



DPC: 18 / 30362652 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: + 44 (0)20 8996 9000

Fax: + 44 (0)20 8996 7400

www.bsigroup.com

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Responsible Committee Secretary: **Committee Service Centre (BSI)**
Direct tel: **020 8996 7009**
E-mail: **csc@bsigroup.com**

Introduction

This draft standard is based on international discussions in which the UK has taken an active part. Your comments on this draft are invited and will assist in the preparation of the consequent standard. Comments submitted will be reviewed by the relevant BSI committee before sending the consensus UK vote and comments to the international secretariat, which will then decide appropriate action on the draft and the comments received.

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Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	(7)
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/ Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

DRAFT INTERNATIONAL STANDARD

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Secretariat: **SIS**

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2018-04-09

Voting terminates on:
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Geographic information — Referencing by coordinates

Information géographique — Système de références par coordonnées

ICS: 35.240.70

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CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
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Contents

Foreword	viii
Introduction.....	x
1 Scope	1
2 Conformance requirements	2
3 Normative references	3
4 Terms and definitions.....	3
5 Conventions.....	12
5.1 Symbols	12
5.2 Abbreviated terms	13
5.3 Unified Modeling Language notation	13
5.4 Attribute status	14
6 Referencing by coordinates - data model overview	15
7 Coordinates package	16
7.1 Relationship between coordinates and coordinate reference system	16
7.2 Coordinate reference system identification.....	17
7.3 Requirements for coordinate metadata.....	18
7.3.1 Requirements class: static CRS coordinate metadata	18
7.3.2 Requirements class: dynamic CRS coordinate metadata.....	18
7.4 UML schema for the Coordinates package.....	18
7.5 UML schema for change of coordinates.....	20
8 Common Classes package	22
8.1 General attributes	22
8.1.1 Introduction	22
8.1.2 Name and alias	22
8.1.3 Identifier.....	22
8.1.4 Scope and Domain of Validity	23
8.2 UML schema for the Common Classes package.....	23
9 Coordinate Reference Systems package	28
9.1 Coordinate reference system	28
9.1.1 General	28
9.1.2 Principal subtypes of coordinate reference system	28
9.2 Derived coordinate reference system.....	29
9.2.1 General	29
9.2.2 Projected coordinate reference system	29
9.3 Compound coordinate reference system.....	29
9.3.1 General	29
9.3.2 Spatial compound coordinate reference system	30
9.3.3 Spatio-temporal compound coordinate reference system.....	30
9.3.4 Spatio-parametric compound coordinate reference system.....	30
9.3.5 Spatio-parametric-temporal compound coordinate reference system.....	30
9.4 UML schema for the Coordinate Reference Systems package	30
10 Coordinate Systems package.....	41
10.1 Coordinate system - general.....	41
10.2 Parametric coordinate system	42
10.3 Temporal coordinate system	43
10.4 Coordinate system axis	43
10.5 UML schema for the Coordinate Systems package	44

11	Datums (reference frames) package	59
11.1	Types of datum and reference frame	59
11.2	Geodetic reference frame	59
11.2.1	Prime meridian	59
11.2.2	Ellipsoid	59
11.3	Dynamic reference frame	59
11.4	Datum ensemble	60
11.5	Temporal datum	60
11.6	UML schema for the Datums package	60
12	Coordinate Operations package	71
12.1	General characteristics of coordinate operations	71
12.2	UML schema for the Coordinate Operations package	72
	Annex A (normative) Abstract test suite	84
	Annex B (informative) Spatial referencing by coordinates – Geodetic concepts	88
	Annex C (informative) Spatial referencing by coordinates – Context for modelling	93
	Annex D (informative) Temporal referencing by coordinates – Context for modelling	108
	Annex E (informative) Examples	113
	Annex F (informative) Recommended best practice for interfacing to ISO 19111	152
	Annex G (informative) Backward compatibility with ISO 19111:2007	153
	Bibliography	158

Figures

Figure 1	Context of referencing by coordinates	x
Figure 2	UML model packages and dependencies	15
Figure 3	Conceptual model for coordinate operations to produce a merged coordinate set	16
Figure 4	Conceptual model for a coordinate operation to change coordinate epoch	17
Figure 5	UML diagram — Relationship of coordinates and coordinate metadata	18
Figure 6	UML diagram — Relationship of coordinate operation and coordinate metadata	21
Figure 7	UML diagram — Common Classes package	24
Figure 8	UML diagram — Data types from ISO 19115-1:2014 (Metadata)	25
Figure 9	UML diagram — Coordinate Reference Systems package	32
Figure 10	UML diagram — Derived Coordinate Reference Systems	33
Figure 11	UML diagram — Coordinate Systems package	45
Figure 12	UML diagram — Coordinate System type associations with Coordinate Reference System type	46
Figure 13	UML diagram — Datums package	61
Figure 14	UML diagram — Datum type associations with Coordinate Reference System type	62
Figure 15	UML diagram — Coordinate Operations package part 1	73
Figure 16	UML diagram — CoordinateOperations package part 2	74
Figure B.1	Ellipsoidal and gravity-related heights	89

Tables

Table 1 — Conformance classes	2
Table 2 — Defining elements of Coordinates::CoordinateMetadata class	19
Table 3 — Defining elements of Coordinates::CoordinateSet class.....	19
Table 4 — Defining elements of Coordinates::DataEpoch class.....	20
Table 5 — Defining elements of Common Classes::IdentifiedObject class	26
Table 6 — Defining elements of Common Classes::ObjectUsage class	26
Table 7 — Defining elements of Common Classes::ObjectDomain class	27
Table 8 — Defining elements of Coordinate Reference Systems::CRS class.....	34
Table 9 — Defining elements of Coordinate Reference Systems::SingleCRS class.....	34
Table 10 — Defining elements of Coordinate Reference Systems::GeodeticCRS class.....	35
Table 11 — Defining elements of Coordinate Reference Systems::GeographicCRS class.....	35
Table 12 — Defining elements of Coordinate Reference Systems::VerticalCRS class.....	36
Table 13 — Defining elements of Coordinate Reference Systems::ParametricCRS class.....	36
Table 14 — Defining elements of Coordinate Reference Systems::EngineeringCRS class	36
Table 15 — Defining elements of Coordinate Reference Systems::TemporalCRS class.....	37
Table 16 — Defining elements of Coordinate Reference Systems::DerivedCRS class	37
Table 17 — Defining elements of Coordinate Reference Systems::ProjectedCRS class	37
Table 18 — Defining elements of Coordinate Reference Systems::DerivedProjectedCRS class	38
Table 19 — Defining elements of Coordinate Reference Systems::DerivedGeodeticCRS class.....	38
Table 20 — Defining elements of Coordinate Reference Systems::DerivedGeographicCRS class	38
Table 21 — Defining elements of Coordinate Reference Systems::DerivedVerticalCRS class.....	39
Table 22 — Defining elements of Coordinate Reference Systems::DerivedParametricCRS class	39
Table 23 — Defining elements of Coordinate Reference Systems::DerivedEngineeringCRS class	39
Table 24 — Defining elements of Coordinate Reference Systems::DerivedTemporalCRS class....	39
Table 25 — Defining elements of Coordinate Reference Systems::CompoundCRS class.....	40
Table 26 — Subtypes of coordinate system and constraints in its relationship with coordinate reference system.....	42
Table 27 — Naming constraints for coordinate system axis	44
Table 28 — Defining elements of CoordinateSystems::CoordinateSystem class.....	47
Table 29 — Defining elements of CoordinateSystems::AffineCS class	47
Table 30 — Defining elements of CoordinateSystems::CartesianCS class	47
Table 31 — Defining elements of CoordinateSystems::CylindricalCS class.....	48
Table 32 — Defining elements of CoordinateSystems::EllipsoidalCS class	48

