OGC® DOCUMENT: 23-049

External identifier of this OGC® document: http://www.opengis.net/doc/AS/temporal-conceptual-model/1.0

Open Geospatial Consortium

TOPIC 24 - TEMPORAL ABSTRACT CONCEPTUAL MODEL

ABSTRACT SPECIFICATION TOPIC

CANDIDATE SWG DRAFT

Version: 1.0
Submission Date: 2023-05-23
Approval Date: 2023-05-23
Publication Date: 2023-08-21
Editor: Chris Little, Charles Heazel

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I ABSTRACT

Traditionally, geospatial communities used 2D coordinates and the vertical and temporal aspects were considered attributes rather than fully fledged coordinate systems. In an increasingly dynamic, speedier and multidimensional world, much confusion and lack of interoperability has occurred because of inconsistent approaches to time. Much effort has been expended by various international bodies to establish the Gregorian Calendar as a consistent timeline. This suffices for low precision, such as to the nearest minute, but not so when second or sub-second accuracy is required. For example, there has been differing practices and no consensus on whether leap seconds should be part of the Gregorian timeline.

The fundamental concepts of events, clocks, timescales, coordinates and calendars have been long established, but there is no clear, straightforward defining document. This document aims to to give clear consistent definitions of the fundamental concepts and terminology, so that people are well aware of the advantages and disadvantages of adopting a particular technological approach and then perhaps they can contribute to building better and more interoperable systems using other more detailed documents such as logical and implementation standards that have an agreed common conceptual basis and terminology.

This document is consistent with ISO 19111 and W3C REC-owl-time-20171019 in OWL.

The aim of this document is to establish clear concepts and terminology.

II KEYWORDS

The following are keywords to be used by search engines and document catalogues.

ogcdoc, OGC document, abstract specification, conceptual model, time, temporal referencing, referencing by coordinates, calendar, clock, timescale

III PREFACE

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IV SECURITY CONSIDERATIONS

No security considerations have been made for this document.

V SUBMITTING ORGANIZATIONS

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

- U.K. Met Office, HeazelTech

VI SUBMITTERS

All questions regarding this submission should be directed to the editor or the submitters:

NAME	AFFILIATION
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VII INTRODUCTION

When OGC standards involve time, they generally refer to the ISO documents such as ISO 19108 (now largely superseded), ISO 19111, ISO 8601, and their freely available OGC equivalents, such as [OGC_18-005r4] (the equivalent to ISO 19111).

Much effort over decades has gone into establishing complex structures to represent calendar based time, such as the ISO 8601 notation, and many date-time schemas. Because of this effort, many people use calendar based “coordinates”, with the attendant ambiguities, imprecision and inappropriate scope.

The aim of this document is to establish clear concepts and terminology, so that people are well aware of the advantages and disadvantages of adopting a particular technological approach and then perhaps contribute to building better interoperable systems.

2

CONFORMANCE

2 CONFORMANCE

Clause 6 of this International Standard uses the Unified Modeling Language (UML) to present conceptual schemas for describing the higher level classes of time and temporal reference systems. These schemas define conceptual classes that

a) may be considered to comprise a cross-domain application schema, or

b) may be used in application schemas, profiles and implementation specifications.

This flexibility is controlled by a set of UML types that can be implemented in a variety of manners. Use of alternative names that are more familiar in a particular application is acceptable, provided that there is a one- to-one mapping to classes and properties in this International Standard. The UML model in this International Standard defines conceptual classes; various software systems define implementation classes or data structures. All of these reference the same information content. The same name may be used in implementations as in the model, so that types defined in the UML model may be used directly in application schemas.

Annex A defines a set of conformance tests that will support applications whose requirements range from the minimum necessary to define data structures to full object implementation.

1

SCOPE

1 SCOPE

This document defines the major underlying concepts regarding time. It does not define any concrete temporal reference systems or give detailed guidance on implementations.

3

NORMATIVE REFERENCES

3 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: ISO 19103:2015, *Geographic information – Conceptual schema language*, 2015, https://www.iso.org/standard/56734.html

ISO: ISO 19111:2019, *Geographic information – Referencing by coordinates*, 2019, https://www.iso.org/standard/74039.html

W3C: Time Ontology in OWL, 2017, https://www.w3.org/TR/2017/REC-owl-time-20171019/

4

TERMS AND DEFINITIONS

4 TERMS AND DEFINITIONS

This document uses the terms defined in OGC Policy Directive 49, which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this document and OGC documents do not use the equivalent phrases in the ISO/IEC Directives, Part 2.

This document also uses terms defined in the OGC Standard for Modular specifications (OGC 08-131r3), also known as the ‘ModSpec’. The definitions of terms such as standard, specification, requirement, and conformance test are provided in the ModSpec.

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

4.1. conceptual model

description of common concepts and their relationships, particularly in order to facilitate exchange of information between parties within a specific domain. A conceptual model is explicitly chosen to be independent of design or implementation concerns.

[**SOURCE:**]

5

CONVENTIONS

5 CONVENTIONS

5.1. Abbreviated terms

CRS	Coordinate Reference System
TRS	Temporal Reference System
UML	Unified Modelling Language
2D	2-dimensional
3D	3-dimensional

5.2. Identifiers

The normative provisions in this standard are denoted by the URI:

`http://www.opengis.net/doc/AS/temporal-conceptual-model/1.0`

All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base.

6

CHARACTERISTICS OF AN ABSTRACT CONCEPTUAL MODEL

6 CHARACTERISTICS OF AN ABSTRACT CONCEPTUAL MODEL

The terms and definitions clause in this Abstract Specification provides a short definition for “conceptual model”. This clause provides additional information on the OGC use of “conceptual model”.

A conceptual model organizes the vocabulary needed to communicate consistently and thoroughly about the know-how of a problem domain. The aim of a conceptual model is to express the meaning of terms and concepts used by domain experts to discuss the problem, and to find the correct relationships between different concepts.

A conceptual model:

1. is a representation of a system, made of the composition of concepts which are used to help people know, understand, or simulate a subject the model represents. A documented conceptual model represents ‘concepts’ (entities), the relationships between them, and a vocabulary;
2. is explicitly defined to be independent of design or implementation concerns;
3. organizes the vocabulary needed to communicate consistently and thoroughly about the know-how of a problem domain;
4. starts with a glossary of terms and definitions. There is a very high premium on high-quality, design-independent definitions, free of data or implementation biases; the model also emphasizes rich vocabulary; and
5. is always about identifying the correct choice of terms to use in communications, including statements of rules and requirements, especially where high precision and subtle distinctions need to be made. The core concepts of a temporal geospatial problem domain are typically quite stable over time.

7

TEMPORAL ABSTRACT CONCEPTUAL MODEL

7 TEMPORAL ABSTRACT CONCEPTUAL MODEL

This attempt at a Temporal Abstract Conceptual Model follows ISO 19111, which is the ISO adoption of [OGC_18-005r4].

The model is also informed by W3C REC-owl-time-20171019.

NOTE: This Mermaid diagram should be converted to PlantUML for Metanorma, by replacing the Mermaid container with the following.

```
[plantuml] @startuml . . @enduml
```

```
classDiagram
class ReferenceSystem {
       <<Abstract Class>>
       Dimension 1..*
       ApplicableLocationTimeOrDomain 1
    }
class SpatialReferenceSystem {
       <<Abstract Class>>
       Dimension 1..3
       ApplicableLocationTimeOrDomain 1
    }
class TemporalReferenceSystem {
       <<Abstract Class>>
       Dimension 1
       ApplicableLocationTimeOrDomain 1
    }
note for ReferenceSystem "Note: Has at least one of:\nSpatialReferenceSystem,
or \nTemporalReferenceSystem"
ReferenceSystem "1" o-- "0..*" SpatialReferenceSystem : has a
ReferenceSystem "1" o-- "0..*" TemporalReferenceSystem : has a
class TemporalCoordinateReferenceSystem {
       Dimension 1
       ApplicableLocationTimeOrDomain 1
    }
class Calendar {
       Dimension 1
       ApplicableLocationTimeOrDomain 1
    }
class OrdinalTemporalReferenceSystem {
       Dimension 1
       ApplicableLocationTimeOrDomain 1
    }
note for TemporalReferenceSystem "Note: Consists of one only of:\nTemporalCoord
inateReferenceSystem,\nCalendar, or \nOrdinalTemporalReferenceSystem"
    TemporalReferenceSystem "0..1" o-- "1" TemporalCoordinateReferenceSystem :
consists of
    TemporalReferenceSystem "0..1" o-- "1" Calendar : consists of
    TemporalReferenceSystem "0..1" o-- "1" OrdinalTemporalReferenceSystem:
consists of
TemporalCoordinateReferenceSystem "1" o-- "1" Timescale
TemporalCoordinateReferenceSystem "1" o-- "1" Epoch
TemporalCoordinateReferenceSystem "1" --> "1..*" Notation
Calendar "1" o-- "0..1" Epoch
Calendar "1" o-- "1..*" Timescale
Calendar "1" o-- "1" Algorithm
Calendar "1" --> "1..*" Notation
```

```
OrdinalTemporalReferenceSystem "1" o-- "0..1" Epoch
OrdinalTemporalReferenceSystem "1" o-- "2..*" Event
OrdinalTemporalReferenceSystem "1" --> "1..*" Notation
Timescale "1" o-- "1" Clock
```

Figure 1

8

TEMPORAL REGIMES

8 TEMPORAL REGIMES

8.1. General

To help us think more clearly about time, this paper adopts the term “Regime” to describe the fundamentally different types of time and its measurement under consideration. This is a pragmatic approach that allows the grouping of recommendations and best practices in a practical way, but without obscuring the connection to the underlying theoretical components.

The first three regimes have deep underlying physical and mathematical foundations which cannot be legislated away. The fourth regime, of calendars, uses a seemingly random mixture of ad hoc algorithms, arithmetic, numerology and measurements. Paradoxically, this regime has historically driven advances in mathematics and physics.

The regimes are applicable to other planets and outer space, but with due consideration.

8.2. Events and Operators

The simplest way of relating entities in time is by events that can be ordered, that is, established in a sequence, and this sequence is used as an approximate measure of the passage of time.

In this regime, no clocks or time measurements are defined, only events, that are ordered in relation to each other. For example, geological layers, sediment or ice core layers, archaeological sequences, sequential entries in computer logs without coordinated time.

One set of events may be completely ordered with respect to each other, but another set of similar internally consistent events cannot be cross-referenced until extra information is available. Even then, only partial orderings may be possible.

In this regime, the Allen Operators (Maintaining Knowledge about Temporal Intervals) can be used. If A occurs before B and B occurs before C, then we can correctly deduce that A occurs before C. The full set of operators also covers pairs of intervals. So in our example, B occurs in the interval (A,C). However, we cannot perform arithmetic operations like (B-A) or (C-A) as we have not defined any timescale or measurements. For example, ‘subtracting’ Ordovician from Jurassic is meaningless.

This regime constitutes an Ordinal Temporal Reference System, with discrete enumerated ordered events.

8.3. Simple Clocks and Discrete Timescales

In this regime, a clock is defined as any regularly repeating physical phenomena, such as pendulum swings, earth's rotation about sun, earth's rotation about its axis, heart beats, vibrations of electrically stimulated quartz crystals or the resonance of the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom. Some phenomena make better clocks that others, in terms of the number of repetitions possible, the consistency of each repetition and the precision of each 'tick'. A mechanism for counting, or possibly measuring, the ticks is desirable.

It is an assumption that the ticks are regular and homogeneous.

There is no sub-division between two successive clock ticks. Measuring time consists of counting the complete number of repetitions of ticks since the clock started, or since some other event at a given clock count.

There is no time measurement before the clock started, or after it stops.

It may seem that time can be measured between 'ticks' by interpolation, but this needs another clock, with faster ticks. This process of devising more precise clocks continues down to the atomic scale, and then the process of physically trying to interpolate between ticks is not possible.

The internationally agreed atomic time, TAI, is an example of a timescale with an integer count as the measure of time, though in practice it is an arithmetic compromise across about two hundred separate atomic clocks, corrected for differing altitudes and temperatures.

In this regime, the Allen Operators (Maintaining Knowledge about Temporal Intervals) also can be used. If A occurs before B and B occurs before C, then we can correctly deduce that A occurs before C. The full set of operators also covers pairs of intervals. So if B occurs in the interval (A,C), we can now perform integer arithmetic operations like (B-A) or (C-A) as we have defined a timescale or measurement.

This regime constitutes a Temporal Coordinate Reference System, with discrete integer units of measure which can be subject to integer arithmetic.

8.4. CRS and Continuous Timescales

This regime takes a clock from the previous regime ands assumes that between any two adjacent ticks, it is possible to interpolate indefinitely to finer and finer precision, using ordinary arithmetic, rather than any physical device.

Alternatively, it may be that the ticks are not counted but measured, and the precision of the clock is determined by the precision of the measurements, such as depth in an ince core, or angular position of an astronomical body,such as the sun, moon or a star.

It is also assumed that time can be extrapolated to before the time when the clock started and into the future, possibly past when the clock stops.

