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Australian/New Zealand Standard™

Geographic information — Referencing by coordinates



AS/NZS ISO 19111:2019

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- Bureau of Meteorology (Australian Government)
- Australian Bureau of Statistics
- Australian Maritime Safety Authority
- CSIRO
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- Department of Defence (Australian Government)
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Australian/New Zealand Standard™

Geographic information — Referencing by coordinates

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee IT-004, Geographical Information/Geomatics, to supersede AS/NZS ISO 19111:2008, *Geographic information — Spatial referencing by coordinates*.

A1 Amendment No. 1 (October 2021) to this Standard was prepared by the Australia/Standards New Zealand Committee IT-004, Geographical Information/Geomatics. **A1**

The objective of this Standard is to define the conceptual schema for the description of referencing by coordinates. It describes the minimum data required to define coordinate reference systems. This document supports the definition of—

- (a) spatial coordinate reference systems where coordinate values do not change with time. The system may—
 - (i) be geodetic and apply on a national or regional basis; or
 - (ii) apply locally such as for a building or construction site; or
 - (iii) apply locally to an image or image sensor; or
 - (iv) be referenced to a moving platform such as a car, a ship, an aircraft or a spacecraft. Such a coordinate reference system can be related to a second coordinate reference system which is referenced to the Earth through a transformation that includes a time element;
- (b) spatial coordinate reference systems in which coordinate values of points on or near the surface of the earth change with time due to tectonic plate motion or other crustal deformation. Such dynamic systems include time evolution, however they remain spatial in nature;
- (c) parametric coordinate reference systems which use a non-spatial parameter that varies monotonically with height or depth;
- (d) temporal coordinate reference systems which use dateTime, temporal count or temporal measure quantities that vary monotonically with time; and
- (e) mixed spatial, parametric or temporal coordinate reference systems.

A1 This Standard is identical with, and has been reproduced from, ISO 19111:2019, *Geographic information — Referencing by coordinates* and its Amendment No. 1 (2021) which has been added at the end of the source text. **A1**

As this document has been reproduced from an International Standard, a full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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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*, in close collaboration with [the Open Geospatial Consortium \(OGC\)](http://www.opengeospatial.org).

This third edition cancels and replaces the second edition (ISO 19111:2007), which has been technically revised. This document also incorporates the provisions of ISO 19111-2:2009, which is cancelled.

The changes in this edition compared to the previous edition are:

- inclusion of applicable modern geodetic terminology;
- extension to describe dynamic geodetic reference frames;
- extension to describe geoid-based vertical coordinate reference systems;
- extension to allow triaxial ellipsoid for planetary applications;
- extension to describe three-dimensional projected coordinate reference systems;
- addition of 'datum ensembles' to allow grouping of related realizations of a reference frame where for lower accuracy applications the differences are insignificant;
- clarification in the modelling of derived coordinate reference systems;
- remodelling of the metadata elements scope and extent;
- addition of requirements to describe coordinate metadata and the relationship between spatial coordinates;
- additional modelling of temporal coordinate reference system components sufficient for spatio-temporal coordinate referencing;
- consolidation of the provisions of ISO 19111-2:2009 (*Spatial referencing by coordinates — Extension for parametric values*) into this document;

- change in name from 'Spatial referencing by coordinates' to 'Referencing by coordinates', due to the inclusion of the non-spatial coordinate reference system subtypes of parametric (from ISO 19111-2) and temporal;
- the correction of minor errors.

Further details are given in [Annex G](#).

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

Geographic information is inherently four-dimensional and includes time. The spatial component relates the features represented in geographic data to positions in the real world. Spatial references fall into two categories:

- those using coordinates;
- those based on geographic identifiers.

Spatial referencing by geographic identifiers is defined in ISO 19112[5]. This document describes the data elements, relationships and associated metadata required for spatial referencing by coordinates, expanded from a strictly spatial context to include time. The temporal element is restricted to temporal coordinate systems having a continuous axis. The temporal element excludes calendars and ordinal reference systems due to their complexities in definition and in transformation. The context is shown in [Figure 1](#).

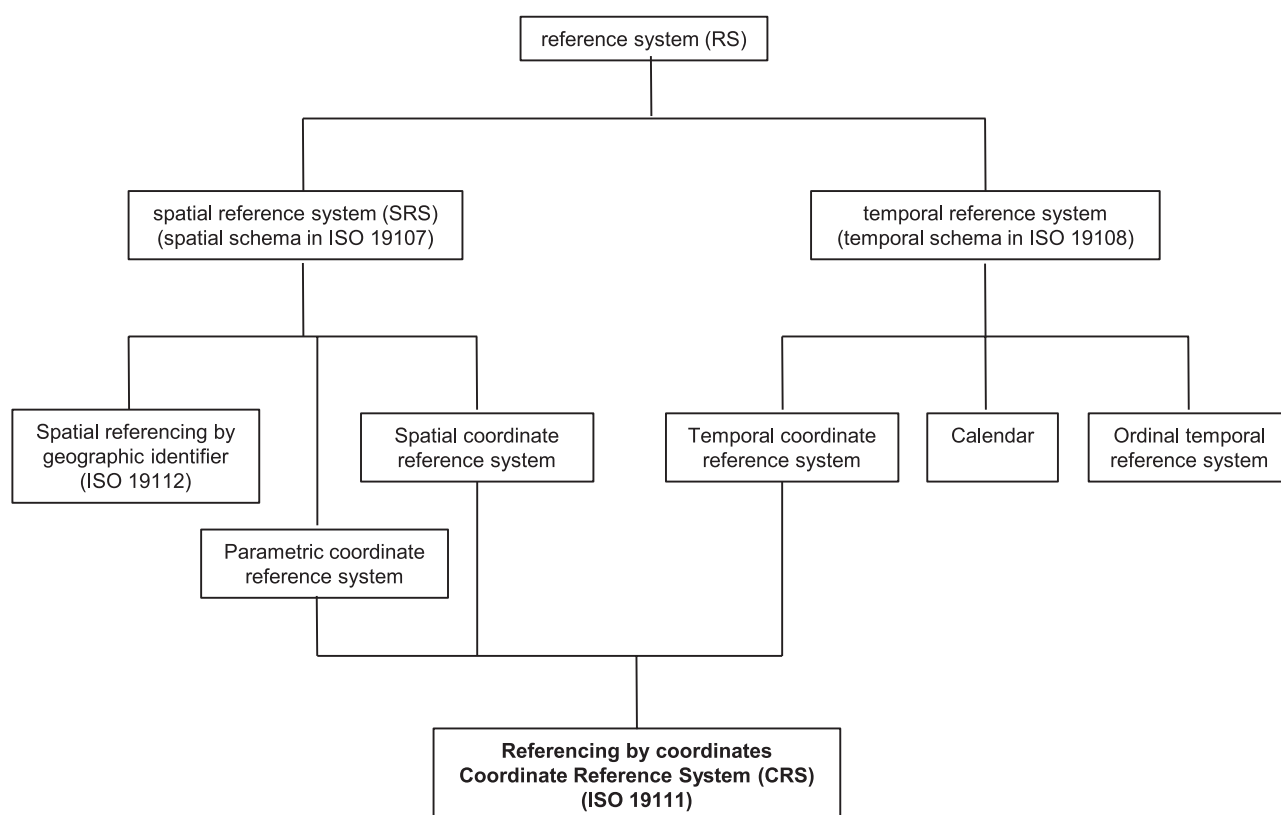


Figure 1 — Context of referencing by coordinates

Certain scientific communities use three-dimensional systems where horizontal position is combined with a non-spatial parameter. In these communities, the parameter is considered to be a third, vertical, axis. The parameter, although varying monotonically with height or depth, does not necessarily vary in a simple manner. Thus conversion from the parameter to height or depth is non-trivial. The parameters concerned are normally absolute measurements and the datum is taken with reference to a direct physical measurement of the parameter. These non-spatial parameters and parametric coordinate reference system modelling constructs were previously described in ISO 19111-2:2009 but have been incorporated into this revision because the modelling constructs are identical to the other coordinate reference system types included in this document.

This document describes the elements that are necessary to fully define various types of coordinate reference systems applicable to geographic information. The subset of elements required is partially dependent upon the type of coordinates. This document also includes optional fields to allow for the

inclusion of metadata about the coordinate reference systems. The elements are intended to be both machine and human readable.

In addition to describing a coordinate reference system, this document provides for the description of a coordinate operation between two different coordinate reference systems or a coordinate operation to account for crustal motion over time. With such information, spatial data referenced to different coordinate reference systems can be referenced to one specified coordinate reference system at one specified time. This facilitates spatial data integration. Alternatively, an audit trail of coordinate manipulations can be maintained.

Australian/New Zealand Standard

Geographic information — Referencing by coordinates

1 Scope

This document defines the conceptual schema for the description of referencing by coordinates. It describes the minimum data required to define coordinate reference systems. This document supports the definition of:

- spatial coordinate reference systems where coordinate values do not change with time. The system may:
 - be geodetic and apply on a national or regional basis, or
 - apply locally such as for a building or construction site, or
 - apply locally to an image or image sensor;
 - be referenced to a moving platform such as a car, a ship, an aircraft or a spacecraft. Such a coordinate reference system can be related to a second coordinate reference system which is referenced to the Earth through a transformation that includes a time element;
- spatial coordinate reference systems in which coordinate values of points on or near the surface of the earth change with time due to tectonic plate motion or other crustal deformation. Such dynamic systems include time evolution, however they remain spatial in nature;
- parametric coordinate reference systems which use a non-spatial parameter that varies monotonically with height or depth;
- temporal coordinate reference systems which use `dateTime`, temporal count or temporal measure quantities that vary monotonically with time;
- mixed spatial, parametric or temporal coordinate reference systems.

The *definition* of a coordinate reference system does not change with time, although in some cases some of the defining parameters can include a rate of change of the parameter. The coordinate values within a dynamic and in a temporal coordinate reference system can change with time.

This document also describes the conceptual schema for defining the information required to describe operations that change coordinate values.

In addition to the minimum data required for the definition of the coordinate reference system or coordinate operation, the conceptual schema allows additional descriptive information - coordinate reference system metadata - to be provided.

This document is applicable to producers and users of geographic information. Although it is applicable to digital geographic data, the principles described in this document can be extended to many other forms of spatial data such as maps, charts and text documents.

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 8601, *Data elements and interchange formats — Information interchange — Representation of dates and times*

ISO 19103, *Geographic information — Conceptual schema language*

ISO 19115-1:2014, *Geographic information — Metadata — Part 1: Fundamentals*



Documents

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3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1

affine coordinate system

coordinate system in Euclidean space with straight axes that are not necessarily mutually perpendicular

3.1.2

Cartesian coordinate system

coordinate system in Euclidean space which gives the position of points relative to n mutually perpendicular straight axes all having the same unit of measure

Note 1 to entry: n is 2 or 3 for the purposes of this document.

Note 2 to entry: A Cartesian coordinate system is a specialisation of an affine coordinate system.

3.1.3

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.

3.1.4

concatenated operation

coordinate operation consisting of the sequential application of multiple coordinate operations

3.1.5

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.

3.1.6

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.

3.1.7

coordinate epoch

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

3.1.8

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

3.1.9

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.

3.1.10

coordinate set

collection of coordinate tuples referenced to the same coordinate reference system and if that coordinate reference system is dynamic also to the same coordinate epoch

3.1.11

coordinate system

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

3.1.12

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.

3.1.13

coordinate tuple

tuple composed of coordinates

Note 1 to entry: The number of coordinates in the coordinate tuple equals the dimension of the coordinate system; the order of coordinates in the coordinate tuple is identical to the order of the axes of the coordinate system.

3.1.14

cylindrical coordinate system

three-dimensional coordinate system in Euclidean space in which position is specified by two linear coordinates and one angular coordinate

3.1.15

datum

reference frame

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

3.1.16

datum ensemble

group of multiple realizations of the same terrestrial or vertical reference system that, for approximate spatial referencing purposes, are not significantly different

Note 1 to entry: Datasets referenced to the different realizations within a datum ensemble may be merged without coordinate transformation.

Note 2 to entry: 'Approximate' is for users to define and typically is in the order of under 1 decimetre but may be up to 2 metres.