Table 33 — Defining elements of CoordinateSystems::LinearCS class	48
Table 34 — Defining elements of CoordinateSystems::OrdinalCS class	49
Table 35 — Defining elements of CoordinateSystems::ParametricCS class	49
Table 36 — Defining elements of CoordinateSystems::PolarCS class	49
Table 37 — Defining elements of CoordinateSystems::SphericalCS class	50
Table 38 — Defining elements of CoordinateSystems::TemporalCS class	50
Table 39 — Defining elements of CoordinateSystems::DateTimeTemporalCS class	50
Table 40 — Defining elements of CoordinateSystems::TemporalCountCS class	51
Table 41 — Defining elements of CoordinateSystems::TemporalMeasureCS class	51
Table 42 — Defining elements of CoordinateSystems::VerticalCS class	51
Table 43 — Defining elements of CoordinateSystems::DerivedProjectedCS class	52
Table 44 — Defining elements of CoordinateSystems::EngineeringCS class	52
Table 45 — Defining elements of CoordinateSystems::GeodeticCS class	52
Table 46 — Defining elements of CoordinateSystems::CoordinateDataType class	53
Table 47 — Defining elements of CoordinateSystems::CoordinateSystemAxis class	54
Table 48 — Defining elements of CoordinateSystems::DateTimeCoordinateSystemAxis class	55
Table 49 — Defining elements of CoordinateSystems::RangeMeaning class	55
Table 50 — Defining elements of CoordinateSystems::AxisDirection class	56
Table 51 — Defining elements of Datums::Datum class	63
Table 52 — Defining elements of Datums::GeodeticReferenceFrame class	64
Table 53 — Defining elements of Datums::DynamicGeodeticReferenceFrame class	64
Table 54 — Defining elements of Datums::PrimeMeridian class	65
Table 55 — Defining elements of Datums::Ellipsoid class	65
Table 56 — Defining elements of Datums::SecondDefiningParameter class	66
Table 57 — Defining elements of Datums::VerticalReferenceFrame class	66
Table 58 — Defining elements of Datums::RealizationMethod class	67
Table 59 — Defining elements of Datums::DynamicVerticalReferenceFrame class	67
Table 60 — Defining elements of Datums::ParametricDatum class	68
Table 61 — Defining elements of Datums::DefiningParameter class	68
Table 62 — Defining elements of Datums::EngineeringDatum class	68
Table 63 — Defining elements of Datums::TemporalDatum class	69
Table 64 — Defining elements of Datums::Calendar class	69
Table 65 — Defining elements of Datums::DatumEnsemble class	70
Table 66 — Defining elements of Coordinate Operations::CoordinateOperation class	75
Table 67 — Defining elements of Coordinate Operations::PassThroughOperation class	76
Table 68 — Defining elements of Coordinate Operations::ConcatenatedOperation class	76
Table 69 — Defining elements of Coordinate Operations::SingleOperation class	77
Table 70 — Defining elements of Coordinate Operations::Transformation class	77

Table 71 — Defining elements of Coordinate Operations::Conversion class	78
Table 72 — Defining elements of Coordinate Operations::PointMotionOperation class.....	78
Table 73 — Defining elements of Coordinate Operations::OperationMethod class.....	79
Table 74 — Defining elements of Coordinate Operations::Formula class	79
Table 75 — Defining elements of Coordinate Operations::GeneralOperationParameter class.....	79
Table 76 — Defining elements of Coordinate Operations::OperationParameterGroup class.....	80
Table 77 — Defining elements of Coordinate Operations::OperationParameter class	80
Table 78 — Defining elements of Coordinate Operations::GeneralParameterValue class.....	80
Table 79 — Defining elements of Coordinate Operations::ParameterValueGroup class.....	81
Table 80 — Defining elements of Coordinate Operations::OperationParameterValue class.....	81
Table 81 — Defining elements of Coordinate Operations::ParameterValue class	82
Table 82 — Defining elements of Coordinate Operations::GeographicObject class	83
Table 83 — Defining elements of Coordinate Operations::RegisterOperations class.....	83

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).

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For an explanation on 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).

The committee responsible for this document is Technical Committee ISO/TC 211 *Geographic information/Geomatics*, in close collaboration with the Open Geospatial Consortium (OGC).

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 19111-2) and temporal.
- the correction of minor errors.

Further details are given in Annex G.

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^[4]. 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; it excludes calendars and ordinal reference systems due to their complexities in definition and in transformation. The context is shown in Figure 1.

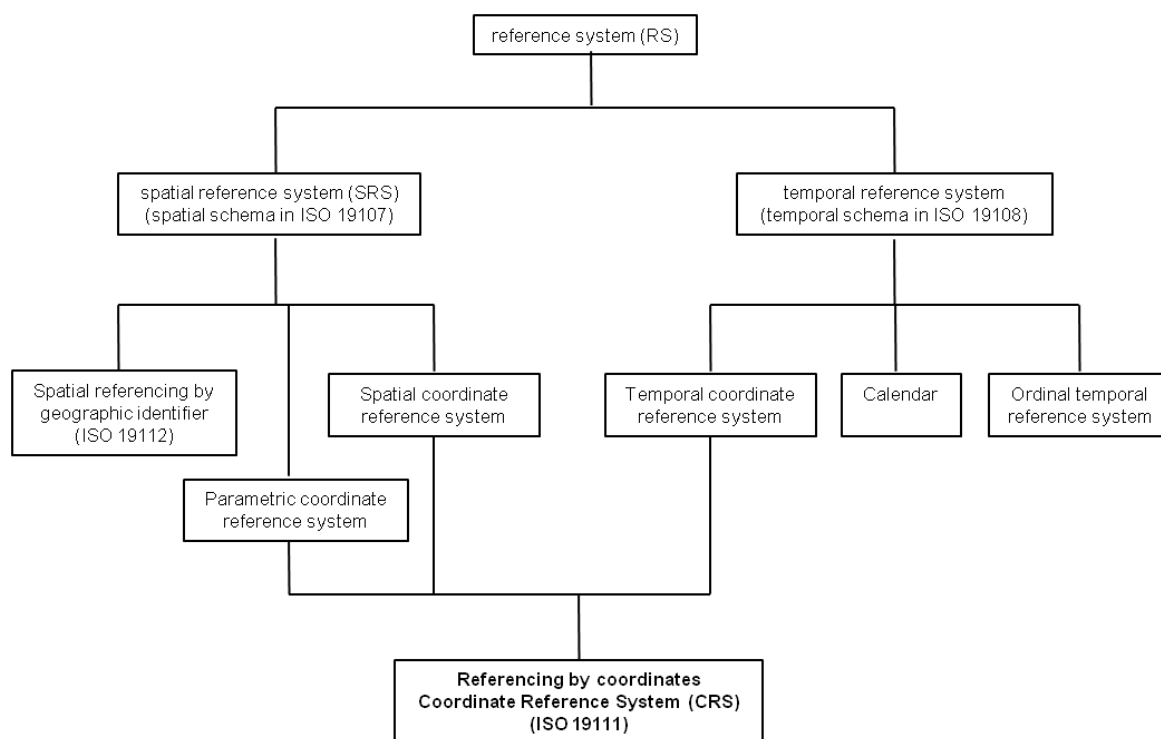


Figure 1 — Context of referencing by coordinates

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 elevation 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

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 may 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 may include a time element. The coordinate values within a dynamic and in a temporal coordinate reference system may 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, it 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, its principles can be extended to many other forms of spatial data such as maps, charts and text documents.