This gives us a continuous number line to perform theoretical measurements. It is a coordinate system. With a datum/origin/epoch, a unit of measure (a name for the 'tick marks' on the axis), positive and negative directions and the full range of normal arithmetic. It is a Coordinate Reference System.

In this regime, the Allen Operators (Maintaining Knowledge about Temporal Intervals) also can be used. If A occurs before B and B occurs before C, then we can correctly deduce that A occurs before C. The full set of operators also covers pairs of intervals. So if B occurs in the interval (A,C), we can now perform real number arithmetic operations like (B-A) or (C-A) as we have defined a timescale or measurement, and between any two instants, we can always find an infinite number of other instants.

Some examples are:

- Unix milliseconds since 1970-01-01T00:00:00.0Z
- Julian Days, and fractions of a day, since noon on 1st January, 4713 BCE.

This regime constitutes a Temporal Coordinate Reference System, with continuous, floating-point, units of measure, which can be subject to the full range of real arithmetic.

8.5. Calendars

In this regime, counts and measures of time are related to the various combinations of the rotations of the earth, moon and sun or other astronomical bodies. There is no simple arithmetic, so for example, the current civil year count of years in the Current Era (CE) and Before Current Era (BCE) is a calendar, albeit a very simple one, as there is no year zero. That is, Year 14CE – Year 12CE is a duration of 2 years, and Year 12BCE — Year 14BCE is also two years. However Year 1CE — Year 1BCE is one year, not two as there is no year 0CE or 0BCE.

Calendars are social constructs made by combining several clocks and their associated timescales.

This paper only addresses the internationally agreed Gregorian calendar. Astronomical Algorithms provides overwhelming detail for conversion to numerous other calendars that have developed around the world and over the millennia and to meet the various social needs of communities, whether agricultural, religious or other. The reference is comprehensive but not exhaustive, as there are calendars that have been omitted.

A Calendar is a Temporal Reference System, but it is not a Temporal Coordinate Reference System nor an Ordinal Temporal Reference System.

8.6. Other Regimes

There may in fact be a series of other regimes, which are out of scope of this document. This could include local solar time, useful, for example, for the calculation of illumination levels and the length of shadows on aerial photography, or relativistic time.

8.6.1. Local Solar Time

Local solar time may or may not correspond to the local statutory or legal time in a country. Local solar time can be construed as a clock and timescale, with an angular measure of of the apparent position of the sun along the ecliptic (path through the sky) as the basic physical principle.

8.6.2. Spacetime

When dealing with moving objects, we find that the location of the object in space depends on its location in time. That is to say, that the location is an event in space and time.

Originally developed by Hermann Minknowski to support work in Special Relativity, the concept of Spacetime is useful whenever the location of an object in space is dependent on its location in time.

Since the speed of light in a vacum is a constant, Spacetime uses that constant to create a coordinate axis with spatial units of measure (meters per second * seconds = meters). The result is coordinate reference system with four orthagonal axis all with the same units of measure.

8.6.3. Relativistic

A regime may be needed for ‘space-time’, off the planet Earth, such as for recording and predicting space weather approaching from the sun, where the speed of light and relativistic effects may be relevant.

Once off the planet Earth, distances and velocities grow very large. The speed of light becomes a limiting factor in measuring both where and when an event takes place. Special Relativity deals with the accurate measurement of Spacetime events as measured between two moving objects. The core concepts are the Lorentz Transforms. These transforms allow one to calculate the degree of “contraction” a measurement undergos due to the relative velocity between the observing and observed object.

The key to this approach is to ensure each moving feature of interest has its own local clock and time, known as its ‘proper time’. This example can be construed as a fitting into the clock and timescale regime. The relativistic effects are addressed through the relationships between the separate clocks, positions and velocities of the features.

Relativistic effects may need to be taken into account for satellites and other space craft because of their relative speed and position in Earth’s gravity well.

8.6.4. Accountancy

The financial and administrative domains often use weeks, quarters, and other calendrical measures. These may be convenient (though often not!) for the requisite tasks, but are usually inappropriate for scientific or technical purposes.

9

NOTATION

9 NOTATION

There are often widely agreed, commonly accepted, notations used for temporal reference systems, but few have been standardised. Any particular notation may be capable of expressing a wider range of times than are valid for the reference system.

Example : The [IETF_RFC_3999] timestamp notation, a restrictive profile of [ISO_8601], can express times before 1588CE, when the Gregorian calendar was first introduced in some parts of the world.

10

ATTRIBUTES OF THE REGIMES/CLASSES

10 ATTRIBUTES OF THE REGIMES/CLASSES

The top level `Reference System` is a super-class and does not have many attributes or properties. So far, only the dimension of the reference system and the Location, Time or Domain of Applicability have been identified as essential.

The Dimension is one for time, or a vertical reference system, but may be as much as 6 for spatial location and orientation.

Besides the conventional space and time, there may be other reference systems, such as wavelength/frequency, that can be addressed by the Abstract Conceptual Model.

10.1. Attributes of Events and Ordinal Temporal Reference Systems

1. Name/Id
2. Listed or enumerated sequence of events
3. First and last events
4. Optional Epoch, defined in some other temporal reference system
5. Optional location or region of applicability
6. Optional notations

Example : Ancient annals of a country may give a sequence of emperors which could be used to 'date' another event such as "Emperor Xi built a canal", or may be used to date a particular reign. For example: "In the reign of Emperor Yi, a comet was sighted" and later research identifies this as an appearance of Hailey's Comet.

The events from the list may be instants, such as the change of reign, or intervals, such as the complete reign of each emperor.

Other documents may enable two such 'king lists' to be related, though not completely.

10.2. Attributes of simple Clock and Discrete Timescale

1. Name/Id

2. Optional Epoch/starting time defined in some other temporal reference system
3. Optional name for each tick
4. Optional End time or count
5. Optional location
6. Optional Notation

Example : A well preserved fossilised log is recovered and the tree rings establish an annual 'tick'. The start and end times may be known accurately by comparison and matching with other known tree ring sequences, or perhaps only dated imprecisely via Carbon Dating, or its archaeological or geological context.

10.3. Attributes of a CRS and Continuous Timescales

1. Name/Id
2. Optional Epoch/starting time, defined in some other temporal reference system
3. Optional name for the measure
4. Optional End time or measure
5. Optional location
6. Optional Notation

Example : A long ice core is retrieved from a stable ice-sheet. From long term meteorological observations, the rate of accumulation of ice is known, so linear length can be equated to time (assuming a stable climate too). This enable the dates of some previously unknown large scale volcanic eruptions to be identified and timed. Identifiable nuclear fallout from specific atmospheric atomic bomb tests increase the confidence in the timing accuracy.

11

ATTRIBUTES OF CALENDARS

11 ATTRIBUTES OF CALENDARS

1. Name/id
2. Astronomical Type (e.g. solar, sidereal, lunar, luni-solar)
3. Predictive type (e.g. observed or calculated)
4. Epoch/start time
5. Optional end time
6. Optional location or region of applicability
7. Constituent units or clocks and counts or timescales
8. Optional Notation

Example 1: The modern Gregorian calendar is calculated solar calendar, with various epochs from 1588 CE through to 1922 CE depending on location or country.

+ The constituent timescales are days (earth's rotations), months (moon's orbit around the earth), years (earth's orbit around the sun) and seconds determined by atomic clocks. To accommodate discrepancies, leap days and leap seconds are intercalated in some years. The commonest notations for the Gregorian calendar are ISO 8601 and its various restrictive profiles.

Example 2: The modern Islamic calendar is an observed lunar calendar, and the major religious dates progress throughout the year, year on year. The important months are determined by the observation of new moons from Mecca.

Example 3: The modern Jewish calendar is a calculated luni-solar calendar, and discrepancies in the solar year are addressed by adding 'leap months' every few years.

Example 4: The Ba'hai calendar is a calculated solar calendar, but without any other astronomical aspects. The year consists of 19 months of 19 days each, with 4 or 5 intercalated days for a new year holiday.

Example 5: The West African Yoruba traditional calendar is a solar calendar with months, but rather than subdividing a nominal month of 28 days into 4 weeks, 7 weeks of 4 days are used. This perhaps gave rise to the fortnightly (every 8 days) markets in many villages in the grasslands of north-west Cameroun.

Example 6: Teams controlling remote vehicles on Mars use a solar calendar, with Martian years and martian days (called sols). Months are not used because there are two moons, with different, rather short, 'months'.

12

SYNCHRONISATION OF CLOCKS

12 SYNCHRONISATION OF CLOCKS

If there are two or more clocks, stationary with respect to each other, and a practical method of communicating their times to each other, the clocks can be perfectly synchronized.

However, if the clocks are moving with respect to each other, they cannot be precisely coordinated (unless the communication is instantaneous). As communication speed is limited by the finite constant speed of light, perfect synchronisation is not possible, though repetitive protocols can be used to reduce the synchronization error to any practical desired level.

See A Brief History of Timekeeping, Page 187-191.

13

TEMPORAL ABSTRACT FORMAL CONCEPTUAL MODEL

13 TEMPORAL ABSTRACT FORMAL CONCEPTUAL MODEL

The Temporal Abstract Conceptual Model has been built using a UML model. This provides formalization of the astract concepts which can be evaluated against other related ISO and OGC standards.

13.1. Context

When OGC standards involve time, they generally refer to the ISO documents such as ISO 19108, ISO 19111, ISO 8601, and their freely available OGC equivalents, such as Abstract Specification Topic 2 Referencing by Coordinates (equivalent to <<iso19111,ISO 19111>).

When dealing with temporal reference systems, it is necessary to understand all of these standards and how they interact. ISO Technical Committee 211 (ISO/TC211) provides a useful tool for integrating their standards. The ISO/TC 211 Harmonized Model Management Group provides a single integrated model for most of the ISO/TC 211 standards. That model will provide the foundation for the Abstract Temporal Reference Model.

The Abstract Temporal Reference Model is a “Conceptual” model. It both defines concepts and the associations between those concepts. This “conceptual” model is an extension of a higher level “Semantic” model.

13.2. OWL Ontology

The W3C Time Ontology (W3C REC-owl-time-20171019) is illustrated below.

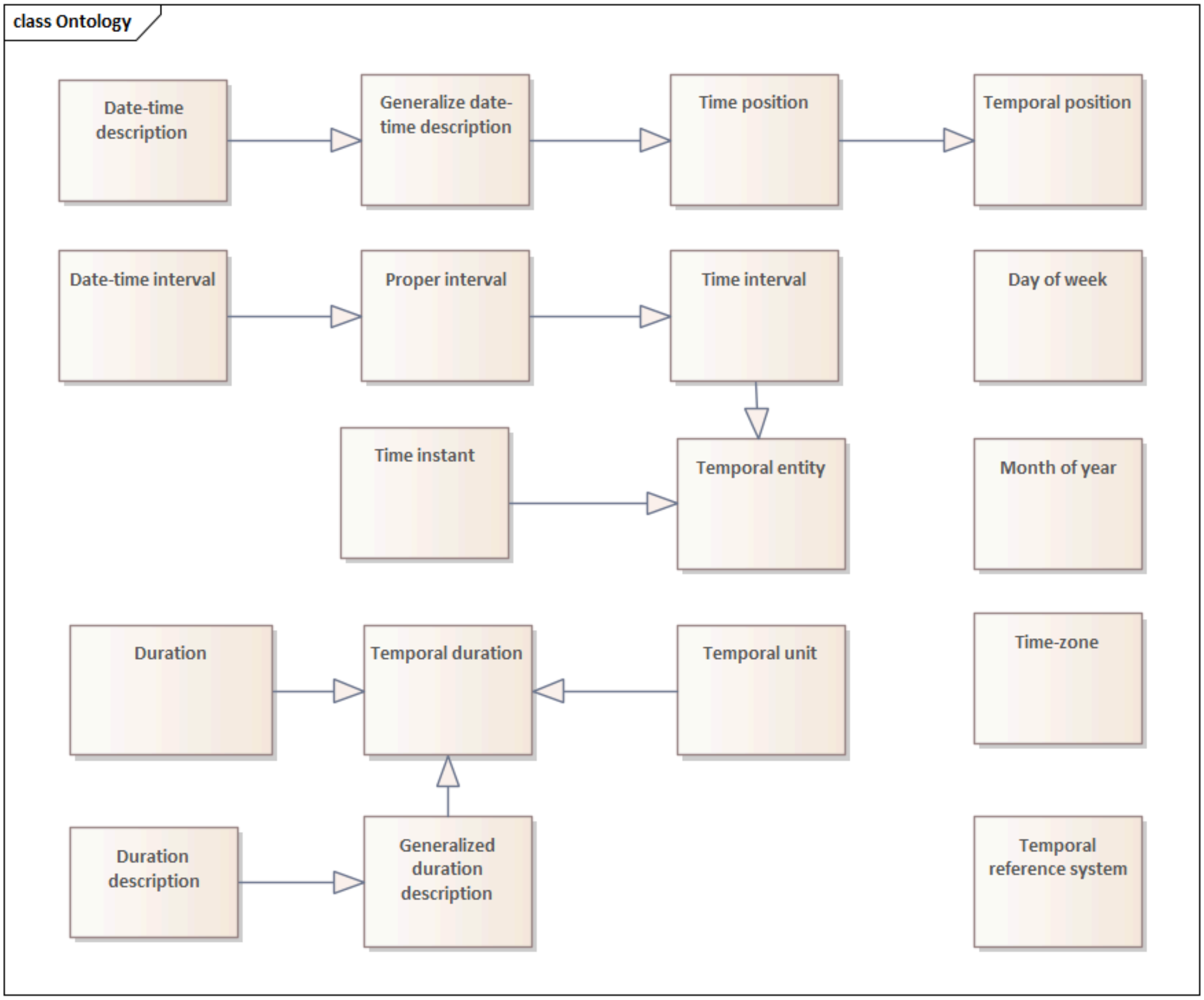

Figure 2

13.3. Abstract Temporal Model

The Abstract Temporal Model divides the world into Spatial, Temporal, and SpatialTemporal Reference Systems.