EXAMPLE "WGS 84" as an undifferentiated group of realizations including WGS 84 (TRANSIT), WGS 84 (G730), WGS 84 (G873), WGS 84 (G1150), WGS 84 (G1674) and WGS 84 (G1762). At the surface of the Earth these have changed on average by 0.7 m between the TRANSIT and G730 realizations, a further 0.2 m between G730 and G873, 0.06 m between G873 and G1150, 0.2 m between G1150 and G1674 and 0.02 m between G1674 and G1762).

3.1.17

depth

distance of a point from a chosen vertical reference surface downward along a line that is perpendicular to that surface

Note 1 to entry: The line direction may be straight, or be dependent on the Earth's gravity field or other physical phenomena.

Note 2 to entry: A depth above the vertical reference surface will have a negative value.

3.1.18

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.

3.1.19

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.

3.1.20

dynamic reference frame

dynamic datum

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.

3.1.21 easting

E

distance in a coordinate system, eastwards (positive) or westwards (negative) from a north-south reference line

3.1.22 ellipsoid

reference ellipsoid

<geodesy> geometric reference surface embedded in 3D Euclidean space formed by an ellipse that is rotated about a main axis

Note 1 to entry: For the Earth the ellipsoid is bi-axial with rotation about the polar axis. This results in an oblate ellipsoid with the midpoint of the foci located at the nominal centre of the Earth.

3.1.23 ellipsoidal coordinate system

geodetic coordinate system

coordinate system in which position is specified by geodetic latitude, geodetic longitude and (in the three-dimensional case) ellipsoidal height

3.1.24 ellipsoidal height

geodetic height

h

distance of a point from the reference ellipsoid along the perpendicular from the reference ellipsoid to this point, positive if upwards or outside of the reference ellipsoid

Note 1 to entry: Only used as part of a three-dimensional ellipsoidal coordinate system or as part of a three-dimensional Cartesian coordinate system in a three-dimensional projected coordinate reference system, but never on its own.

3.1.25 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.

3.1.26 engineering datum

local datum

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.

3.1.27 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.

3.1.28 flattening

f

ratio of the difference between the semi-major axis (a) and semi-minor axis (b) of an ellipsoid to the semi-major axis: $f = (a - b)/a$

Note 1 to entry: Sometimes inverse flattening $1/f = a/(a - b)$ is given instead; $1/f$ is also known as reciprocal flattening.

3.1.29 frame reference epoch

epoch of coordinates that define a dynamic reference frame

3.1.30 geocentric latitude

angle from the equatorial plane to the direction from the centre of an ellipsoid through a given point, northwards treated as positive

3.1.31 geodetic coordinate reference system

three-dimensional coordinate reference system based on a geodetic reference frame and having either a three-dimensional Cartesian or a spherical coordinate system

Note 1 to entry: In this document a coordinate reference system based on a geodetic reference frame and having an ellipsoidal coordinate system is geographic.

3.1.32 geodetic latitude

ellipsoidal latitude

φ

angle from the equatorial plane to the perpendicular to the ellipsoid through a given point, northwards treated as positive

3.1.33 geodetic longitude

ellipsoidal longitude

λ

angle from the prime meridian plane to the meridian plane of a given point, eastward treated as positive

3.1.34 geodetic reference frame

reference frame or datum describing the relationship of a two- or three-dimensional coordinate system to the Earth

Note 1 to entry: In the data model described in this document, the UML class GeodeticReferenceFrame includes both modern terrestrial reference frames and classical geodetic datums.

3.1.35 geographic coordinate reference system

coordinate reference system that has a geodetic reference frame and an ellipsoidal coordinate system

3.1.36 geoid

equipotential surface of the Earth's gravity field which is perpendicular to the direction of gravity and which best fits mean sea level either locally, regionally or globally

3.1.37**gravity-related height***H*

height that is dependent on the Earth's gravity field

Note 1 to entry: This refers to, amongst others, orthometric height and Normal height, which are both approximations of the distance of a point above the mean sea level, but also may include Normal-orthometric heights, dynamic heights or geopotential numbers.

Note 2 to entry: The distance from the reference surface may follow a curved line, not necessarily straight, as it is influenced by the direction of gravity.

3.1.38**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*).

3.1.39**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.

3.1.40**map projection**

coordinate conversion from an ellipsoidal coordinate system to a plane

3.1.41**mean sea level**

MSL

<geodesy> average level of the surface of the sea over all stages of tide and seasonal variations

Note 1 to entry: Mean sea level in a local context normally means mean sea level for the region calculated from observations at one or more points over a given period of time. To meet IHO standards that period should be one full lunar cycle of 19 years. Mean sea level in a global context differs from a global geoid by not more than 2 m.

3.1.42**meridian**

intersection of an ellipsoid by a plane containing the shortest axis of the ellipsoid

Note 1 to entry: This term is generally used to describe the pole-to-pole arc rather than the complete closed figure.

3.1.43**northing***N*

distance in a coordinate system, northwards (positive) or southwards (negative) from an east-west reference line

3.1.44**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.

3.1.45**parametric coordinate reference system**

coordinate reference system based on a parametric datum

3.1.46**parametric coordinate system**

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

3.1.47**parametric datum**

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

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

3.1.48**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.

3.1.49**polar coordinate system**

two-dimensional coordinate system in Euclidean space in which position is specified by one distance coordinate and one angular coordinate

Note 1 to entry: For the three-dimensional case, see spherical coordinate system.

3.1.50**prime meridian**

meridian from which the longitudes of other meridians are quantified

3.1.51**projected coordinate reference system**

coordinate reference system derived from a geographic coordinate reference system by applying a map projection

Note 1 to entry: May be two- or three-dimensional, the dimension being equal to that of the geographic coordinate reference system from which it is derived.

Note 2 to entry: In the three-dimensional case the horizontal coordinates (geodetic latitude and geodetic longitude coordinates) are projected to northing and easting and the ellipsoidal height is unchanged.

3.1.52**reference frame**

datum

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

3.1.53**semi-major axis***a*

semi-diameter of the longest axis of an ellipsoid

3.1.54**semi-minor axis***b*

semi-diameter of the shortest axis of an ellipsoid

3.1.55**sequence**

finite, ordered collection of related items (objects or values) that may be repeated

3.1.56**spatial reference**

description of position in the real world

Note 1 to entry: This may take the form of a label, code or coordinate tuple.

3.1.57**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”.

3.1.58**spatio-parametric-temporal coordinate reference system**

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

3.1.59**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

3.1.60**spherical coordinate system**

three-dimensional coordinate system in Euclidean space in which position is specified by one distance coordinate and two angular coordinates

Note 1 to entry: Not to be confused with an ellipsoidal coordinate system based on an ellipsoid ‘degenerated’ into a sphere.

3.1.61**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.

3.1.62**static reference frame**

static datum

reference frame in which the defining parameters exclude time evolution

3.1.63**temporal coordinate reference system**

coordinate reference system based on a temporal datum

3.1.64**temporal coordinate system**

<geodesy> one-dimensional coordinate system where the axis is time

3.1.65**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.

3.1.66**terrestrial reference system**

TRS

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.

3.1.67**transformation reference epoch**

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

Note 1 to entry: Coordinates first need to be propagated to this epoch before the coordinate transformation is applied. This is in contrast to a *parameter reference epoch* where the transformation parameter values first need to be propagated to the epoch of the coordinates before the coordinate transformation is applied.

3.1.68**tuple**

ordered list of values

[SOURCE: ISO 19136:2007, 4.1.63]

3.1.69**unit**

defined quantity in which dimensioned parameters are expressed

Note 1 to entry: In this document, the subtypes of units are length units, angular units, scale units, parametric quantities and time quantities.

3.1.70**vertical coordinate reference system**

one-dimensional coordinate reference system based on a vertical reference frame

3.1.71**vertical coordinate system**

one-dimensional coordinate system used for gravity-related height or depth measurements

3.1.72**vertical reference frame**

vertical datum

reference frame describing the relation of gravity-related heights or depths to the Earth

Note 1 to entry: In most cases, the vertical reference frame will be related to mean sea level. Vertical datums include sounding datums (used for hydrographic purposes), in which case the heights may be negative heights or depths.

Note 2 to entry: Ellipsoidal heights are related to a three-dimensional ellipsoidal coordinate system referenced to a geodetic reference frame.

3.1.73

vertical reference system

VRS

set of conventions defining the origin, scale, orientation and time evolution that describes the relationship of gravity-related heights or depths to the Earth

Note 1 to entry: The abstract concept of a VRS is realised through a vertical reference frame.

3.2 Symbols

a	semi-major axis of ellipsoid
b	semi-minor axis of bi-axial ellipsoid
E	easting
f	flattening
H	gravity-related height
h	ellipsoidal height
N	northing
λ	geodetic longitude
φ	geodetic latitude
$E, N, [h]$	Cartesian coordinates in a projected coordinate reference system
X, Y, Z	Cartesian coordinates in a geodetic coordinate reference system
$i, j, [k]$	Cartesian coordinates in an engineering coordinate reference system
r, θ	polar coordinates in a 2D engineering coordinate reference system
r, Ω, θ	spherical coordinates in a 3D engineering coordinate reference system
NOTE In this document Ω is the polar (zenith) angle and θ is the azimuthal angle.	
$\varphi, \lambda, [h]$	ellipsoidal coordinates in a geographic coordinate reference system

3.3 Abbreviated terms

CC	coordinate conversion
CCRS	compound coordinate reference system
CRS	coordinate reference system
CT	coordinate transformation
MSL	mean sea level
pixel	a contraction of “picture element”, the smallest element of a digital image to which attributes are assigned

PMO	point motion operation
SI	le Système International d'unités (International System of Units)
UML	Unified Modeling Language
URI	Uniform Resource Identifier
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional

4 Conformance requirements

This document defines

- two classes of conformance for relating coordinates to coordinate metadata; and
- twenty six classes of conformance for the definition of a coordinate reference system (CRS) or of a coordinate operation.

These are differentiated by type, as shown in [Table 1](#). Implementations should indicate which conformance classes they comply with. Any implementations claiming conformance shall satisfy the requirements in [Annex A](#).

Table 1 — Conformance classes

Conformance class	Description	Conformance requirements given in
Conformance for relating coordinates to coordinate metadata		A.2
1	CRS with static reference frame	
2	CRS with dynamic reference frame	
Conformance of a CRS definition		A.3
3	Geodetic CRS	
	with static reference frame	
	with dynamic reference frame	
	derived geodetic CRS	
6	Geographic CRS	
	with static reference frame	
	with dynamic reference frame	
	derived geographic CRS	
9	Projected CRS	
	derived projected CRS	
11	Vertical CRS	
	with static reference frame	
	with dynamic reference frame	
	derived vertical CRS	
14	Parametric CRS	
	derived parametric CRS	
16	Engineering CRS	

Table 1 (continued)

Conformance class	Description	Conformance requirements given in
17	derived engineering CRS	
18	Temporal CRS	
19	dateTime	
20	temporal count	
21	temporal measure	
22	derived temporal CRS	
23	CRS with datum ensemble	
24	Compound CRS	A.3
Conformance of a coordinate operation definition		A.4
25	Coordinate conversion	
26	Coordinate transformation	
27	Point motion operation	
28	Concatenated operation	
29	Pass-through operation	

The requirements classes for the definition of a coordinate reference system or a coordinate operation are described in this document through tables grouped by UML package. The requirements are then brought together in the conformance classes in [Annex A](#). This retains the package-based layout for describing requirements used in previous versions of this document.

5 Conventions

5.1 Unified Modeling Language notation

In this document, the conceptual schema for describing coordinate reference systems and coordinate operations are presented in the Unified Modeling Language (UML). ISO 19103 presents the specific profile of UML used in this document.

In the UML diagrams in this document, a grey background surround to boxes indicates classes from other standards.

5.2 Attribute status

In this document the conceptual schema is described in [Clauses 6 to 12](#) through tables. In these tables:

- attributes and associations are given an obligation status:

T

Obligation	Definition	Meaning
M	mandatory	This attribute shall be supplied.
C	conditional	This attribute shall be supplied if the condition (given in the attribute description) is true. It may be supplied if the condition is false.
O	optional	This attribute may be supplied.

he Maximum Occurrence column in the tables indicates the maximum number of occurrences of attribute values that are permissible, with N indicating no upper limit.

