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*RL supplementary additions*

*Needs editing for OGC CRS Json*

*Issue*

{

"$id": "https://proj.org/schemas/v0.7/projjson.schema.json",

"$schema": "http://json-schema.org/~~draft-07~~draft/2020-12/schema#",

*"$comment": "[RL] JSON schema version to match that of OGC JSON-FG [=latest JSON Schema]"*

"description": "Schema for ~~PROJJSON (v0.7)~~OGC CRS JSON vM.N",

"$comment": ~~"This document is copyright Even Rouault and PROJ contributors, 2019-2023, and subject to the MIT license. This file exists both in data/ and in schemas/vXXX/. Keep both in sync. And if changing the value of $id, change PROJJSON\_DEFAULT\_VERSION accordingly in io.cpp"~~,

"oneOf": [

{ "$ref": "#/definitions/crs" },

{ "$ref": "#/definitions/datum" },

{ "$ref": "#/definitions/datum\_ensemble" },

{ "$ref": "#/definitions/ellipsoid" },

{ "$ref": "#/definitions/prime\_meridian" },

{ "$ref": "#/definitions/single\_operation" },

{ "$ref": "#/definitions/concatenated\_operation" },

{ "$ref": "#/definitions/coordinate\_metadata" }

],

*"$comment": "[RL] Should scope be limited to 'top level' entities, i.e. CRSs and coordinate operations? If so, remove from this list the lower level entities: datum, datum\_ensemble, ellipsoid and prime meridian. (These [and other] lower level entities will be needed as components of the top level entities so are not eliminated from the schema, just changing the schema to define only top level entities)."*

"definitions": {

"**abridged\_transformation**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["AbridgedTransformation"] },

"name": { "type": "string" },

"source\_crs": {

"$ref": "#/definitions/crs",

"$comment": "Only present when the source\_crs of the bound\_crs does not match the source\_crs of the AbridgedTransformation. No equivalent in WKT"

},

"method": { "$ref": "#/definitions/method" },

"parameters": {

"type": "array",

"items": { "$ref": "#/definitions/parameter\_value" }

},

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "method", "parameters" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] the concepts of bound\_crs and abridged\_transformation are not recognised in* [*Topic 2 (18-005r8)*](https://docs.ogc.org/as/18-005r8/18-005r8.pdf) *but are defined in* [*CRS WKT (18-010r11)*](https://www.ogc.org/standard/wkt-crs/)*. Should they be included in CRS JSON?"*

"**affine\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain an affine CS to have 2 or 3 axes."*

"**axis**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Axis"] },

"name": { "type": "string" },

"abbreviation": { "type": "string" },

"direction": { "type": "string",

"enum": [ "north",

"northNorthEast",

"northEast",

"eastNorthEast",

"east",

"eastSouthEast",

"southEast",

"southSouthEast",

"south",

"southSouthWest",

"southWest",

"westSouthWest",

"west",

"westNorthWest",

"northWest",

"northNorthWest",

"up",

"down",

"geocentricX",

"geocentricY",

"geocentricZ",

"columnPositive",

"columnNegative",

"rowPositive",

"rowNegative",

"displayRight",

"displayLeft",

"displayUp",

"displayDown",

"forward",

"aft",

"port",

"starboard",

"clockwise",

"counterClockwise",

"towards",

"awayFrom",

"future",

"past",

"unspecified" ] },

"meridian": { "$ref": "#/definitions/meridian" },

"bearing": { "$ref": "#/definitions/bearing" },

"unit": { "$ref": "#/definitions/unit" },

"minimum\_value": { "type": "number" },

"maximum\_value": { "type": "number" },

"range\_meaning": { "type": "string", "enum": [ "exact", "wraparound"] },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "abbreviation", "direction" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] For most subtypes of CS (ordinal and temporalDateTime excepted) 19111/Topic 2 (and WKT2) has constraints requiring the axis to have units. Not clear that the above includes these constraints and the exceptions."*

*"$comment": "[RL] meridian is an attribute in WKT2 not found in 19111/Topic2 ..."*

*"$comment": "... WKT2 has a bearing attribute applied to the clockwise and counterClockwise direction values in polar CSs. (also not found in 19111/Topic 2)."*

*"$comment": "[RL] 19111 Topic 2 and WKT2 have constraints on axis names and abbreviations covered further in comments under the CS subtype schema holding places inserted below. Some prohibit both of axis name and axis abbreviation."*

"**bbox**": {

"type": "object",

"properties": {

"east\_longitude": { "type": "number" },

"west\_longitude": { "type": "number" },

"south\_latitude": { "type": "number" },

"north\_latitude": { "type": "number" }

},

"required" : [ "east\_longitude", "west\_longitude",

"south\_latitude", "north\_latitude" ],

"additionalProperties": false

},

*"$comment": "[RL] ISO 19115 has constraints on the bbox limits*

-180 <= West Bounding Longitude Value <= 180

-180 <= East Bounding Longitude Value <= 180

-90 <= South Bounding Latitude Value <= 90; South Bounding Latitude Value <= North bounding Latitude Value