2 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	
4	with dynamic reference frame	
5	derived geodetic CRS	
6	Geographic CRS with static reference frame	
7	with dynamic reference frame	
8	derived geographic CRS	
9	Projected CRS	
10	derived projected CRS	
11	Vertical CRS with static reference frame	
12	with dynamic reference frame	
13	derived vertical CRS	
14	Parametric CRS	
15	derived parametric CRS	
16	Engineering CRS	
17	derived engineering CRS	
18	Temporal CRS dateTime	
19	temporal count	
20	temporal measure	
21	derived temporal CRS	
22	CRS with datum ensemble	

Conformance class	Description	Conformance requirements given in
23	Compound CRS	
Conformance of a coordinate operation definition		A.4
24	Coordinate conversion	
25	Coordinate transformation	
26	Point motion operation	
27	Concatenated operation	
28	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.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8601:2004, *Data elements and interchange formats — Information interchange — Representation of dates and times*

ISO 19103:2015, *Geographic information — Conceptual schema language*

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

4 Terms and definitions

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

4.1

affine coordinate system

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

4.2

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.

4.3

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.

4.4

concatenated operation

coordinate operation consisting of the sequential application of multiple coordinate operations

4.5

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.

4.6

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 feet to metres.

4.7

coordinate epoch

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

4.8

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

4.9

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.

4.10

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

4.11

coordinate system

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

4.12

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.

4.13**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.

4.14**cylindrical coordinate system**

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

4.15**datum**

reference frame

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

4.16**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 but 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 0.7m between the TRANSIT and G730 realizations, a further 0.2m between G730 and G873, 0.06m between G873 and G1150, 0.2m between G1150 and G1674 and 0.02m between G1674 and G1762).

4.17**depth**

distance of a point from a chosen vertical reference surface measured 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.

4.18**derived coordinate reference system**

coordinate reference system that is defined through the application of one or more specified coordinate conversions 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: Coordinate conversions between the base and derived coordinate reference system are implemented using the parameters and formula(s) specified in the definition of the coordinate conversion.

4.19

dynamic coordinate reference system

coordinate reference system that has a dynamic reference frame with or without an associated deformation model or that has a static reference frame with an associated deformation model

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.

4.20

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.

4.21

easting

E

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

4.22

ellipsoid

reference ellipsoid

<geodesy> geometric reference surface embedded in 3D Euclidean space represented by an ellipsoid

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.

4.23

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

4.24

ellipsoidal height

geodetic height

h

distance of a point from the reference ellipsoid measured 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.

4.25

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.

4.26**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.

4.27**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.

4.28**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.**4.29****frame reference epoch**

epoch of coordinates that define a dynamic reference frame

4.30**geocentric latitude**

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

4.31**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 (4.35).

4.32**geodetic latitude**

ellipsoidal latitude

 φ

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

4.33**geodetic longitude**

ellipsoidal longitude

 λ

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

4.34

geodetic reference frame

geodetic datum

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

4.35

geographic coordinate reference system

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

4.36

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

4.37

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.

4.38

height

h, H

distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface

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

4.39

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.

4.40

map projection

coordinate conversion from an ellipsoidal coordinate system to a plane

4.41

mean sea level

MSL

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.

4.42**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.

4.43**northing**

N

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

4.44**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.

4.45**parametric coordinate reference system**

coordinate reference system based on a parametric datum

4.46**parametric coordinate system**

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

4.47**parametric datum**

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

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

4.48**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.

4.49**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.

4.50**prime meridian**

meridian from which the longitudes of other meridians are quantified

4.51

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.

4.52

reference frame

datum

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

4.53

semi-major axis

a

semi-diameter of the longest axis of an ellipsoid

4.54

semi-minor axis

b

semi-diameter of the shortest axis of an ellipsoid

4.55

sequence

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

4.56

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.

4.57

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”.

4.58

spatio-parametric-temporal coordinate reference system

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

4.59

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

4.60**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.

4.61**static coordinate reference system**

coordinate reference system that has a static reference frame without an associated deformation model or a dynamic reference frame with coordinates referenced to a single fixed epoch

Note 1 to entry: Coordinates of points which are referenced to a static coordinate reference system do not change with time.

4.62**static reference frame**

static datum

reference frame in which the defining parameters exclude time evolution

4.63**temporal coordinate reference system**

coordinate reference system based on a temporal datum

4.64**temporal coordinate system**

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

4.65**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.

4.66**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 the term geodetic reference frame is used instead of terrestrial reference frame.

4.67**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* (4.44) where the transformation parameter values first need to be propagated to the epoch of the coordinates before the coordinate transformation is applied.

4.68**tuple**

ordered list of values

[SOURCE: ISO 19136:2007, 4.1.63]

4.69

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 and time quantities.

4.70

vertical coordinate reference system

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

4.71

vertical coordinate system

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

4.72

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.

4.74

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.

5 Conventions

5.1 Symbols

a	semi-major axis of ellipsoid
b	semi-minor axis of 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, ϱ, θ	spherical coordinates in a 3D engineering coordinate reference system Note: In this document ϱ is the polar (zenith) angle and θ is the azimuthal angle.
$\varphi, \lambda, [h]$	ellipsoidal coordinates in a geographic coordinate reference system

5.2 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
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

5.3 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 *Conceptual schema language* 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.

5.4 Attribute status

In this document the conceptual schema is described in clauses 6 through 12 through tables. In these tables, attributes are given an obligation status:

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.

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

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).

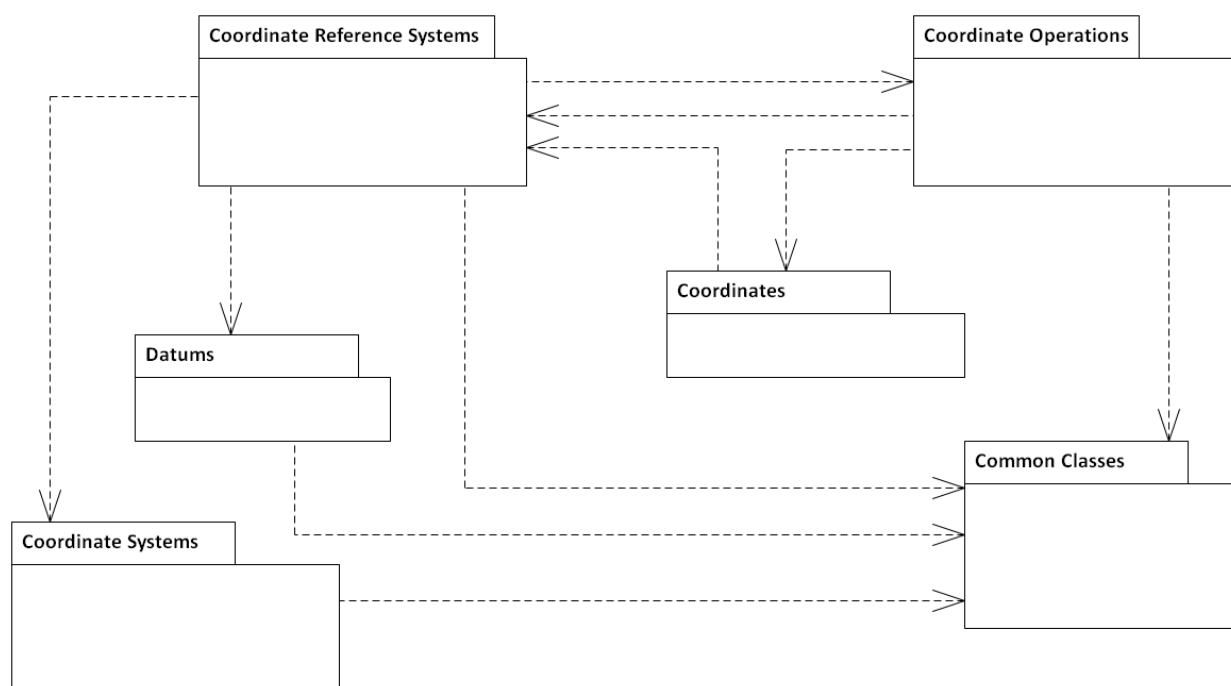


Figure 2 — UML model packages and dependencies

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 through 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 through 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.