- non-navigable associations are not included in the UML diagrams or tables.

In the event of any discrepancies between the UML diagrams and text, the UML shall prevail.

6 Referencing by coordinates — Data model overview

The specification for referencing by coordinates is described in this document in the form of a UML model with supplementary text. The UML model contains six UML packages, as shown in [Figure 2](#). Each box represents a package, and contains the package name. Each arrowed line shows the dependency of one package upon another package (at the head of the arrow).

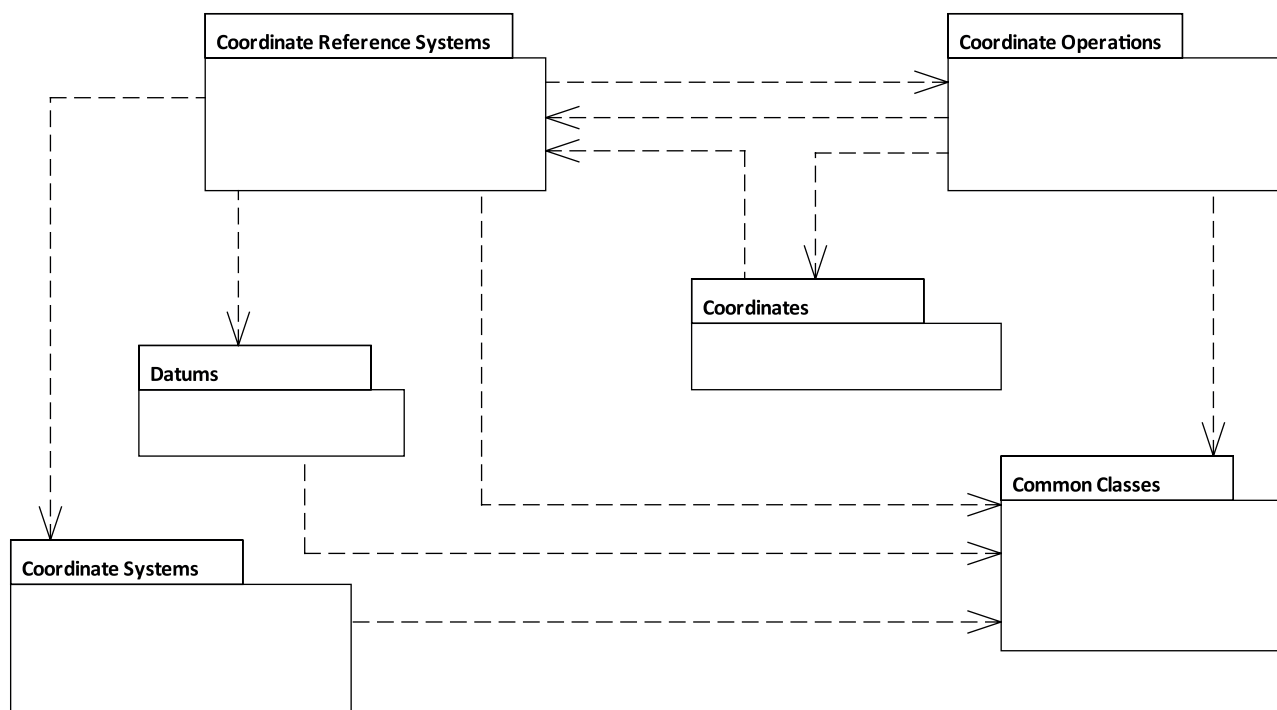


Figure 2 — UML model packages and dependencies

Coordinates require metadata that fully specifies the coordinate reference system to which they are referenced; without this CRS reference the description of position is ambiguous. The UML package for coordinates and their metadata is described in [Clause 7](#). This includes aspects of coordinate operations required to change coordinate values when the coordinate reference system is changed.

A coordinate reference system is usually comprised of two components, one coordinate system and one datum. In modern geodetic terminology the datum is referred to as a reference frame. Some geodetic concepts underpinning spatial referencing by coordinates are given in [Annex B](#). The information required to fully specify a coordinate reference system is described in [Clauses 9 to 11](#), with attributes common to all three packages described in [Clause 8](#).

Some coordinate reference systems have a third component, a defining coordinate conversion from another pre-existing CRS. In this document a CRS having this third component is a derived CRS. The specification for describing coordinate operations, including a defining coordinate conversion, is described in [Clause 12](#).

Further context for the requirements of [Clauses 8 to 12](#) is given in [Annexes C and D](#). Examples illustrating how the specifications of this document can be applied when defining a coordinate reference system or a coordinate operation are given in [Annex E](#). Recommendations for referencing to classes defined

in this document are given in [Annex F](#). Changes between this document and the previous version ISO 19111:2007 are described in [Annex G](#).

7 Coordinates package

7.1 Relationship between coordinates and coordinate reference system

In this document, a *coordinate* is one of n scalar values that define the position of a single point. In other contexts, the term *ordinate* is used for a single value and coordinate for multiple ordinates. Such usage is not part of this document.

A *coordinate tuple* is an ordered list of coordinates that define the position of a single point. The coordinates within a coordinate tuple are mutually independent. The number of coordinates in a tuple is equal to the dimension of the coordinate space.

A *coordinate set* is a collection of coordinate tuples referenced to the same coordinate reference system. For a coordinate set, one CRS identification or definition may be associated with the coordinate set and then all coordinate tuples in that coordinate set inherit that association. If only one point is being described, the association between coordinate tuple and coordinate reference system is direct.

The concepts of dynamic and static coordinate reference systems are outlined in [B.3](#). If the coordinate reference system is dynamic, operations on the geometry of the tuples within the coordinate set are valid only if all tuples are referenced to the same coordinate epoch. In this document all coordinate tuples in a spatial coordinate set are referenced to one specified coordinate epoch.

Together the coordinate reference system and the coordinate epoch are the coordinate metadata.

Coordinate sets referenced to one CRS may be referenced to another CRS through the application of a coordinate operation. A coordinate operation operates on coordinates, not on coordinate reference systems. A coordinate operation may be single or concatenated: refer to [Clause 12](#). The high level conceptual model for changing coordinates is shown in [Figure 3](#).

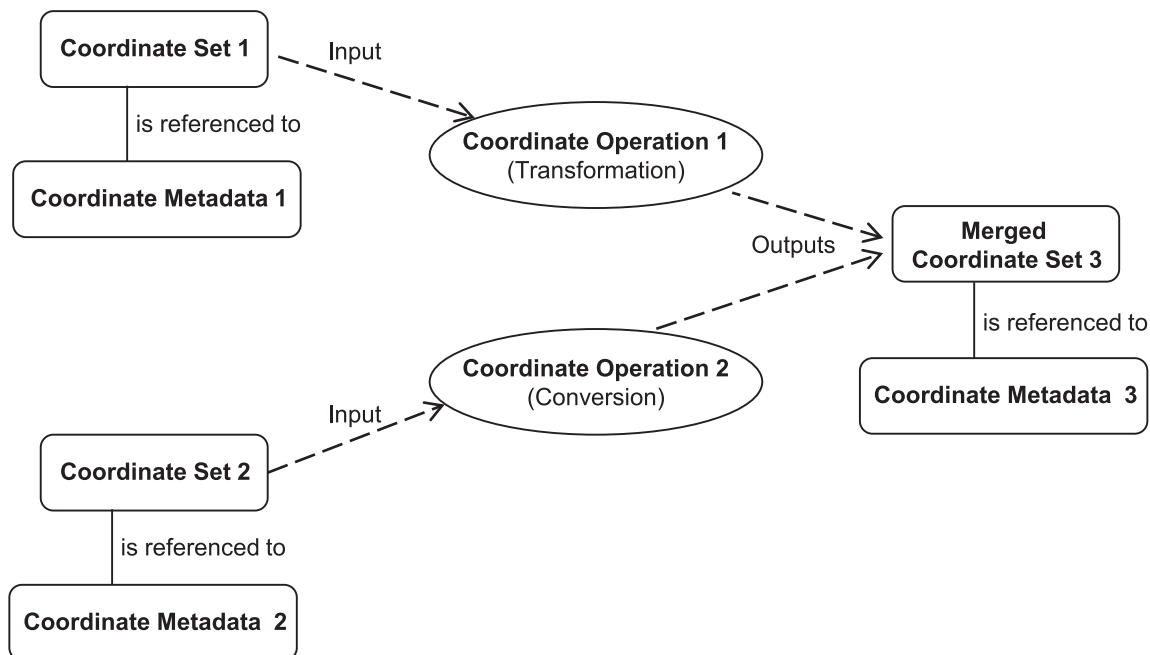


Figure 3 — Conceptual model for coordinate operations to produce a merged coordinate set

Coordinate sets referenced to a dynamic CRS at a given coordinate epoch t_1 may be converted to another coordinate epoch t_2 through a point motion coordinate operation that includes time evolution, often described using velocities, as shown schematically in [Figure 4](#).

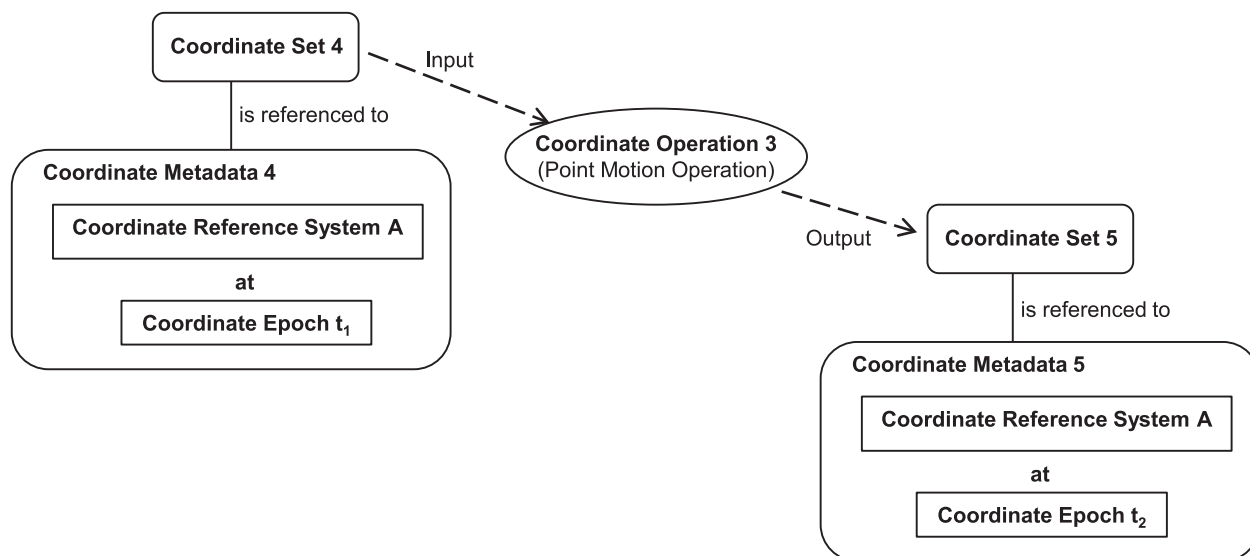


Figure 4 — Conceptual model for a coordinate operation to change coordinate epoch

It is also possible to change coordinates from being referenced to one dynamic CRS at one coordinate epoch to being referenced to another dynamic CRS at another coordinate epoch, or to change coordinates between a dynamic CRS and a static CRS or vice-versa. Further information is in [C.1](#) and [C.5](#).

The description of quality of coordinates is covered by the provisions of ISO 19157[8].

7.2 Coordinate reference system identification

The elements required for the definition of coordinate reference systems and coordinate operations are described in [Clauses 8](#) to [12](#).

CRS or coordinate operation identification may be through:

- a) a full description, as defined in this document; or
- b) reference to a full description in a register of geodetic parameters (the reference is made to the register and to the identifier of the object description within that register); or
- c) both a full description and a reference to a full description in a register. If there is a conflict between the two, the object full description should prevail over the reference to a register.

a) and b) are alternative means of providing a full description. b) is recommended for simplicity, but if it is not available from a register the description is required to be given explicitly and in full. In both methods, the order of coordinates in each coordinate tuple is required to be as given in the coordinate reference system's coordinate system description.

