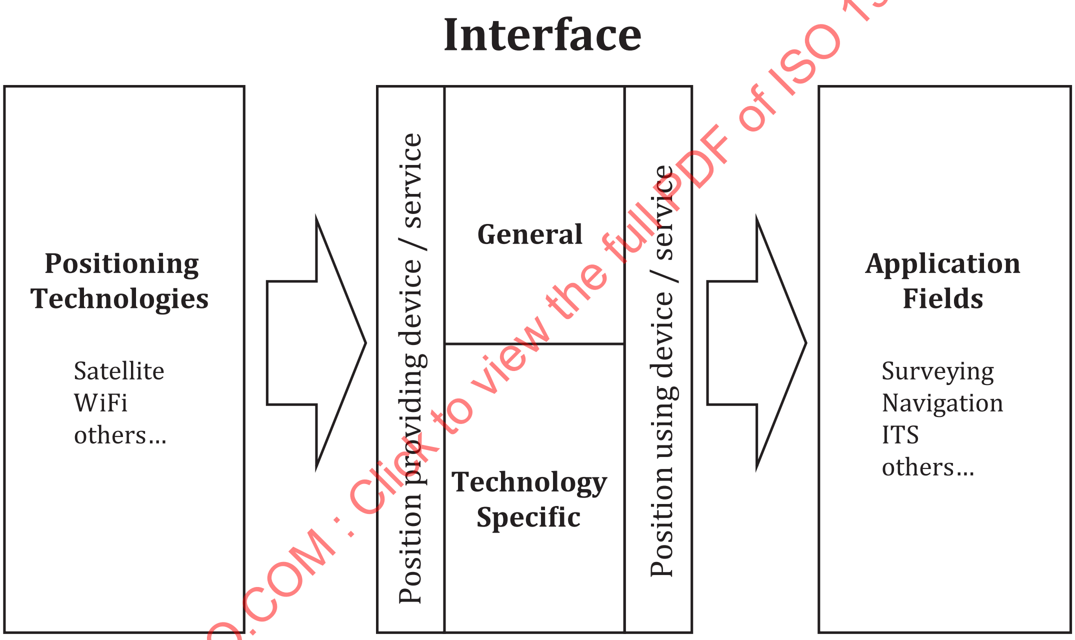

Figure 1 — Positioning services overview

Electronic positioning technology can measure the coordinates of a location on or near the Earth with great speed and accuracy, thereby allowing geographic information systems to be populated with any number of objects. However, the technologies for position determination have neither a common structure for expression of position information, nor common structures for expression of accuracy and reliability. The positioning services interface specified in this document provides data structures and operations that allow spatially oriented systems to employ positioning technologies with greater efficiency and interoperability.

Geographic information — Positioning services

1 Scope

This document specifies the data structure and content of an interface that permits communication between position-providing device(s) and position-using device(s) enabling the position-using device(s) to obtain and unambiguously interpret position information and determine, based on a measure of the degree of reliability, whether the resulting position information meets the requirements of the intended use.

A standardized interface for positioning allows the integration of reliable position information obtained from non-specific positioning technologies and is useful in various location-focused information applications, such as surveying, navigation, intelligent transportation systems (ITS), and location-based services (LBS).

2 Normative references

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

ISO 19103, *Geographic information — Conceptual schema language*

ISO 19107, *Geographic information — Spatial schema*

ISO 19111, *Geographic information — Referencing by coordinates*

ISO 19115-1, *Geographic information — Metadata — Part 1: Fundamentals*

ISO 19157, *Geographic information — Data quality*

3 Terms and definitions

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

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

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

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

3.1
absolute accuracy
external accuracy
closeness of reported coordinate values to values accepted as or being true

Note 1 to entry: 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.

[SOURCE: ISO/TS 19159-2:2016, 4.1 modified — NOTES 1 and 2 have been deleted and replaced by a new Note 1 to entry.]

3.2
accuracy
closeness of agreement between a test result or measurement result and the true value

Note 1 to entry: For positioning services, the test result is a measured value or set of values.

[SOURCE: ISO 3534-2:2006, 3.3.1, modified — NOTES 1, 2 and 3 have been deleted and replaced by a new Note 1 to entry.]

3.3
attitude
orientation of a body, described by the angles between the axes of that body's coordinate system and the axes of an external coordinate system

Note 1 to entry: In positioning services, this is usually the orientation of the user's platform, such as an aircraft, boat, or automobile.

3.4
coordinate
one of a sequence of numbers designating the position of a point

Note 1 to entry: In a spatial coordinate reference system, the coordinate numbers are qualified by units.

[SOURCE: ISO 19111:2019, 3.1.5]

3.5
coordinate conversion
coordinate operation that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system in which both coordinate reference systems are based on the same datum

Note 1 to entry: A coordinate conversion uses parameters which have specified values.

EXAMPLE 1 A mapping of ellipsoidal coordinates to Cartesian coordinates using a map projection.

EXAMPLE 2 Change of units such as from radians to degrees or from feet to metres.

[SOURCE: ISO 19111:2019, 3.1.6]

3.6
coordinate operation
process using a mathematical model, based on a one-to-one relationship, that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system, or that changes coordinates at a source coordinate epoch to coordinates at a target coordinate epoch within the same coordinate reference system

[SOURCE: ISO 19111:2019, 3.1.8]

3.7
coordinate reference system
coordinate system that is related to an object by a datum

Note 1 to entry: Geodetic and vertical datums are referred to as reference frames.

Note 2 to entry: For geodetic and vertical reference frames, the object will be the Earth. In planetary applications, geodetic and vertical reference frames may be applied to other celestial bodies.

[SOURCE: ISO 19111:2019, 3.1.9]

3.8
coordinate system
set of mathematical rules for specifying how coordinates are to be assigned to points

[SOURCE: ISO 19111:2019, 3.1.11]

3.9
coordinate transformation
coordinate operation that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system in which the source and target coordinate reference systems are based on different datums

Note 1 to entry: A coordinate transformation uses parameters which are derived empirically. Any error in those coordinates will be embedded in the coordinate transformation and when the coordinate transformation is applied the embedded errors are transmitted to output coordinates.

Note 2 to entry: A coordinate transformation is colloquially sometimes referred to as a 'datum transformation'. This is erroneous. A coordinate transformation changes coordinate values. It does not change the definition of the datum. In this document coordinates are referenced to a coordinate reference system. A coordinate transformation operates between two coordinate reference systems, not between two datums.

[SOURCE: ISO 19111:2019, 3.1.12]

3.10
datum
reference frame
parameter or set of parameters that realize the position of the origin, the scale, and the orientation of a coordinate system

[SOURCE: ISO 19111:2019, 3.1.15]

3.11
height
distance of a point from a chosen reference surface positive upward along a line perpendicular to that surface

Note 1 to entry: A height below the reference surface will have a negative value.

Note 2 to entry: Generalisation of ellipsoidal height (h) and gravity-related height (H).

[SOURCE: ISO 19111:2019, 3.1.38]

3.12
inertial positioning system
positioning system employing accelerometers, gyroscopes, and computers as integral components to determine coordinates of points or objects relative to an initial known reference point

3.13
instant
0-dimensional geometric primitive representing position in time

Note 1 to entry: The geometry of time is discussed in ISO 19108:2002.

[SOURCE: ISO 19108:2002, 4.1.17]

3.14
integrated positioning system
positioning system incorporating two or more positioning technologies

Note 1 to entry: The measurements produced by each positioning technology in an integrated system may be of any position, motion, or attitude. There may be redundant measurements. When combined, a unified position, motion, or attitude is determined.

3.15
linear positioning system
positioning system that measures distance from a reference point along a route (feature)

EXAMPLE An odometer used in conjunction with predefined mile or kilometre origin points along a route and provides a linear reference to a position.

3.16
map projection
coordinate conversion from an ellipsoidal coordinate system to a plane

[SOURCE: ISO 19111:2019, 3.1.40]

3.17
measurement precision
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 to entry: 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 to entry: 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).

Note 3 to entry: Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.

Note 4 to entry: Sometimes "measurement precision" is erroneously used to mean measurement accuracy.

[SOURCE: ISO/IEC Guide 99:2007, 2.15]

3.18
motion
change in the position of an object over time, represented by change of coordinate values with respect to a particular reference frame

EXAMPLE This may be motion of the position sensor mounted on a vehicle or other platform or motion of an object being tracked by a positioning system.

3.19
operating conditions
parameters influencing the determination of coordinate values by a positioning system

Note 1 to entry: Measurements acquired in the field are affected by many instrumental and environmental factors, including meteorological conditions, computational methods and constraints, imperfect instrument construction, incomplete instrument adjustment or calibration, and, in the case of optical measuring systems, the personal bias of the observer. Solutions for positions may be affected by the geometric relationships of the observed data and/or mathematical model employed in the processing software.

3.20
optical positioning system
positioning system that determines the position of an object by means of the properties of light

EXAMPLE Total Station: Commonly used term for an integrated optical positioning system incorporating an electronic theodolite and an electronic distance-measuring instrument into a single unit with an internal microprocessor for automatic computations.

3.21
performance indicator
internal parameters of positioning systems indicative of the level of performance achieved

Note 1 to entry: Performance indicators can be used as quality-control evidence of the positioning system and/or positioning solution. Internal quality control may include such factors as signal strength of received radio signals [signal-to-noise ratio (SNR)], figures indicating the dilution of precision (DOP) due to geometric constraints in radiolocation systems, and system-specific figure of merit (FOM).

3.22
positional accuracy
closeness of coordinate value to the true or accepted value in a specified reference system

Note 1 to entry: 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.

3.23
positional reliability
degree to which a positioning service provides agreed or expected absolute accuracy during a defined instant under specified conditions

Note 1 to entry: The wording of the definition has been adopted from ISO/IEC 16350:2015, 4.29.

3.24
positioning system
system of instrumental and computational components for determining position

EXAMPLE Inertial, integrated, linear, optical and satellite are examples of positioning systems.

3.25
relative position
position of a point with respect to the positions of other points

Note 1 to entry: The spatial relationship of one point relative to another may be one-, two- or three-dimensional.

3.26
relative accuracy
internal accuracy
closeness of the relative positions of features in a data set to their respective relative positions accepted as or being true

Note 1 to entry: Closely related terms, such as local accuracy, are employed in various countries, agencies and application groups. Where such terms are utilized, it is necessary to provide a description of the term.

Note 2 to entry: The wording of the definition is from ISO 19157: 2013, 7.3.4, and was later added as a terminology entry by ISO/TS 19159-2:2016, 4.32.

[SOURCE: ISO/TS 19159-2:2016, 4.23 modified — NOTE 1 has been deleted and replaced by a new Note 1 to entry, a new Note 2 to entry has been added.]

3.27
satellite positioning system
positioning system based upon receipt of signals broadcast from satellites

Note 1 to entry: In this context, satellite positioning implies the use of radio signals transmitted from "active" artificial objects orbiting the Earth and received by "passive" instruments on or near the Earth's surface to determine position, velocity, and/or attitude of an object.

EXAMPLE GPS and GLONASS are types of satellite positioning system platforms.

3.28
uncertainty
parameter, associated with the result of measurement, that characterizes the dispersion of values that could reasonably be attributed to the measurand

Note 1 to entry: 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.

3.29
unit of measure
reference quantity chosen from a unit equivalence group

Note 1 to entry: In positioning services, the usual units of measurement are either angular units or linear units. Implementations of positioning services shall clearly distinguish between SI units and non-SI units. When non-SI units are employed, their relation to SI units shall be specified.

4 Symbols, abbreviated terms, backwards compatibility, UML notation, and packages

4.1 Symbols and abbreviated terms

BDS	BeiDou Navigation Satellite System
C/A	Coarse/Acquisition code transmissions of the GPS and GLONASS
CRS	Coordinate Reference System
DOP	Dilution of Precision
DGPS	Differential GPS
FOM	Figure of Merit
Galileo	Galileo GNSS
GDOP	Geometric Dilution of Precision
GIS	Geographic Information System
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
L*n*	Signal transmission in a specified portion of the L band of the radio spectrum; suffix “*n*” indicates portion of the band for a defined frequency such as GPS L1 or GLONASS L1
LORAN-C	LOcation and RANging radiolocation system
NAD*yy*	North American Datum; suffix “*yy*” indicates last two digits of year
NAVIC	Indian Regional Navigation Satellite System
NFC	Near Field Communication

NMEA	National Marine Electronics Association
PDOP	Positional Dilution of Precision
PPS	Precise Positioning Service of a Global Navigation Satellite System
QZSS	Quasi-Zenith Satellite System (Japan)
RAIM	Receiver Autonomous Integrity Monitoring
RINEX	Receiver INdependent EXchange Format
RMS	Root Mean Square
RMSE	Root Mean Square Error
RSSI	Received Signal Strength Indicator
SI	Système International d'unités (International System of Units)
SNR	Signal to Noise Ratio
SV	Space Vehicle
TDOP	Time Dilution of Precision
UML	Unified Modeling Language
UTC	Coordinated Universal Time
VDOP	Vertical Dilution of Precision

4.2 Backwards compatibility

Backwards compatibility issues were carefully considered during the revision process. However, due to the age of the document and the significant revisions of related standards, various technical revisions were necessary in carrying out the revision work.

Following ISO/TC 211 guidelines for modular standards development, requirements that were written directly into the clause paragraphs of ISO 19116:2004 were identified and then reformatted into independent requirements text and formatted as such. Later, as the models were updated, these requirements were rechecked for consistency with the model. Where necessary the requirements were revised or retained as regular text.

4.3 UML notation

In this document, conceptual schemas are presented in the Unified Modeling Language (UML). The user shall refer to ISO 19103 for the specific profile of UML used in this document.

4.4 UML packages

UML packages used in this document are shown in Table 1. Like the original version of ISO 19116:2004, this revised version retains the two letter prefixes used to denote the package that contains a class. These prefixes precede class names, connected by a "_". A list of these prefixes is shown in Table 1, together with a reference to the reference standard in which these classes are located.

Table 1 — UML packages used in this document

Prefix	Description	Reference standard
CI	Citation	ISO 19115-1
DQ	Data quality	ISO 19157
MD	Metadata	ISO 19115-1
PS	Positioning services	this document

5 Conformance

5.1 Overview

This document defines three categories of conformance:

a) Conceptual model — conformance tests for the conceptual model;

b) Requirements — conformance tests for requirements;

c) Operations — conformance tests for operations.

Any positioning service implementation or product claiming conformance with this document shall pass all conformance requirements described in the corresponding abstract test suite defined in Annex A.

5.2 Conformance requirements

Table 2 lists the conformance classes URI for the conceptual model defined in this document.

Table 2 — Conformance classes defined in this document

Conformance class URI[a]	Standardization target	References
/conf/conceptual-model	Conceptual model	A.2
/conf/requirements	Requirements	A.3
/conf/operations	Operations	A.4

[a] All conformance class URIs are HTTP URIs, with the prefix http://standards.isotc211.org/19116/-1/2.

5.3 Structure of requirements clauses

Table 3 lists the conformance class URI identifiers for each specific group of requirements by class.