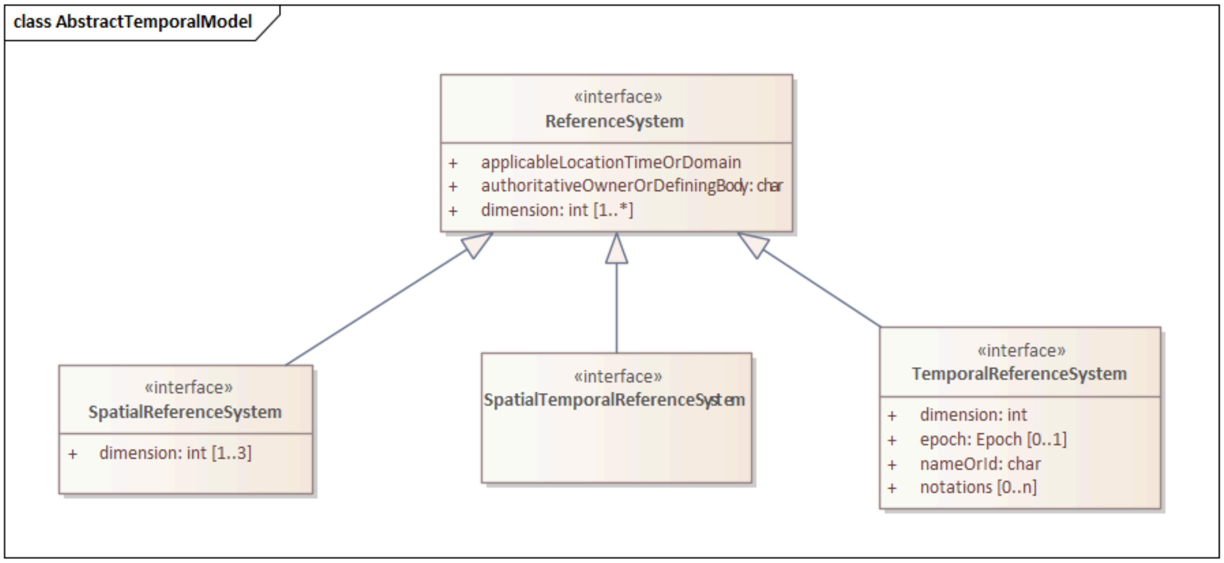

Figure 3

13.4. Temporal Reference Systems

The Temporal Reference System is further divided into Temporal Coordinate Reference Systems and Temporal Ordinal Reference Systems.

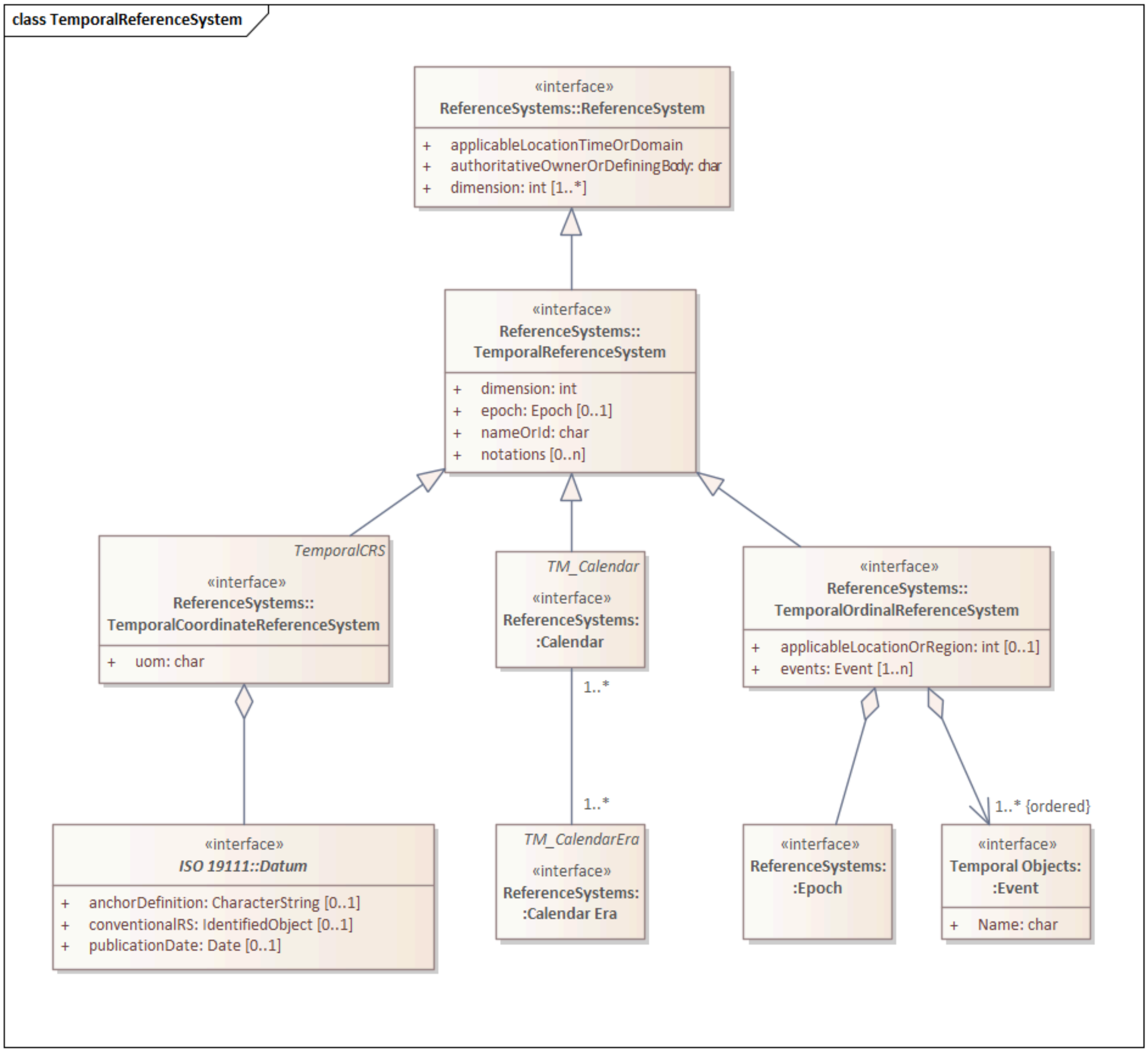

Figure 4

The Temporal Coordinate Reference Systems provide a link to ISO 19111 — Geographic information — Referencing by coordinates.

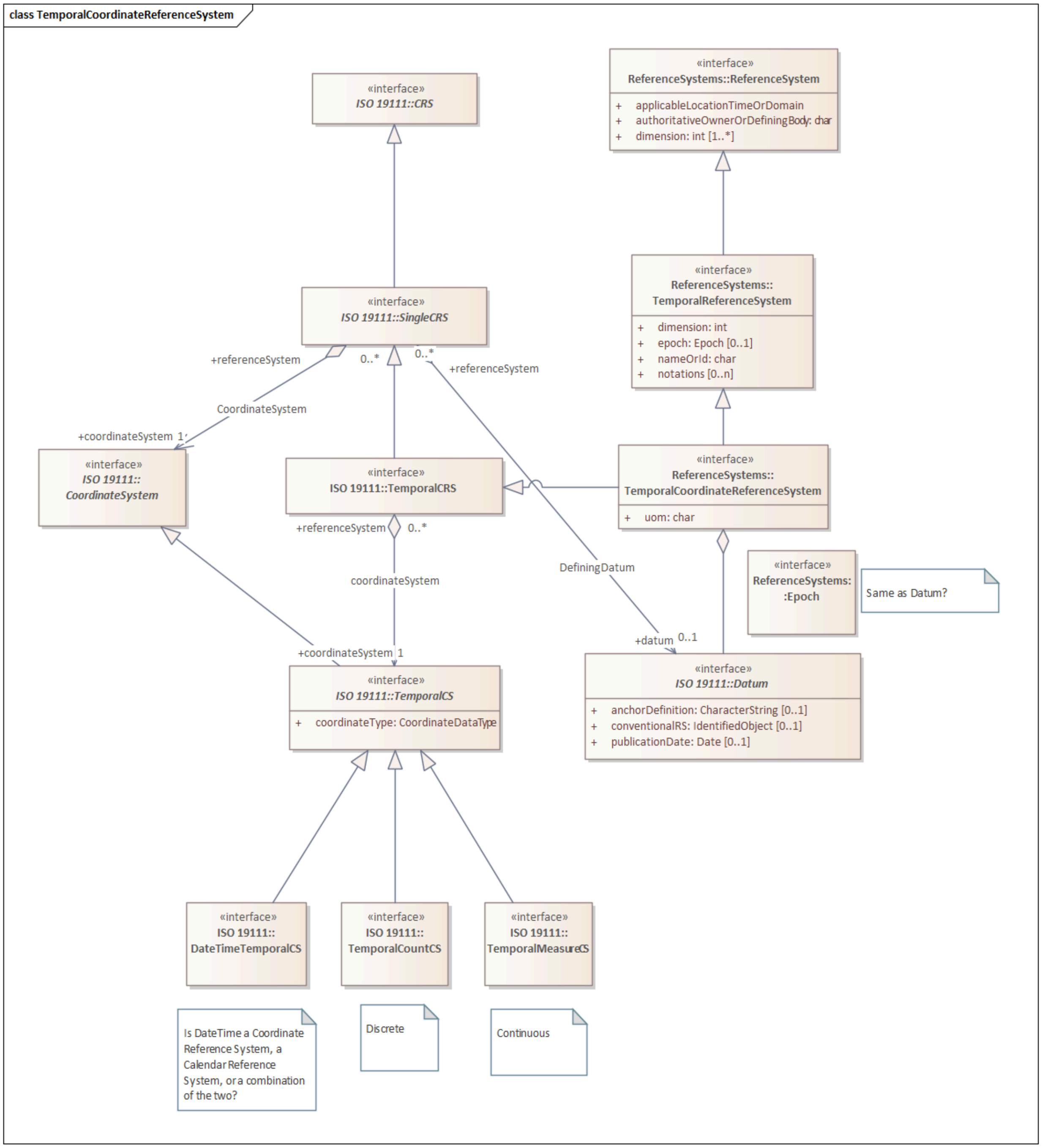
class TemporalCoordinateReferenceSystem
«interface»
ISO 19111::CRS
«interface»
ReferenceSystems::ReferenceSystem
+ applicableLocationTimeOrDomain
+ authoritativeOwnerOrDefiningBody: char
+ dimension: int [1..*]
«interface»
ReferenceSystems::
TemporalReferenceSystem
+ dimension: int
+ epoch: Epoch [0..1]
+ nameOrId: char
+ notations [0..n]
«interface»
ISO 19111::SingleCRS
+referenceSystem
0..*
0..*
+referenceSystem
CoordinateSystem
+coordinateSystem 1
«interface»
ISO 19111::
CoordinateSystem
«interface»
ISO 19111::TemporalCRS
«interface»
ReferenceSystems::
TemporalCoordinateReferenceSystem
+ uom: char
+referenceSystem
0..*
coordinateSystem
DefiningDatum
«interface»
ReferenceSystems:
:Epoch
Same as Datum?
+coordinateSystem 1
+datum 0..1
«interface»
ISO 19111::TemporalCS
+ coordinateType: CoordinateDataType
«interface»
ISO 19111::Datum
+ anchorDefinition: CharacterString [0..1]
+ conventionalRS: IdentifiedObject [0..1]
+ publicationDate: Date [0..1]
«interface»
ISO 19111::
DateTimeTemporalCS
«interface»
ISO 19111::
TemporalCountCS
«interface»
ISO 19111::
TemporalMeasureCS
Is DateTime a Coordinate Reference System, a Calendar Reference System, or a combination of the two?
Discrete
Continuous