When using method b), reference to a register, applications that are required only to confirm the *identification* of a CRS or coordinate operation can do so through the register citation and the identifier from that register. They do not need to retrieve the elements that constitute the full description from the register unless there is a need to quote these or to perform a coordinate operation on the coordinate set.

7.3 Requirements for coordinate metadata

7.3.1 Requirements class: Static CRS coordinate metadata

Requirement 1: All coordinate tuples in a coordinate set shall be referenced to the same coordinate reference system.

7.3.2 Requirements class: Dynamic CRS coordinate metadata

CRS is described in [Clause 9](#) and datum or reference frame in [Clause 11](#). The following subtypes of CRS may have a dynamic reference frame and therefore may be dynamic CRSs: geodetic, geographic, vertical, projected and derived variants of these subtypes. Implementers are warned that CRSs of these subtypes are not necessarily dynamic; their reference frame attributes need to be examined to clarify this.

Requirement 2: When the coordinate reference system to which a coordinate set is referenced is dynamic, all coordinate tuples in the coordinate set shall be referenced to the same coordinate epoch.

7.4 UML schema for the Coordinates package

[Figure 5](#) shows the UML class diagram for coordinate metadata. The definition of the classes in the package are provided in [Tables 2](#) to [4](#).

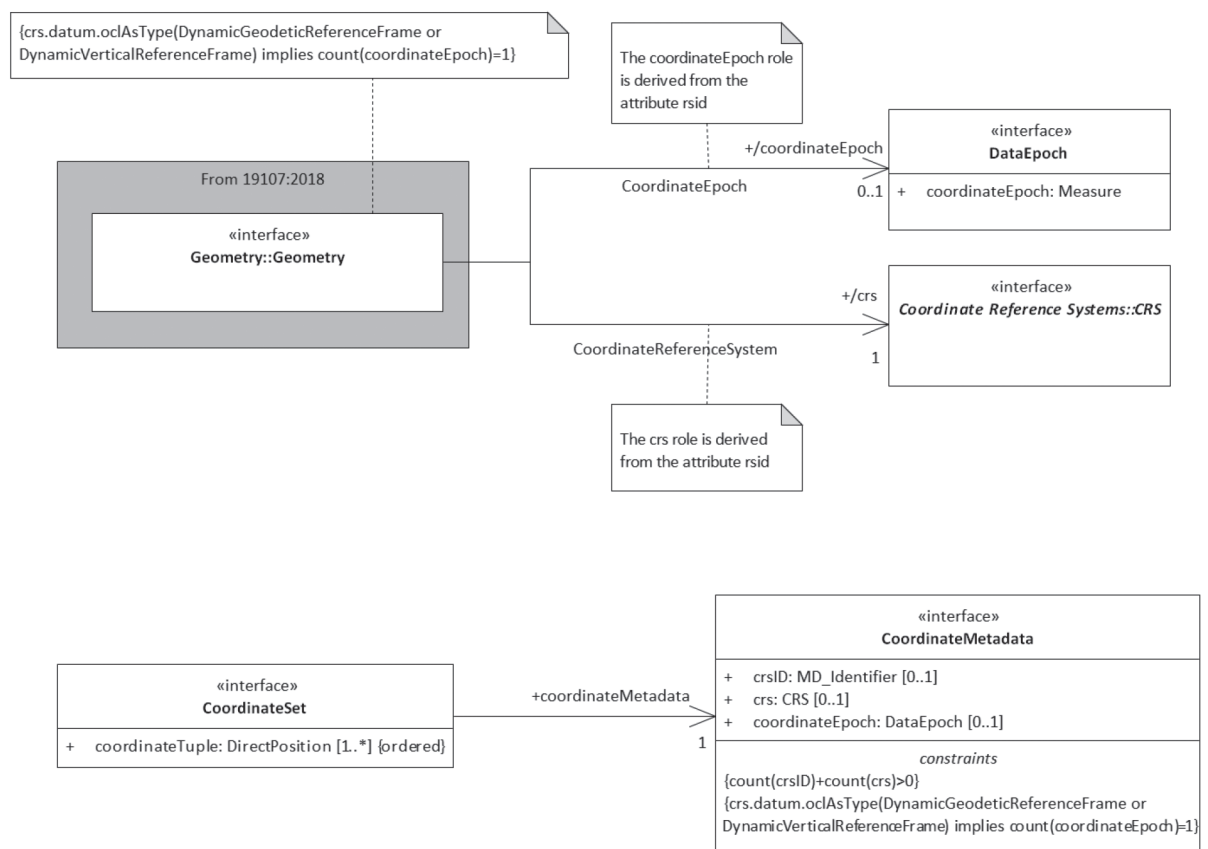


Figure 5 — UML diagram — Relationship of coordinates and coordinate metadata

Table 2 — Defining elements of Coordinates::CoordinateMetadata class

Definition:	metadata required to reference coordinates				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	(none)				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute definition
CRS ID	crsID	MD_Identifier	C	1	identifier of the coordinate reference system to which a coordinate set is referenced
CRS definition	crs	CRS	C	1	full description of the coordinate reference system to which a coordinate set is referenced
Coordinate epoch	coordinateEpoch	DataEpoch	C	1	epoch at which a coordinate set referenced to a dynamic CRS is valid
					NOTE Required if the CRS is dynamic, otherwise should not be given.
Constraints:	{count(crsID)+count(CRS)>0}				
	Remarks: See 7.2 .				
	{crs.datum.oclAsType(DynamicGeodeticReferenceFrame or DynamicVerticalReferenceFrame) implies count(coordinateEpoch)=1}				
	Remarks: The constraint provides the conditionality for coordinate epoch.				

The association of a coordinate set to a coordinate reference system (including the special case of a coordinate set containing only one tuple) is mandatory. The defining elements of the coordinate reference system class are described in [Clause 9](#).

The constraint on coordinate metadata (repeated on geometry) specifies that if the coordinate reference system is dynamic then the coordinate set additionally is required to be related to a specified coordinate epoch. This enforces the conditionality of the coordinateEpoch attribute. Whether the CRS is dynamic is determined through the CRS's reference frame definition ([Clause 11](#)).

Table 3 — Defining elements of Coordinates::CoordinateSet class

Definition:	description of the coordinate tuples in a coordinate set				
	NOTE A single coordinate tuple is treated as a special case of coordinate set containing only one member.				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	(none)				
Association roles:					
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
(not named)	coordinateMetadata	CoordinateMetadata	M	1	coordinate metadata to which this coordinate set is referenced
Public attributes:					
<u>Attribute name</u>	<u>UML identifier</u>	<u>Data type</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Attribute definition</u>
Coordinate tuple	coordinateTuple	DirectPosition {ordered}	M	N	position described by a coordinate tuple

Table 4 — Defining elements of Coordinates::DataEpoch class

Definition:	time attribute of a coordinate set that is referenced to a dynamic CRS				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	(none)				
Used by:	Coordinates::CoordinateMetadata				
Association roles:	(Note attached to association from Geometry::Geometry: "The coordinateEpoch role is derived from the attribute rsid". See ISO 19107).				
Public attributes:					
<u>Attribute name</u>	<u>UML identifier</u>	<u>Data type</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Attribute definition</u>
Coordinate epoch	coordinateEpoch	Measure	M	1	date at which coordinates are referenced to a dynamic coordinate reference system, expressed as a decimal year in the Gregorian calendar EXAMPLE 2017-03-25 in the Gregorian calendar is epoch 2017.23.

7.5 UML schema for change of coordinates

Coordinates may be changed to be referenced to a different CRS. If the CRS is dynamic, coordinates also may be referenced to a different coordinate epoch, or to both a different CRS and different coordinate epoch.

In this document the CoordinateOperation class has two purposes:

- a) to define the requirements for describing a coordinate operation;
- b) to apply the coordinate operation to change coordinates.

The defining elements for the CoordinateOperation class and its associated classes and their use in the definition of a coordinate operation are given in [Clause 12](#). Only those attributes relevant to the change of coordinates are elaborated here.

[Figure 6](#) shows the UML class diagram for the application of a coordinate operation to coordinate metadata.

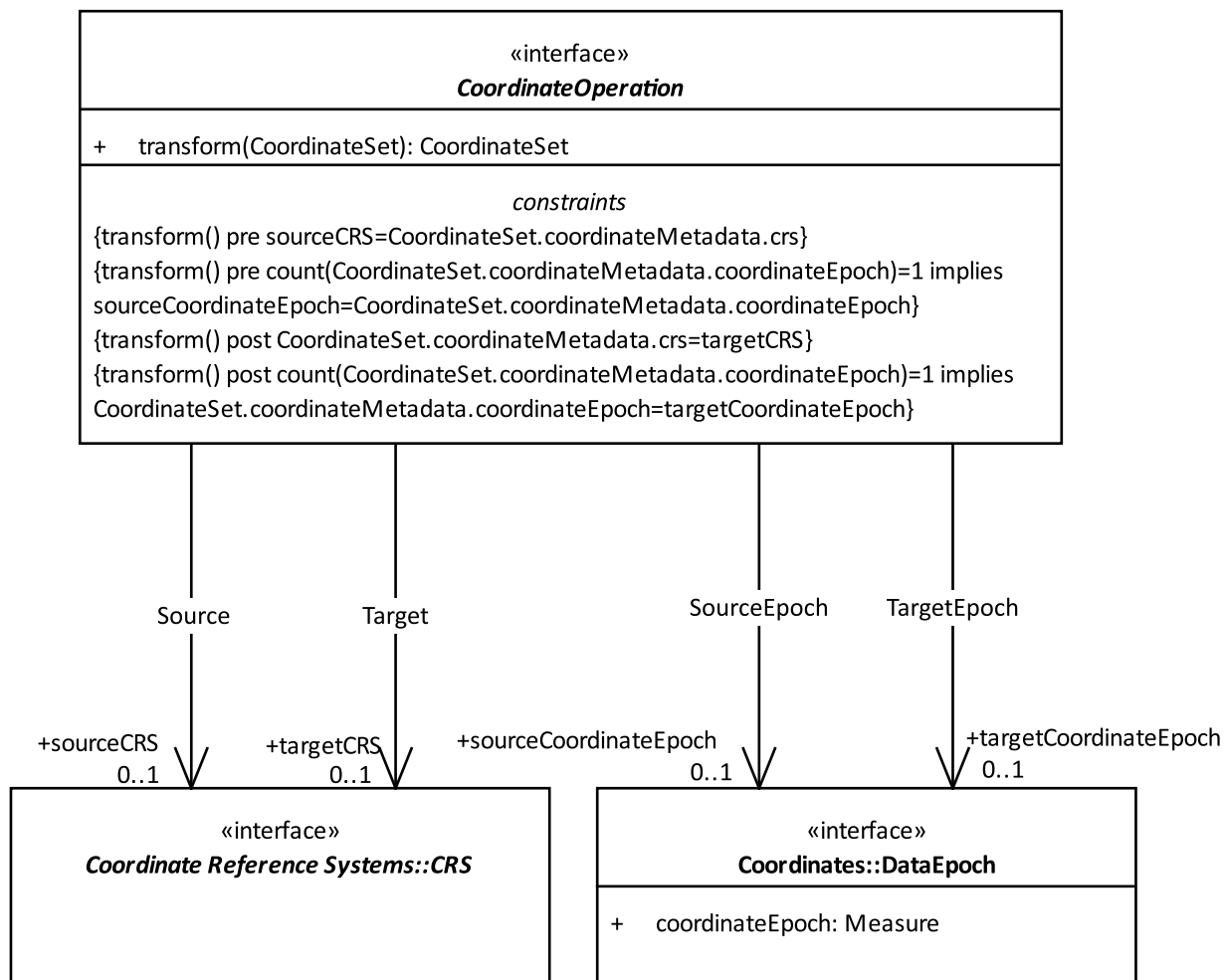


Figure 6 — UML diagram — Relationship of coordinate operation and coordinate metadata

The operation `CoordinateOperation.transform(CoordinateSet)` changes coordinates

- from being referenced to one CRS to being referenced to a second CRS, and/or
- in the case of a dynamic CRS, from being referenced to one coordinate epoch to being referenced to a second coordinate epoch.