Table 3 — Identifier URIs for the requirements defined in this document

Requirement	Identifier
Req. 1	http://standards.isotc211.org/19116/-1/2/req/ps_system
Req. 2 – Req. 7	http://standards.isotc211.org/19116/-1/2/req/ps_observationmode
Req. 8 – Req. 9	http://standards.isotc211.org/19116/-1/2/req/ps_observation
Req. 10	http://standards.isotc211.org/19116/-1/2/req/ps_qualitymode
Req. 11 – Req. 13	http://standards.isotc211.org/19116/-1/2/req/ps_positioningservice
Req. 14 – Req. 15	http://standards.isotc211.org/19116/-1/2/req/ps_reliabilitytable

6 Positioning services model

6.1 Overview

Positioning services provide a means to obtain position information regarding a point or object. Data communication with a positioning service is structured using the following four classes:

a) System information — held in the PS_System class, identifies the system and its capabilities;

b) Session information — held in the PS_Session class, identifies a session of system operation;

c) Mode information — held in the PS_ObservationMode class, identifies the configuration used in each mode of operation, the positioning observations (results) and any associated quality information;

d) Reliability information — held in the PS_ReliabilityTable class, identifies reliability value of the returned position.

These classes apply elements defined in ISO 19115-1, ISO 19111, ISO 19157, ISO 19107, and other ISO 19100 series standards. Figure 2 depicts the relationships among these elements as UML packages.

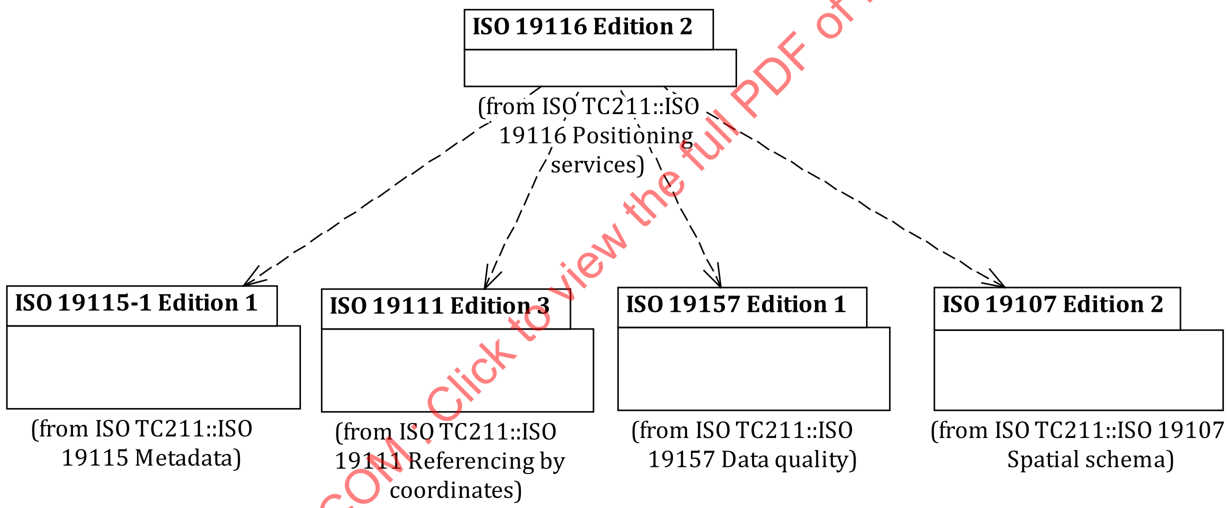

Figure 2 — Package diagram showing relationship with elements in other ISO standards

A detailed overview of positioning services is presented in Annex C, while Annex G describes various use case examples for positioning services.

6.2 Static data structures of a positioning service

The service is accessed through an interface that operates on these data classes, creating and destroying instances as necessary, and setting and getting information needed from the positioning service. This document can be implemented as an interface between software modules within a system or as an interface between different systems. The relationships among these classes are depicted in Figure 3, while the details of these classes are specified in Clause 7.

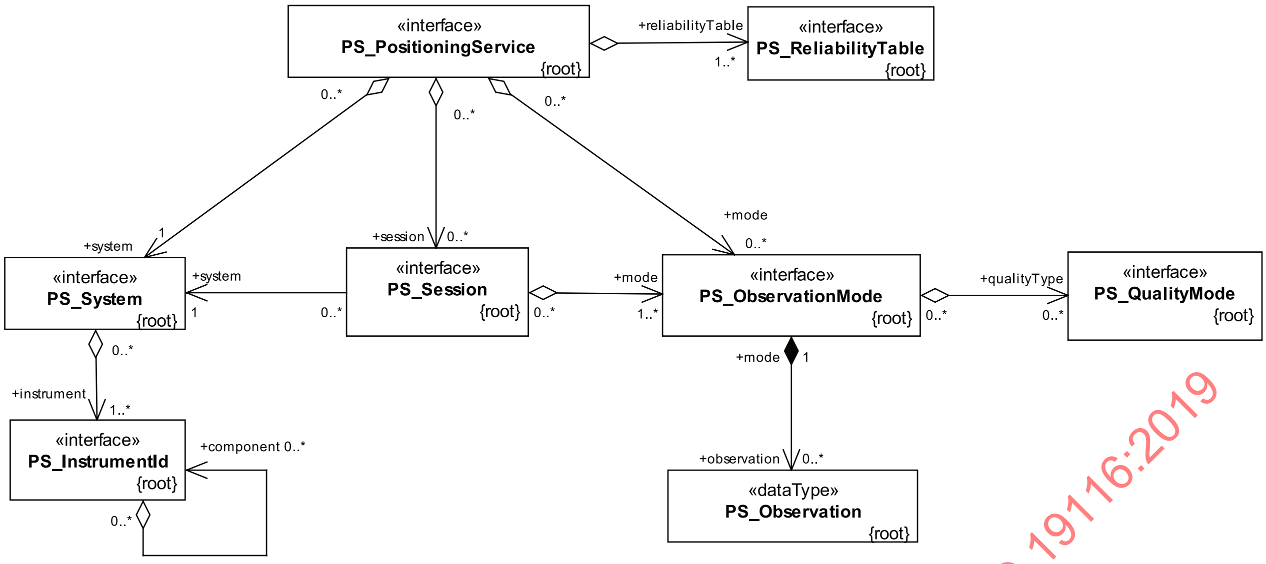

Figure 3 — UML diagram — Major data classes of positioning services

System information (PS_System) provides for identification and characterization of the positioning instrument(s) applied by the positioning service to perform observations so that any necessary details can be obtained for operational purposes and for legacy metadata.

Observation mode information (PS_ObservationMode) encompasses all configuration and set-up parameters, including the spatial and temporal reference systems on which the observation results are cast. Associated with the mode there may exist data-quality configuration information, held in the PS_QualityMode class, that characterizes how quality results will be evaluated and expressed.

Positioning services can produce several types of observations:

— position,

— orientation (attitude),

— motion, and

— rotation (angular motion).

Each type of observation is cast in its own type of reference system having a separate instance of the PS_ObservationMode class for each type of observation where the type is an attribute of the mode.

Observations are aggregated to each mode so that the information needed for interpretation is associated with each observation. A positioning service can create as many mode instances as needed for its various observation types and reference systems. Numerous observation results can belong to each mode.

Observations aggregated to modes of operation (PS_ObservationMode) can be further aggregated in sessions (PS_Session). The concept of observation sessions is widely employed when positioning observations are recorded for land survey or GIS applications. Sessions associate the observations with system information, attributes of the session, and all modes of operation employed in making a discrete group of positioning observations and any associated quality information. Positioning services that do not provide for the recording of observation results, such as certain navigation systems, may omit implementation of the PS_Session class.

Positioning-result information is segregated from configuration information to avoid excessive repetition of the configuration when the positioning service reports numerous observations. Similarly, quality-result information is segregated at the same level as positioning results, so that numerous quality reports of the same type, evaluated by the same procedure, can be reported without repetition of the element identification and evaluation procedure citation.

Quality results are associated directly with positioning observation results and are held in the qualityResult attribute of the PS_Observation class.

The reliability model, PS_ReliabilityTable, consists of a dictionary which contains reliability values and a definition of those values for retrieving information about the reliability of the positioning results.

6.3 Basic and extended information from a positioning service

As specified in Table 4 and Figure 3, basic information from a positioning service includes the following:

— system information (PS_System),

— session information (PS_Session),

— mode of operation (PS_ObservationMode),

— observation information (PS_Observation),

— observation quality information (PS_QualityMode), and

— reliability information (PS_ReliabilityTable).

A dataset that conforms to this document will include sufficient information for a user to know how these relate to a common frame of reference specified by the referencing method and the referencing system.

EXAMPLE A coordinate reference system will include the reference frame (datum), the units of measure, map projection information, etc.

Table 4 — Static data structures of a positioning service

Conformance levels	Classes	Class properties
Basic information (all technologies: see Clauses 7 and 8)	System information PS_System (Table 5)	System capabilities Referencing method Instrument identification
	Session information PS_Session (Table 10)	Session identification Dataset initiative Observer identification
	Mode of operation PS_ObservationMode (Table 11)	Coordinate reference system Link to reference system Coordinate operations applied
	PS_QualityMode (Table 18)	Quality evaluation method and quality result type
	Observation PS_Observation (Table 14)	Observation date time Result Object ID Offset
	PS_ObservationQuality	Quality result
	Reliability information	Category
	PS_ReliabilityTable (Table 20)	Weighting
	PS_ReliabilityValue (Table 21)	Value Description

Table 4 *(continued)*

Conformance levels	Classes	Class properties
Extended information (technology specific, see Clause 9)	Positioning technology PS_OperatingConditions (Table 23)	Operating conditions Measurement Conditions Performance indicators Solution vector Raw measurement

Positioning services can employ various technologies. Thus, when the getObservation operation (7.6.2) returns the PS_Observation class, it can contain technology-specific information in the operatingConditions attribute.

EXAMPLE When GNSS is used for positioning, information like the dilution of precision (DOP) values, satellite selection, and performance indicators is provided.

7 Basic information definition and description

7.1 Overview

A positioning system is defined as a system of instrumental and computational components for determining position. There are a number of types of positioning systems, each based on various instruments and components, using different methods to determine position. Satellite positioning is a well-known system based upon the receipt of signals, broadcast from satellites, by instruments on or near the Earth's surface. BDS, Galileo, GLONASS, GPS, NAVIC, and QZSS are some examples of satellite positioning system platforms. An optical positioning system is another common type of positioning system that determines the position of an object by means of the properties of light. A total-station, a commonly used term, is an integrated optical positioning system incorporating an electronic theodolite and an electronic distance-measuring instrument into a single optical positioning system. Measuring linear distance from a reference point along a route, using an odometer, is an example of a linear positioning system. A positioning system that uses accelerometers, gyroscopes and computers as integral components to determine coordinates of points or objects relative to an initial known reference point is referred to as an inertial positioning system. It is also common that various positioning systems can use two or more positioning technologies. Such systems are referred to as integrated positioning systems.

Basic information provided by positioning services is structured into four main elements:

a) system information — identifying the system type and capabilities (7.2);

b) session information — identifying the specific instrument, mission and session (7.3);

c) observation information — containing configuration and result values (7.4);

d) quality information — containing a quality evaluation method (7.5).

In addition to the four main elements, a set of operations and a reliability class are also defined:

e) operations — containing positioning services operations (7.6);

f) reliability of positioning results — reliability value of the returned position (8).

The location of an object at an instant of time is completely specified by two groups of dimensions:

— a three-dimensional position vector, and

— a three-dimensional orientation (attitude) vector.

Similarly, the rate of change in location of that object over time is specified by:

— a three-dimensional motion (velocity) vector, and

— a three-dimensional rotation (angular velocity) vector.

A positioning service may provide values for all or a subset of these four groups of dimensions, as four types of observations.

The observation information element provides structures for positioning results in these four types of observations and the associated ancillary information needed by a user to interpret them unambiguously. This associated information includes the reference system, link to the reference frame, and the observation quality element report of quality parameters.

7.2 System information

7.2.1 Overview

The system information data element (PS_System) identifies the positioning data source, the type of technology applied, and its capabilities.

The capability attribute (PS_System.capability) may be queried to determine what data types are available according to the System Capability codes. This allows a user to request and interpret position observations of the appropriate types.

The positioning-technology attribute (PS_System.positioningTechnology) may be queried so that the user can apply interpretive techniques appropriate to that technology.

EXAMPLE 1 The accuracy of GNSS receivers is affected by reflected radio signals (multipath), whereas inertial systems are unaffected because they do not employ radio reception. However, the accuracy of inertial systems degrades over time after initialization due to gyroscope drift, whereas GNSS systems are not subject to this type of drift. Therefore, a user should know which type of technology is employed in order to know what kinds of errors to expect.

The referencing method attribute (PS_System.referencingMethod) identifies the generalized method by which the positioning service represents a position. Results from PS_System.referencingMethod are available for interpretation by the user.

EXAMPLE 2 The location of a road intersection can be specified by a pair of coordinates in a coordinate reference system, or by a route number and distance in a linear referencing system. Though these refer to the same place by means of a pair of numbers, the means of interpretation of these numbers is fundamentally different.

The instrument-identification class (PS_InstrumentID) provides details about the equipment employed by the positioning service to obtain positioning results and may be used to create metadata regarding the origin of a dataset or be used by software to adjust model and version specific details of operation.

The instrument-identification data may be iterated to identify as many components of the system as needed.

UML models for both the PS_System and PS_InstrumentID classes and their attributes are shown in Figure 4.