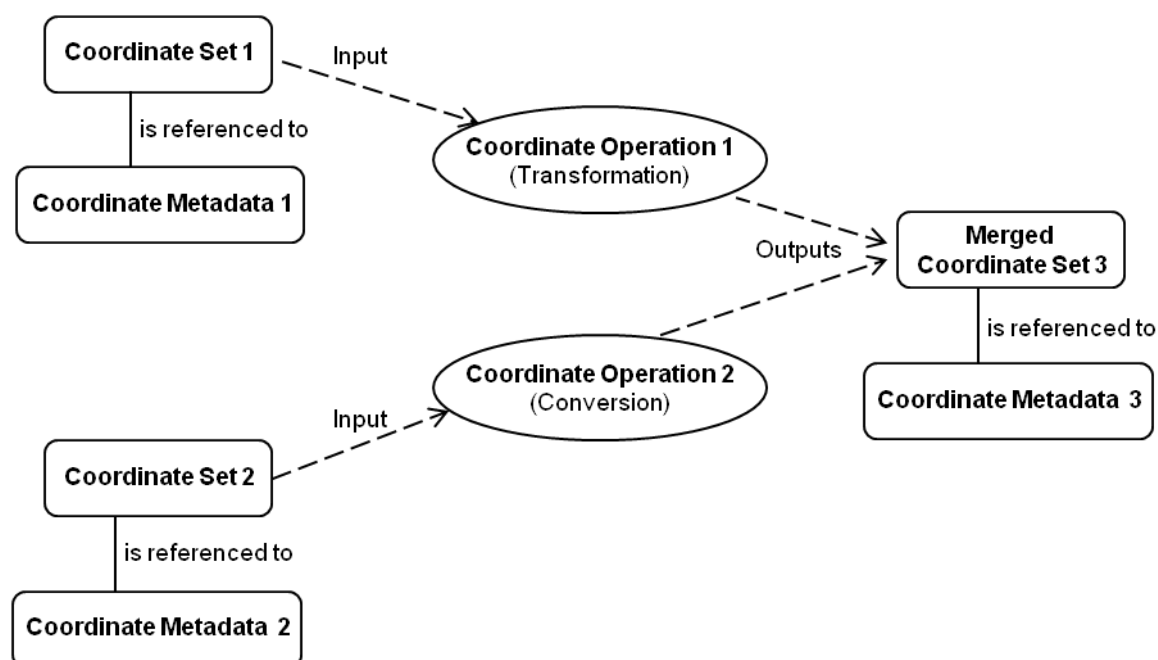


Figure 3 — Conceptual model for coordinate operations to produce a merged coordinate set

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.

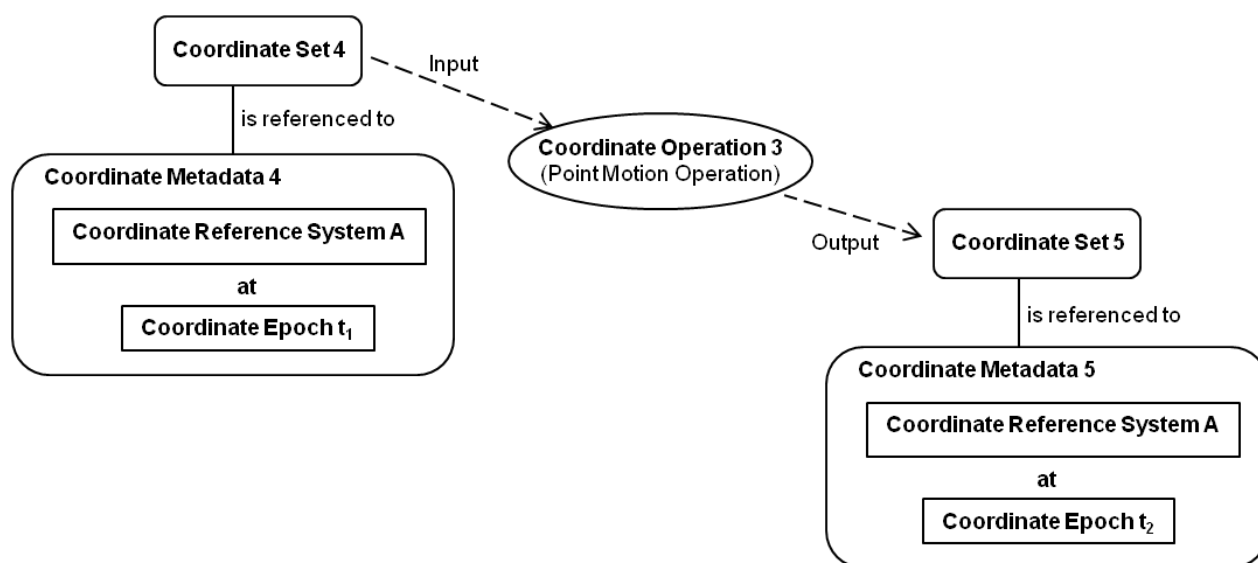


Figure 4 — Conceptual model for a coordinate operation to change coordinate epoch

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^[7].

7.2 Coordinate reference system identification

The elements required for the definition of coordinate reference systems and coordinate operations are described in Clauses 8 through 12.

CRS or coordinate operation identification may be through:

- a full description, as defined in this document, or
- 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
- 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 the description is not available from a register, it shall be given explicitly and in full. In both methods, the order of coordinates in each coordinate tuple shall 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 or be associated with a velocity model and therefore may be dynamic CRSs: geodetic, geographic, vertical, projected and derived variants of these subtypes.

NOTE Implementers are warned that CRSs of these subtypes are not necessarily dynamic; their reference frame attributes and association to a PointMotionOperation 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 through 4.