Further information regarding commutation is given in [C.1.3](#).

`transform(CoordinateSet)` has four constraints which collectively require that

- the source CRS and/or the source coordinate epoch shall be those to which the input coordinate set is referenced, and that
- the target CRS and/or the target coordinate epoch shall be those associated with the output coordinate set.

`transform(CoordinateSet)` operates on coordinate tuples which have the data type `DirectPosition` and are ordered. This implies that when `transform(CoordinateSet)` is applied to a coordinate set containing multiple coordinate tuples, the order of the tuples in the coordinate set is preserved.

NOTE `transform(CoordinateSet)` operates on coordinate tuples and does not deal with interpolation of the specific geometry types. When a coordinate set is subjected to a coordinate operation, its geometry might or might not be preserved.

8 Common Classes package

8.1 General attributes

8.1.1 Introduction

The Common Classes package contains attributes common to several objects used in referencing by coordinates. These objects – CRS, datum, coordinate system and coordinate operation, together with some of their associated classes – inherit attribute values from the Common Classes package. This facilitates modular programming of names, identifiers and aliases, and of usage (scope and domain of validity).

8.1.2 Name and alias

One of the attributes is the primary name of the object. The object may have alternative names or aliases.

EXAMPLE A datum name might be “North American Datum of 1983” and its abbreviation “NAD83”.

Object primary names have a data type MD_Identifier which is defined in ISO 19115-1:2014. Aliases have a data type GenericName which is defined in ISO 19103.

8.1.3 Identifier

Another attribute is the identifier. This is a unique code used to reference an object in a given place.

EXAMPLE A geodetic registry might give the NAD83 datum a unique code of “6269”.

Identifiers have a data type of MD_Identifier.

In addition to the use of an identifier as a reference to a definition in a geodetic registry, it may also be included in an object definition to allow reference to that object.

8.1.4 Scope and Domain of Validity

Scope is a description of the primary purpose or purposes to which a coordinate reference system, datum or coordinate operation is applied.

DomainOfValidity is described in ISO 19115-1:2014, the introductory text of which is repeated here for convenience:

The datatype in this [EX_Extent] package is an aggregate of the metadata elements that describe the spatial and temporal extent of resources, objects, events, or phenomena. The EX_Extent class contains information about the geographic (EX_GeographicExtent), temporal (EX_TemporalExtent) and the vertical (EX_VerticalExtent) extent of something. EX_GeographicExtent can be subclassed as EX_BoundingPolygon, EX_GeographicBoundingBox and EX_GeographicDescription. The combined spatial and temporal extent (EX_SpatialTemporalExtent) is an aggregate of EX_GeographicExtent. EX_SpatialTemporalExtent is a subclass of EX_TemporalExtent. The full package is specified in ISO 19115-1:2014, Figure 19.

The EX_Extent class has three optional roles named “geographicElement”, “temporalElement”, and “verticalElement” and an element called “description”. At least one of the four shall be used. The data dictionary for this diagram is located in ISO 19115-1:2014, Table B.15.

In this document Scope and DomainOfValidity are paired through the ObjectUsage.domain attribute. This facilitates descriptions of usage such as 'Purpose 1 in area A, purpose 2 in area B'.

Scope and DomainOfValidity are optional to facilitate a succinct CRS description using Well-Known Text in accordance with ISO 19162[10]. However it is strongly recommended that, in geodetic registries, the entries for coordinate reference systems, datums and coordinate operations should include at least one Scope-DomainOfValidity pairing. Additional Scope-DomainOfValidity pairings may optionally be given.

8.2 UML schema for the Common Classes package

Figure 7 shows the UML class diagram of the Common Classes package. The definition of the classes in the package are provided in Tables 5 to 7.

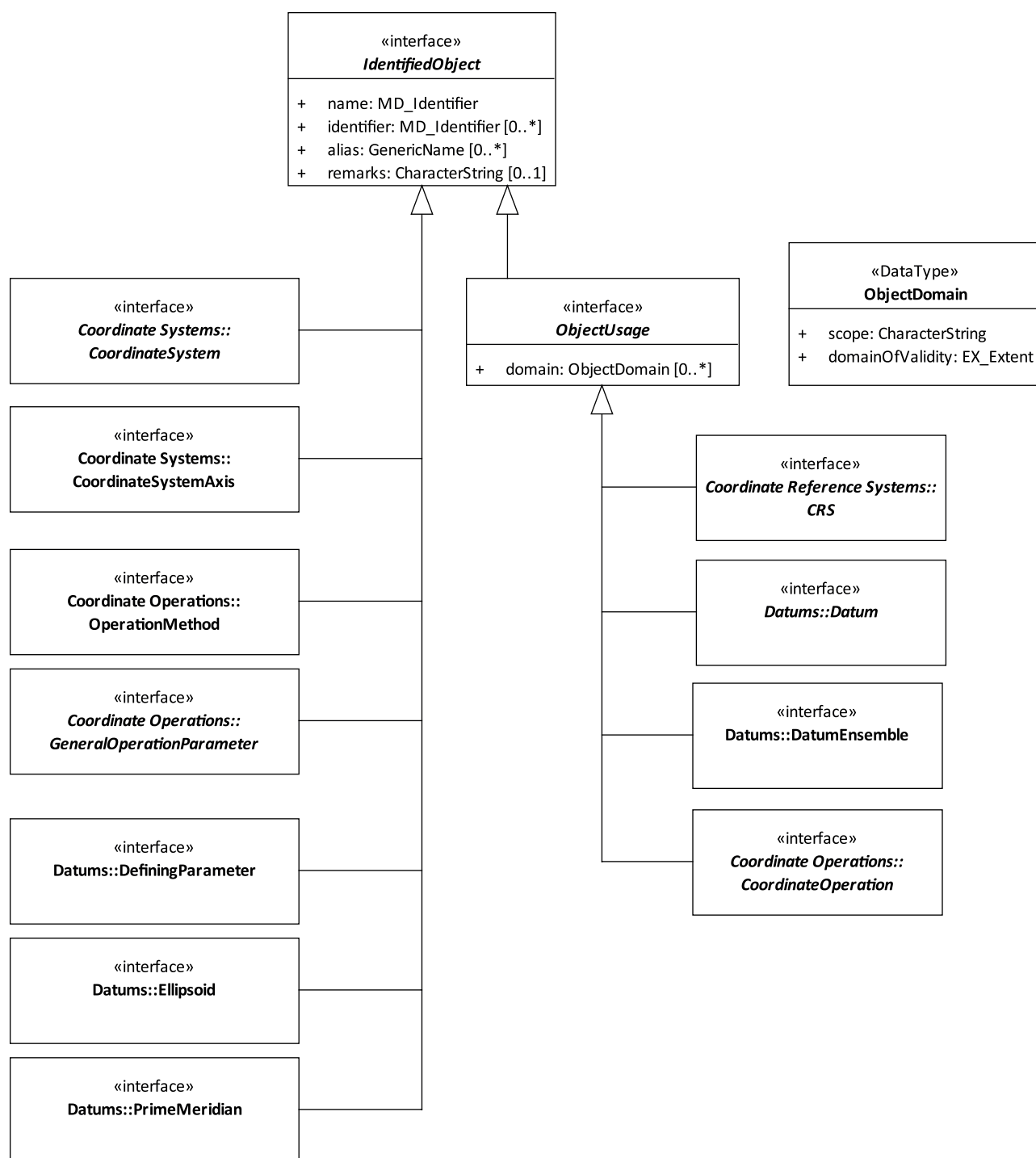


Figure 7 — UML diagram — Common Classes package

The data types MD_Identifier and EX_Extent are defined in ISO 19115-1:2014. The UML class diagram for the attributes in these classes which are of particular relevance to this document are shown in [Figure 8](#). The EX_Extent class contains information about the geographic, vertical and temporal extent. EX_GeographicExtent can be subclassed as EX_BoundingPolygon, EX_GeographicBoundingBox and EX_GeographicDescription.

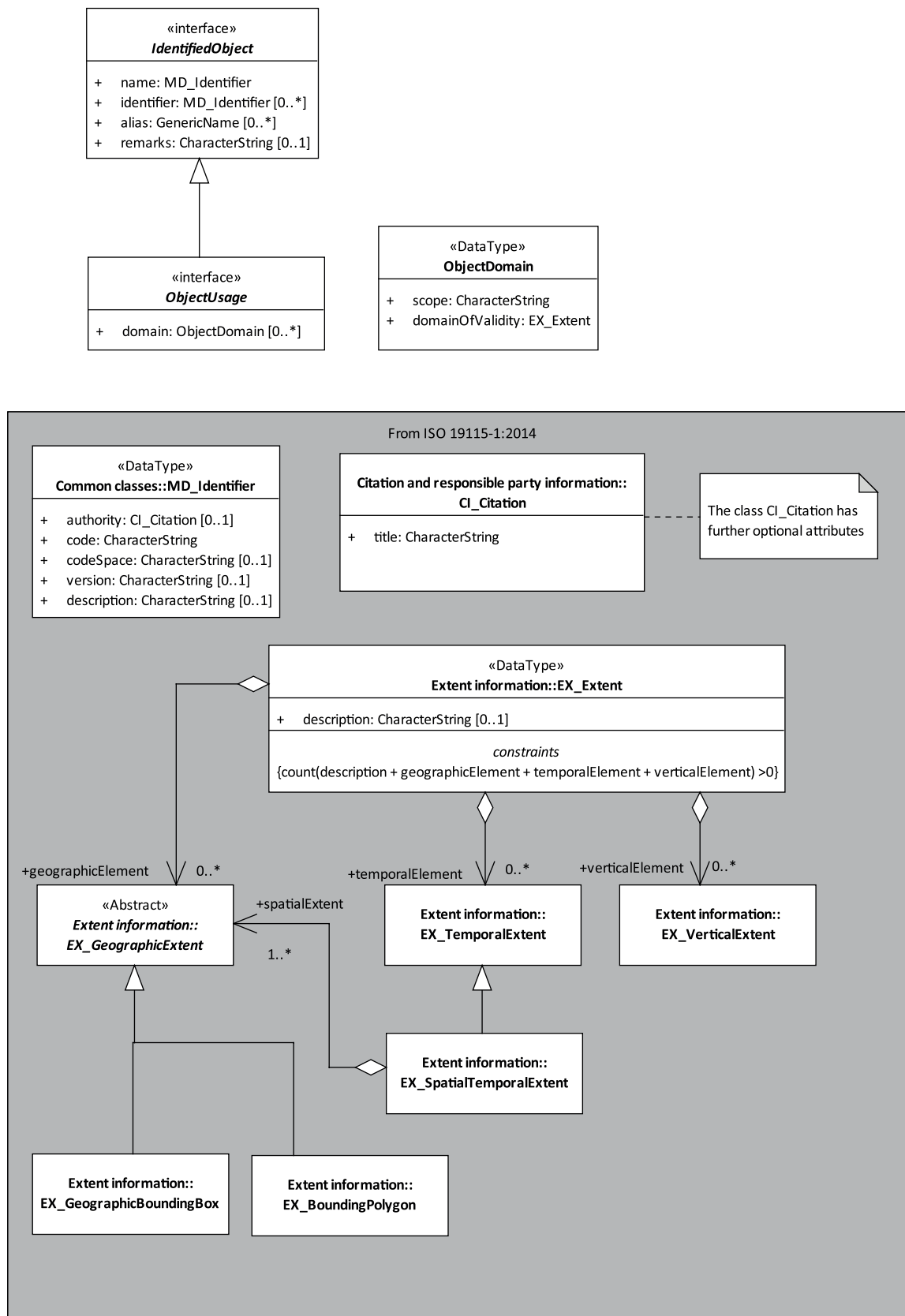


Figure 8 — UML diagram — Data types from ISO 19115-1:2014 (Metadata)