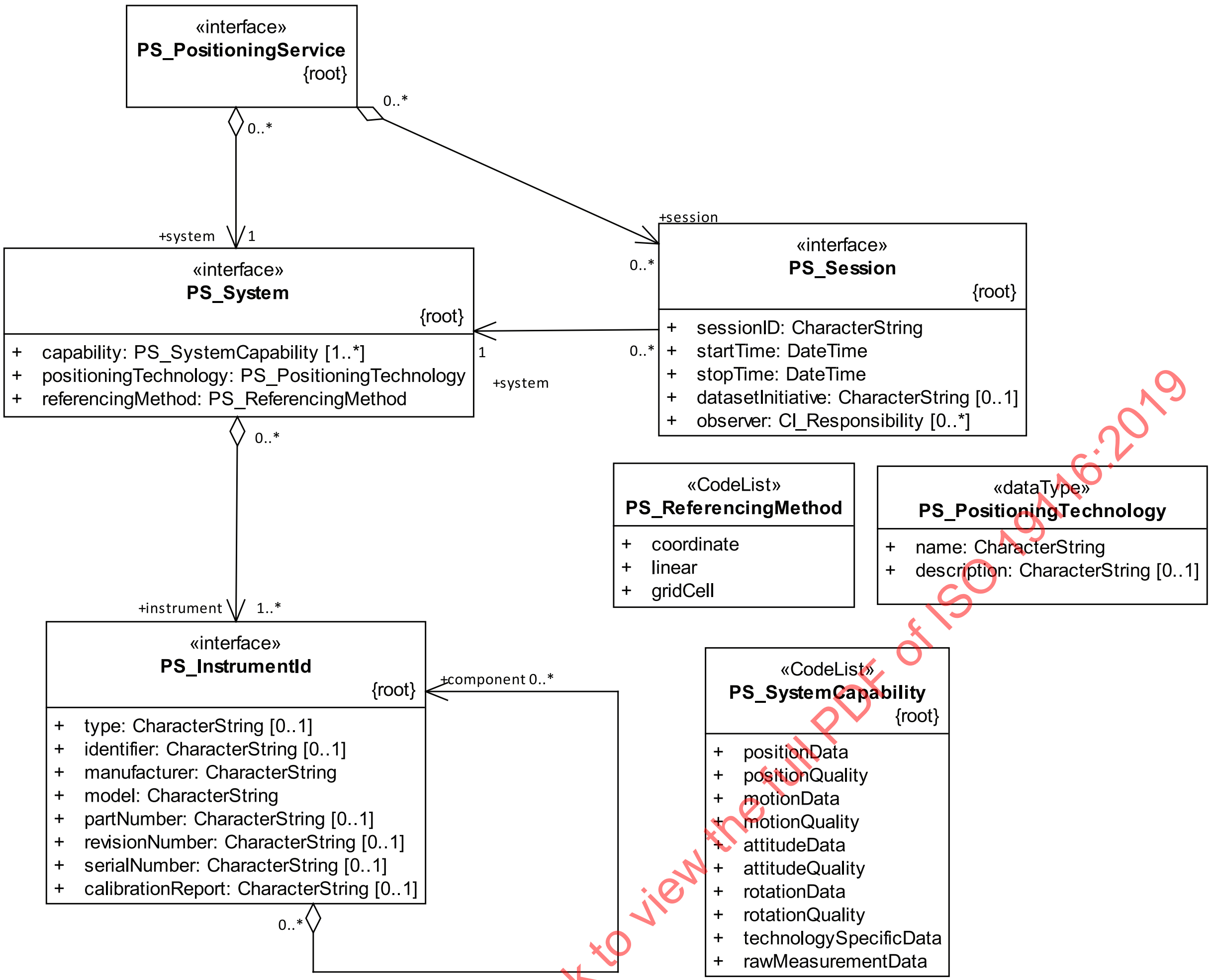

Figure 4 — UML diagram — PS_System and PS_InstrumentId classes

7.2.2 PS_System

Attributes and associations for the PS_System class are shown in Table 5.

Table 5 — PS_System

Class name	PS_System
Attributes	**Descriptions**
capability[1..*]	PS_SystemCapability — code(s) identifying capabilities
positioningTechnology	PS_PositioningTechnology — name of the positioning technology and its description
referencingMethod	PS_ReferencingMethod — code identifying referencing method
Associations	**Descriptions**
instrument[1..*]	to make positioning observations, a positioning system employs an instrument that is characterized by information in the PS_InstrumentID class.

7.2.3 System capability

System capability indicates whether specific data elements are provided by the realized-positioning service. Each code specifies the availability of a data element or sub-element. There is no limit to the number of instances of system capability codes that are required to represent all the capabilities of the realized system.

PS_SystemCapability is a list of codes by which the capabilities of a positioning service are identified and is shown in Table 6.

Table 6 — PS_SystemCapability codelist

Class name	PS_SystemCapability
Codes	**Descriptions**
positionData	the service is capable of providing position data
positionQuality	the service is capable of providing position-quality data
motionData	the service is capable of providing motion data
motionQuality	the service is capable of providing motion-quality data
attitudeData	the service is capable of providing attitude data
attitudeQuality	the service is capable of providing attitude-quality data
rotationData	the service is capable of providing rotation data
rotationQuality	the service is capable of providing rotation-quality data
technologySpecificData	the service is capable of providing technology-specific data
rawMeasurementData	the service is capable of providing raw-measurement data

7.2.4 Positioning technology

The characteristics of capabilities and the behaviour of various positioning technologies may differ from each other, therefore users of those positioning results require knowledge about the different technologies employed.

EXAMPLE GNSS reception is degraded or blocked when the system is operated inside buildings or tunnels, but inertial systems can operate continuously in such environments, yet inertial systems require initialization at known points whereas GNSS does not. Similarly, the accuracy characteristics of GNSS positioning instruments depend upon factors different from those of inertial systems, and from those of hyperbolic radio location systems, such as LORAN-C.

The following class, PS_PositioningTechnology, shown in Table 7, is used to identify the positioning technology employed by a positioning service:

Table 7 — PS_PositioningTechnology

Class name	PS_PositioningTechnology
Attributes	**Descriptions**
name	*CharacterString* — Identification of the positioning technology
description[0..1]	*CharacterString* — Additional information to describe the positioning technology when the technology is not well-known.

7.2.5 Referencing method

Knowledge of the referencing method employed by a positioning system is essential to interpretation of the positioning results. Though many practical positioning systems employ spatial referencing by coordinates, other referencing methods are also available.

EXAMPLE Linear referencing is widely applied in transportation as route-distance (kilometre post or milepost) pairs. The linear reference to a point in a transportation network is as unambiguous as a coordinate and can be more appropriate for particular uses. In such cases, positioning systems operating with a linear referencing method can be employed.

As technology evolves, additional referencing methods may be implemented, requiring new referencing method codes.

The following codes, shown in Table 8, are used to identify which basic referencing method is used by a positioning service.

Table 8 — PS_ReferencingMethod codelist

Class name	PS_ReferencingMethod
Codes	**Descriptions**
coordinate	Coordinate Referencing
linear	Linear Referencing
gridCell	Alphanumeric Locator Grid

Annex F provides examples of categories of positioning results. The user can extend the PS_ReferencingMethod codelist and positioning service to obtain a category of a positioning result as shown in Annex F.

7.2.6 Instrument identification

Identification of the specific positioning service instrument in use is required so that the measurements can be traced to their origin, and that information related to the characteristics of the device (or version of the device) can be applied by the position-using system. Many positioning systems employ a receptive device such as a GNSS antenna for which the particular type is important in attaining accurate calibration of the system; therefore, the instrument identification may be repeated as necessary to identify the components.

To make positioning observations, a positioning system employs an instrument that is characterized by information in the PS_InstrumentID class. If the instrument has components requiring identification, this class may be repeated. Attributes and associations of the PS_IntrumentID class are shown in Table 9.

Table 9 — PS_InstrumentID

Class name	PS_InstrumentID
Attributes	**Descriptions**
type[0..1]	*CharacterString* — Instrument type
identifier[0..1]	*CharacterString* — Label or number assigned to the specific instrument
manufacturer	*CharacterString* — Instrument manufacturer
model	*CharacterString* — Model name, number, or product type identifier
partNumber[0..1]	*CharacterString* — Manufacturer's part number identifying the production version
revisionNumber[0..1]	*CharacterString* — Instrument version or revision identifier
serialNumber[0..1]	*CharacterString* — Instrument serial number
calibrationReport[0..1]	*CharacterString* — Calibration report regarding the instrument
Associations	**Descriptions**
component[0..*]	identifier for the instrumentation employed. PS_InstrumentID may be repeated to describe additional components

7.3 Session

7.3.1 Overview

Observations made by a positioning service may be aggregated into sessions, which may correspond to any time period of significance to the user.

The session information, depicted in Figure 5, includes an identifier, the starting and ending times, identification of the mission or task, and identification of the observer or other responsible party.

This information may be applied in populating metadata items regarding data source and legacy. Implementation of these data elements is optional.

EXAMPLE The time period in PS_Session (startTime, stopTime) refers to examples such as a data collection session to populate GIS themes, a navigation session between an origin and destination, or hourly, daily, or other observation files recorded as units of information.

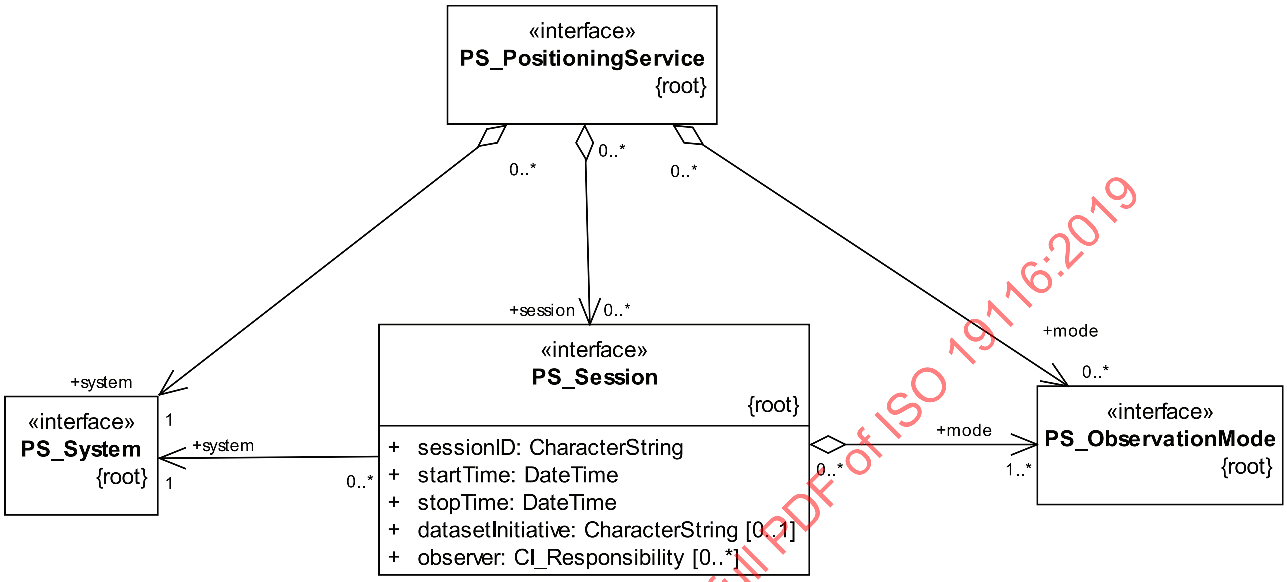

Figure 5 — UML diagram — PS_Session class

7.3.2 PS_Session

The PS_Session class identifies an observation session and aggregates observations made within that session with their associated system information and mode(s) of operation. The attributes and associations for the PS_Session class are shown in Table 10.

Table 10 — PS_Session

Class name	PS_Session
Attributes	**Descriptions**
sessionID	*CharacterString* — Identifies the session by number, name, or another identifier
startTime	*DateTime* — Date and time session was initiated
stopTime	*DateTime* — Date and time session terminated
datasetInitiative[0..1]	*CharacterString* — Identifies the agency, task, or mission
observer[0..*]	*CI_Responsibility* — Identifies observer, operator, manager or similar party responsible for session
Associations	**Descriptions**
system	Holds the characteristics of the positioning system employed to conduct that session
mode[1..*]	Holds the characteristics of the mode(s) of operation applied to conduct that session and aggregates to each mode the corresponding observations

7.4 Observation information

7.4.1 Overview

Positioning observations can be expressed in numerous ways, e.g. using various datums, map projections, units of measure. The mode of the operation class specifies the way in which a particular set of observations is expressed and includes:

— name of mode;

— type of measurement;

— spatial coordinate reference system;

— temporal coordinate reference system;

— links through which the positioning service accesses the reference systems(s);

— coordinate operation(s) (coordinate transformation and/or conversion operation) applied to the measurements.

Information about the mode of operation includes all pertinent details about the representation of results so that they can be interpreted without ambiguity.

EXAMPLE 1 If an observation result presented the numbers 45.75 and -108.5 without explanation, the user does not know whether they were coordinates in degrees of latitude and longitude, metres on a local coordinate grid, or speed and heading in metres/second and degrees from true north. If the numbers in this example were coordinates, the coordinate reference system upon which they were cast would have to be known.

Information contained in the PS_ObservationMode class specifies this information, so that a user is not faced with ambiguity in the interpretation of positioning results. Information in the PS_ObservationMode class may be used both in real-time applications and as the basis for metadata to be stored with datasets acquired by use of the positioning service.

NOTE Although this document does not specify how often a system should supply the positioning service data elements, it is likely that many systems will transmit mode data early in a session to establish metadata for the session to prepare the user to interpret the positioning data stream. Numerous transactions of positioning observations and (optional) quality results then can proceed as needed for the application.

Each mode of operation may optionally be given a name to facilitate reference to the entire set of configuration values.

Req. 1	/req/ps_system/op-measurement-details All measurement types, including position, orientation (attitude), motion (velocity) or rotation (angular velocity), for each operating mode of a positioning instrument shall be identified.

As mentioned above, observation results cannot be interpreted without knowledge of their respective reference system(s), therefore identification of the temporal reference system and the spatial reference system are mandatory.

Information detailing the links through which the positioning service accesses its reference systems may optionally be provided. Such information is often needed when high accuracy is sought or when a user requires traceability of the measurement's results or accuracy report.

Identification of the (concatenated) coordinate operations applied in producing the positioning results may optionally also be provided. This information is often required in geodetic measurements when high accuracy is required.

Req. 2	/req/ps_observationmode/mode-of-operation Positioning services reporting several types of measurements simultaneously shall instantiate a mode of operation for each type of measurement.

The axes and units of measure for the various measurement types may differ from each other.

EXAMPLE 2 Position can be reported in degrees of latitude and longitude and height, while motion can be reported as speed in meters per second on a heading expressed in degrees from north.

7.4.2 PS_ObservationMode

The PS_ObservationMode class, shown in Figure 6, holds information about the configuration of a positioning service to provide a particular type of positioning result. The positioning service may create as many PS_ObservationMode instances as needed to provide the various types of results requested by its user.

Req. 3	/req/ps_observationmode/config-info One PS_ObservationMode instance shall hold each set of configuration information, whether several types of results, such as position, motion and orientation are presented simultaneously, or one type of result is presented in several different reference systems.

EXAMPLE 1 Positioning results presented in several different reference systems, such as position reported in geodetic latitude and longitude, and as metres in a projected coordinate reference system, is one type of output from PS_ObservationMode.