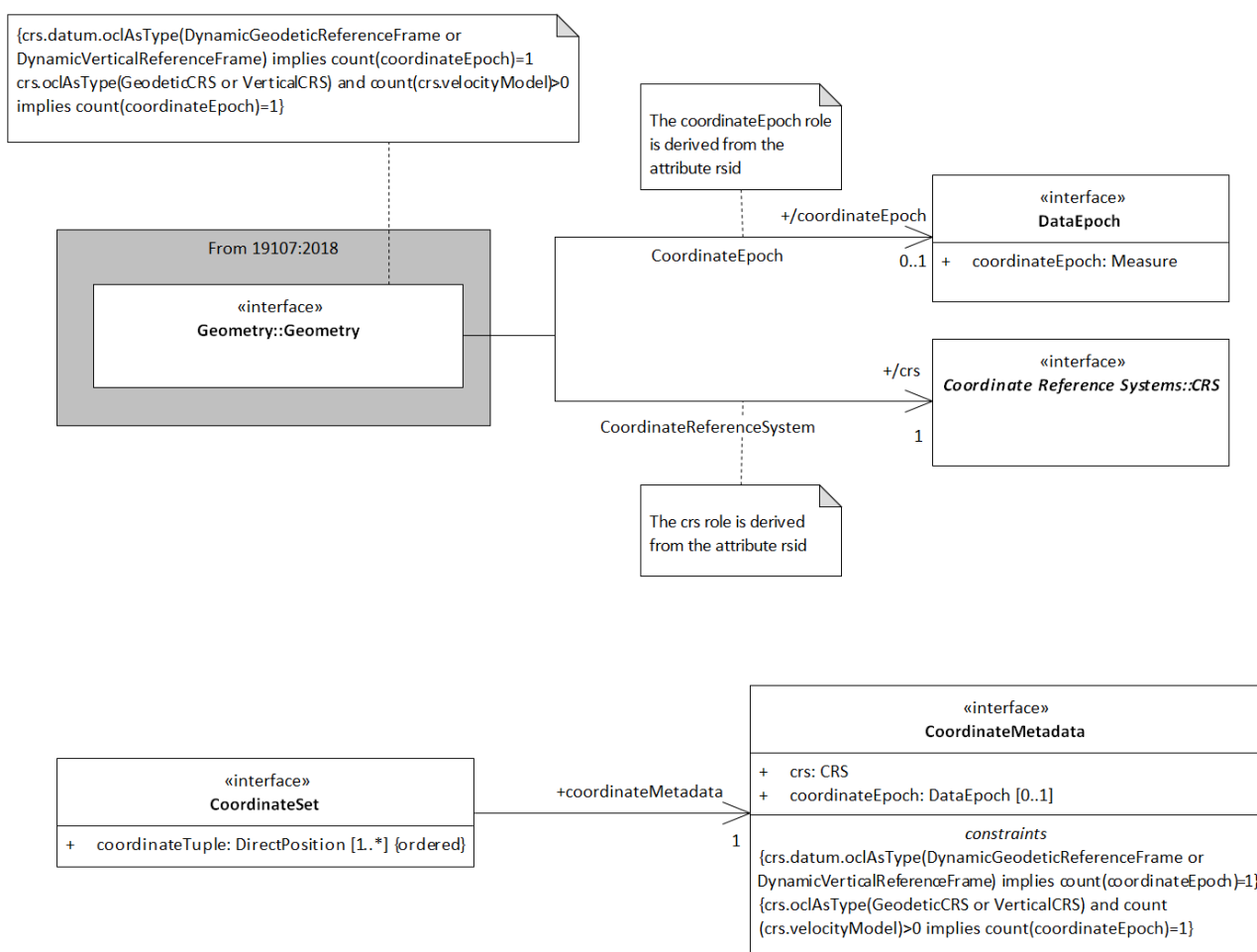


Figure 5 — UML diagram — Relationship of coordinates and coordinate metadata

Table 2 — Defining elements of Coordinates::CoordinateMetadata class

Description:	Metadata required to reference coordinates.				
Stereotype:	Interface				
Class attribute:	Concrete				
Inheritance from:	(none)				
Association roles:	coordinateMetadata from CoordinateSet [1]				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute description
CRS ID	crs	CRS	M	1	Identifier of the coordinate reference system to which a coordinate set is referenced.
Coordinate epoch	coordinateEpoch	DataEpoch	C	1	Epoch at which coordinate referenced to a dynamic CRS are valid.
Constraints: {crs.datum.ocAsType(DynamicGeodeticReferenceFrame or DynamicVerticalReferenceFrame) implies count(coordinateEpoch)=1} {crs.ocAsType(GeodeticCRS VerticalCRS) and count(crs.velocityModel)>0 implies count(coordinateEpoch)=1}					

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 shall be related to a specified coordinate epoch. This enforces the conditionality of the coordinateEpoch attribute. Whether the CRS is dynamic is determined either through the CRS's reference frame definition (Clause 11) or through the CRS having an association *velocityModel* to a point motion operation (Clause 12).

Table 3 — Defining elements of Coordinates::CoordinateSet class

Description:	Description of the coordinate tuples in a coordinate set. 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:	coordinateMetadata to CoordinateMetadata [1]				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute description
Coordinate tuple	coordinateTuple	DirectPosition {ordered}	M	N	Position described by a coordinate tuple.

Table 4 — Defining elements of Coordinates::DataEpoch class

Description:	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:	(derived) coordinateEpoch from Geometry [0..1], association named <i>CoordinateEpoch</i> {note attached} sourceCoordinateEpoch from Coordinate Operations::CoordinateOperation [0..1], association named <i>SourceEpoch</i> targetCoordinateEpoch from Coordinate Operations::CoordinateOperation [0..1], association named <i>TargetEpoch</i>				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute description
Coordinate epoch	coordinateEpoch	Measure	M	1	The 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.
Note attached to association from Geometry::Geometry: The coordinateEpoch role is derived from the attribute rsid.					

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:

- i) To define the requirements for describing a coordinate operation
- ii) 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.

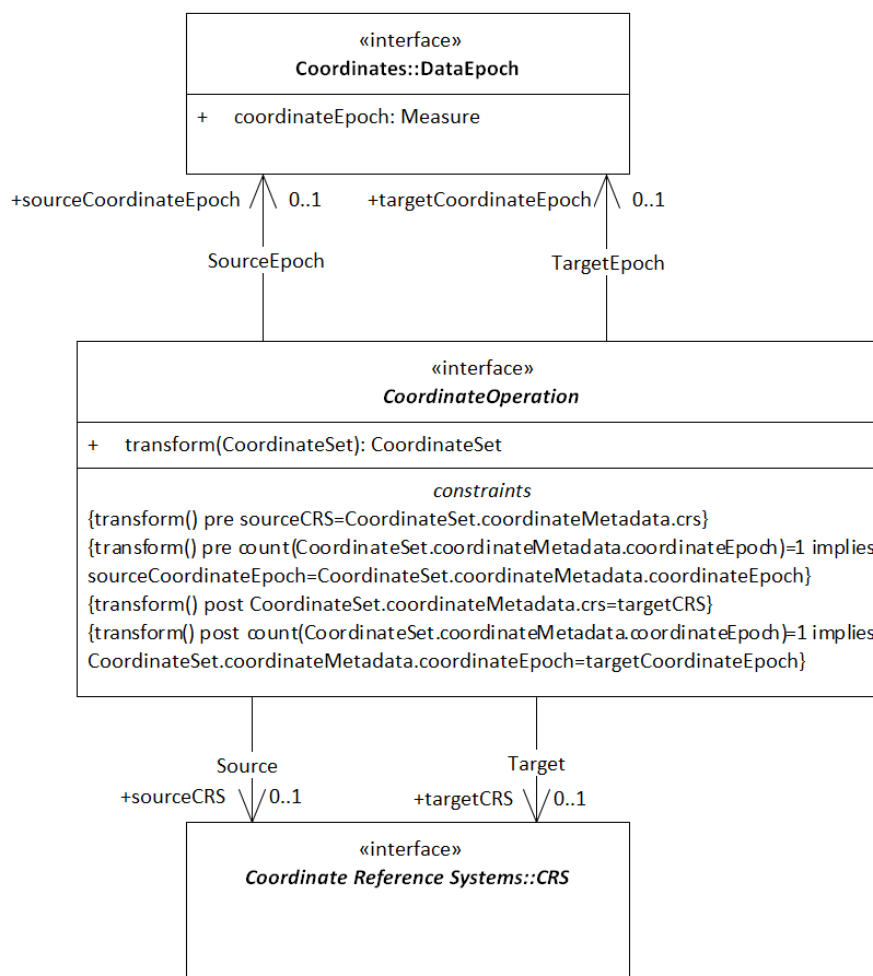


Figure 6 — UML diagram — Relationship of coordinate operation and coordinate metadata

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, the geometry may 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^[9]. 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 through 7.