Table 5 — Defining elements of Common Classes::IdentifiedObject class

Definition:	identifications of a CRS-related object				
Stereotype:	Interface				
Class attribute:	Abstract				
Inheritance from:	(none)				
Generalization of:	ObjectUsage, Coordinate Systems::CoordinateSystem, Coordinate Systems:: CoordinateSystemAxis Datums::DefiningParameter, Datums::Ellipsoid, Datums::PrimeMeridian Coordinate Operations::GeneralOperationParameter, Coordinate Operations::OperationMethod				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute Definition
Object name	name	MD_Identifier	M	1	primary name by which this object is identified
Object identifier	identifier	MD_Identifier	O	N	identifier which references elsewhere the object's defining information; alternatively an identifier by which this object can be referenced
Object alias	alias	GenericName	O	N	alternative name by which this object is identified
Object remarks	remarks	CharacterString	O	1	comments on or information about this object, including data source information

Table 6 — Defining elements of Common Classes::ObjectUsage class

Definition:	usage of a CRS-related object				
Stereotype:	Interface				
Class attribute:	Abstract				
Inheritance from:	IdentifiedObject				
Generalization of:	Coordinate Reference Systems::CRS, Datums::Datum, Datums::DatumEnsemble, Coordinate Operations::CoordinateOperation				
Public attributes:	4 attributes (name, identifier, alias and remarks) inherited from IdentifiedObject, plus:				
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute Definition
Object usage	domain	ObjectDomain	O	N	scope and validity of a CRS-related object

Table 7 — Defining elements of Common Classes::ObjectDomain class

Definition:	scope and validity of a CRS-related object				
Stereotype:	DataType				
Class attribute:	Concrete				
Inheritance from:	(none)				
Used by:	ObjectUsage				

Table 7 (continued)

Public attributes:					
<u>Attribute name</u>	<u>UML identifier</u>	<u>Data type</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Attribute Definition</u>
Object scope	scope	CharacterString	M	1	description of usage, or limitations of usage, for which this object is valid NOTE If unknown, enter "not known".
Object validity	domainOfValidity	EX_Extent	M	1	spatial and temporal extent in which this object is valid

9 Coordinate Reference Systems package

9.1 Coordinate reference system

9.1.1 General

In this document, a coordinate reference system (CRS) definition generally consists of two components: one coordinate system (CS, [Clause 10](#)) and either one datum or one datum ensemble ([Clause 11](#)). Derived coordinate reference systems have a third component: a coordinate conversion ([Clause 12](#)). Each of these components has a number of attributes.

A datum (in modern geodesy, a reference frame) specifies the relationship of a coordinate system to an object, thus ensuring that the abstract mathematical concept “coordinate system” can be applied to the practical problem of describing positions of features by means of coordinates. The object will generally, but not necessarily, be the Earth or a feature on the Earth such as a building. For certain coordinate reference systems, the object may be a moving platform such as a car, ship, aircraft or spacecraft.

In this document, the *definition* of a coordinate reference system does not change with time. For coordinate reference systems where the object to which they are related is a moving platform, the transformation from the platform CRS to an Earth-fixed CRS may include a time element. For a dynamic coordinate reference system, locations on or near the surface of the Earth will move (very slowly) within the CRS due to crustal motion or deformation and then the CRS's reference frame definition may include time evolution and/or the CRS may have an associated crustal deformation model.

9.1.2 Principal subtypes of coordinate reference system

The classification criteria for the subtyping of coordinate reference system is firstly by type of datum associated with the coordinate reference system, and, in some cases, secondly by type of coordinate system. The following principal subtypes of coordinate reference system are distinguished:

- a) **Geodetic** – a two- or three-dimensional coordinate reference system used to describe spatial location over the whole Earth or substantial parts of it.

It has one subtype, **geographic**, when its coordinate system type is ellipsoidal.

- b) **Engineering** – a coordinate reference system used locally for which three broad categories are recognised:

- 1) coordinate reference systems used to describe spatial location over small areas of the Earth using a flat-Earth approximation of the Earth's surface: corrections for Earth-curvature are not applied. Typical applications are for civil engineering construction and building information management.

NOTE 1 These applications are not restricted to using engineering CRSs: they often utilise projected and sometimes geodetic CRSs.

- 2) coordinate reference systems used to describe spatial location on moving objects such as road vehicles, vessels, aircraft or spacecraft.

- 3) coordinate reference systems used to describe spatial location internally on an image.

NOTE 2 The CRS internal to the image is not geo-referenced. The image can be georeferenced by relating the engineering CRS to a geodetic or projected CRS through a coordinate transformation. In this document engineering coordinate reference systems for images have continuous axes. Grids based on these CRSs are described in ISO 19123[6].

- c) **Vertical** – a one-dimensional coordinate reference system making use of the direction of gravity to define height or depth.
- d) **Parametric** – a one-dimensional coordinate reference system that uses a parameter or function as a coordinate.

EXAMPLE Pressure used as a vertical coordinate.

- e) **Temporal** – a one-dimensional coordinate reference system that describes time.

These principal subtypes of spatial coordinate reference system are described further in [C.2.1](#).

9.2 Derived coordinate reference system

9.2.1 General

A derived coordinate reference system is defined by applying a coordinate conversion to another pre-existing coordinate reference system which is referred to as the base CRS. The derived CRS inherits its datum (reference frame) or datum ensemble ([Clause 11](#)) from its base CRS. Consequently most derived CRSs are of the same CRS type as their base CRS. Most derived CRSs have a coordinate system which must be of the same CS type as is allowed for principal CRSs of that CRS type.

EXAMPLE 1 A derived geographic CRS will have an ellipsoidal CS because a geographic CRS must have an ellipsoidal CS.

EXAMPLE 2 A derived parametric CRS will have a parametric CS because a parametric CRS must have a parametric CS.

NOTE An exception is a CRS derived from a projected CRS - see [9.2.2](#).

Further information on derived coordinate reference systems is given in [C.2.2.2](#).

9.2.2 Projected coordinate reference system

A projected CRS is a coordinate reference system which is derived from a base geographic CRS by applying the coordinate conversion known as a map projection to latitude and longitude ellipsoidal coordinate values. Projected CRSs are modelled as a special case of derived CRS because of their importance in geographic information. A projected CRS is constrained to have a Cartesian coordinate system. In the 3D case the ellipsoidal height from the base CRS is retained to form a three-dimensional Cartesian coordinate system.

A projected CRS may act as the base CRS for a derived projected CRS. A derived projected CRS is not constrained to have a Cartesian coordinate system: it may have one of several other types of coordinate system.

NOTE The term 'derived projected CRS' is used for consistency in the UML modelling. A derived projected CRS is not a projected CRS - 'derived from projected CRS' would be a more accurate description. However, in addition to inheriting its datum or reference frame from its base projected CRS, a derived projected CRS inherits the projection distortions of its base projected CRS.

9.3 Compound coordinate reference system

9.3.1 General

A compound coordinate reference system is a non-repeating sequence of two or more coordinate reference systems none of which can itself be compound.

EXAMPLE 1 A projected CRS having easting and northing coordinates with a vertical CRS having a gravity-related height as a coordinate.

EXAMPLE 2 A geographic CRS having latitude and longitude coordinates with a parametric CRS having pressure as a coordinate.

Nesting of compound coordinate reference systems is not permitted; the individual single systems are aggregated together. Further information on compound coordinate reference system is given in [C.2.2.3](#).

9.3.2 Spatial compound coordinate reference system

For spatial coordinates, a number of constraints exist for the construction of compound CRSs. Coordinate reference systems that are combined are required to not contain any duplicate or redundant axes. Valid combinations shall be the following.

- a) Geographic 2D + Vertical.
- b) Geographic 2D + Engineering 1D (near vertical).
- c) Projected 2D + Vertical.
- d) Projected 2D + Engineering 1D (near vertical).
- e) Engineering (horizontal 2D) + Vertical.
- f) Engineering (1D linear) + Vertical.

9.3.3 Spatio-temporal compound coordinate reference system

Any single spatial coordinate reference system, or any of the combinations of spatial compound coordinate reference systems listed in [9.3.2](#), may be associated with a temporal coordinate reference system to form a spatio-temporal compound coordinate reference system. More than one temporal coordinate reference system may be included if these axes represent different time quantities: examples are given in [E.4.4](#) and [E.4.5](#).

9.3.4 Spatio-parametric compound coordinate reference system

A spatio-parametric coordinate reference system is a compound CRS in which one component is a geographic 2D, projected 2D or engineering 2D CRS, supplemented by a parametric CRS to create a three-dimensional CRS: an example is included in [E.3.3](#). More than one parametric coordinate reference system may be included if these represent independent parametric quantities.

9.3.5 Spatio-parametric-temporal compound coordinate reference system

Any of the above-listed combinations of spatial, parametric and temporal CRSs may be associated to form a spatio-parametric-temporal compound coordinate reference system.

9.4 UML schema for the Coordinate Reference Systems package

[Figure 9](#) shows the UML class diagram of the Coordinate Reference Systems package. Subtypes of derived CRS are detailed in [Figure 10](#). The definition of the object classes of the package are provided in [Tables 8 to 25](#).

The CRS package UML class diagram shows an association named `CoordinateSystem` from the `SingleCRS` class to the `CoordinateSystem` class. This association is included to indicate that all of the subclasses of `SingleCRS` have a direct association to `CoordinateSystem` or one of its subclasses, as later detailed in [Clause 10](#). Constraints on associations between CRSs and coordinate systems are detailed in [Clause 10](#).

The CRS UML class diagram also shows an association named `DefiningDatum` from the `SingleCRS` class to the `Datum` class. This association indicates that many, but not all, of the subclasses of `SingleCRS` have a direct association to `Datum` or to one of its subclasses. A single CRS may alternatively be associated with a *datum ensemble* rather than with a datum. Constraints on associations between CRSs and datums or datum ensembles are detailed in [Clause 11](#). Derived CRSs do not use this association to datum or datum ensemble: instead a Derived CRSs inherits its datum or datum ensemble from the base CRS from which it has been derived.

The CRS UML diagram additionally shows an association named `Definition` from the `DerivedCRS` class to the `Conversion` class. This will usually be implemented as a coordinate conversion embedded within the derived CRS definition. A coordinate conversion is a type of coordinate operation. The UML model for coordinate operations is detailed in [Clause 12](#).

Further information on the modelling of CRSs is given in [C.2](#).