Figure 5

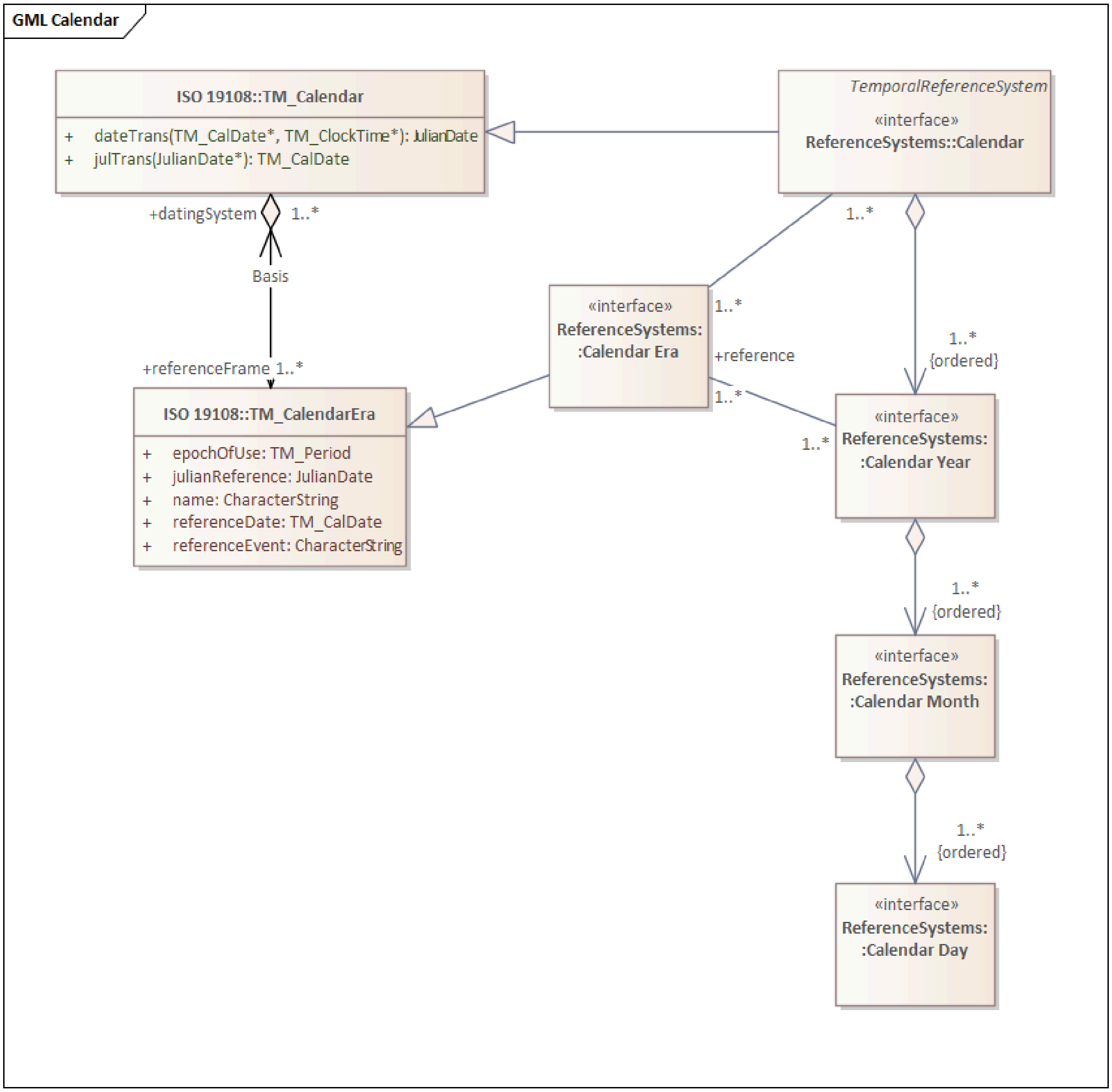
GML Calendar
ISO 19108::TM_Calendar
+ dateTrans(TM_CalDate*, TM_ClockTime*): JulianDate
+ julTrans(JulianDate*): TM_CalDate
TemporalReferenceSystem
«interface»
ReferenceSystems::Calendar
+datingSystem
1..*
1..*
Basis
«interface»
ReferenceSystems:
:Calendar Era
1..*
1..*
{ordered}
+reference
+referenceFrame 1..*
1..*
ISO 19108::TM_CalendarEra
+ epochOfUse: TM_Period
+ julianReference: JulianDate
+ name: CharacterString
+ referenceDate: TM_CalDate
+ referenceEvent: CharacterString
1..*
«interface»
ReferenceSystems:
:Calendar Year
1..*
{ordered}
«interface»
ReferenceSystems:
:Calendar Month
1..*
{ordered}
«interface»
ReferenceSystems:
:Calendar Day

Figure 6

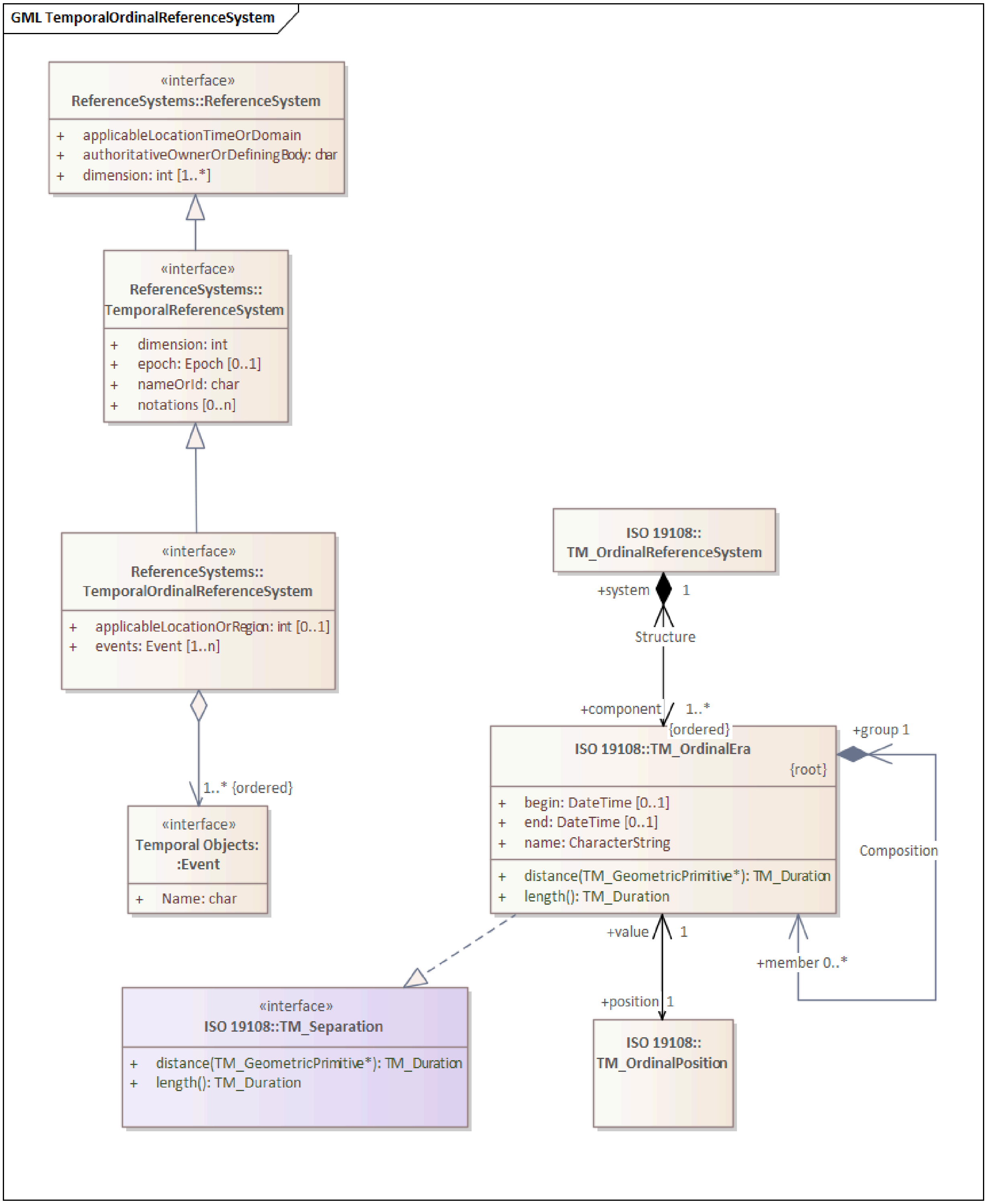
GML TemporalOrdinalReferenceSystem
«interface»
ReferenceSystems::ReferenceSystem
+ applicableLocationTimeOrDomain
+ authoritativeOwnerOrDefiningBody: char
+ dimension: int [1..*]
«interface»
ReferenceSystems::
TemporalReferenceSystem
+ dimension: int
+ epoch: Epoch [0..1]
+ nameOrId: char
+ notations [0..n]
«interface»
ReferenceSystems::
TemporalOrdinalReferenceSystem
+ applicableLocationOrRegion: int [0..1]
+ events: Event [1..n]
1..* {ordered}
«interface»
Temporal Objects:
:Event
+ Name: char
ISO 19108::
TM_OrdinalReferenceSystem
+system
1
Structure
+component
1..*
{ordered}
ISO 19108::TM_OrdinalEra
{root}
+ begin: DateTime [0..1]
+ end: DateTime [0..1]
+ name: CharacterString
+ distance(TM_GeometricPrimitive*): TM_Duration
+ length(): TM_Duration
+group 1
Composition
+member 0..*
+value
1
+position
1
«interface»
ISO 19108::TM_Separation
+ distance(TM_GeometricPrimitive*): TM_Duration
+ length(): TM_Duration
ISO 19108::
TM_OrdinalPosition