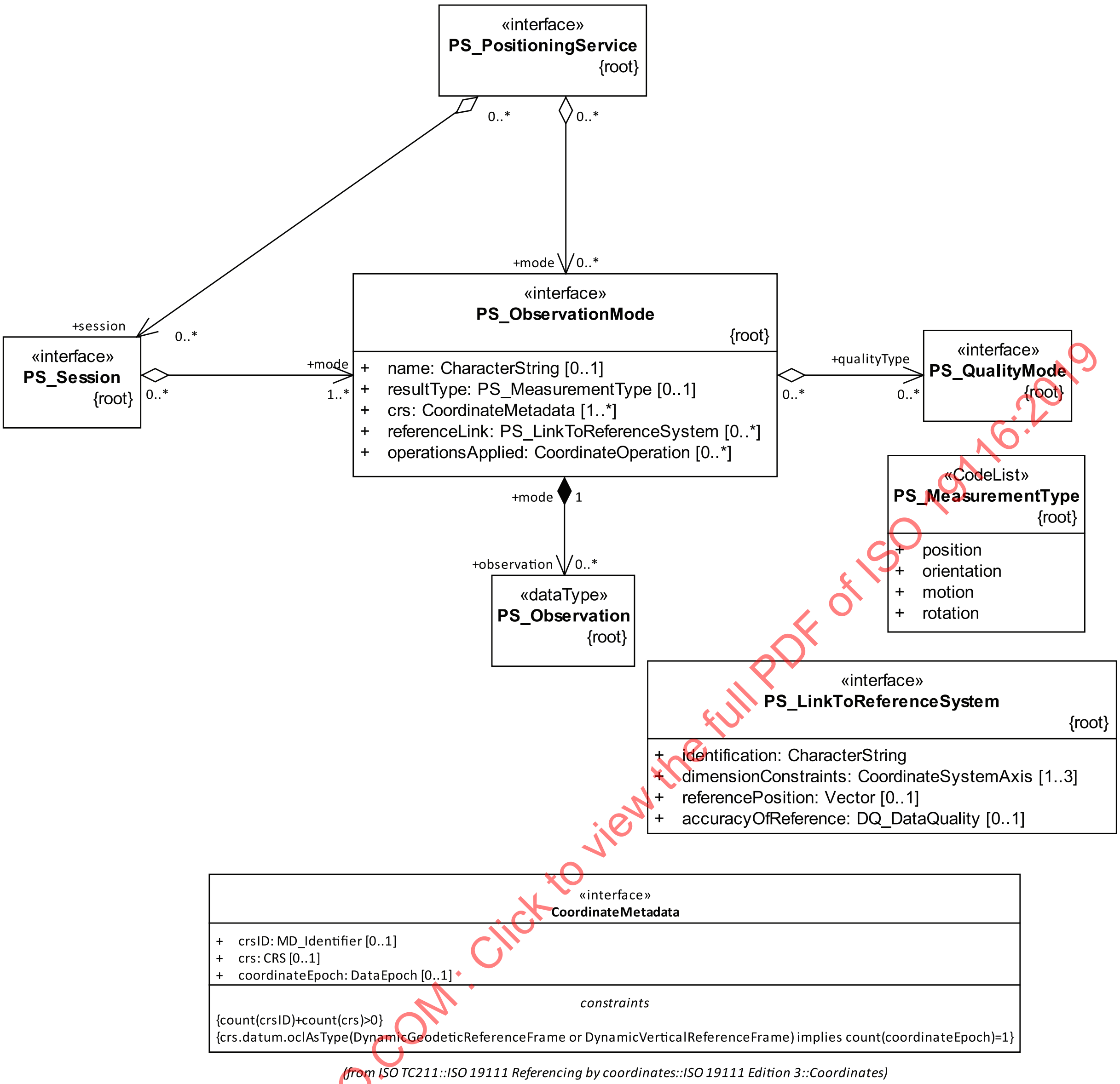

Figure 6 — UML diagram — PS_ObservationMode class and related data types

Table 11 shows the attributes and associations for the PS_ObservationMode class.

Table 11 — PS_ObservationMode

Class name	PS_ObservationMode
Attributes	**Descriptions**
name[0..1]	*CharacterString* — Word or phrase identifying the mode of operation
resultType[0..1]	*PS_MeasurementType* — Code identifying the type of measurement made in this mode. Measurement types are position, motion, orientation and rotation
crs[1..*]	*CoordinateMetadata* — Spatial, temporal, or spatio-temporal coordinate reference system in use
referenceLink[0..*]	*PS_LinkToReferenceSystem* — Identifies links through which a positioning service accesses the reference system(s) (positional or temporal)
operationsApplied[0..*]	*CoordinateOperation* — Coordinate operations (Coordinate transformations and/or conversions) applied
Associations	**Descriptions**
qualityType[0..*]	A positioning service may provide quality information regarding its positioning observations. That quality information can be used to decide upon the fitness of the observation result for certain uses.
observation[0..*]	Any number of observations may be made in a particular mode of operation, but a PS_Observation will be ambiguous unless associated with a PS_ObservationMode.

Temporal coordinate reference systems are accessed through some type of reference clock which can be well coordinated, such as that of the GNSS satellites or of the UTC broadcasting beacons, or only approximate, such as the internal clock in a computer system. The accuracy of the results depends upon this linkage.

The coordinate reference systems used for a positioning service as specified in this document refer to classes defined in ISO 19111.

Req. 4	/req/ps_observationmode/reference-systems The temporal coordinate reference systems and spatial coordinate reference systems shall be described in accordance with ISO 19111, and its identifier shall enable users to reach the detailed information of these coordinate reference systems.
Req. 5	/req/ps_observationmode/ref-system-type The type of the spatial coordinate reference system used for this positioning service is specified with the attribute resultType. When the value of resultType is orientation, motion, or rotation the EngineeringCRS defined in ISO 19111 shall be used to describe this spatial coordinate reference system.

In any realization of a positioning service, there are one or more links through which the positioning service accesses the spatial and temporal coordinate reference systems. These may be survey-control monuments, a set of GNSS ground stations from which a predicted ephemeris is derived, a differential-correction beacon, or the initialization point of an inertial navigation system.

When traceability or high accuracy of the result is needed, the user may require recording of the link(s) to the reference system.

Often, when a positioning service is required to present results in a reference system different from its internal computational reference system, coordinate transformations are applied. These coordinate transformations may have inherent inaccuracies, and when traceability or high accuracy is required, a record of the operations applied may be needed.

Coordinate transformations are an operation that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system in which the source and target coordinate reference systems are based on different datums.

The CoordinateOperation class defined in ISO 19111 specifies the identification of these operations.

Req. 6	/req/ps_observationmode/quality-status If quality information is reported by the positioning service regarding its positioning results, the PS_QualityMode shall be associated with the PS_ObservationMode, so that quality results associated with positioning results are properly characterized as to the quality element type, sub-element type, and evaluation descriptor.

Req. 7	/req/ps_observationmode/multiplicity Zero to many instances of PS_Observation aggregate to each PS_ObservationMode. A PS_ObservationMode shall be instantiated prior to making observations; therefore, a PS_ObservationMode can exist with no observations.

7.4.3 PS_LinkToReferenceSystem

PS_LinkToReferenceSystem identifies a link through which a positioning service accesses the reference system. Table 12 shows the attributes for the PS_LinkToReferenceSystem class.

Table 12 — PS_LinkToReferenceSystem

Class name	PS_LinkToReferenceSystem
Attributes	**Descriptions**
identification	*CharacterString* — identifier of reference link point, such as a reference station of a differential GNSS broadcast service
dimensionConstraints[1..3]	*CoordinateSystemAxis* — axis (e.g. latitude, longitude, and height) for which values are held as good
referencePosition[0..1]	*Vector* — coordinates of the point that accesses the reference system
accuracyOfReference[0..1]	*DQ_DataQuality* — accuracy of the reference coordinates in their specified reference system

7.4.4 PS_MeasurementType

Class PS_MeasurementType is a list of codes to identify the types of measurements provided by a positioning service and is shown in Table 13. These measurements are specific to a particular CRS.

Table 13 — PS_MeasurementType codelist

Class name	PS_MeasurementType
Codes	**Descriptions**
position	this mode of operation reports position
orientation	this mode of operation reports orientation
motion	this mode of operation reports motion
rotation	this mode of operation reports rotation

7.4.5 Observation

Results of positioning observations are reported in the PS_Observation class, of which, as shown in Figure 7, instances are aggregated under instances of PS_ObservationMode that hold descriptors of the mode of operation that are common to all the observations in that set.

The PS_Observation attributes includes the date and time of the positioning observation and the result vector in accordance with the reference system specified in the related PS_ObservationMode. Additional information about the observation is held in this class, including the identification of an object to which it applies, any offset between the positioning sensor and an object of interest, and any pertaining technology-specific operating information. Quality information associated with each observation can be reported as an attribute of each observation, which is specified in 7.5.

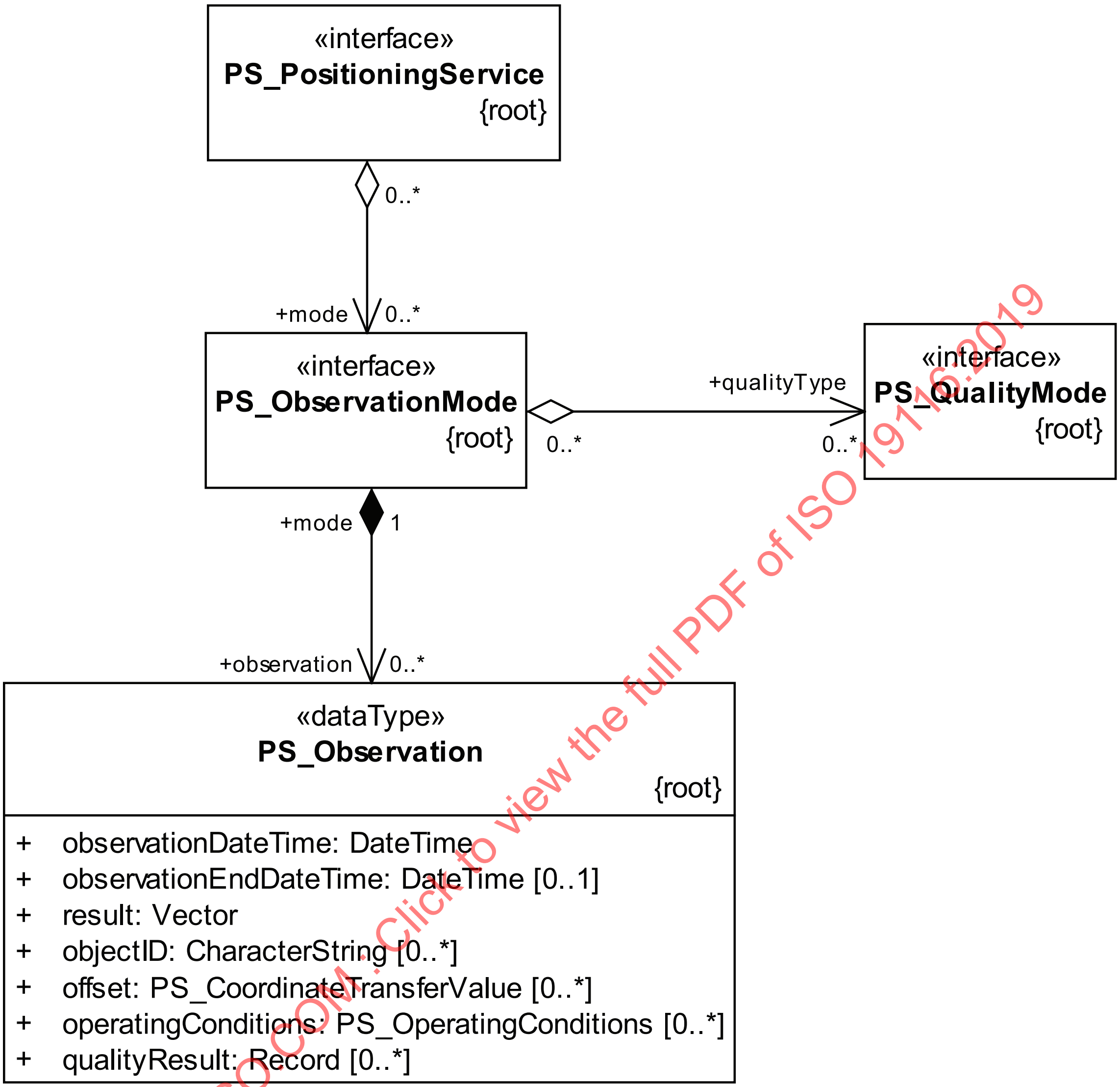

Figure 7 — UML diagram — PS_Observation class

The objectID identifier provides a means to link the position data to other geographic object attributes, such as a navigational waypoint, a geographic feature, a control point, or an aerial photographic exposure station. The presence of this identifier is optional because many positioning instruments in current use, including many GNSS receivers, do not provide an identifier for each position fix for navigation purposes. However, one or more such identifiers may be employed in surveying and GIS development.

Implementations may employ a single objectID that serves as an index or key that relates to a table of other descriptors, or multiple objectIDs may be employed as indices or keys that relate to multiple tables of descriptors.

EXAMPLE The first objectID instance could be used to enumerate the observed locations, and a second objectID instance could be used to identify sequences or groups of observations, such as groups of points that collectively represent the centrelines of segments of roadway.

Req. 8	/req/ps_observation/result-vector When the results from a positioning service are reported as a relative positioning vector, the objectID shall identify the vector's endpoint, and the PS_ObservationMode referenceLink shall identify the vector's origin point.

Examples of positioning services results in the form of a relative positioning vector are:

— GNSS static;

— kinematic;

— real-time kinematic relative positioning.

Req. 9	/req/ps_observation/result-temporal When the results from a positioning service are computed over an observation interval rather than estimating an instantaneous position, the observationDateTime shall state the date and time at which observations used in this result were commenced and the observationEndDateTime shall state the date and time at which observations included in this result were terminated.

Attributes and associations for the PS_Observation class are shown in Table 14.

Table 14 — PS_Observation

Class name	PS_Observation
Attributes	**Descriptions**
observationDateTime	*DateTime* — Date and time the observation(s) were made (or commenced)
observationEndDateTime[0..1]	*DateTime* — Date and time measurements were concluded (if not instantaneous)
result	*Vector* — Vector containing the result values
objectID[0..*]	*CharacterString* — Identifying an associated object or event
offset[0..*]	*PS_CoordinateTransferValue* — Values relating the result to an associated object
operatingConditions[0..*]	*PS_OperatingConditions* — Technology specific operating conditions data
qualityResult [0..*]	*Record* — A container for the quality result, described in PS_QualityMode

7.4.6 Coordinate transfer (offset) values

Position measurement, as illustrated in Figure 8, can be made to a location that is offset from an object of interest, Figure 8 a), or the actual point, Figure 8 b), due to requirements of the positioning service sensor equipment or for convenience of operation. In such cases, provision is made for transfer of coordinates from the measured point to the desired point through the PS_CoordinateTransferValue class, depicted in Figure 9. This offset may be the difference in location between the GPS L1 phase centre of the antenna and a mounting reference point used in high accuracy geodetic measurements.

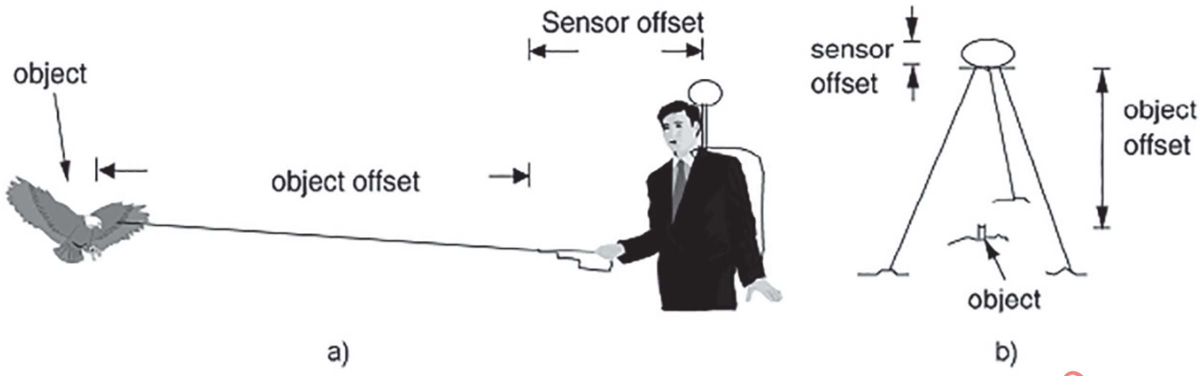

Figure 8 — Sensor and object offsets

When the offset between the sensor position and the point of interest is important, the user needs to acquire and store the values involved. These values consist of the sensor offset and the object offset. The sensor offset values are used to store any offset between the actual point of measurement, such as the phase centre of a GNSS antenna, and a reference point representing the measurement system or platform.