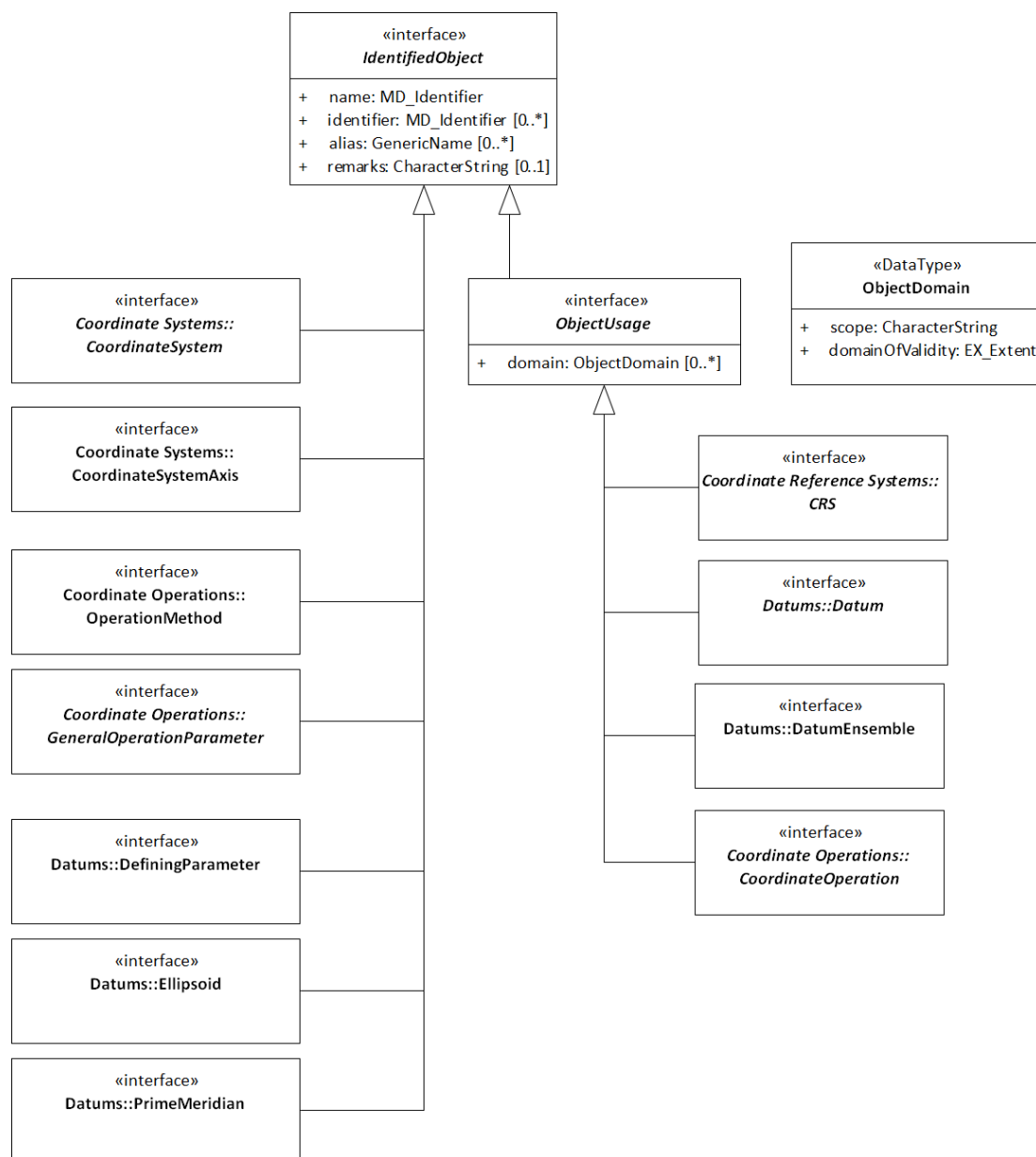


Figure 7 — UML diagram — Common Classes package

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.

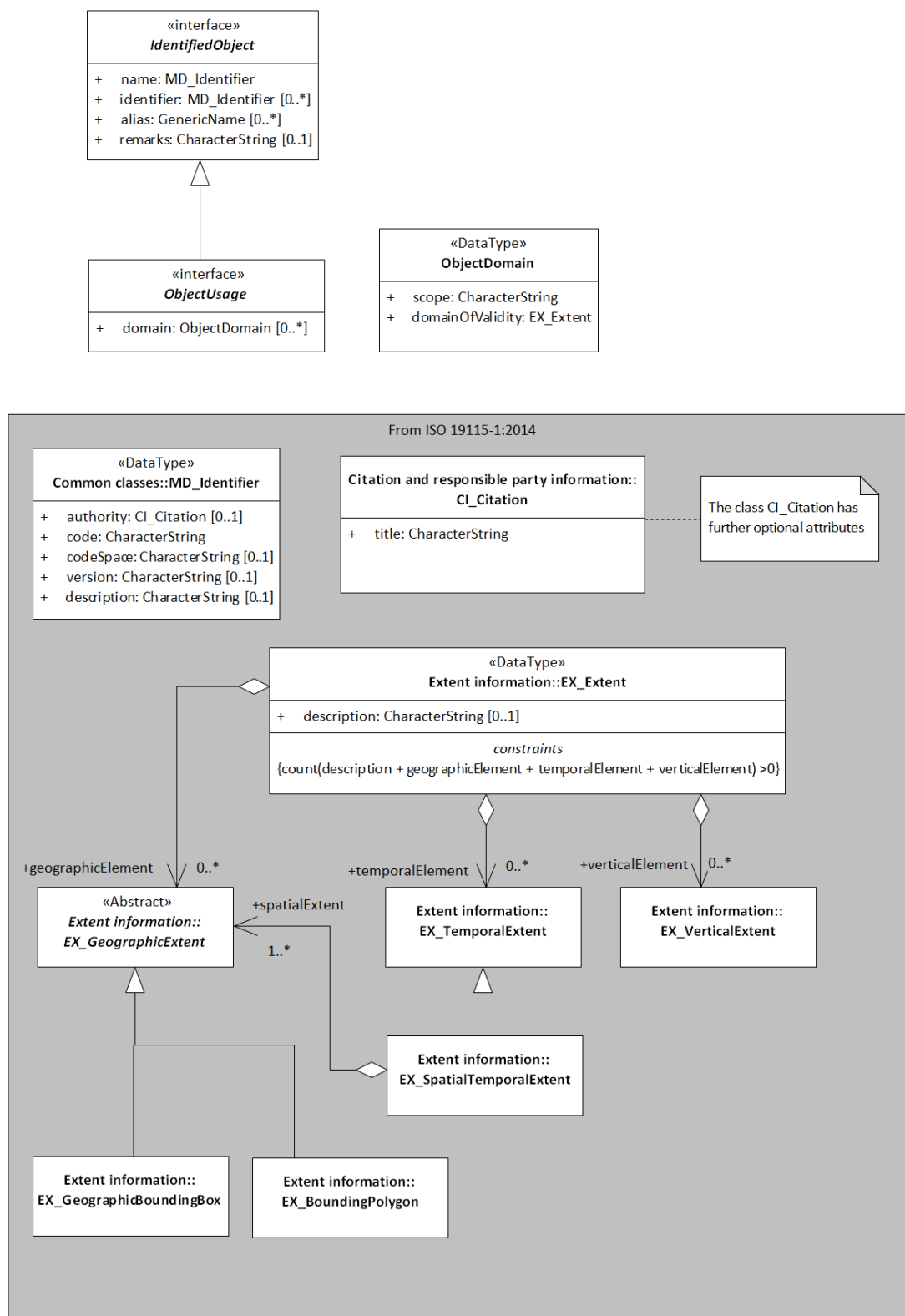


Figure 8 — UML diagram — Data types from ISO 19115-1:2014 (Metadata)