Figure 7

13.5. Temporal Objects

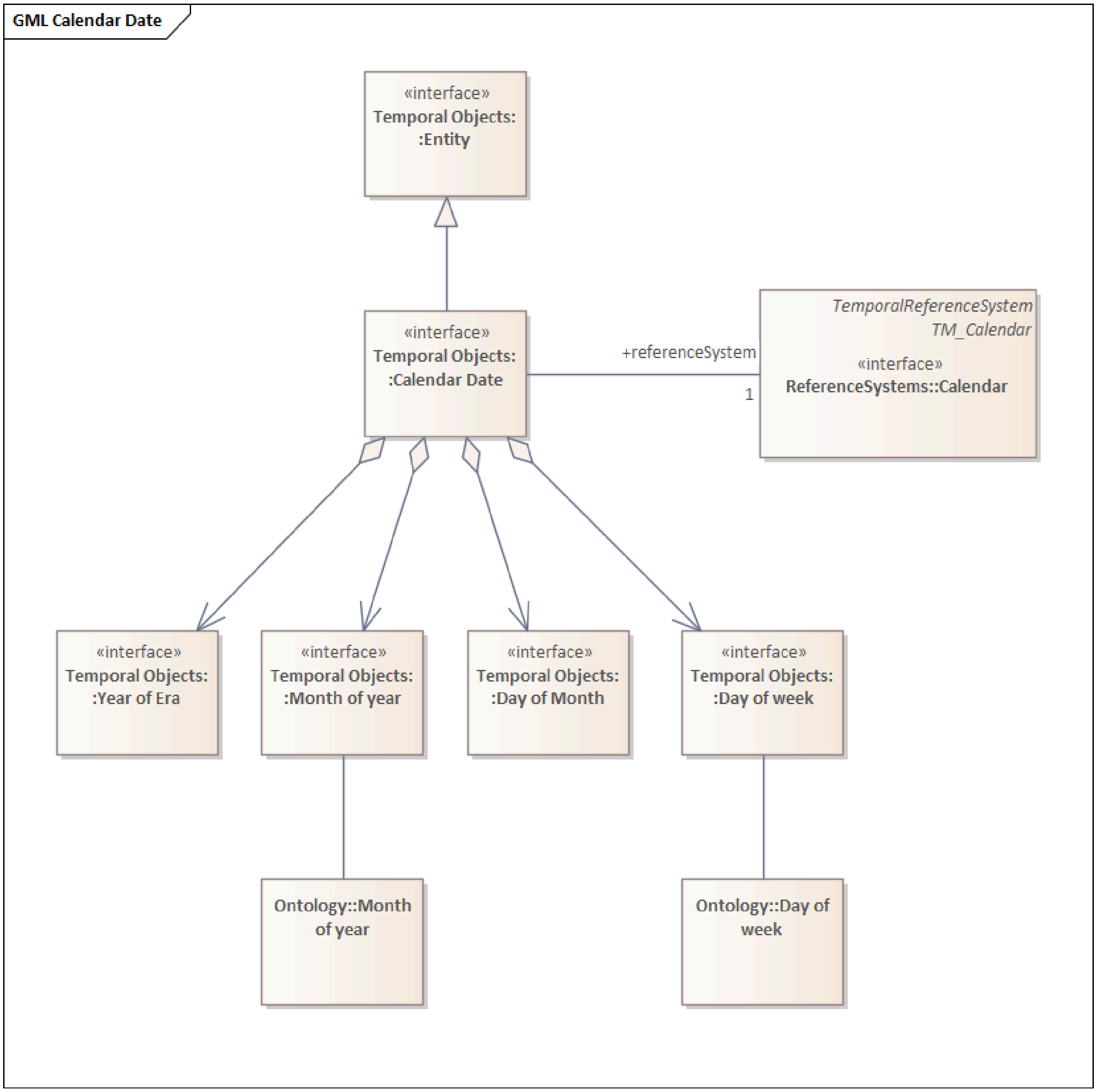

Figure 8

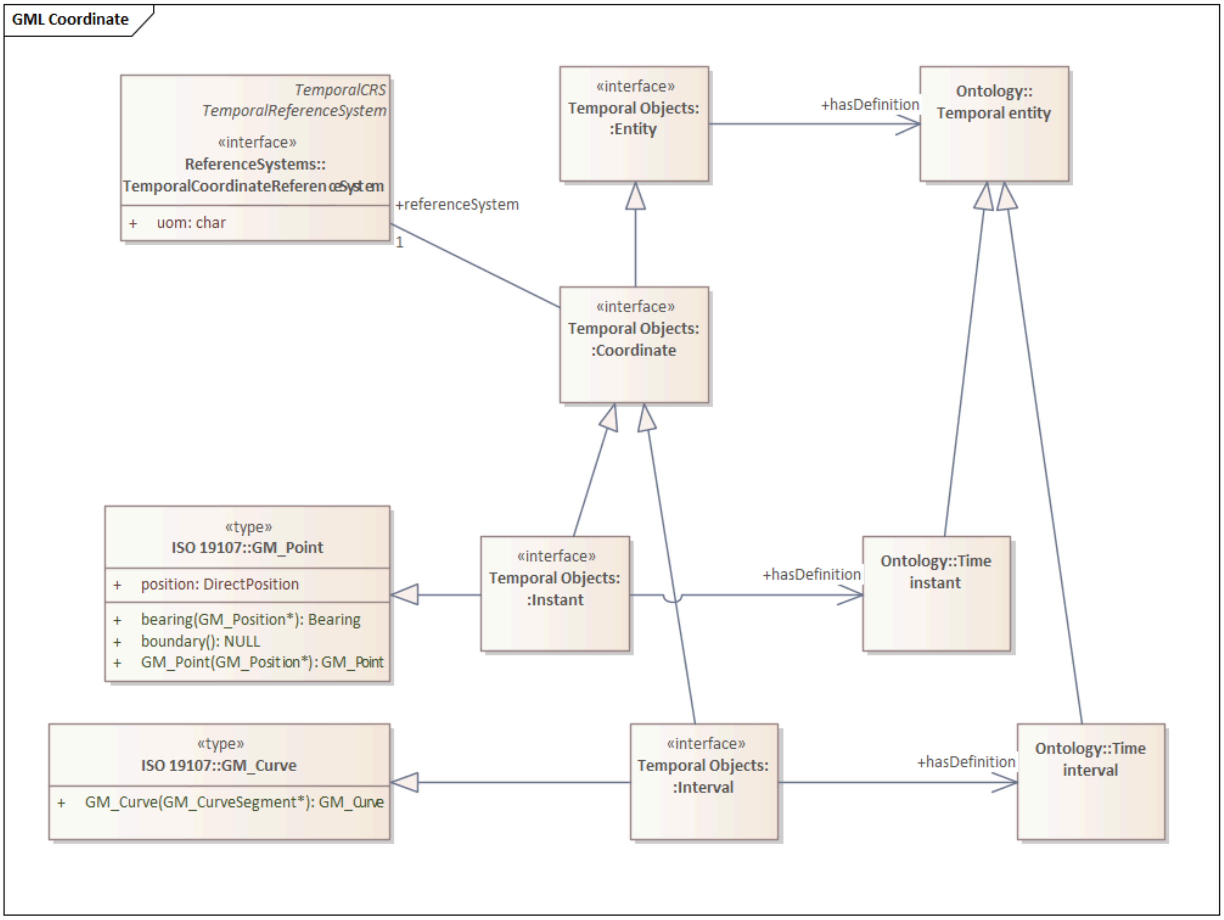
GML Coordinate
TemporalCRS
TemporalReferenceSystem
«interface»
ReferenceSystems::
TemporalCoordinateReferenceSystem
+ uom: char
+referenceSystem
1
«interface»
Temporal Objects:
:Entity
+hasDefinition
Ontology::
Temporal entity
«interface»
Temporal Objects:
:Coordinate
«type»
ISO 19107::GM_Point
+ position: DirectPosition
+ bearing(GM_Position*): Bearing
+ boundary(): NULL
+ GM_Point(GM_Position*): GM_Point
«interface»
Temporal Objects:
:Instant
+hasDefinition
Ontology::Time
instant
«type»
ISO 19107::GM_Curve
+ GM_Curve(GM_CurveSegment*): GM_Curve
«interface»
Temporal Objects:
:Interval
+hasDefinition
Ontology::Time
interval

Figure 9

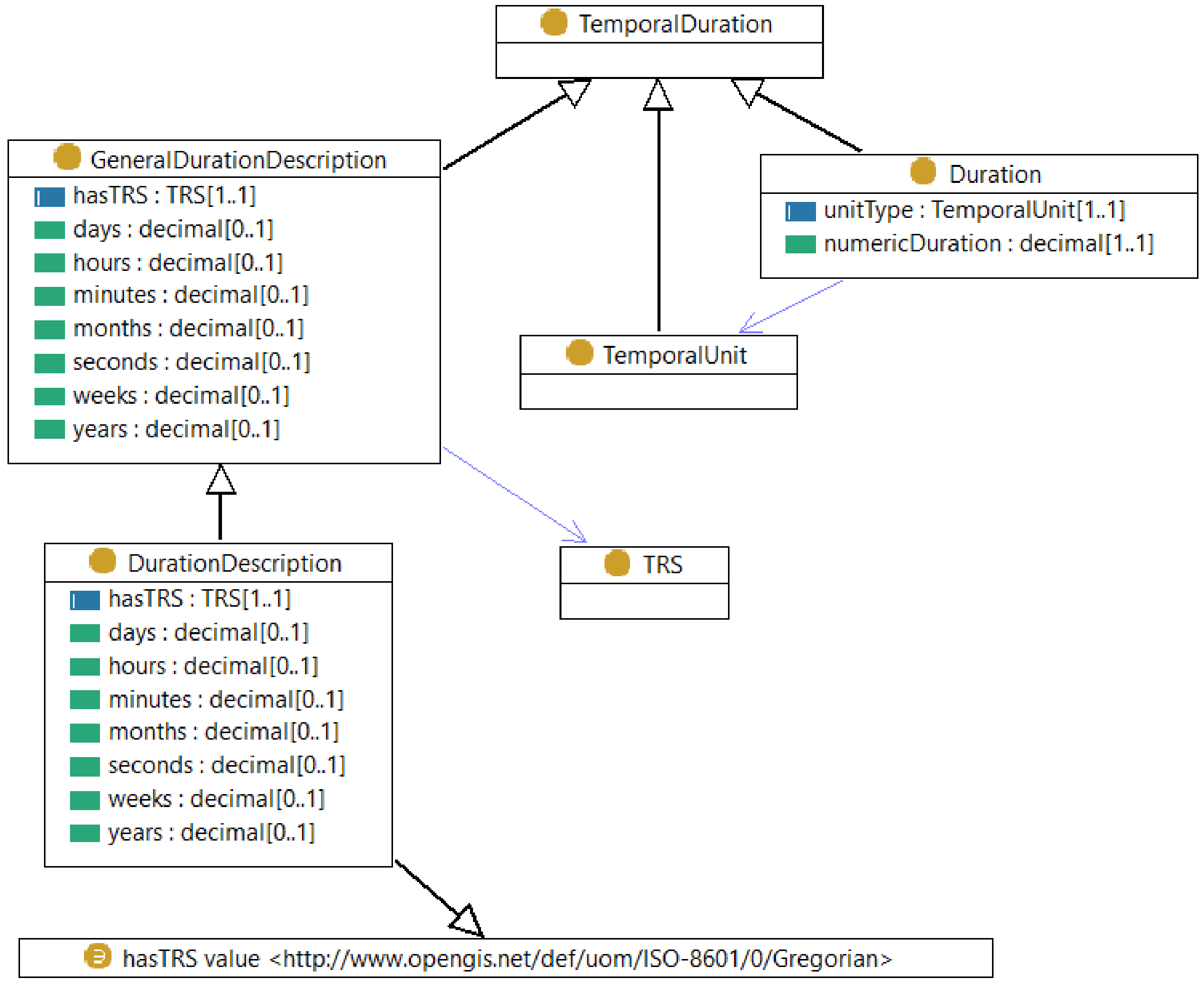
TemporalDuration
GeneralDurationDescription
hasTRS : TRS[1..1]
days : decimal[0..1]
hours : decimal[0..1]
minutes : decimal[0..1]
months : decimal[0..1]
seconds : decimal[0..1]
weeks : decimal[0..1]
years : decimal[0..1]
Duration
unitType : TemporalUnit[1..1]
numericDuration : decimal[1..1]
TemporalUnit
DurationDescription
hasTRS : TRS[1..1]
days : decimal[0..1]
hours : decimal[0..1]
minutes : decimal[0..1]
months : decimal[0..1]
seconds : decimal[0..1]
weeks : decimal[0..1]
years : decimal[0..1]
TRS
hasTRS value <http://www.opengis.net/def/uom/ISO-8601/0/Gregorian>

Figure 10

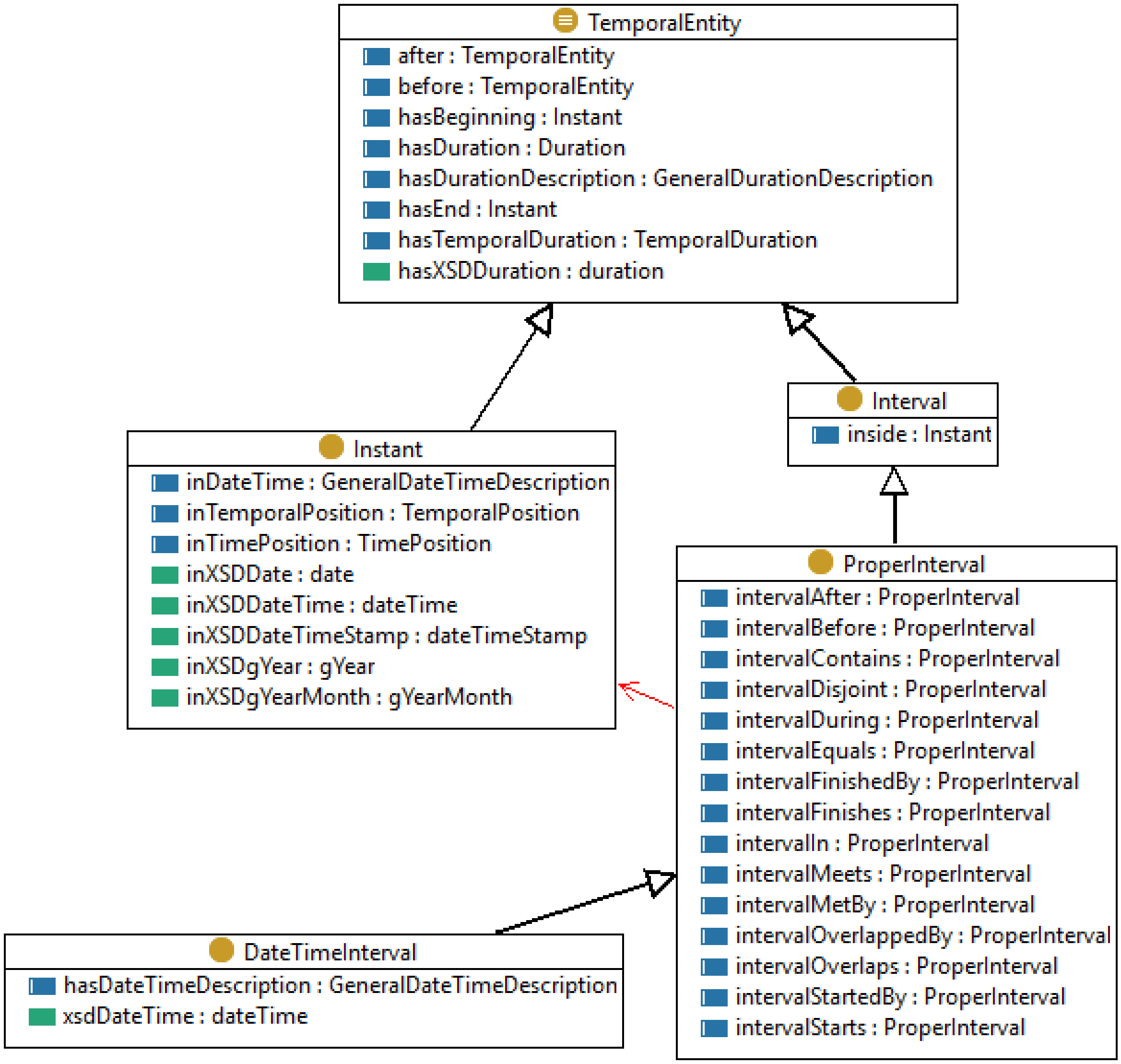
TemporalEntity
after : TemporalEntity
before : TemporalEntity
hasBeginning : Instant
hasDuration : Duration
hasDurationDescription : GeneralDurationDescription
hasEnd : Instant
hasTemporalDuration : TemporalDuration
hasXSDDuration : duration
Interval
inside : Instant
Instant
inDateTime : GeneralDateTimeDescription
inTemporalPosition : TemporalPosition
inTimePosition : TimePosition
inXSDDate : date
inXSDDateTime : dateTime
inXSDDateTimeStamp : dateTimeStamp
inXSDgYear : gYear
inXSDgYearMonth : gYearMonth
ProperInterval
intervalAfter : ProperInterval
intervalBefore : ProperInterval
intervalContains : ProperInterval
intervalDisjoint : ProperInterval
intervalDuring : ProperInterval
intervalEquals : ProperInterval
intervalFinishedBy : ProperInterval
intervalFinishes : ProperInterval
intervalIn : ProperInterval
intervalMeets : ProperInterval
intervalMetBy : ProperInterval
intervalOverlappedBy : ProperInterval
intervalOverlaps : ProperInterval
intervalStartedBy : ProperInterval
intervalStarts : ProperInterval
DateTimeInterval
hasDateTimeDescription : GeneralDateTimeDescription
xsdDateTime : dateTime