EXAMPLE Several bodies publish antenna-offset values for many manufacturers' GNSS antenna models. The object-offset values then are used to store any offset between that reference point and the object of interest (i.e. a geographic feature). These object offsets could be the antenna height above a mark or could be the offset to a distant object measured by a laser rangefinder and compass.

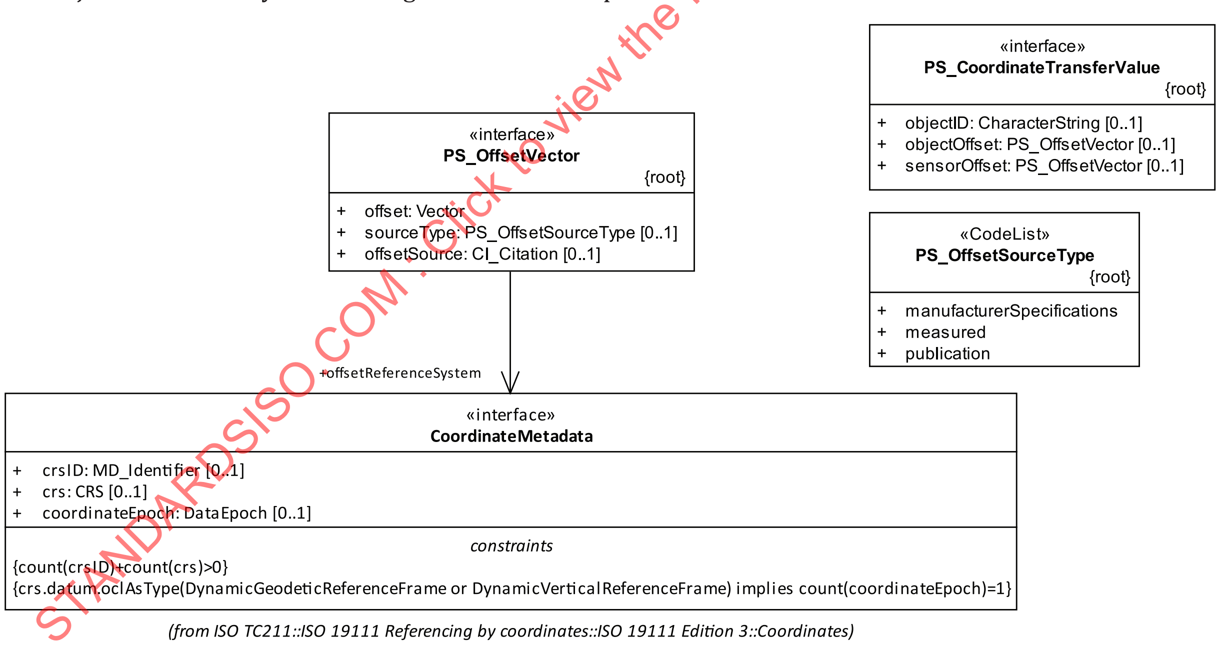

Figure 9 — UML diagram — PS_CoordinateTransferValues class

Values that specify the spatial relationships by which coordinates are transferred from the sensor location to the location of the point or object of interest are conveyed by the PS_CoordinateTransferValue class. This consists of offset between the sensing element and a fiducial point on the instrumentation, and from that fiducial point to an object of interest.

Attributes and associations for the PS_CoordinateTransferValues class are shown in Table 15.

Table 15 — PS_CoordinateTransferValues

Class name	PS_CoordinateTransferValues
Attributes	**Descriptions**
objectID[0..1]	*CharacterString* — Identifier of the object of interest
objectOffset[0..1]	*PS_OffsetVector* — Offset from a fiducial point on the instrument to a point or object of interest
sensorOffset[0..1]	*PS_OffsetVector* — Offset from a fiducial point to the sensing point of the instrument

7.4.7 Offset vector

Table 16 shows the attributes and associations for the PS_OffsetVector class.

Table 16 — PS_OffsetVector

Class name	PS_OffsetVector
Attributes	**Descriptions**
offset	*Vector* — Vector holding the offset value(s)
sourceType[0..1]	*PS_OffsetSourceType* — Type of source from which the offset vector was obtained
offsetSource[0..1]	*CI_Citation* — Citation of source of the offset vector
Associations	**Descriptions**
offsetReferenceSystem	Spatial reference system in which the offset vector is cast This could or could not be identical to the reference system in which positioning results are cast due to the fact that some offset measurements are made separately from the primary positioning measurements.

EXAMPLE A positioning service using a GNSS sensor can have an offset between the phase centre of the receiving antenna and a fiducial mark by which the antenna is aligned. The service can be reporting coordinates in degrees of latitude and longitude, though the offset is measured in millimetres above/below the fiducial mark and its axis is aligned to the local vertical. Further, if a theodolite or laser range finder is employed to measure the offset to an object of interest, that instrument could report its measurement of distance in metres on an azimuth from true or magnetic north and an elevation angle from the local horizontal, leaving application of the offset in a geodetic forward calculation to the system.

7.4.8 PS_OffsetSourceType

PS_OffsetSourceType is a list of codes by which the type of source from which an offset vector has been obtained are identified and are shown in Table 17.

Table 17 — PS_OffsetSourceType codelist

Class name	PS_OffsetSource
Codes	**Descriptions**
manufacturerSpecifications	The values have been obtained from manufacturer's specifications.
measured	The values have been measured
publication	The values have been obtained from a publication other than the manufacturer's specifications.

7.5 Quality information

7.5.1 Overview

A positioning service may (optionally) provide quality information regarding its positioning observations, as illustrated in Figure 10. That quality information can be used to decide upon the fitness of the observation result for certain uses.

EXAMPLE 1 Quality information, depending upon the fitness of the observation result could be used in land surveying or in populating a GIS with geographic features if their accuracy meets the specifications of the project. Observation-quality information can also be carried with the data to use in quality evaluations of larger datasets.

Positioning services generally report positioning observations in real time or near real time, therefore quality evaluation differs somewhat from that pertaining to GIS themes or similar spatial datasets. Quality evaluation may be performed on each observation, or on observations in small reporting groups acquired over brief intervals. Therefore, many quality measures may be computed using the same evaluation procedure and reported during a session.

Measured values are considered to have some amount of uncertainty contained in them, and, therefore, repetitions of the measurement will yield values dispersed over some range. A statement of uncertainty asserts that the value provided is not exact and attempts to express that inexactness quantitatively. The magnitude of the uncertainty of a result is one of the most important aspects of its quality.

Generally, uncertainty cannot be determined directly, but must be estimated by appropriate quality evaluation procedures. Estimates of uncertainty can be based on statistical methods, previous experience with the system or professional judgement considering knowledge of measuring methods, field conditions, equipment capabilities, computational methods, and geometric characteristics among others.

Req. 10	/req/ps_qualitymode/quality-eval-system The means for quality evaluation shall be characterized in accordance with the specifications of ISO 19157 when quality measures and associated with positioning results.

When an uncertainty estimation is made with respect to values that can best be accepted as approximating truth, the uncertainty expression is termed “*absolute accuracy*” or “*external accuracy*”.

When an uncertainty estimation is made with respect to values best approximating the closeness of the relative positions of features in a data set to their respective relative positions accepted as or being true, the uncertainty expression is termed “*relative accuracy*” or "*internal accuracy*".

When an uncertainty estimation is made with respect to the consistency of repeated measurements, made under similar conditions, with each other but without comparison to independent values acceptable as approximations of truth, the uncertainty expression is termed "*measurement precision*" or “*precision*”.

Ideally, the accuracy of positioning observations would be reported by stating an estimated value for the residual uncertainty, but this is not always feasible within the positioning service itself. Often there is no real-time access to an independent source of higher accuracy values for comparison.

Annex B presents informative examples for implementing accuracy reports for positioning services.

In such cases, though, it may be possible to estimate observation precision, e.g. the repeatability of measurements, rather than to estimate the actual accuracy. For this reason, an additional quality sub-element, precision, is defined for positioning services. Additional quality sub-elements may also be user-defined in accordance with ISO 19157 for use in positioning services implementations.

To avoid repetition of information, the PS_QualityMode class is associated with the PS_ObservationMode so that when the configuration information for a mode of operation is specified, the corresponding quality reporting configuration can be associated with it. This allows the positioning observations made in a particular mode of operation to be associated with quality measures made by a particular evaluation procedure without ambiguity.

The evaluation descriptor is held in the PS_QualityMode class.

Data-quality results can be quantitative results or conformance results, and both kinds are applicable to positioning observations.

EXAMPLE 2 Accuracy and precision values are quantitative results, however coded performance indicators and system integrity monitors are conformance results.

Due to the complexity of positioning calculations it is important that positioning services clearly specify the evaluation procedure by which quality results are obtained. This includes specifying whether the quality pertains to horizontal, vertical or three-dimensional errors. When three-dimensional values are reported, distinguish whether each of the three dimensions has either a separate quality value or a single value that is reported by a spherical quality estimator. It is necessary to state the nature of the statistical quantity utilized, such as mean error, probable (median) error, or standard (RMS) error, and whether the statistic itself is based upon a one-, two- or three-dimensional distribution function. It is also essential to clearly identify the source of comparison values in making accuracy or precision evaluations.

Positioning services may make quality evaluations based on internal evidence, such as comparison of closely spaced repeat measurements, signal characteristics, and geometric factors, or computations involving overdetermined observables. In such cases, precision, or some user-defined sub-elements, will be more appropriate quality measures than accuracy.

In addition to the quality information defined here, this document extends the original positioning service model specified in the first edition of ISO 19116 by adding new operations, specified in Clause 8, to determine the positional reliability of the positioning results. The term "*Positional reliability*" is defined as a degree to which a positioning service provides agreed or expected positional absolute accuracy during a defined instant under specified conditions.

When neither independent sources of comparison nor internal evidence is available, positioning services may report quality information based upon typical performance under similar circumstances. In such cases, the basis of such reporting and the nature of validation testing should be explicitly stated.

Implementations of positioning services may provide substantial portions of the evaluation procedure information in the product documentation accompanying the system and convey the reference to that documentation in the quality data structures by citation.

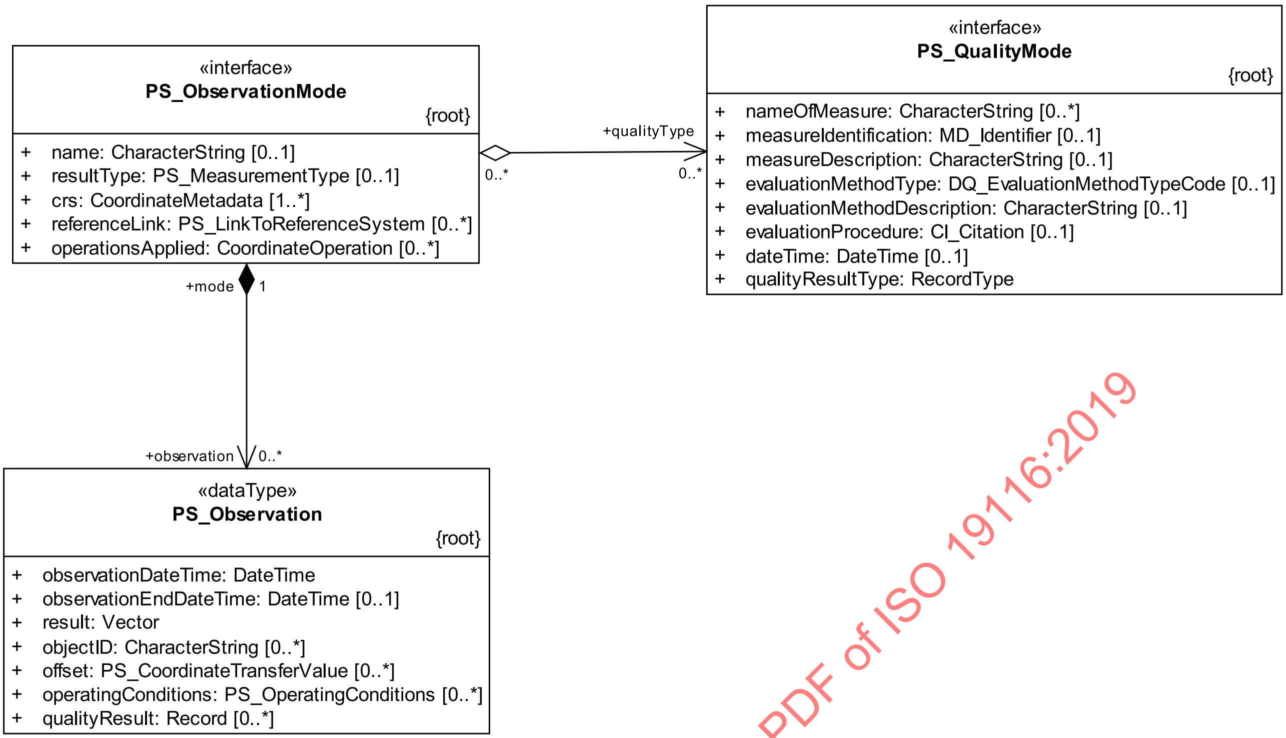

Figure 10 — UML diagram — Positioning services quality reporting classes

7.5.2 PS_QualityMode

PS_QualityMode holds attributes that are similar to those of DQ_Element described in ISO 19157, and identifies the data-quality element to be reported and the evaluation procedure by which it is evaluated. This information is expected to be employed in generation of the DQ_Element metadata or similar reports or for automated decision processes requiring quality information about the observation results. Attributes and associations for the PS_QualityMode class are shown in Table 18.

Table 18 — PS_QualityMode

Class name	PS_QualityMode
Attributes	**Descriptions**
nameOfMeasure[0..*]	*CharacterString* — name of the test applied to the data
measureIdentification[0..1]	*MD_Identifier* — code identifying a registered standard procedure
measureDescription[0..1]	*CharacterString* — description of the measure being determined
evaluationMethodType[0..1]	*DQ_EvaluationMethodTypeCode* — type of method used to evaluate quality of the dataset
evaluationMethodDescription[0..1]	*CharacterString* — description of the evaluation method
evaluationProcedure[0..1]	*CI_Citation* — reference to the procedure information
dateTime[0..1]	*DateTime* — date or range of dates on which a data quality measure was applied
qualityResultType	*RecordType* — identifies elements in the corresponding quality result record(s)

7.6 Positioning services operations

7.6.1 Definition of positioning services operations

The operations of the positioning service interface, shown in Figure 11, create, set, get, and end (destroy) instances of these classes as needed to convey the configuration and observation information.