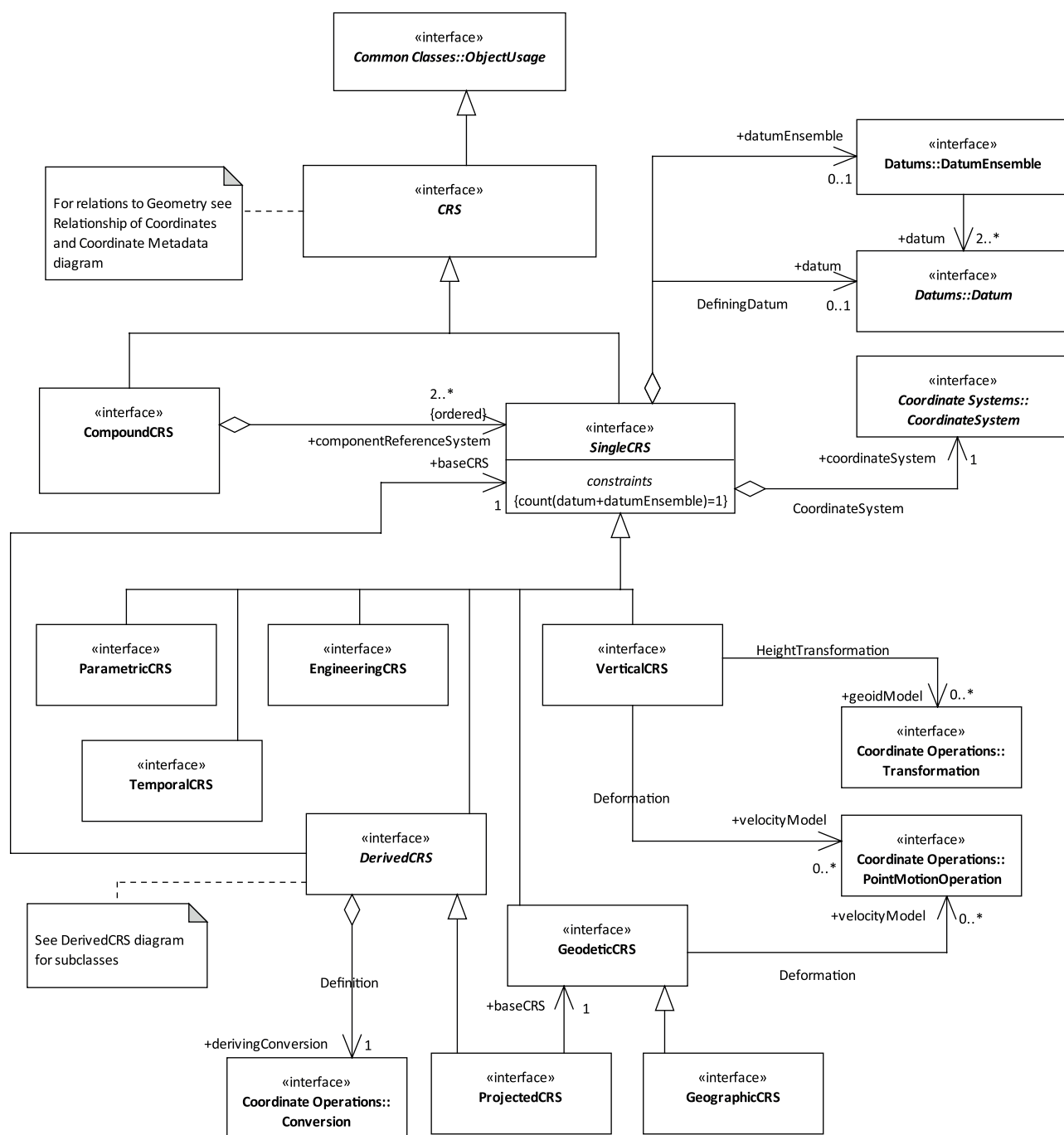


Figure 9 — UML diagram — Coordinate Reference Systems package

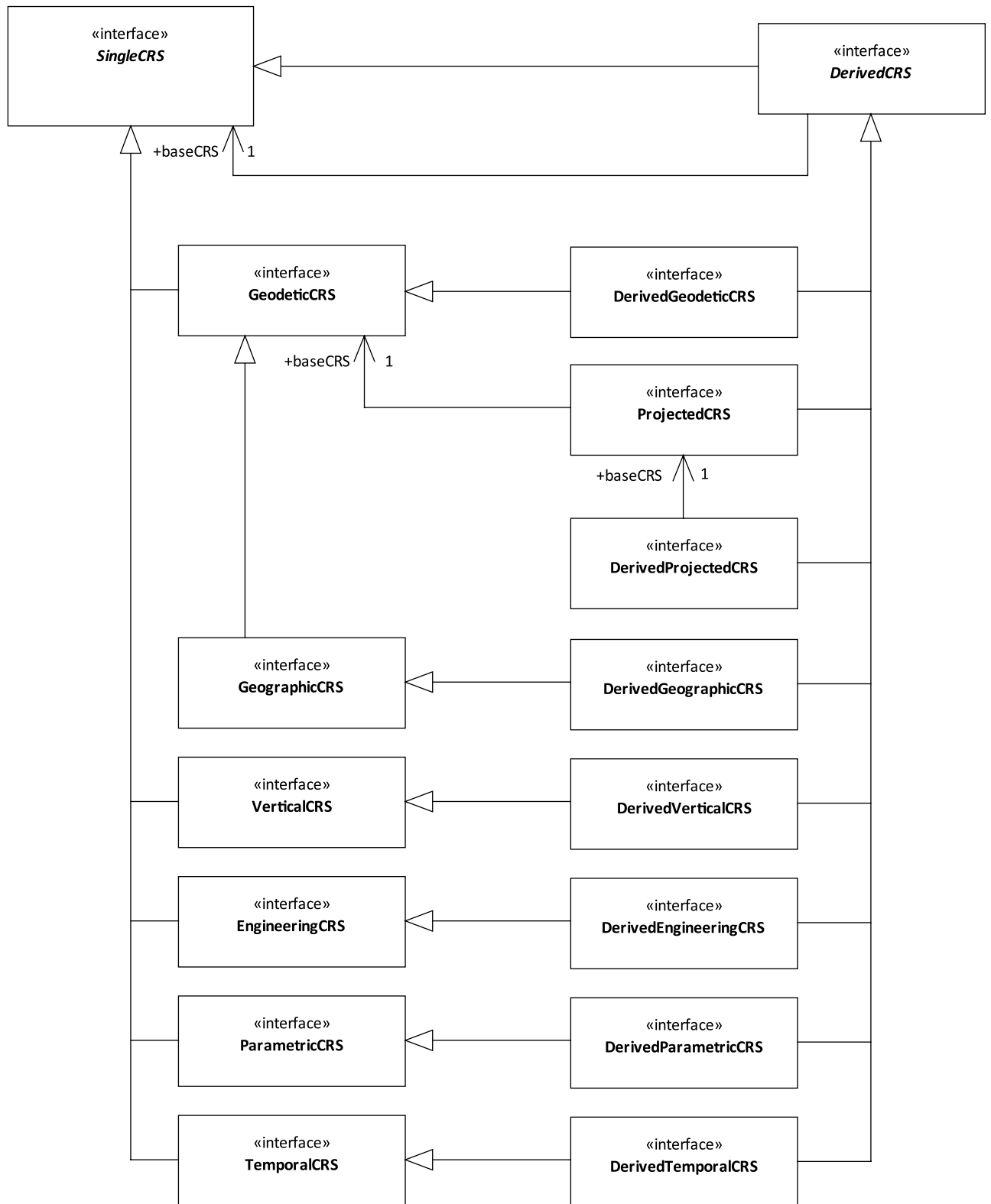


Figure 10 — UML diagram — Derived Coordinate Reference Systems

Table 8 — Defining elements of Coordinate Reference Systems::CRS class

Definition	coordinate reference system which is usually single but may be compound
Stereotype:	Interface
Class attribute:	Abstract
Inheritance from:	Common Classes::ObjectUsage
Generalization of:	SingleCRS, CompoundCRS
Association roles:	(Note attached to association from Geometry::Geometry: "The crs role is derived from the attribute rsid". See ISO 19107)
Public attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 9 — Defining elements of Coordinate Reference Systems::SingleCRS class

Definition:	coordinate reference system consisting of one coordinate system and either one datum or one datum ensemble				
Stereotype:	Interface				
Class attribute:	Abstract				
Inheritance from:	CRS				
Generalization of:	GeodeticCRS, VerticalCRS, ParametricCRS, EngineeringCRS, TemporalCRS, DerivedCRS				
Association roles:	associations inherited from CRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::CoordinateSystem	M	1	coordinate system that is a component of this single coordinate reference system
Defining Datum	(aggregation) datum	Datums::Datum	C	1	datum that is a component of this single coordinate reference system
(not named)	(aggregation) datumEnsemble	Datums::DatumEnsemble	C	1	datum ensemble that is a component of this single coordinate reference system
Constraints:	{count(datum) + count(datumEnsemble) = 1}				
Remarks:	The constraint requires a singleCRS to be associated with either a datum (reference frame) or a datum ensemble.				
Public attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

Table 10 — Defining elements of Coordinate Reference Systems::GeodeticCRS class

Definition:	coordinate reference system associated with a geodetic reference frame and a three-dimensional Cartesian or spherical coordinate system NOTE If the geodetic reference frame is dynamic then the geodetic CRS is dynamic, else it is static.				
Stereotype:	Interface				
Class attribute	Concrete				
Inheritance from:	SingleCRS				
Generalization of:	GeographicCRS, DerivedGeodeticCRS				
Association roles:	associations inherited from SingleCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::GeodeticCS	M	1	coordinate system that is a component of this geodetic coordinate reference system
Defining Datum	(aggregation) datum	Datums::GeodeticReferenceFrame	O	1	geodetic reference frame that is a component of this geodetic coordinate reference system
Deformation	velocityModel	CoordinateOperations::PointMotionOperation	O	N	velocity model(s) or deformation grid(s) that may be applied to this geodetic coordinate reference system
Constraints:	constraints inherited from SingleCRS, plus: {coordinateSystem.ocl As Type(EllipsoidalCS) implies count(datum.ellipsoid)=1}				

Table 10 (continued)

Remarks:	The constraint enforces the requirement on geographicCRS to be associated with an ellipsoid. It is made through the GeodeticCRS class because GeographicCRS is related to Datum and hence Ellipsoid only through its subtyping from the GeodeticCRS class. GeodeticCRSs should be associated with a Cartesian coordinate system or with a spherical coordinate system.
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 11 — Defining elements of Coordinate Reference Systems::GeographicCRS class

Definition:	coordinate reference system associated with a geodetic reference frame and a two- or three-dimensional ellipsoidal coordinate system NOTE If the geodetic reference frame is dynamic then the geographic CRS is dynamic, or else it is static.				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	GeodeticCRS				
Generalization of:	DerivedGeographicCRS				
Association roles:	associations inherited from GeodeticCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::EllipsoidalCS	M	1	ellipsoidal coordinate system that is a component of this geographic coordinate reference system
Constraints:	constraints inherited from GeodeticCRS				
Remarks:	The constraint {coordinateSystem.ocl As Type(EllipsoidalCS) implies count(datum.ellipsoid)=1} which is inherited from geodeticCRS enforces the requirement on GeographicCRS to be associated with an ellipsoid. It is made through the GeodeticCRS class because GeographicCRS is related to Datum and hence Ellipsoid only through its subtyping from the GeodeticCRS class.				
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

Table 12 — Defining elements of Coordinate Reference Systems::VerticalCRS class

Definition:	coordinate reference system having a vertical reference frame and a one-dimensional vertical coordinate system used for recording gravity-related heights or depths; vertical CRSs make use of the direction of gravity to define the concept of height or depth, but the relationship with gravity may not be straightforward. NOTE 1 If the vertical reference frame is dynamic then the vertical CRS is dynamic, or else it is static. NOTE 2 Ellipsoidal heights cannot be captured in a vertical coordinate reference system. They exist only as an inseparable part of a 3D coordinate tuple defined in a geographic 3D coordinate reference system.				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	SingleCRS				
Generalization of:	DerivedVerticalCRS				
Association roles:	associations inherited from SingleCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::GeodeticCS	M	1	vertical coordinate system that is a component of this vertical coordinate reference system
Defining Datum	(aggregation) datum	Datums::Geodetic ReferenceFrame	0	1	vertical reference frame that is a component of this vertical coordinate reference system
Height Transformation	geoidModel	from DerivedCRS	0	N	geoid model or height correction model that is associated with this vertical coordinate reference system
Deformation	velocityModel	CoordinateOperations::PointMotionOperation	0	N	velocity model or deformation grid that is applied to this vertical coordinate reference system

Table 12 (continued)

Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.
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Table 13 — Defining elements of Coordinate Reference Systems::ParametricCRS class

Definition:	coordinate reference system having a parametric datum and a one-dimensional parametric coordinate system which uses parameter values or functions				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	SingleCRS				
Generalization of:	DerivedParametricCRS				
Association roles:	associations inherited from SingleCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::ParametricCS	M	1	parametric coordinate system that is a component of this parametric coordinate reference system
Defining Datum	(aggregation) datum	Datums::ParametricDatum	0	1	parametric datum that is a component of this parametric coordinate reference system
Public attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

Table 14 — Defining elements of Coordinate Reference Systems::EngineeringCRS class

Definition:	contextually local coordinate reference system associated with an engineering datum and which is applied either to activities on or near the surface of the Earth without geodetic corrections, or on moving platforms such as road vehicles, vessels, aircraft or spacecraft, or as the internal CRS of an image				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	SingleCRS				
Generalization of:	DerivedEngineeringCRS				
Association roles:	associations inherited from SingleCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::EngineeringCS	M	1	coordinate system that is a component of this engineering coordinate reference system
Defining Datum	(aggregation) datum	Datums::EngineeringDatum	0	1	engineering datum that is a component of this engineering coordinate reference system
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

Table 15 — Defining elements of Coordinate Reference Systems::TemporalCRS class

Definition:	coordinate reference system associated with a temporal datum and a one-dimensional temporal coordinate system				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	SingleCRS				
Generalization of:	DerivedTemporalCRS				
Association roles:	associations inherited from SingleCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::TemporalCS	M	1	temporal coordinate system that is a component of this temporal coordinate reference system
Defining Datum	(aggregation) datum	Datums::TemporalDatum	0	1	temporal datum that is a component of this temporal coordinate reference system

Table 15 (continued)

Public attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.
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Table 16 — Defining elements of Coordinate Reference Systems::DerivedCRS class

Definition:	single coordinate reference system that is defined through the application of a specified coordinate conversion to the definition of a previously established single coordinate reference system referred to as the base CRS NOTE A derived coordinate reference system inherits its datum (or datum ensemble) from its base CRS. 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.				
Stereotype:	Interface				
Class attribute:	Abstract				
Inheritance from:	SingleCRS				
Generalization of:	ProjectedCRS, DerivedProjectedCRS, DerivedGeodeticCRS, DerivedGeographicCRS, DerivedVerticalCRS, DerivedEngineeringCRS, DerivedParametricCRS, DerivedTemporalCRS				
Association roles:	associations inherited from SingleCRS, including (aggregation) coordinateSystem to CoordinateSystems::CoordinateSystem, [1] association named CoordinateSystem), plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
(not named)	baseCRS	SingleCRS	M	1	coordinate reference system that is the baseCRS for this derived coordinate reference system
Definition	(aggregation) derivingConversion	CoordinateOperations::Conversion	M	1	conversion that is a component of this derived coordinate reference system
Constraints:	{count(baseCRS.datum)=1 implies datum=baseCRS.datum} {count(baseCRS.datumEnsemble)=1 implies datumEnsemble=baseCRS.datum}				
Remarks:	The constraints require the derived CRS to take the datum or datum ensemble (whichever one is applicable) of its base CRS.				
Public attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from CommonClasses::IdentifiedObject and CommonClasses::ObjectUsage.				