Figure 11

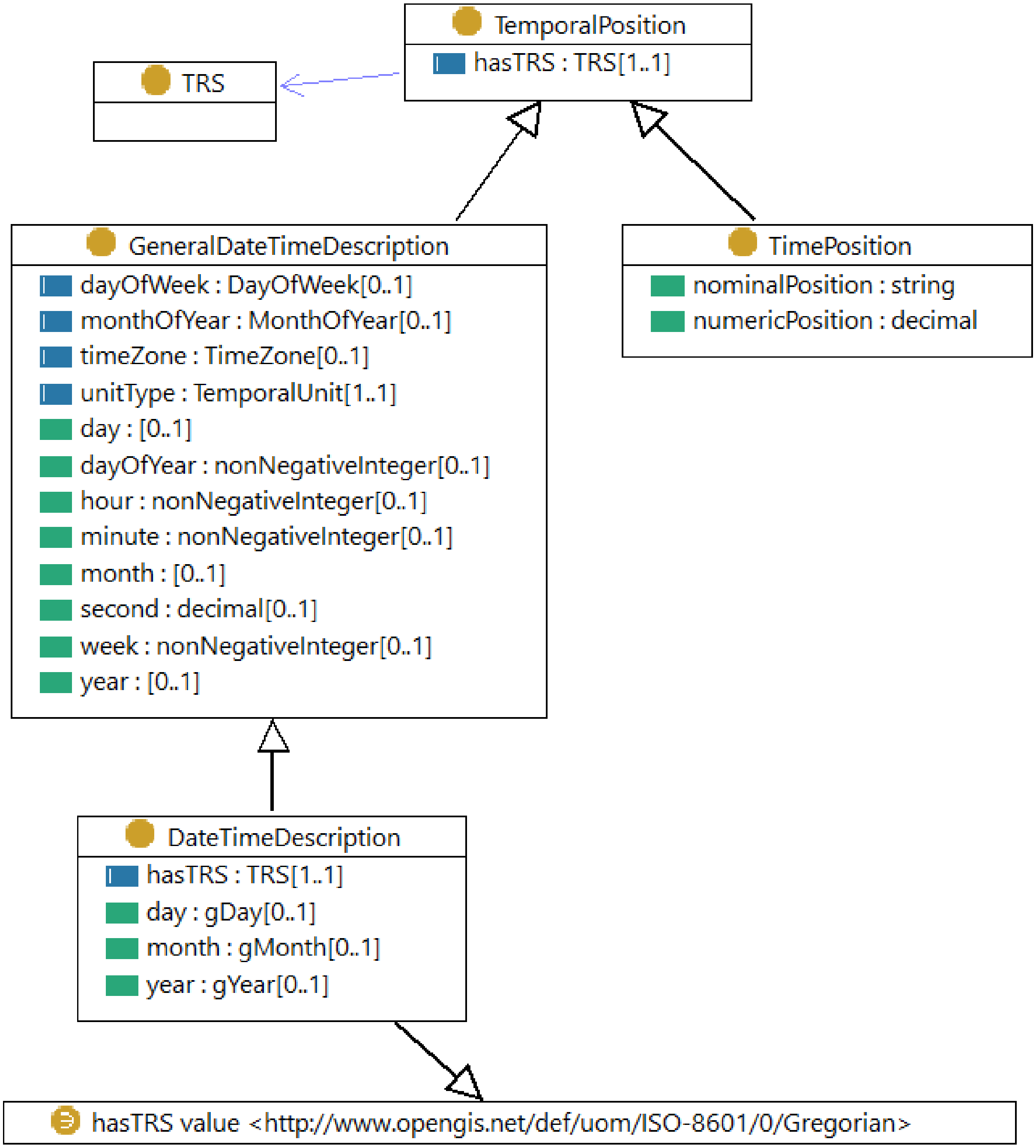

Figure 12

13.6. Temporal Transformations

ISO 19111 provides a model for coordinate transformations which can be re-used for temporal coordinate reference systems.

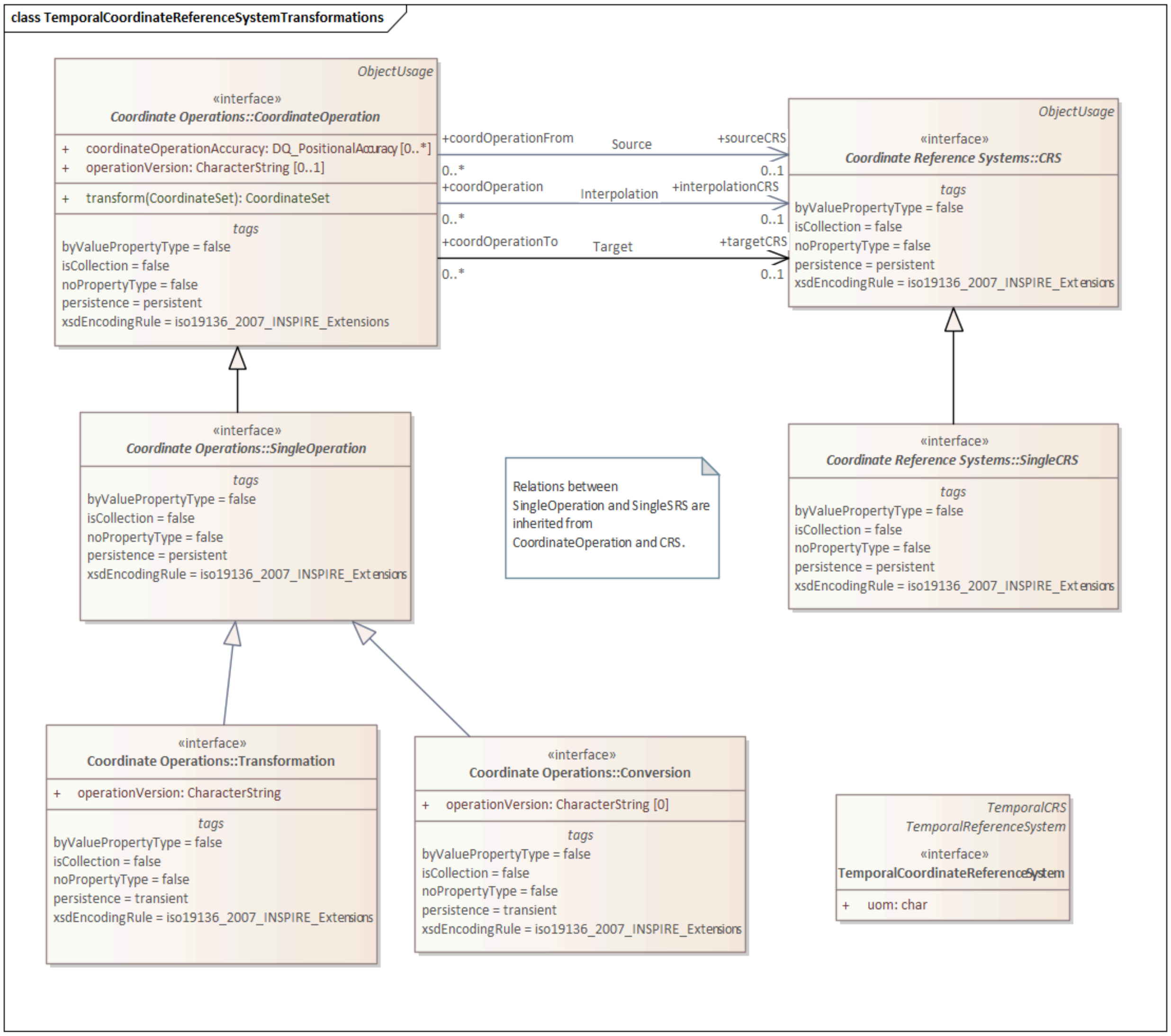
class TemporalCoordinateReferenceSystemTransformations
ObjectUsage
«interface»
Coordinate Operations::CoordinateOperation
+ coordinateOperationAccuracy: DQ_PositionalAccuracy [0..*]
+ operationVersion: CharacterString [0..1]
+ transform(CoordinateSet): CoordinateSet
tags
byValuePropertyType = false
isCollection = false
noPropertyType = false
persistence = persistent
xsdEncodingRule = iso19136_2007_INSPIRE_Extensions
+coordOperationFrom
Source
+sourceCRS
0..*
0..1
+coordOperation
Interpolation
+interpolationCRS
0..*
0..1
+coordOperationTo
Target
+targetCRS
0..*
0..1
ObjectUsage
«interface»
Coordinate Reference Systems::CRS
tags
byValuePropertyType = false
isCollection = false
noPropertyType = false
persistence = persistent
xsdEncodingRule = iso19136_2007_INSPIRE_Extensions
«interface»
Coordinate Operations::SingleOperation
tags
byValuePropertyType = false
isCollection = false
noPropertyType = false
persistence = persistent
xsdEncodingRule = iso19136_2007_INSPIRE_Extensions
Relations between SingleOperation and SingleSRS are inherited from CoordinateOperation and CRS.
«interface»
Coordinate Reference Systems::SingleCRS
tags
byValuePropertyType = false
isCollection = false
noPropertyType = false
persistence = persistent
xsdEncodingRule = iso19136_2007_INSPIRE_Extensions
«interface»
Coordinate Operations::Transformation
+ operationVersion: CharacterString
tags
byValuePropertyType = false
isCollection = false
noPropertyType = false
persistence = transient
xsdEncodingRule = iso19136_2007_INSPIRE_Extensions
«interface»
Coordinate Operations::Conversion
+ operationVersion: CharacterString [0]
tags
byValuePropertyType = false
isCollection = false
noPropertyType = false
persistence = transient
xsdEncodingRule = iso19136_2007_INSPIRE_Extensions
TemporalCRS
TemporalReferenceSystem
«interface»
TemporalCoordinateReferenceSystem
+ uom: char

Figure 13

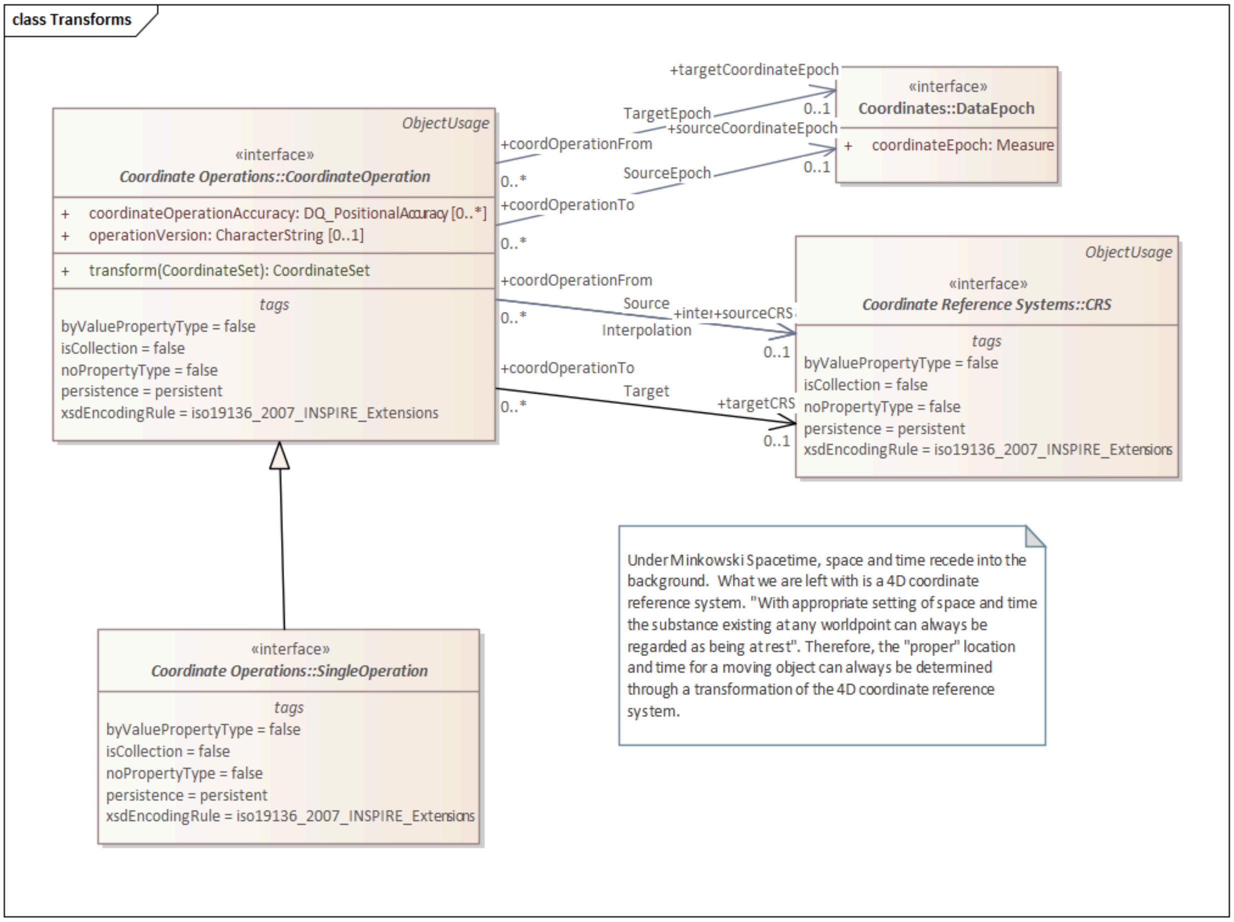

Figure 14

Some Observations:

1. Many temporal reference systems are not coordinate reference systems
2. There is no temporal equivalent to the Compound Reference System
3. DateTime should be represented as a compound reference system consisting of a TM_Calendar and TM_Clock reference system.
4. TM_Calendar could be a type of TM_OrdinalReferenceSystem.
5. TM_Clock should not be defined in terms of a “day”. Many clocks count elapsed time since an epoch. Date and time are not considered.
6. TM_Clock should be a type of TM_CoordinateSystem
7. TM_Calendar can be defined as a Compound Reference System composed of days, months, and years. This would allow to define meaningful calendars for the Moon, Mars, and other non-Terrestrial environments.
8. Is there an ordinal equivalent to TM_Clock. Sunrise, noon, sunset, and midnight?

9. Can a calendar be defined in terms of planting season, Saints days, or other arbitrary events?

14

DATA DICTIONARY

14 DATA DICTIONARY

14.1. Reference Systems

Table 1

Algorithm

Definition:	
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 2

Calendar

Definition:	
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalReference System []	
	Calendar Year [1..*]	
	Calendar Era [1..*]	
	TM_Calendar []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Calendar Day-section]]

Table 3

Calendar Day

Definition:	
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Calendar Era-section]]

Table 4

Calendar Era

Definition:	Calendar Era: division of a calendar composed of a sequence of periods of one type counted from a specified date (ISO 19108)
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TM_CalendarEra []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Calendar Month-section]]

Table 5

Calendar Month

Definition:	A month corresponds nominally to the period of a lunar cycle – either the cycle of the phases of the moon, or that of the moon’s revolution around the Earth. (ISO 19108)
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	Calendar Day [1..*]	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Calendar Year-section]]

Table 6

Calendar Year

Definition:	calendar year: period approximately equal in duration to the periodic time of the revolution of the Earth around the sun (ISO 19108)
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
reference	Calendar Era [1..*]	
	Calendar Month [1..*]	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 7

Clock

Definition:	
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TimeScale []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 8

Epoch

Definition:	
Subclass of:	<<-section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalOrdinal ReferenceSystem []	
definition	Undefined []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 9

ReferenceSystem

Definition:	
Subclass of:	<<-section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
applicable LocationTime OrDomain	<<←section,>>	
authoritative Owner OrDefiningBody	char	
dimension	int [1..*]	

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 10

SpatialReferenceSystem

Definition:	
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	ReferenceSystem []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
dimension	int [1..3]	

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 11

SpatialTemporalReferenceSystem

Definition:	

Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	ReferenceSystem []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 12

TemporalCoordinateReferenceSystem

Definition:	
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
definition	Undefined []	
	TemporalReference System []	
	TemporalCRS []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
uom	char	

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 13

TemporalOrdinalReferenceSystem

Definition:	
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalReference System []	
definition	Undefined []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
applicable Location OrRegion	int [0..1]	
events	Event [1..n]	

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 14

TemporalReferenceSystem

Definition:	
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
definition	Temporal reference system []	
	ReferenceSystem []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
dimension	int	
epoch	Epoch [0..1]	
nameOrId	char	
notations	<<←section,>> [0..n]	

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 15

TimeScale

Definition:	
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalCoordinate ReferenceSystem []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

14.2. Temporal Objects

[[Calendar Date-section]]

Table 16

Calendar Date

Definition:	A data type that shall be used to identify temporal position within a calendar. (ISO 19108)
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	Day of week []	
	Day of Month []	
	Month of year []	
	Entity []	
referenceSystem	Calendar [1]	
	Year of Era []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 17

Coordinate

Definition:	

Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	Entity []	
referenceSystem	TemporalCoordinate ReferenceSystem [1]	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Day of Month-section]]

Table 18

Day of Month

Definition:	
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Day of week-section]]

Table 19

Day of week

Definition:	The day of week day: period having a duration nominally equivalent to the periodic time of the Earth's rotation around its axis (ISO 19108)
Subclass of:	<<section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	Day of week []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 20

Entity

Definition:	A temporal interval or instant.
Subclass of:	<<section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
hasDefinition	Temporal entity []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 21

Event

Definition:	Event: action which occurs at an instant (ISO 19108)
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalOrdinal ReferenceSystem []	
definition	Undefined []	
isA	Temporal entity []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
Name	char	

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 22

Instant

Definition:	A temporal entity with zero extent or duration instant: point representing position in time (ISO 19108)
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
hasDefinition	Time instant []	
	GM_Point []	
	Coordinate []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 23

Interval

Definition:	A temporal entity with an extent or duration
Subclass of:	<<--section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
hasDefinition	Time interval []	
	Coordinate []	
	GM_Curve []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Month of year-section]]

Table 24

Month of year

Definition:	The month of the year Month: period approximately equal in duration to the periodic time of a lunar cycle (ISO 19108)
Subclass of:	<<--section,>>

Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	Month of year []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Time of day-section]]

Table 25

Time of day

Definition:	time of day: designation of the temporal position of a particular instant within a calendar day (ISO 19108)
Subclass of:	<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

[[Year of Era-section]]

Table 26

Year of Era

Definition:	calendar year: period approximately equal in duration to the periodic time of the revolution of the Earth around the sun (ISO 19108)

Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

14.3. ISO 19107

Table 27

GM_Curve

Definition:	GM_Curve (Figure 11) is a descendent subtype of GM_Primitive through GM_Orientable Primitive. It is the basis for 1-dimensional geometry. A curve is a continuous image of an open interval and so could be written as a parameterized function such as c(t):(a, b)®En where “t” is a real parameter and En is Euclidean space of dimension n (usually 2 or 3, as determined by the coordinate reference system). Any other parameterization that results in the same image curve, traced in the same direction, such as any linear shifts and positive scales such as e(t) = c(a + t(b-a)):(0,1) ®En, is an equivalent representation of the same curve. For the sake of simplicity, GM_Curves should be parameterized by arc length, so that the parameterization operation inherited from GM_GenericCurve (see 6.4.7) will be valid for parameters between 0 and the length of the curve. Curves are continuous, connected, and have a measurable length in terms of the coordinate system. The orientation of the curve is determined by this parameterization, and is consistent with the tangent function, which approximates the derivative function of the parameterization and shall always point in the “forward” direction. The parameterization of the reversal of the curve defined by c(t):(a, b)®En would be defined by a function of the form s(t) = c(a + b — t):(a, b)®En. A curve is composed of one or more curve segments. Each curve segment within a curve may be defined using a different interpolation method. The curve segments are connected to one another, with the end point of each segment except the last being the start point of the next segment in the segment list.
Subclass of:	<<←section,>>
Stereotype:	«type»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».		

Table 28

GM_Point

Definition:	GM_Point (Figure 9) is the basic data type for a geometric object consisting of one and only one point.
Subclass of:	<←section,>>
Stereotype:	«type»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
position	DirectPosition	The attribute "position" shall be the DirectPosition of this GM_Point. GM_Point::position [1] : DirectPosition NOTE In most cases, the state of a GM_Point is fully determined by its position attribute. The only exception to this is if the GM_Point has been subclassed to provide additional non-geometric information such as symbology.
Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».		

14.4. ISO 19108

14.5. ISO 19111

Table 29

CRS

Definition:	coordinate reference system which is usually single but may be compound
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 30

SingleCRS

Definition:	coordinate reference system consisting of one coordinate system and either one datum or one datum ensemble
Subclass of:	<<←section,>>
Stereotype:	«interface»
Constraint:	count(datum)+count(datumEnsemble)=1 (OCL):

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	CRS []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 31

TemporalCRS

Definition:	coordinate reference system associated with a temporal datum and a one-dimensional temporal coordinate system
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	SingleCRS []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 32

CoordinateSystem

Definition:	non-repeating sequence of coordinate system axes that spans a given coordinate space Note: A coordinate system is derived from a set of mathematical rules for specifying how coordinates in a given space are to be assigned to points. The coordinate values in a coordinate tuple shall be recorded in the order in which the coordinate system axes associations are recorded.
Subclass of:	<<←section,>>
Stereotype:	«interface»
Constraint:	axis→forAll(count(axisUnitID)=1) (Invariant): axis.axisUnitID is mandatory for all axis

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
referenceSystem	SingleCRS [0..*]	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 33

Datum

Definition:	specification of the relationship of a coordinate system to an object, thus creating a coordinate reference system Note: For geodetic and vertical coordinate reference systems, it relates a coordinate system to the Earth. With other types of coordinate reference systems, the datum may relate the coordinate system to another physical or virtual object. A datum uses a parameter or set of parameters that determine the location of the origin of the coordinate reference system. Each datum subtype can be associated with only specific types of coordinate reference systems.
Subclass of:	<<←section,>>
Stereotype:	«interface»

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
referenceSystem	SingleCRS [0..*]	
	TemporalCoordinate ReferenceSystem []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
anchorDefinition	CharacterString [0..1]	description, possibly including coordinates of an identified point or points, of the relationship used to anchor a coordinate system to the Earth or alternate object Note: For modern geodetic reference frames the anchor may be a set of station coordinates; if the reference frame is dynamic it will also include coordinate velocities. For a traditional geodetic datum, the anchor may be a point known as the fundamental point, which is traditionally the point where the relationship between geoid and ellipsoid is defined, together with a direction from that point. - For a vertical reference frame the anchor may be the zero level at one or more defined locations or a conventionally defined surface. - For an engineering datum, the anchor may be an identified physical point with the orientation defined relative to the object.
conventionalRS	IdentifiedObject [0..1]	name, identifier, alias and remarks for the terrestrial reference system or vertical reference system realized by this reference frame Examples:

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
		“ITRS” for ITRF88 through ITRF2008 and ITRF2014, or “EVRS” for EVRF2000 and EVRF2007.
publicationDate	Date [0..1]	date on which the datum definition was published

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 34

DateTimeTemporalCS

Definition:	one-dimensional coordinate system used to record time in dateTime representation as defined in ISO 8601. Note: A DateTimeTemporalCS shall have one axis association. It does not use axisUnitID; the temporal quantities are defined through the ISO 8601 representation.
Subclass of:	<<section,>>
Stereotype:	«interface»
Constraint:	coordinateType=dateTime (Invariant):
Constraint:	axis→forAll(count(axisUnitID)=0) (Invariant): axis.axisUnitID shall not be used

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalCS []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 35

TemporalCountCS

Definition:	one-dimensional coordinate system used to record time as an integer count Note: A TemporalCountCS shall have one axis association.

Subclass of:	<<←section,>>
Stereotype:	«interface»
Constraint:	coordinateType=integer (Invariant):

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalCS []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 36

TemporalCS

Definition:	one-dimensional coordinate system used to record time Note: A TemporalCS shall have one axis association.
Subclass of:	<<←section,>>
Stereotype:	«interface»
Constraint:	axis→size()=1 (Invariant): a Temporal CS shall have exactly one axis

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
referenceSystem	TemporalCRS [0..*]	
	CoordinateSystem []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION
coordinateType	CoordinateDataType	datatype of coordinate values

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

Table 37

TemporalMeasureCS

Definition:	one-dimensional coordinate system used to record a time as a real number Note: A Temporal MeasureCS shall have one axis association.
Subclass of:	<<—section,>>
Stereotype:	«interface»
Constraint:	coordinateType=real (Invariant):

ROLE NAME	TARGET CLASS AND MULTIPLICITY	DEFINITION
	TemporalCS []	

ATTRIBUTE	VALUE TYPE AND MULTIPLICITY	DEFINITION

Note: Unless otherwise specified, all attributes and role names have the stereotype «Property».