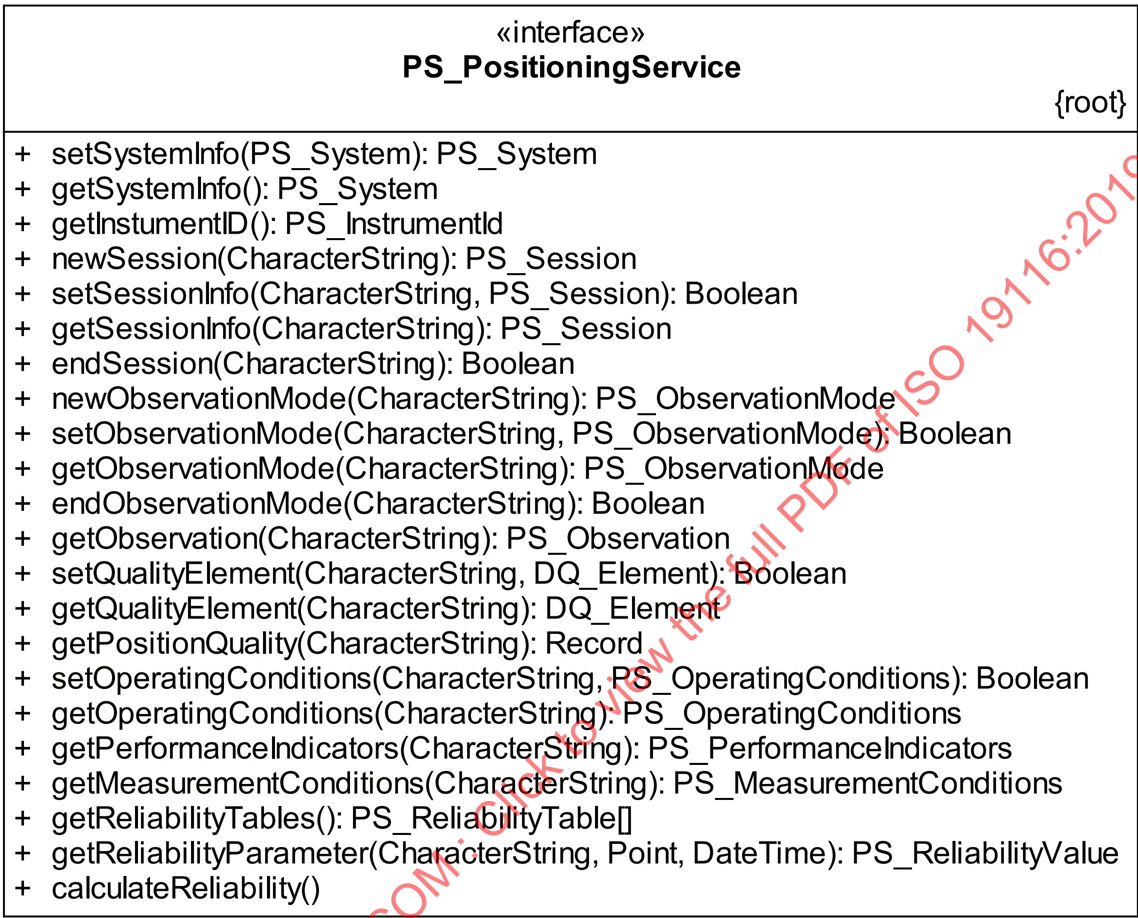

Figure 11 — UML diagram — Operations of positioning services

7.6.2 Requirements for positioning service operations

The following requirements for the PS_PositioningService operations are defined in Table 19 and are mandatory when implementing a positioning service.

Req. 11	req/ps_positioningservice/operations Implementations of a positioning service shall define the operations specified in Table 19.

Table 19 — PS_PositioningService operations

Operations	Descriptions
setSystemInfo(initialization)	will cause the positioning service to set current information regarding the description of the positioning service itself to values held in an argument 'initialization' that is of the PS_System class.
getSystemInfo()	will cause the positioning service to return a result object instance of the PS_System class with attribute values reflecting current information regarding the description of the positioning service itself.

Table 19 *(continued)*

Operations	Descriptions
getInstrumentID()	will cause the positioning service to return a result instance of the PS_InstrumentID class with attribute values reflecting current information regarding the identification of the instrumentation employed by the positioning service for the determination of positioning observations.
newSession(sessionID)	will cause the positioning service to create one instance of a data object of the PS_Session class populated with current values of parameters identifying an operating session of the service and set the current value of its sessionID attribute to the value contained in the argument 'sessionID', which is of the CharacterString type. The PS_Session instance, created by newSession(sessionID), aggregates one or more instances of objects of the PS_Operating mode class within it, and thereby aggregate one or more positioning observations and quality measures within each PS_OperatingMode object.
setSessionInfo(sessionID, sessionInfo)	will cause the positioning service to set current information describing an object of the PS_Session class, of which the sessionID attribute value matches the sessionID argument value, to the values contained in the sessionInfo argument, which is of the PS_Session class.
getSessionInfo(sessionID)	will cause the positioning service to get current information describing an object of the PS_Session class.
endSession(sessionID)	will cause the positioning service to disable aggregation of operating mode class objects to the instance of a PS_Session class object that has a sessionID attribute value matching the sessionID argument value of the operation and cause all instances of PS_ObservationMode objects within it to cease aggregating positioning observations and quality measures.
newObservationMode(name)	will cause the positioning service to create an instance of the PS_ObservationMode class and assign to its 'name' attribute the value of the 'name' argument of the operation, associate it with the currently active instance of the PS_Session class if such exists, and enable it to aggregate one or more PS_Observation objects and associate with zero or more PS_QualityMode objects with their quality records that are held in PS_Observation objects as qualityResult(s).
setObservationMode(name, desiredObservationMode)	will cause the positioning service to set operating mode parameters of the positioning instruments employed to the values contained in the desiredObservationMode argument so far as possible, and to set the values of the PS_ObservationMode attributes to reflect the operating mode achieved.
getObservationMode(name)	will cause the positioning service to return a result object of the PS_ObservationMode class with attributes holding the current values of the instance of PS_ObservationMode with a name attribute matching the value of the name argument.
endObservationMode(name)	will cause the positioning service to disable the instance of PS_ObservationMode with name attribute matching the value of the name argument from aggregating PS_Observation objects, from associating with PS_QualityMode objects, and destroy that instance of PS_ObservationMode.
getObservation (PS_ObservationMode.name)	will cause the positioning service to return a result object of the PS_Observation type with attributes reflecting the current position values including the dateTime of observation and the result vector. The observation may optionally have quality result(s) obtained by use of the getPositionQuality operation.
setQualityElement (PS_ObservationMode.Name, desiredQualityElement)	will cause the positioning service to create an instance of the PS_QualityMode class having attributes with the values contained in the desiredQualityElement argument and associate it with the PS_ObservationMode instance with a name attribute matching the PS_ObservationMode.name argument and to act upon the instruments and computational components of the positioning service to effect the performance of quality evaluations of the positioning observations in accordance with the desiredQualityElement argument.
getQualityElement (PS_ObservationMode.name)	will cause the positioning service to return a result object of the PS_QualityMode class with attributes reflecting the currently selected quality evaluation parameters associated with the PS_ObservationMode instance with a name attribute matching the value of the PS_ObservationMode.name argument.
getPositionQuality	will cause the positioning service to return a quality result record with attributes reflecting the results of quality evaluation performed upon the currently associated PS_Observation by the procedures specified in the PS_QualityMode instance associated with this PS_ObservationMode instance.

Table 19 *(continued)*

Operations	Descriptions
setOperatingConditions (instrumentName, desiredOperatingConditions)	will cause the positioning service to set user adjustable parameters of the instrument with a name matching the instrumentName argument to the values contained in the desiredOperatingCondtitions.
getOperatingConditions (instrumentName)	will cause the positioning service to return a result object of the PS_OperatingConditions class with attributes reflecting the current operating conditions of the instrument with a name matching the instrumentName argument.
getPerformanceIndicators (instrumentName)	will cause the positioning service to return a result object of the PS_PerformanceIndicators class with attributes reflecting the current performance indicators of the instrument with a name matching the instrumentName argument.
getMeasurementConditions (instrumentName)	will cause the positioning service to return a result object of the PS_MeasurementConditions class with attributes reflecting the current measurement conditions of the instrument with a name matching the instrumentName argument.
getReliabilityTables()	will cause the positioning service to return all PS_ReliabilityTable objects which are aggregated by the service through the role "reliabilityTable".
getReliabilityParameter (PS_ReliabilityTable.name, position, time)	will cause the positioning service to return an object of PS_ReliabilityValue which matches the specified position and time from the specified object of PS_ReliabilityTable. If a positioning service has more than one table, the parameter PS_ReliabilityTable.name is mandatory.
CalculateReliability()	will cause the positioning service to calculate positioning reliability using reliability parameters which are received through a getReliabilityParameter operation.
NOTE 1 Regarding getInstrumentID(): the identification of instrumentation is often used for traceability and authentication of results. Therefore, setting of identification parameters such as model and serial number is performed by the manufacturer or by authorized operators using means outside the scope of the positioning services interface defined in this document. NOTE 2 Regarding setOperatingConditions: technological and manufacturing considerations are outside the scope of this document and therefore not all technology-specific operating conditions are required to be adjustable by the user through the use of the setOperatingConditions operation. NOTE 3 Regarding getReliabilityParameter: "position:Point" can be calculated from "result: Vector", and “time:DateTime” can be calculated from “observationDateTime:DateTime” and “observationEndDateTime:DateTime”.	

7.6.3 Applying the positioning services operations

Naturally, one of the primary operations of a positioning service is getObservation, which returns an instance of the PS_Observation. Among the attributes of the PS_Observation class are the positioning result values, offsets, and object identification. The PS_Observation class may also be associated with one or more PS_ObservationQuality classes containing quality results.

Technology-specific data are reported in the operatingConditions attribute of the PS_Observation class. This document does not require that operations be performed in any specific sequence, because it is recognized that various implementations will perform these operations in sequences appropriate to various uses of the systems.

Req. 12	/req/ps_positioningservice/non-supported-request-response When operations are requested to getObservation in a sequence that is illogical or not supported by an implementation of a positioning service, the service shall respond with a null result without disruption of operation.

Positioning services do not directly provide the metadata structures specified in ISO 19115-1, but they provide data classes from which such standard metadata can readily be derived when needed.

Metadata supporting the interpretation of the position values are provided by the getSystemInfo operation and the getObservationMode operation, which return the PS_System and PS_ObservationMode classes, respectively. In the PS_System class are values that indicate the type of technology employed in the positioning instrumentation, how it represents position, and identifies the specific instruments employed. In the PS_ObservationMode class are the configuration parameters pertaining to the generation of particular types of positioning results, such as the temporal and spatial reference systems. Associated with the PS_ObservationMode may be PS_QualityMode instances holding quality evaluation and reporting configuration information.

Additional metadata supporting the citation of the source of position values are handled by the setSessionInfo and getSessionInfo operations, which employ the PS_Session class. In the PS_Session class are values that identify the agency, mission, and observers for which the position information is being obtained.

8 Reliability of positioning results

8.1 Overview

The reliability model, defined in 8.2, consists of a dictionary which contains reliability values and a definition of those values. The model also defines two operations for retrieving information about the reliability of the positioning results.

Examples for using the reliability model are presented in the following Annexes:

— Reliability evaluation methods and calculation of the degree of reliability of the position (Annex E);

— Examples for Extending Positioning Service Results, (Annex F).

8.2 Reliability model

A reliability model contains two operations, *getReliabilityTables()*, and *getReliabilityParameter(CharacterString, Point, DateTime)* which are defined for retrieving various information about the reliability of positioning results.

The operation *getReliabilityTables()* is an operation for retrieving the PS_ReliabilityTable.

Req. 13	/req/ps_positioningservice/reliability-table-presence A positioning service shall have at least one instance of PS_ReliabilityTable.

PS_ReliabilityTable is a dictionary of positioning reliability. It contains a list of reliability values, *PS_ReliabilityValue*.

In PS_ReliabilityValue, the attribute *value* specifies a reliability value and the attribute *definition* contains a definition of the reliability value.

Instances of PS_ReliabilityTable can be shared among multiple positioning services, therefore the association between PS_PositioningService and PS_ReliabilityTable is an aggregation having optional attributes *name* and *description*.

The operation *getReliabilityParameter(CharacterString, Point, DateTime)* retrieves the reliability of a specified location at a specified date and time.

Req. 14	/req/ps_reliabilitytable/get-reliability-value The returned value of *getReliabilityParameter(CharacterString, Point, DateTime)* shall coincide with the value defined in the referenced table.

The reliability model is shown below in Figure 12.

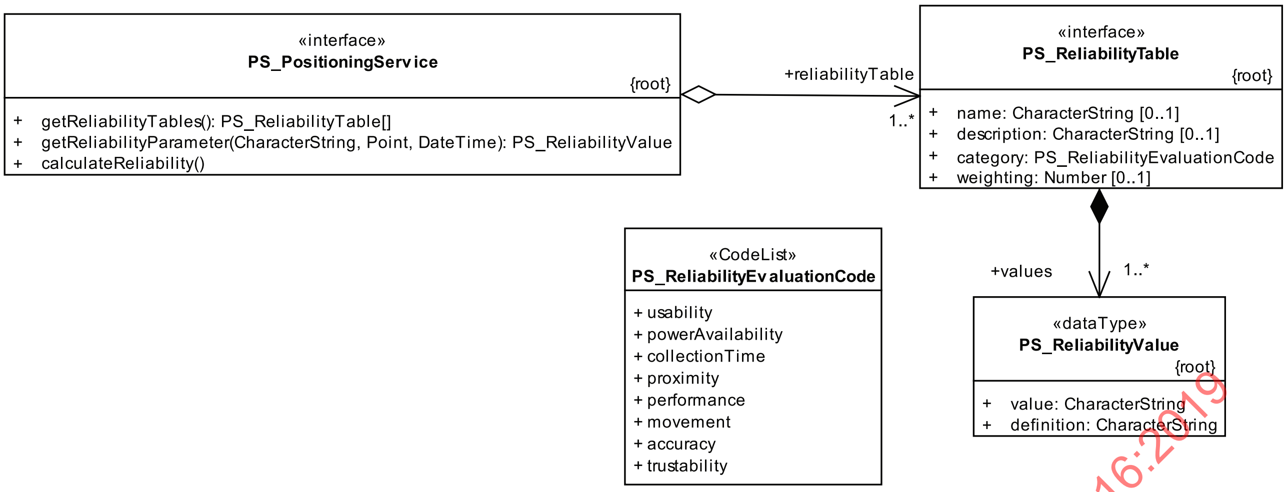

Figure 12 — UML diagram — Reliability model

The attributes and associations for the PS_ReliabilityTable class are shown in Table 20.