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::GeneralCoordinateSystemAxis Datums::DefiningParameter Datums::Ellipsoid Datums::PrimeMeridian Coordinate Operations::GeneralOperationParameter Coordinate Operations::OperationMethod				
Association roles:	(none)				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute Definition
Object name	name	MD_Identifier	M	1	The primary name by which this object is identified.
Object identifier	identifier	MD_Identifier	0	N	An identifier which references elsewhere the object's defining information; alternatively an identifier by which this object can be referenced.
Object alias	alias	GenericName	0	N	An alternative name by which this object is identified.
Object remarks	remarks	CharacterString	0	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				
Association roles:	(none)				
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	0	N	The scope and validity of the object.

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

Definition:	The scope and validity of a CRS-related object.				
Stereotype:	DataType				
Class attribute:	Concrete				
Inheritance from:	(none)				
Used by:	ObjectUsage				
Association roles:	(none)				
Public attributes:					
Attribute name	UML identifier	Data type	Obligation	Maximum Occurrence	Attribute Definition
Object scope	scope	CharacterString	M	1	Description of usage, or limitations of usage, for which this object is valid. If unknown, enter "not known".
Object validity	domainOfValidity	EX_Extent	M	1	The 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 shall consist 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 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 The CRS internal to the image is not geo-referenced. The image may 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^[5].

- 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 from its base CRS (clause 11). 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 below.

Further information on derived coordinate reference systems is given in C.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 be 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 shall 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: an example is given in E.4.4.

9.3.4 Spatio-parametric compound coordinate reference system

A spatio-parametric coordinate reference system shall be 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. More than one parametric coordinate reference system may be included if these represent independent parametric quantities: an example is included in E.3.3.

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 through 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.