Table 17 — Defining elements of Coordinate Reference Systems::ProjectedCRS class

Definition:	derived coordinate reference system which has a geodetic (usually geographic) coordinate reference system as its base CRS, thereby inheriting a geodetic reference frame, is converted using a map projection, and has a Cartesian coordinate system, usually two-dimensional but may be three-dimensional NOTE In the 3D case the base geographic CRSs ellipsoidal height is passed through unchanged and forms the vertical axis of the projected CRS's Cartesian coordinate system.				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	DerivedCRS				
Association roles:	associations inherited from DerivedCRS, plus:				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
(not named)	baseCRS	GeodeticCRS	M	1	geodetic or geographic coordinate reference system that is the baseCRS for this projected coordinate reference system
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems::CartesianCS	M	1	Cartesian coordinate system that is a component of this projected coordinate reference system
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

Table 18 — Defining elements of Coordinate Reference Systems::DerivedProjectedCRS class

Definition:	derived coordinate reference system which has a projected coordinate reference system as its base CRS, thereby inheriting a geodetic reference frame, but also inheriting the distortion characteristics of the base projected CRS
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Table 18 (continued)

Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	DerivedCRS				
Association roles:	associations inherited from DerivedCRS, plus:				
Association name	UML identifier	Association with	Obligation	Maximum Occurrence	Association definition
(not named)	baseCRS	ProjectedCRS	M	1	projected coordinate reference system that is the baseCRS for this derived projected coordinate reference system
Coordinate System	(aggregation) coordinateSystem	CoordinateSystems:: DerivedProjectedCS	M	1	coordinate system that is a component of this derived projected coordinate reference system
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

Table 19 — Defining elements of Coordinate Reference Systems::DerivedGeodeticCRS class

Definition:	derived coordinate reference system which has either a geodetic or a geographic coordinate reference system as its base CRS, thereby inheriting a geodetic reference frame, and associated with a 3D Cartesian or spherical coordinate system
Stereotype	Interface
Class attribute:	Concrete
Inheritance from:	GeodeticCRS DerivedCRS
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 20 — Defining elements of Coordinate Reference Systems::DerivedGeographicCRS class

Definition:	derived coordinate reference system which has either a geodetic or a geographic coordinate reference system as its base CRS, thereby inheriting a geodetic reference frame, and an ellipsoidal coordinate system NOTE A derived geographic CRS can be based on a geodetic CRS only if that geodetic CRS definition includes an ellipsoid.
Stereotype:	Interface
Class attribute:	Concrete
Inheritance from:	GeographicCRS DerivedCRS NOTE Constraints inherited through GeographicCRS include: Ellipsoid is mandatory.
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 21 — Defining elements of Coordinate Reference Systems::DerivedVerticalCRS class

Definition:	derived coordinate reference system which has a vertical coordinate reference system as its base CRS, thereby inheriting a vertical reference frame, and a vertical coordinate system
Stereotype:	Interface
Class attribute:	Concrete
Inheritance from:	VerticalCRS DerivedCRS
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 22 — Defining elements of Coordinate Reference Systems::DerivedParametricCRS class

Definition:	derived coordinate reference system which has a parametric coordinate reference system as its base CRS, thereby inheriting a parametric datum, and a parametric coordinate system
Stereotype:	Interface
Class attribute:	Concrete

Table 22 (continued)

Inheritance from:	ParametricCRS DerivedCRS
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 23 — Defining elements of Coordinate Reference Systems::DerivedEngineeringCRS class

Definition:	derived coordinate reference system which has an engineering coordinate reference system as its base CRS, thereby inheriting an engineering datum, and is associated with one of the coordinate system types within the engineeringCS class
Stereotype:	Interface
Class attribute:	Concrete
Inheritance from	EngineeringCRS DerivedCRS
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 24 — Defining elements of Coordinate Reference Systems::DerivedTemporalCRS class

Definition:	derived coordinate reference system which has a temporal coordinate reference system as its base CRS, thereby inheriting a temporal datum, and is associated with a temporal coordinate system
Stereotype:	Interface
Class attribute:	Concrete
Inheritance from:	TemporalCRS DerivedCRS
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.

Table 25 — Defining elements of Coordinate Reference Systems::CompoundCRS class

Definition:	coordinate reference system describing the position of points through two or more independent single coordinate reference systems				
	NOTE Two coordinate reference systems are independent of each other if coordinate values in one cannot be converted or transformed into coordinate values in the other.				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	CRS				
Association roles:	associations inherited from CRS, plus				
<u>Association name</u>	<u>UML identifier</u>	<u>Association with</u>	<u>Obligation</u>	<u>Maximum Occurrence</u>	<u>Association definition</u>
(not named)	(aggregation) componentReferenceSystem	SingleCRS (ordered)	M (minimum 2)	N	coordinate reference system that is a component of this compound coordinate reference system
Public Attributes:	6 attributes (CRS name, CRS alias, CRS identifier, CRS scope, CRS validity and CRS remarks) inherited from Common Classes::IdentifiedObject and Common Classes::ObjectUsage.				

10 Coordinate Systems package

10.1 Coordinate system — General

In this document, the Coordinate Systems package models two main concepts: coordinate system and coordinate system axis. A coordinate system has to be composed of a non-repeating sequence of coordinate system axes. One coordinate system may be used by multiple coordinate reference systems. The dimensions of the coordinate space, the names, the units of measure, the directions and sequence of the axes all form part of the coordinate system definition. The number of axes is required to be equal to the dimensions of the space. The number of coordinates in a coordinate tuple is required to be equal to

the number of coordinate axes in the coordinate system. Coordinates in coordinate tuples are required to be supplied in the order in which the coordinate system's axes are defined.

In this document, coordinate systems are divided into subtypes by the geometric properties of the coordinate space spanned and the geometric properties of the axes themselves (straight or curved; perpendicular or not). Certain subtypes of coordinate system are required to be used only with specific subtypes of coordinate reference system as shown in [Table 26](#) and [Figure 12](#).

Coordinate systems are described further in [C.3](#).

10.2 Parametric coordinate system

A coordinate system is of type parametric if a physical or material property or function is used as the dimension. The parameter can be measured or could be a function defined in other contexts, but in parametric coordinate systems it forms the coordinate system axis.

EXAMPLE 1 Pressure in meteorological applications.

EXAMPLE 2 Density (isopycnals) in oceanographic applications.

A parametric coordinate system is required to be one-dimensional and have one axis.

10.3 Temporal coordinate system

This document supports three forms of temporal coordinate system:

- DateTimeTemporalCS: coordinate values are dateTimes in the proleptic Gregorian calendar as described in ISO 8601.
- TemporalCountCS: coordinate values are integer numbers having units, they are counts of a temporal quantity.
- TemporalMeasureCS: coordinate values are real numbers having units, they are measures of a temporal quantity.

A temporal coordinate system is required to be one-dimensional and to have one axis. Further information is provided in [Annex D](#).

Table 26 — Subtypes of coordinate system and constraints in its relationship with coordinate reference system

CS subtype	Description	Used with CRS type(s)
affine	two- or three-dimensional coordinate system in Euclidean space with straight axes that are not necessarily orthogonal.	engineering derivedEngineering derivedProjected
Cartesian	two- or three-dimensional coordinate system in Euclidean space which gives the position of points relative to orthogonal straight axes. All axes are required to have the same unit of measure.	geodetic projected engineering derivedGeodetic derivedProjected derivedEngineering
cylindrical	three-dimensional coordinate system in Euclidean space consisting of a polar coordinate system extended by a straight coordinate axis perpendicular to the plane spanned by the polar coordinate system.	engineering derivedEngineering derivedProjected
ellipsoidal	two- or three-dimensional coordinate system in which position is specified by geodetic latitude, geodetic longitude and (in the three-dimensional case) ellipsoidal height.	geographic derivedGeographic

Table 26 (continued)

CS subtype	Description	Used with CRS type(s)
linear	one-dimensional coordinate system that consists of the points that lie on the single axis described. Example: usage of the line feature representing a pipeline to describe points on or along that pipeline. This document only lends itself to be used for simple (=continuous) linear systems. For a more extensive treatment of the subject, particularly as applied to the transportation industry, refer to ISO 19148[Z].	engineering derivedEngineering
ordinal	an n-dimensional coordinate system using integer indexing.	engineering derivedEngineering derivedProjected
parametric	one-dimensional coordinate system where the axis units are parameter values which are not inherently spatial.	parametric derivedParametric
polar	two-dimensional coordinate system in Euclidean space in which position is specified by distance from the origin and the angle between the line from origin to point and a reference direction.	engineering derivedEngineering derivedProjected
spherical	three-dimensional coordinate system in Euclidean space with one distance, measured from the origin, and two angular coordinates. Note: not to be confused with an ellipsoidal coordinate system based on an ellipsoid 'degenerated' into a sphere.	geodetic engineering derivedGeodetic derivedEngineering derivedProjected
temporal	one-dimensional coordinate system where the axis is time.	temporal derivedTemporal
vertical	one-dimensional coordinate system used to record the heights (or depths) of points dependent on the Earth's gravity field. An exact definition is deliberately not provided as the complexities of the subject fall outside the scope of this document.	vertical derivedVertical

10.4 Coordinate system axis

A coordinate system is composed of a non-repeating sequence of coordinate system axes. Each of its axes is completely characterized by a unique combination of axis name, axis abbreviation, axis direction and axis unit.

Aliases for these attributes may be used as described in [Clause 7](#).

EXAMPLE 1 The combination {Latitude, ϕ , north, degree} would lead to one instance of the object class "coordinate system axis"; the combination {Latitude, ϕ , north, radian} to another instance, the axis unit being different.

EXAMPLE 2 The combination {Easting, E, east, metre} would lead to one instance of the object class "coordinate system axis"; the combination {Easting, X, east, metre} to another instance, the axis abbreviation being different.

In this document, usage of coordinate system axis names is constrained by geodetic custom, depending on the coordinate reference system type. These constraints are shown in [Table 27](#). This constraint is required to work in two directions.

EXAMPLE 3 As "geodetic latitude" and "geodetic longitude" are used as names for coordinate axes forming a geographic coordinate reference system, these terms cannot be used in another context.

Aliases for these constrained names are permitted.

Table 27 — Naming constraints for coordinate system axis

CS type	When used in CRS type	Permitted coordinate system axis names
Cartesian	geodetic	geocentric X, geocentric Y, geocentric Z