Table 20 — PS_ReliabilityTable

Class name	PS_ReliabilityTable
Attributes	**Descriptions**
name[0..1]	*CharacterString* — an identifiable name of the table. If a positioning service has more than one table, this attribute is mandatory, and each table shall have a unique name
description[0..1]	*CharacterString* — description of the table
category	*PS_ReliabilityEvalationCode* — reliability category
weighting[0..1]	*Number* — weighting among tables. A positioning service can use values from the weighting attribute for calculating reliability
Associations	**Descriptions**
values [1..*]	values of PS_ReliabilityValue contained in an object of PS_ReliabilityTable

PS_ReliabilityValue is a type for an entry in a PS_ReliabilityTable and consists of a reliability value definition pair.

Req. 15	/req/ps_reliabilitytable/has-reliability-value A positioning reliability table shall have at least one instance of PS_ReliabilityValue.

PS_ReliabilityValue has 2 attributes, value and definition, as shown in Table 21.

Table 21 — PS_ReliabilityValue

Class name	PS_ReliabilityValue
Attributes	**Descriptions**
Value	*CharacterString* — reliability value. Each value is unique in a PS_ReliabilityTable.
Definition	*CharacterString* — description of the value

The reliability evaluation of positioning results is performed based on information described in the PS_ReliabilityTable. The value used for each reliability evaluation differs depending on the positioning technology adopted by the positioning service. Therefore, the actual content of PS_ReliabilityTable is defined and provided by the positioning service itself.

Class PS_ReliabilityEvaluationCode shown in Table 22, is a list of evaluation categories.

Table 22 — PS_ReliabilityEvaluationCode codelist

Class name	PS_ReliabilityEvaluationCode
Codes	**Descriptions**
usability	degree of effort required in obtaining a derived position from a positioning technology.
powerAvailability	dynamically evaluated power availability of a specific device determining the level of operation.
collectionTime	measured value during acquisition of the positioning information used to determine a level of responsiveness.
proximity	perceived distance the collection device must be to the transmitting device to contact and measure a derived position value.
performance	characteristic measured at acquisition time by the device, based on the received basic signal strength indicator (RSSI) value of the device, in addition to specific performance variables such as GNSS satellite availability.
movement	motion status of the device.
accuracy	combination of factors defining accuracy requirement for a specific positioning technology.
trustability	"level of confidence" about a derived position dependent on the positioning technology being used.

9 Technology-specific information

9.1 Overview

Technology-specific information classes enable a positioning service to obtain and convey information that is not applicable to all technologies but may be needed in the application of specific technologies. The specifications of technology-specific classes may vary from one technology to another.

In the previous version of this document, technology-specific information was defined normatively for one platform, GNSS operating conditions. During the revision of this document, it was decided that to support a wider framework of positioning systems presently available, yet allow for future extension, only the basic framework for technology-specific information would be defined normatively. Hardware or platform specific information would be presented as informative examples.

This clause defines the operating conditions model. Annex D is a presentation of that model for a GNSS positioning service.

9.2 Operating conditions

The model for technology specific operating conditions is shown in Figure 13.

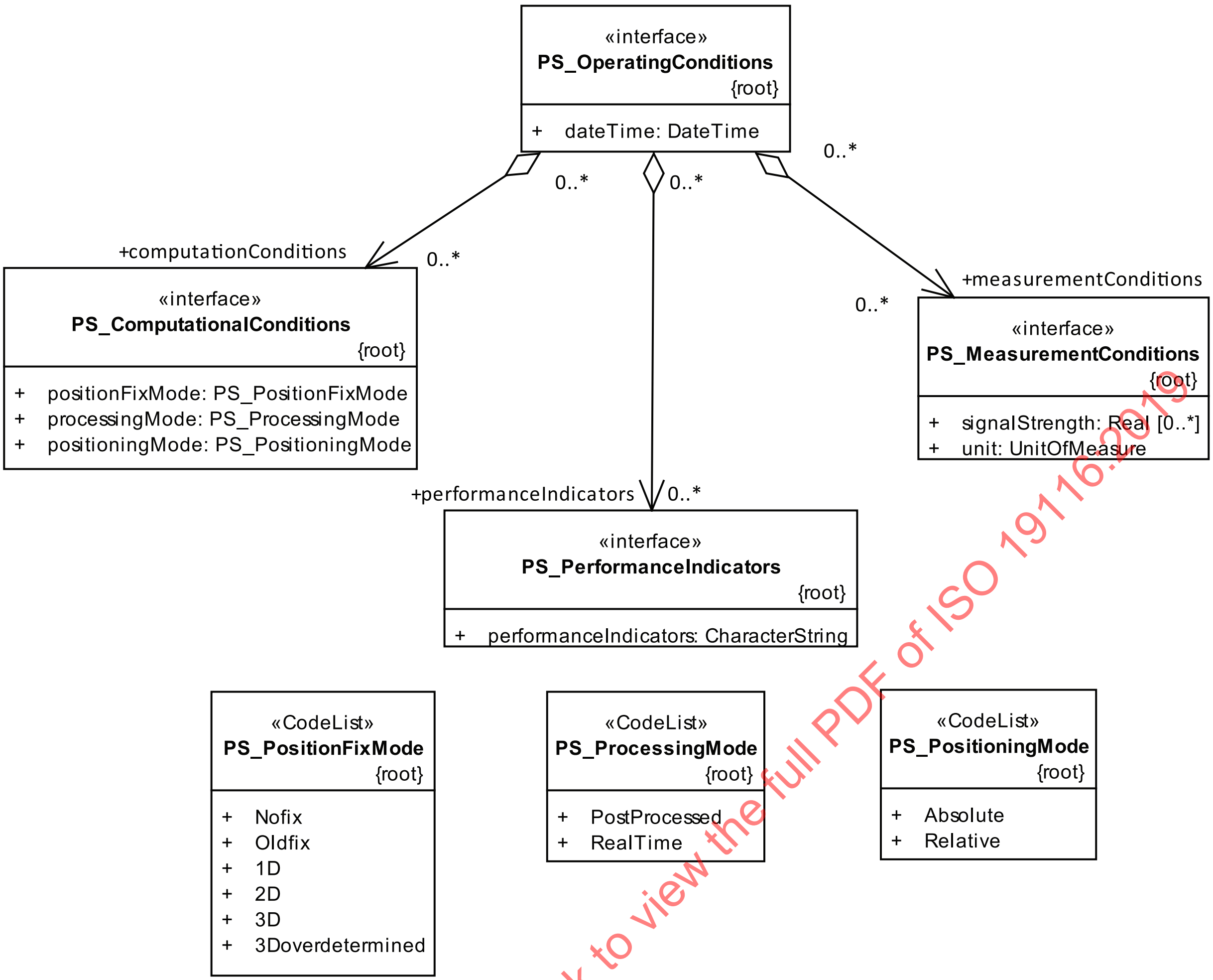

Figure 13 — UML diagram — Technology specific operation conditions

9.2.1 PS_OperatingConditions

PS_OperatingConditions is a class which contains information describing operating conditions. Attribute and associations for the PS_OperatingConditions class are shown in Table 23.

Table 23 — PS_OperatingConditions

Class name	PS_OperatingConditions
Attributes	**Descriptions**
dateTime	*DateTime* — Date and time, the measurements of the Operating Conditions are valid.
Associations	**Descriptions**
computationConditions	Provides parameters that indicate method of position computation
performanceIndicators	Provides parameters that indicate level or quality of system performance
measurementConditions	Provides parameters that indicate conditions under which measurements have been made

9.2.2 PS_ComputationalConditions

Computational conditions data provides those parameters of the positioning service device that indicate its mode of position computation for interpretation by the user or application.

Attributes for the class PS_ComputationalConditions are shown in Table 24.

Table 24 — PS_ComputationalConditions

Class name	PS_ComputationalConditions
Attributes	**Descriptions**
positionFixMode	Type of positioning solution obtained
processingMode	Indicates whether real-time or post-processed solution
positioningMode	Type of algorithm applied for positioning

9.2.3 PS_PositionFixMode

Designations of the positioning solution types according to the number of spatial dimensions that can be determined from the set independent observables available at the time of computation.

Class PS_PositionFixMode is a list of codes to obtain type of positioning solution and is shown in Table 25.

Table 25 — PS_PositionFixMode codelist

Class name	PS_PositionFixMode
Codes	**Descriptions**
Nofix	Insufficient observables are available to compute a position fix
Oldfix	Only available position fix information is stale
1D	Only enough observables are available for time observation
2D	Enough observables are available for a two-dimensional fix
3D	Enough observables are available for a three-dimensional fix
3Doverdetermined	Enough observables are available for a three-dimensional fix with additional degrees of freedom for statistical computations;

9.2.4 PS_PositioningMode

These codes designate the nature of the connection from the positioning system to its reference system.

Class PS_PositioningMode is a list of codes to designate the nature of the connection and is shown in Table 26.

Table 26 — PS_PositioningMode codelist

Class name	PS_PositioningMode
Codes	**Descriptions**
Absolute	position determined directly in the reference system by known parameters of the system
Relative	position determined relative to another point used by the positioning system

EXAMPLE An example of a point positioning mode is an autonomous GNSS positioning and positioning from astronomical observations, whereas an example of relative positioning mode is inertial positioning, double difference GNSS vector positioning (static or kinematic), and positioning with theodolite or total station.

9.2.5 PS_ProcessingMode

Class PS_ProcessingMode is a list of codes to indicate whether a real-time or post-processed solution is in use and is shown in Table 27.

Table 27 — PS_ProcessingMode codelist

Class name	PS_ProcessingMode
Codes	**Descriptions**
postProcessed	indicates the processing mode will be post-processed after collection
RealTime	indicates the processing mode will be in real-time as the data are acquired

9.2.6 Performance indicators

Some systems provide performance-indicator information coded by some indicator (usually numeric) which incorporates system-operating conditions and measurement conditions into a single performance indicator. Consequently, the operator's decisions as to suitability for use can be guided with less complexity than is required to interpret the many operating and measurement-condition values.

The single attribute for the class PS_PerformanceIndicators is shown in Table 28.

Table 28 — PS_PerformanceIndicators

Class name	PS_PerformanceIndicators
Attributes	**Descriptions**
performanceIndicators	*CharacterString* — Values of the system's performance indicators

9.2.7 Measurement conditions

The conditions under which a particular position or related measurement has been made are useful for judging the quality of the result, for diagnosis of problems and/or for archival documentation of how a particular result was derived. Therefore, these conditions are transmitted in a standardized manner.

Attributes for the class PS_MeasurementConditions are shown in Table 29.

Table 29 — PS_MeasurementConditions

Class name	PS_MeasurementConditions
Attributes	**Descriptions**
signalStrength[0..*]	*Real* — Number identifying the strength of the signal
unit	*UnitOfMeasure* — unit of the strength of the signal

9.3 Raw measurement data

Raw measurement data are transmitted by the positioning system instrument to a data-recording instrument for subsequent processing into position solution data. This processing may occur in real time or post mission. In either case, the data recording instrument is responsible for the proper storage of the data structures. Raw measurement data structures are positioning-system dependent.

Annex A
(normative)

Conformance

A.1 General

To verify whether a coordinate reference system or coordinate operation is in conformance with this document, check that it satisfies the requirements for the appropriate conformance class given in A.2 to A.4. Conformance shall be tested against the mandatory and conditional elements (where the condition is true) that are described in Clauses 6 to 9.

Conformance categories are shown in Table A.1.

Table A.1 — Categories of conformance for positioning services

Category	Requirements
Conformance for conceptual model	A.2
Conformance for positioning service requirements	A.3
Conformance for positioning service operations	A.4

Conformance test ids shown in Table A.2 are provided for each conformance class. In each of the conformance classes below the following apply with conformance test id:

Table A.2 — Conformance test id for positioning service

Conformance class id	Conformance test id
/conf/conceptual-model	/conf/conceptual-model/test
/conf/requirements	/conf/requirements/test
/conf/operations	/conf/operations/test

a) Test purpose: To determine whether all of the relevant entities which are specified to be mandatory or mandatory under the conditions specified have been provided in the definition.

b) Test case identifier: Completeness test.

c) Test type: capability.

d) Test method: Check the entity description to ensure that it includes, as a minimum, all of the elements indicated as mandatory for that type of system and that it uses the appropriate data types for, and occurrences of, those elements.

A.2 Conformance for conceptual model

Requirements for conformance to the conceptual model, including classes, associations, and attributes are shown in Table A.3, under the figure and table headings.

Conformance requires adherence to the requirements in all the tables listed for that conformance class.

Table A.3 — Conformance of the conceptual model

Conformance class id	Description	Requirements specified:		
		Clause(s)	Figure(s)	Table(s)
/conf/conceptual-model	This test should examine all classes of the conceptual model shown below			
	PS_PositioningService	6.3, 7.6	3, 11	4, 9
	PS_System	7.2.2	4	5
	PS_Session	7.3.2	5	10
	PS_ObservationMode	7.4.2	6	11
	PS_Observation	7.4.5	7	14
	PS_QualityMode	7.5.2	10	18
	PS_ReliabilityTable	8.2	12	20
	PS_OperatingConditions	9.2	13	23

A.3 Conformance for positioning service requirements

Requirements for conformance of positioning service requirements are shown in Table A.4.

Table A.4 — Conformance of positioning service requirements

Conformance class id	Requirements
/conf/requirements	/req/ps_system/op-measurement-details /req/ps_observationmode/mode-of-operation /req/ps_observationmode/config-info /req/ps_observationmode/reference-systems /req/ps_observationmode/ref-system-type /req/ps_observationmode/quality-status /req/ps_observationmode/multiplicity /req/ps_observation/result-vector /req/ps_observation/result-temporal /req/ps_qualitymode/quality-eval-system /req/ps_positioningservice/operations /req/ps_positioningservice/non-supported-request-response /req/ps_positioningservice/reliability-table-presence /req/ps_reliabilitytable/get-reliability-value /req/ps_reliabilitytable/has-reliability-value

A.4 Conformance for positioning service operations

Requirements for conformance of the definition of positioning service operations are shown in Table A.5. The principle requirement for operations is shown in Table A.5 under the Figure and Table headings. Conformance requires adherence to the requirements in all of these tables.

Table A.5 — Conformance of positioning service operations

Conformance class id	Description	Requirements specified:		
		Clause	Figure	Table
/conf/operations	Definition of operations of a positioning service	7.6	11	19

Annex B
(informative)

Implementing accuracy reports for positioning services

B.1 Overview

A positioning service may report the quality of positioning results so that the devices using this information can potentially screen information for usability and store sufficient information for generation of quality reporting metadata. The following structure is suggested for positioning services specific reporting tasks, showing how the specific positioning services detailed items can be aggregated for reporting as data quality metadata.

B.2 Structure of descriptors for data quality sub-elements

The positional accuracy sub-element is described by the following:

a) Data-quality measure, consisting of

— statistic or indicator, such as standard deviation, RMSE, % confidence interval, probable error;

— conformance with associated dimension, which may be one-dimensional, two-dimensional, three-dimensional;

— associated quality measure component terms, such as

  — base part (constant error term),

  — higher order error terms (seldom used, but allowable).

b) Data-quality value type, consisting of

— characteristic, such as Boolean, distance, angle, ratio, change in position over time;

— associated unit of measure, if dimensional, such as feet, centimetres, metres;

— associated orientation, such as vertical, horizontal, spherical, specified single-axis.

c) Data-quality evaluation procedure, consisting of

— evaluation method, such as statistical calculating procedure;

— with associated basis of comparison, such as short phrase designating the basis to which accuracy is referenced.

d) Data-quality result: the resultant value(s).

e) Data-quality scope: identification of the scope to which a data quality measure has been applied.

f) Data-quality date: one data quality date for each data quality measure.