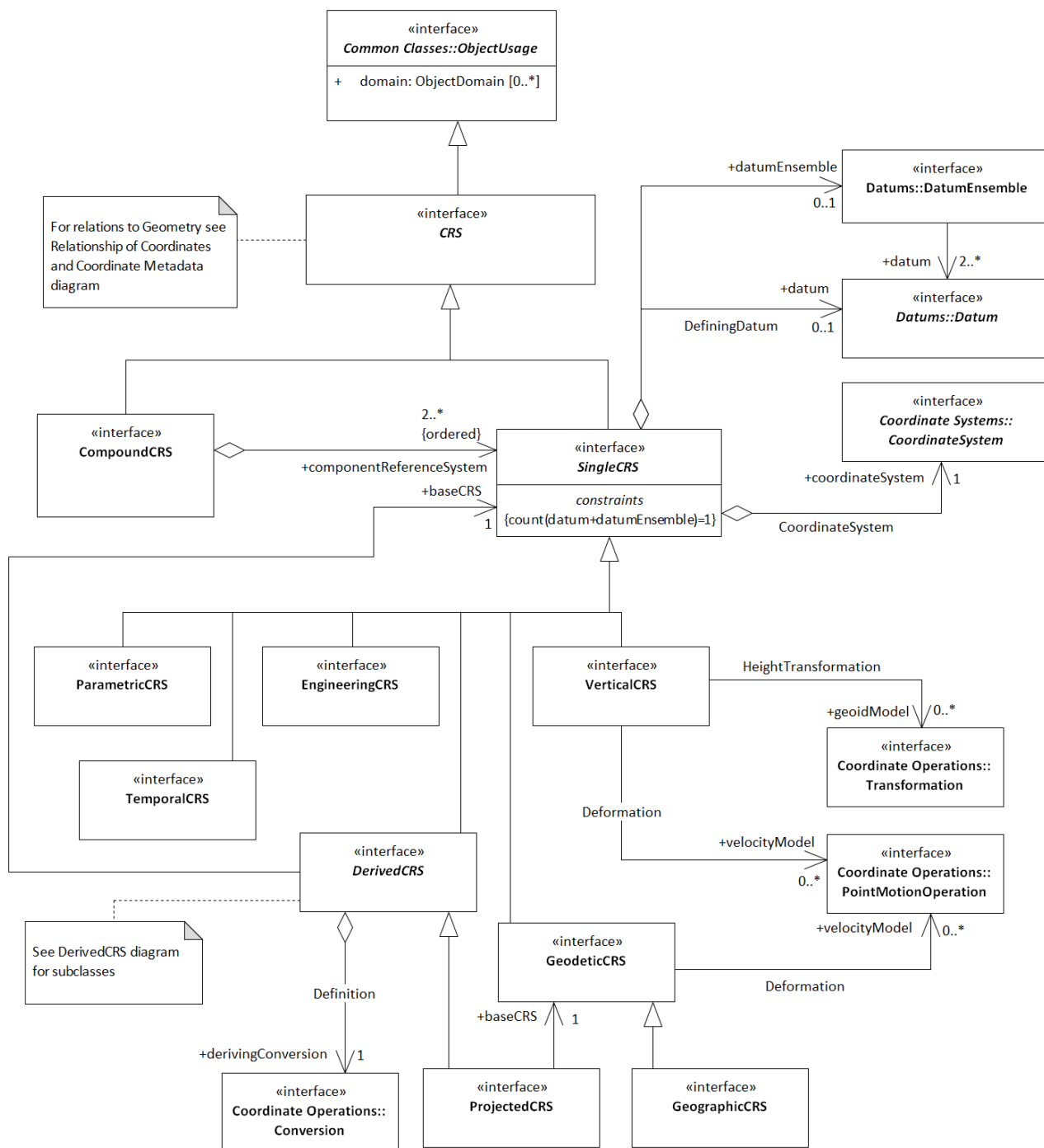


Figure 9 — UML diagram — Coordinate Reference Systems package

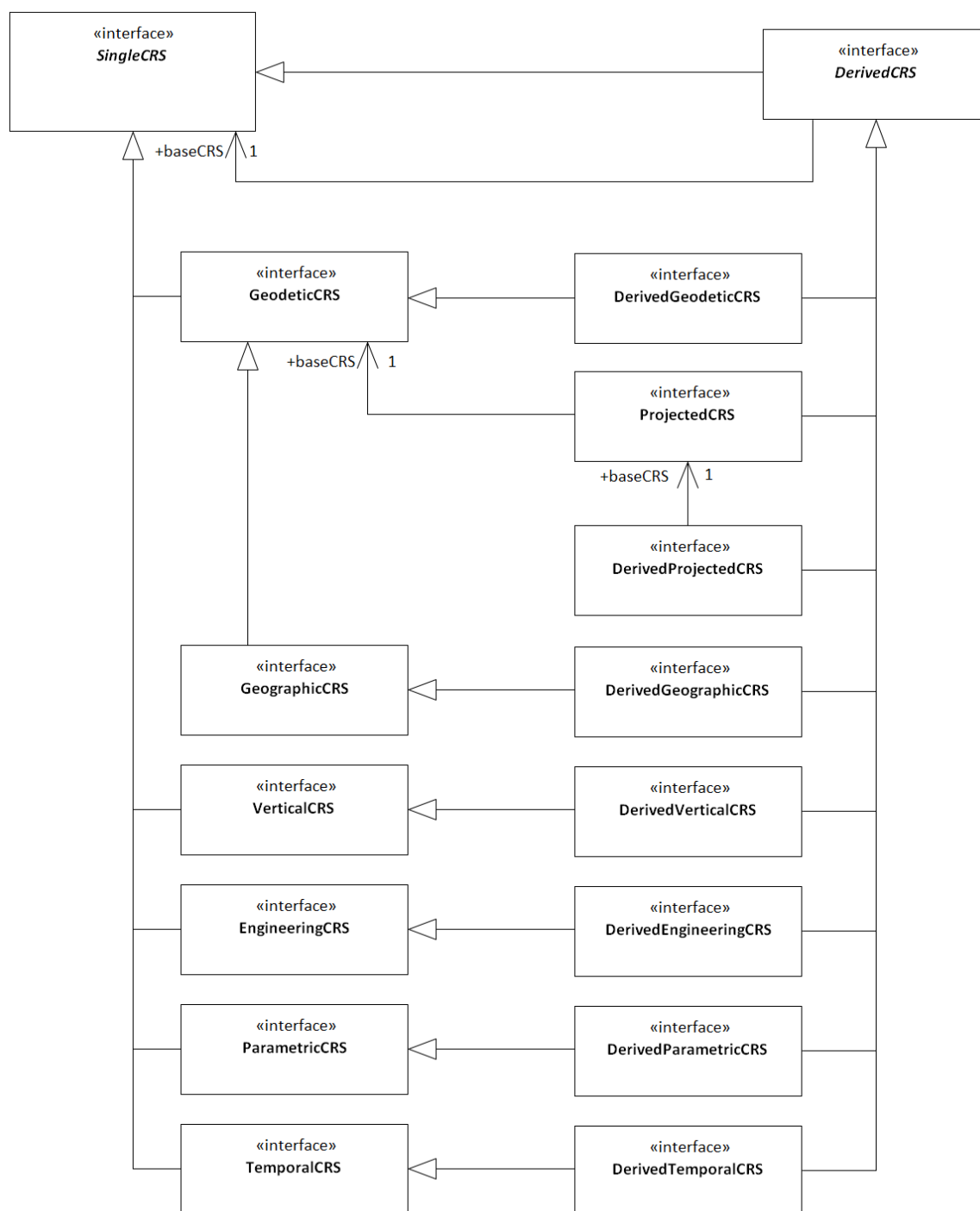


Figure 10 — UML diagram — Derived Coordinate Reference Systems

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:	sourceCRS from CoordinateOperations::CoordinateOperation [0..1], association named <i>Source</i> targetCRS from CoordinateOperations::CoordinateOperation [0..1], association named <i>Target</i> interpolationCRS from CoordinateOperations::CoordinateOperation [0..1], association named <i>Interpolation</i> (derived) crs from Geometry::Geometry [1], association named <i>Coordinate Reference System</i> {note attached}
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.
Note attached to association from Geometry::Geometry: The crs role is derived from the attribute rsid (See ISO 19107)	

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:	(aggregation) coordinateSystem to CoordinateSystems::CoordinateSystem [1], association named <i>CoordinateSystem</i> (aggregation) datum to Datums::Datum [0..1], association named <i>DefiningDatum</i> (see remarks below) (aggregation) datumEnsemble to Datums::DatumEnsemble [0..1] (see remarks below) baseCRS from DerivedCRS [1] (aggregation) componentReferenceSystem from CompoundCRS [2..*] {ordered} (associations inherited from CRS)
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.
Constraint:	{inv: count(datum + datumEnsemble) = 1}
Remarks: This constraint requires a singleCRS to be associated with either a datum (reference frame) or a datum ensemble.	

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

Definition:	A coordinate reference system associated with a geodetic reference frame and a three-dimensional Cartesian or spherical coordinate system. If the geodetic reference frame is dynamic or if the geodetic CRS has an association to a velocity model then the geodetic CRS is dynamic, else it is static.
Stereotype:	Interface
Class attribute:	Concrete
Inheritance from:	SingleCRS
Generalization of:	GeographicCRS DerivedGeodeticCRS
Association roles:	(aggregation) datum to Datums::GeodeticReferenceFrame [0..1], association named <i>DefiningDatum</i> (aggregation) coordinateSystem to CoordinateSystems::GeodeticCS [1], association named <i>CoordinateSystem</i> baseCRS from ProjectedCRS [1] velocityModel to CoordinateOperations::PointMotionOperation [0..*], association named <i>Deformation</i> (associations inherited from SingleCRS)
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.
Constraint:	{coordinateSystem.ocl As Type(EllipsoidalCS) implies count(datum.ellipsoid)=1
Remarks:	This 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. The association Deformation allows a velocity or deformation model to be linked to a geodetic CRS.

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

Definition:	A coordinate reference system associated with a geodetic reference frame and a two- or three-dimensional ellipsoidal coordinate system. If the geodetic reference frame is dynamic or if the geographic CRS has an association to a velocity model then the geodetic CRS is dynamic, else it is static.
Stereotype:	Interface
Class attribute:	Concrete
Inheritance from:	GeodeticCRS
Generalization of:	DerivedGeographicCRS
Association roles:	(aggregation) coordinateSystem to CoordinateSystems::EllipsoidalCS [1], association named <i>CoordinateSystem</i> (associations inherited from GeodeticCRS)
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.
Remarks:	Constraint {coordinateSystem.ocl As Type(EllipsoidalCS) implies count(datum.ellipsoid)=1 inherited from geodeticCRS. This constraint enforces the requirement on GeographicCRS to be associated with an ellipsoid. It is made through the GeodeticCRS class because GeographicCRS is only related to Datum and hence Ellipsoid through subtyping its from the GeodeticCRS class.

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

Definition:	A 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. If the vertical reference frame is dynamic or if the vertical CRS has an association to a velocity model then the CRS is dynamic, else it is static. Note: 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:	(aggregation) datum to Datums::VerticalReferenceFrame [0..1], association named <i>DefiningDatum</i> (aggregation) coordinateSystem to CoordinateSystems::VerticalCS [1], association named <i>CoordinateSystem</i> geoidModel to CoordinateOperations::Transformation [0..*], association named <i>HeightTransformation</i> velocityModel to CoordinateOperations::PointMotionOperation [0..*], association named <i>Deformation</i> (associations inherited from SingleCRS)
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.
Remarks:	The association HeightTransformation allows a geoid height model or height correction model to be linked to a geoid-based vertical CRS. The association Deformation allows a velocity or deformation model to be linked to a vertical CRS.

Table 13 — Defining elements of Coordinate Reference Systems::ParametricCRS class

Definition:	A 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:	(aggregation) datum to Datums::ParametricDatum [0..1], association named <i>DefiningDatum</i> (aggregation) coordinateSystem to CoordinateSystems::ParametricCS [1], association named <i>CoordinateSystem</i> (associations inherited from SingleCRS)
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:	A 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:	(aggregation) datum to Datums::EngineeringDatum [0..1], association named <i>DefiningDatum</i> (aggregation) coordinateSystem to CoordinateSystems::EngineeringCS [1], association named <i>CoordinateSystem</i> (associations inherited from SingleCRS)
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.