A

ANNEX A (NORMATIVE) ANNEX TITLE

A

ANNEX A (NORMATIVE) ANNEX TITLE

<Insert annex content here>

NOTE: Place annex material in sequential order and set `obligation` attribute as “normative” (default) or “informative” according to the case.

B

ANNEX B (INFORMATIVE) ISO GLOSSARY

B

ANNEX B (INFORMATIVE) ISO GLOSSARY

The following concepts from the ISO TC211 Harmonized UML model are referenced by the Temporal Conceptual UML model but do not play a major role in its' definition. They are provided here to support a more complete understanding of the model.

Area
The measure of the physical extent of any topologically 2-D geometric object. Usually measured in "square" units of length.
[ISO 19103]

Boolean
Boolean is the mathematical datatype associated with two-valued logic
[ISO 19103]

CC_CoordinateOperation
A mathematical operation on coordinates that transforms or converts coordinates to another coordinate reference system.
[ISO 19111]

Character
A symbol from a standard character-set.
[ISO 19103]

CharacterString
Characterstring is a family of datatypes which represent strings of symbols from standard character-sets.
[ISO 19103]

CRS
Coordinate reference system which is usually single but may be compound.
[ISO 19111]

CV_DiscreteCoverage
A subclass of CV_Coverage that returns a single record of values for any direct position within a single geometric object in its spatiotemporal domain.
[[iso19123]]

CV_DomainObject
An element of the domain of the CV_Coverage. It is an aggregation of objects that may include any combination of GM_Objects (ISO 19107:2003), TM_GeometricPrimitives (ISO 10108), or spatial or temporal objects defined in other standards, such as the CV_GridPoint defined in this International Standard.

[[iso19123]]

CV_GridPointValuePair
A subtype of CV_GeometryValuePair that has a GM_GridPoint as the value of its geometry attribute.
[[iso19123]]

CV_GridValuesMatrix
The geometry represented by the various offset vectors is in the image plane of the grid.
[[iso19123]]

CV_ReferenceableGrid
A subclass of CV_Coverage that relates the grid coordinates to an external coordinate reference system.
[[iso19123]]

Date
Date gives values for year, month and day. Representation of Date is specified in ISO 8601. Principles for date and time are further discussed in ISO 19108.
[ISO 19103]

DateTime
A DateTime is a combination of a date and a time types. Representation of DateTime is specified in ISO 8601. Principles for date and time are further discussed in ISO 19108.
[ISO 19103]

Distance
Used as a type for returning distances and possibly lengths.
[ISO 19103]

Engineering CRS
A contextually local coordinate reference system which can be divided into two broad categories:

1. earth-fixed systems applied to engineering activities on or near the surface of the earth;
2. CRSs on moving platforms such as road vehicles, vessels, aircraft or spacecraft.
[ISO 19111]

Generic Name
Generic Name is the abstract class for all names in a NameSpace. Each instance of a GenericName is either a LocalName or a ScopedName.
[ISO 19103]

Geometry
Geometry is the root class of the geometric object taxonomy and supports interfaces common to all geographically referenced geometric objects.
[ISO 19107]

GM_CompositePoint
A GM_Complex containing one and only one GM_Point.

[ISO 19107]

GM_CompositeSolid
A set of geometric solids adjoining one another along common boundary geometric surfaces
[ISO 19107]

GM_GenericSurface
GM_Surface and GM_SurfacePatch both represent sections of surface geometry, and therefore share a number of operation signatures. These are defined in the interface class GM_GenericSurface.
[ISO 19107]

GM_LineString
Consists of sequence of line segments, each having a parameterization like the one for GM_LineSegment
[ISO 19107]

GM_MultiPrimitive
The root class for all primitive aggregates. The association role "element" shall be the set of GM_Primitives contained in this GM_MultiPrimitive. The attribute declaration here specializes the one at GM_Aggregate to include only GM_Primitives in this type of aggregate.
[ISO 19107]

GM_OrientableSurface
A surface and an orientation inherited from GM_OrientablePrimitive. If the orientation is "+", then the GM_OrientableSurface is a GM_Surface. If the orientation is "-", then the GM_OrientableSurface is a reference to a GM_Surface with an upNormal that reverses the direction for this GM_OrientableSurface, the sense of "the top of the surface".
[ISO 19107]

GM_PolyhedralSurface
A GM_Surface composed of polygon surfaces (GM_Polygon) connected along their common boundary curves.
[ISO 19107]

GM_Position
A union type consisting of either a DirectPosition or of a reference to a GM_Point from which a DirectPosition shall be obtained.
[ISO 19107]

GM_Primitive
The abstract root class of the geometric primitives. Its main purpose is to define the basic "boundary" operation that ties the primitives in each dimension together.
[ISO 19107]

Integer
An exact integer value, with no fractional part.
[ISO 19103]

Internet of Things

The network of physical objects—“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.
Wikipedia

IO_IdentifiedObjectBase
Supplementary identification and remarks information for a CRS or CRS-related object.
[ISO 19111]

Length
The measure of distance as an integral, i.e. the limit of an infinite sum of distances between points on a curve.
[ISO 19103]

Measure
The result from performing the act or process of ascertaining the extent, dimensions, or quantity of some entity.
[ISO 19103]

Number
The base type for all number data, giving the basic algebraic operations.
[ISO 19103]

Point
GM_Point is the basic data type for a geometric object consisting of one and only one point.
[ISO 19107]

Real
The common binary Real finite implementation using base 2.
[ISO 19103]

RS_ReferenceSystem
Description of a spatial and temporal reference system used by a dataset.
[ISO 19111]

Scoped Name
ScopedName is a composite of a LocalName for locating another NameSpace and a GenericName valid in that NameSpace. ScopedName contains a LocalName as head and a GenericName, which might be a LocalName or a ScopedName, as tail.
[ISO 19103]

Solid
GM_Solid, a subclass of GM_Primitive, is the basis for 3-dimensional geometry. The extent of a solid is defined by the boundary surfaces.
[ISO 19107]

Time
Time is the designation of an instant on a selected time scale, astronomical or atomic. It is used in the sense of time of day.
[ISO 19103]

TM_Duration

A data type to be used for describing length or distance in the temporal dimension.
[ISO 19108]

TM_TemporalPosition
The position of a TM_Instant relative to a TM_ReferenceSystem.
[ISO 19108]

Unit of Measure
Any of the systems devised to measure some physical quantity such distance or area or a system devised to measure such things as the passage of time.
[ISO 19103]

URI
Uniform Resource Identifier (URI), is a compact string of characters used to identify or name a resource
[ISO 19103]

Volume
Volume is the measure of the physical space of any 3-D geometric object.
[ISO 19103]

C

ANNEX C (INFORMATIVE) GLOSSARY

C

ANNEX C (INFORMATIVE) GLOSSARY

C.1. conceptual model

description of common concepts and their relationships, particularly in order to facilitate exchange of information between parties within a specific domain. A conceptual model is explicitly chosen to be independent of design or implementation concerns.

[**SOURCE:**]

C.2. compound coordinate reference system

coordinate reference system using at least two independent coordinate reference systems

Note 1 to entry: Coordinate reference systems are independent of each other if coordinate values in one cannot be converted or transformed into coordinate values in the other.

[**SOURCE:** ISO 19111]

C.3. 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]

C.4. **coordinate epoch**

epoch to which coordinates in a dynamic coordinate reference system are referenced

[**SOURCE:** ISO 19111]

C.5. **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]

C.6. **coordinate system**

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

[**SOURCE:** ISO 19111]

C.7. **datum**

reference frame ADMITTED

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

[**SOURCE:** ISO 19111]

C.8. derived coordinate reference system

coordinate reference system that is defined through the application of a specified coordinate conversion to the coordinates within a previously established coordinate reference system

Note 1 to entry: The previously established coordinate reference system is referred to as the base coordinate reference system.

Note 2 to entry: A derived coordinate reference system inherits its datum or reference frame from its base coordinate reference system.

Note 3 to entry: The coordinate conversion between the base and derived coordinate reference system is implemented using the parameters and formula(s) specified in the definition of the coordinate conversion.

[**SOURCE:** ISO 19111]

C.9. dynamic coordinate reference system

coordinate reference system that has a dynamic reference frame

Note 1 to entry: Coordinates of points on or near the crust of the Earth that are referenced to a dynamic coordinate reference system may change with time, usually due to crustal deformations such as tectonic motion and glacial isostatic adjustment.

Note 2 to entry: Metadata for a dataset referenced to a dynamic coordinate reference system should include coordinate epoch information.

[**SOURCE:** ISO 19111]

C.10. dynamic reference frame

dynamic datum ADMITTED

reference frame in which the defining parameters include time evolution

Note 1 to entry: The defining parameters that have time evolution are usually a coordinate set.

[**SOURCE:** ISO 19111]

C.11. engineering coordinate reference system

coordinate reference system based on an engineering datum

Example 1 System for identifying relative positions within a few kilometres of the reference point, such as a building or construction site.

Example 2 Coordinate reference system local to a moving object such as a ship or an orbiting spacecraft.

Example 3 Internal coordinate reference system for an image. This has continuous axes. It may be the foundation for a grid.

C.12. engineering datum

local datum ADMITTED

datum describing the relationship of a coordinate system to a local reference

Note 1 to entry: Engineering datum excludes both geodetic and vertical reference frames.

[**SOURCE:** ISO 19111]

C.13. epoch

<geodesy> point in time

Note 1 to entry: In this document an epoch is expressed in the Gregorian calendar as a decimal year.

Example 2017-03-25 in the Gregorian calendar is epoch 2017.23.

[**SOURCE:** ISO 19111]

C.14. frame reference epoch

epoch of coordinates that define a dynamic reference frame

[**SOURCE:** ISO 19111]

C.15. linear coordinate system

one-dimensional coordinate system in which a linear feature forms the axis

Example 1 Distances along a pipeline.

Example 2 Depths down a deviated oil well bore.

[**SOURCE:** ISO 19111]

C.16. parameter reference epoch

epoch at which the parameter values of a time-dependent coordinate transformation are valid

Note 1 to entry: The transformation parameter values first need to be propagated to the epoch of the coordinates before the coordinate transformation can be applied.

[**SOURCE:** ISO 19111]

C.17. parametric coordinate reference system

coordinate reference system based on a parametric datum

[**SOURCE:** ISO 19111]

C.18. parametric coordinate system

one-dimensional coordinate system where the axis units are parameter values which are not inherently spatial

[**SOURCE:** ISO 19111]

C.19. parametric datum

datum describing the relationship of a parametric coordinate system to an object

Note 1 to entry: The object is normally the Earth.

[**SOURCE:** ISO 19111]

C.20. point motion operation

coordinate operation that changes coordinates within one coordinate reference system due to the motion of the point

Note 1 to entry: The change of coordinates is from those at an initial epoch to those at another epoch.

Note 2 to entry: In this document the point motion is due to tectonic motion or crustal deformation.

[**SOURCE:** ISO 19111]

C.21. reference frame

datum ADMITTED

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

[**SOURCE:** ISO 19111]

C.22. spatio-parametric coordinate reference system

compound coordinate reference system in which one constituent coordinate reference system is a spatial coordinate reference system and one is a parametric coordinate reference system

Note 1 to entry: Normally the spatial component is “horizontal” and the parametric component is “vertical”.

[**SOURCE:** ISO 19111]

C.23. spatio-parametric-temporal coordinate reference system

compound coordinate reference system comprised of spatial, parametric and temporal coordinate reference systems

[**SOURCE:** ISO 19111]

C.24. spatio-temporal coordinate reference system

compound coordinate reference system in which one constituent coordinate reference system is a spatial coordinate reference system and one is a temporal coordinate reference system

[**SOURCE:** ISO 19111]

C.25. static coordinate reference system

coordinate reference system that has a static reference frame

Note 1 to entry: Coordinates of points on or near the crust of the Earth that are referenced to a static coordinate reference system do not change with time.

Note 2 to entry: Metadata for a dataset referenced to a static coordinate reference system does not require coordinate epoch information.

[**SOURCE:** ISO 19111]

C.26. static reference frame

static datum

reference frame in which the defining parameters exclude time evolution

[**SOURCE:** ISO 19111]

C.27. temporal coordinate reference system

coordinate reference system based on a temporal datum

[**SOURCE:** ISO 19111]

C.28. temporal coordinate system

<geodesy> one-dimensional coordinate system where the axis is time
[**SOURCE:** ISO 19111]

C.29. temporal datum

datum describing the relationship of a temporal coordinate system to an object

Note 1 to entry: The object is normally time on the Earth.

[**SOURCE:** ISO 19111]

C.30. terrestrial reference system

TRS ADMITTED

set of conventions defining the origin, scale, orientation and time evolution of a spatial reference system co-rotating with the Earth in its diurnal motion in space

Note 1 to entry: The abstract concept of a TRS is realised through a terrestrial reference frame that usually consists of a set of physical points with precisely determined coordinates and optionally their rates of change. In this document terrestrial reference frame is included within the geodetic reference frame element of the data model

[**SOURCE:** ISO 19111]

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BIBLIOGRAPHY

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