Table B.1 shows the possible data-quality sub-elements, quality measures and value domain.

Table B.1 — Possible data quality sub-elements, including quality measure and value domain

Data quality sub-element	Data-quality measure	Data-quality value domain	Types of data-quality scopes to which a data quality measure may be applied
Absolute or external accuracy — closeness of reported coordinate values to values best accepted as approximating truth	pass-fail	Boolean variable	dataset series dataset reporting group — features
	error statistic: — standard deviation, RMSE — % confidence level error statistic dimension: — one-dimensional — two-dimensional — three-dimensional measure components: — base error — proportional error	Boolean variable [a, b] angle change in position over time distance number ratio	reporting group — feature attributes: applicable only to feature attributes that supply coordinate values
Relative or internal accuracy — closeness of the positional relationships of features in a dataset to the relationships accepted as or being true	pass-fail	Boolean variable	dataset series dataset reporting group — features
	error statistic:[c] — standard deviation, RMSE — % confidence level error statistic dimension: — one-dimensional — two-dimensional — three-dimensional measure components: — base error	Boolean variable [a, b] angle change in position over time distance number ratio	reporting group — feature attributes: applicable only to feature attributes that supply coordinate values

[a] These data-quality value domains require a statement of the orientation of the domain such as vertical, horizontal, spherical, specific axis, etc.

[b] Dimensional data-quality value domains such as distance require a statement of the unit of measure, such as feet or metres.

[c] Data-quality measures shall be consistent with the coordinate reference system identified in the product specification. For example, a dataset in a compound coordinate system may be tested by both horizontal data quality measures and vertical data quality measures.

B.3 Generalize to dataset accuracy

B.3.1 Example 1 — Accuracy of a map

For a 1:25 000 map meeting national map-accuracy standards, the quality element for positional accuracy may be reported in the following way:

a) Data-quality measure:

Result reported in terms of conformance with the positional requirements of national map-accuracy standards.

b) Data-quality value domain:

The value domain is Boolean (true or false).

c) Data-quality procedure:

Positions on the map are compared with positions of corresponding features obtained by or from an independent source of higher accuracy, for example, a ground survey of positions determined for identifiable points independent of the control points used to produce the map. If the position differences between the map-derived position and ground survey position for the test points fall with allowable limits for distance and percentage of points that must pass the test as specified by national map accuracy standards, the map is in compliance, otherwise it fails the accuracy test.

d) Data-quality result:

Meets or fails positional requirements for national map accuracy standards.

e) Data-quality date:

Date of map publication.

f) Data-quality scope:

Quality is reported at the dataset level, where the dataset is the map. Only positions of "well-defined" points are evaluated to produce the data quality result.

B.3.2 Example 2 — Positional stability of survey marks

The position of a survey mark may change over time due to:

a) plate-tectonic movement;

b) local or regional subsidence;

c) changes to moisture content in reactive soils;

d) other factors.

The movement may cause the published accuracies (determined at the time of computation) to become seriously misleading.

A set of *Positional Stability* parameters has been devised to address this situation. The parameters indicate the rate at which positional accuracy is expected to degrade due to mark movement. A separate parameter is available for each coordinate axis. Note the following:

— The parameters are based on local knowledge of ground conditions.

— The parameters indicate degradation relative to the coordinate system in use. Thus, if a national coordinate system is fixed to a tectonic plate, movement of the plate will not result in positional degradation.

— The parameters do not indicate the actual change in coordinate values. Rather, they indicate the rate at which the published coordinate accuracy is degrading.

B.3.3 Example 3 — Positional accuracy of the horizontal network

a) Data-quality measure:

Result reported in terms of conformance with the horizontal confidence-interval requirements as specified in national coordinate reference-system accuracy standards.

b) Data-quality value domain:

The value domain for the coordinates at the time of measurement is Boolean. This is qualified by the change in position over time.

c) Data-quality procedure:

The coordinate accuracy as derived from the measurements is based on the specified confidence level, e.g. 95 %, relative-error ellipses generated by a statistically valid least squares adjustment. The semi-major axes of the error ellipses are compared against criteria included in national coordinate reference-system accuracy standards.

d) Data-quality result:

Meets or fails criteria specified in the national coordinate-reference system accuracy standards.

e) Data-quality date:

Date of coordinate computation.

f) Data-quality scope:

Quality is reported at the network level.

Annex C
(informative)

Overview of positioning services

C.1 Overview

This interface may be applied to communication among any of the components of systems that generate and use position information. Such systems may incorporate an instrument providing position updates to one or more position-using devices for data processing, storage, and display. For example, a navigation display system may include recording functions that store the history of a vehicle's movement, processing tools that compute guidance updates along a planned course relying on stored waypoints, and a display device that provides the navigator with current position, computed guidance information, and cartographic content from stored coordinate information. This document specifies an interface that carries position and related information among any of these components and should be sufficient for communication between the position providing device and any connected position using devices. Additional interfaces may also exist in such a system, for example providing for cartographic portrayal of stored coordinate information, which are outside the scope of this document.

Standard positioning services provide client systems with operations that access positioning results and related information in a uniform manner, isolating the client from the multiplicity of protocols that may be employed to communicate with the positioning instruments. For example, a realized-positioning service could communicate with a GNSS receiver using the NMEA 2000 protocol, translate the information, and provide the positioning results to a geographic information display client through the standard interface specified in this document. Another realized positioning service could communicate with a GNSS receiver using a manufacturer's proprietary binary protocol. Using standardized positioning service interfaces, the hardware communication protocols become transparent to the client application.

Evolution of new communication protocols that closely follow the revised data structures described in this document are also anticipated. Such communication standards will facilitate efficient fulfilment of the information requirements of the positioning services interface and facilitate modular interchangeability of the positioning technology components.

C.2 Positioning service process flow

The application of this document is illustrated in Figure C.1 by a simplified case for a user obtaining coordinates from a GNSS receiver.

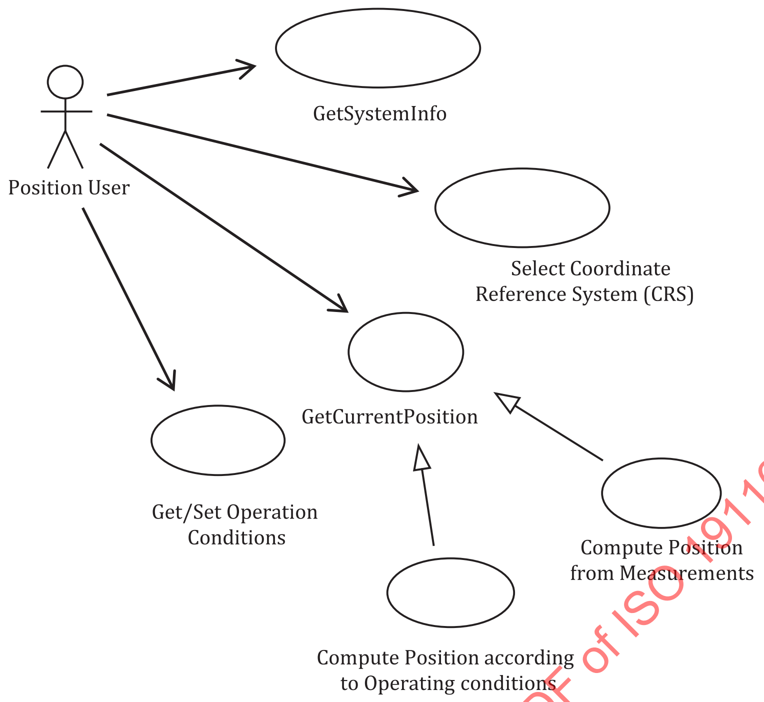

Figure C.1 — Use case for obtaining coordinates from a positioning service

First, the positioning service device transmits system-identification data so that the user can determine the type of positioning system, in this case a GNSS receiver, and whether the system is operational.

Next, the user sets the GNSS receiver to provide coordinates in the desired Coordinate Reference System (CRS) through the interface by performing setMode operations. For instance, the coordinate reference system could be set to NAD27 Virginia State Plane, North Zone, US Survey feet. Note that by using well-recognized CRS names in accordance with the ISO 19111 structure, the user avoids some of the complexity of the definition of the coordinate reference system by using a named datum and map projection, and the system interprets these and loads predefined set of parameters.

By performing technology-specific setOperatingConditions operations, the user also sets certain operating conditions of the system so that the position determination will be performed in a desired manner. For example, the user sets the satellite-elevation mask of the GNSS receiver so that satellites that are at low angles in the sky, and consequently, more affected by signal passage through the atmosphere, are excluded from the computation. Other operating conditions, such as the current actual positions of available satellites, are not controllable by the user and are determined by the system.

The system then performs measurements according to the operating conditions of the signal from the GNSS satellites and uses these measurements to compute a position cast in the specified Coordinate Reference System.

Finally, the computed position is reported to the user through the PS_Observation data object.

The positioning system also reports on certain operating conditions to help the user decide whether to use the position value. For example, one of the indicators of solution quality is the dilution of precision (DOP) value, which is based on the geometry of the satellites observed to determine the position.

Communication of this information is performed through the standard data structures to the user's display device, which portrays it to the user.

Annex D
(informative)

GNSS operating conditions

D.1 Overview

Technology-specific information classes permit a positioning service to obtain and convey information that is not applicable to all technologies but may be needed in the application of specific technologies. The specifications of technology-specific classes may vary from one technology to another. In general, technology-specific information can be categorized into two groups:

a) Operating Conditions — Information pertaining to the operation and performance of the system;

b) Raw Measurement Data — Values of the observables from which the technology derives positioning results.

As an example, this annex provides classes and definitions for the GNSS technology only, though their structure can be used as a basis for extension of this document to other technologies.

D.2 GNSS operating conditions

D.2.1 Overview

To use data application or archival metadata, the communication of details of operating conditions is often required. These details can be grouped into those which indicate the mode of position or related computation (the mathematical model applied to derive the result), those which indicate the measurement conditions (the qualities of the raw data from which a result is derived) and those coded performance indicators which summarize these into a simpler indicator which can guide an operator's decision as to the use of that result. These same values are applied in estimation of accuracy and precision by some implementations, but do not necessarily represent accuracy.

Figure D.1 illustrates the operating conditions for GNSS.

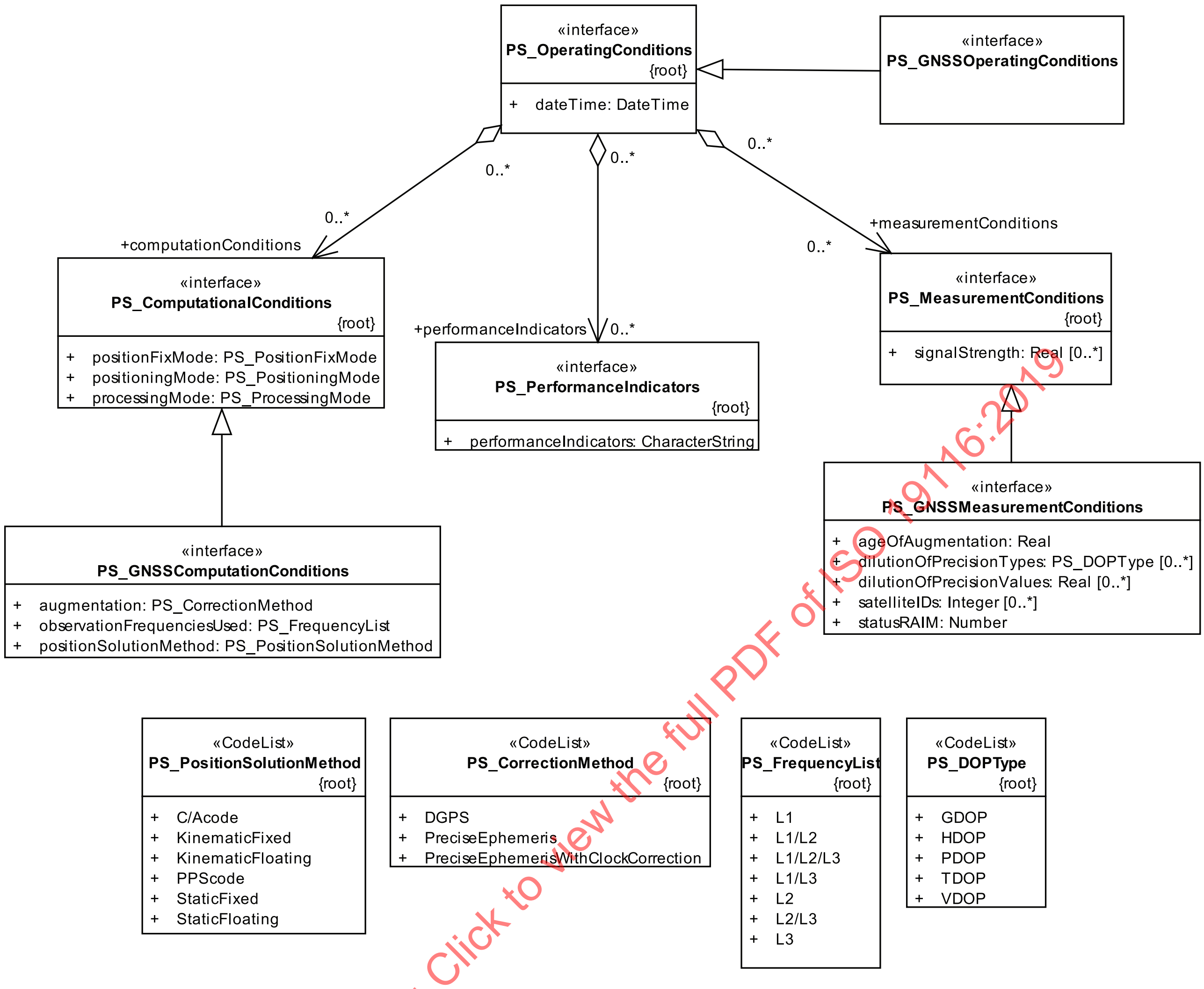

Figure D.1 — UML diagram — PS_GNSSOperatingConditions class

D.2.2 PS_GNSSOperatingConditions

PS_GNSSOperatingConditions inherits from PS_OperatingConditions to specify additional technological information necessary for positioning using GNSS. Associations for the PS_GNSSOperatingConditions class are shown in Table D.1 and are all inherited from PS_OperatingConditions.

Table D.1 — PS_GNSSOperatingConditions

Class name	PS_GNSSOperatingConditions
Associations	**Descriptions**
computationConditions	Provides parameters that indicate method of position computation for GNSS, and associates with PS_GNSSComputationConditions.
performanceIndicators	Provides parameters that indicate level or quality of system performance for GNSS
measurementConditions	Provides parameters that indicate conditions under which measurements have been made for GNSS, and associates with PS_GNSSMeasurementConditions.