-90 <= North Bounding Latitude Value <= 90; North Bounding Latitude Value >= South Bounding Latitude Value

*where the latitude and longitude must be in decimal degrees.*

*EPSG notes that when East Bounding Longitude Value > West Bounding Longitude Value (the usual case) the bbox does not cross the 180° meridian and when West Bounding Longitude Value > East Bounding Longitude Value the bbox crosses the 180° meridian."*

"**bearing**": {

"description": "Defines the cardinal direction of a polar or spherical CS.",

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Bearing"] },

"longitude": { "$ref": "#/definitions/value\_in\_degree\_or\_value\_and\_unit" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "longitude" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] Above cloned from meridian"."*

"**bound\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["BoundCRS"] },

"name": { "type": "string" },

"source\_crs": { "$ref": "#/definitions/crs" },

"target\_crs": { "$ref": "#/definitions/crs" },

"transformation": { "$ref": "#/definitions/abridged\_transformation" },

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "source\_crs", "target\_crs", "transformation" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] the concepts of bound\_crs and abridged\_transformation are defined in* [*CRS WKT (18-010r11)*](https://www.ogc.org/standard/wkt-crs/) *but are not recognised in* [*Topic 2 (18-005r8)*](https://docs.ogc.org/as/18-005r8/18-005r8.pdf)*. Should they be included in CRS JSON?"*

"**Cartesian\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition should constrain a Cartesian CS to have 2 or 3 axes. In 19111/Topic 2 Cartesian is a specialisation of affine CS (perpendicular axes in same units).*

*When a Cartesian CS is used in a geodetic CRS, 19111/Topic 2 constrains axis names to "*geocentric X, geocentric Y, geocentric Z*". This is erroneous (incomplete) as it covers only the geocentric Cartesian CS case: topocentric coordinates referenced to a geodetic reference frame would normally have names relevant to directions on the earth's surface (e.g. north, east, up). For a geocentric Cartesian CS WKT2 forbids axis names and requires axis abbreviations* ‘X’, 'Y' and ‘Z’.

*When a Cartesian CS is used in a projected CRS, 19111/Topic 2 and WKT2 constrains axis names to "*northing or southing, easting or westing, [ellipsoidal height (if 3D)]*". In the 3D case WKT2 requires axis abbreviation for the ellipsoidal height axis to be 'h'.*

*See vertical\_cs below for a possible template for adding these constraints."*

"**compound\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["CompoundCRS"] },

"name": { "type": "string" },

"components": {

"type": "array",

"items": { "$ref": "#/definitions/crs" }

},

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "components" ],

"additionalProperties": false

},

*"$comment": "[RL] The use of both object\_usage and usages in this schema is not clear - for scope and extent they seem to duplicate each other. In ISO 19111 a usage must contain one scope and one extent. The main geodetic entities (CRS, datum, all types of coordinate operation) should have at least one and may have many usages. Should the schema be something like* Usage *towards the end of this document?*

*This comment applies to all other CRS, datum and coordinate operation members in the schema."*

"**concatenated\_operation**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["ConcatenatedOperation"] },

"name": { "type": "string" },

"source\_crs": { "$ref": "#/definitions/crs" },

"target\_crs": { "$ref": "#/definitions/crs" },

"steps": {

"type": "array",

"items": { "$ref": "#/definitions/single\_operation" }

},

"accuracy": { "type": "string" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "source\_crs", "target\_crs", "steps" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

"**conversion**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Conversion"] },

"name": { "type": "string" },

"method": { "$ref": "#/definitions/method" },

"parameters": {

"type": "array",

"items": { "$ref": "#/definitions/parameter\_value" }

},

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "method" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] All operations including conversions should have one or more Usages. Missing here. See comment regarding usage under compound\_crs."*

*"$comment": "[RL] See comment under method."*

"**coordinate\_metadata**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["CoordinateMetadata"] },

"crs": { "$ref": "#/definitions/crs" },

"coordinateEpoch": { "type": "number" }

},

"required" : [ "crs" ],

"additionalProperties": false

},

*"$comment": "[RL] coordinate epoch is mandatory for a coordinate set reference to a dynamic reference frame (datum)."*

"**coordinate\_system**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["CoordinateSystem"] },

"name": { "type": "string" },

"subtype": { "type": "string",

"enum": ["Cartesian",

"spherical",

"ellipsoidal",

"vertical",

"ordinal",

"parametric",

"affine",

"polar",

"linear",

"cylindrical",

"TemporalDateTime",

"TemporalCount",

"TemporalMeasure"] },

"axis": {

"type": "array",

"items": { "$ref": "#/definitions/axis" }

},

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "subtype", "axis" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] 3x CS subtypes missing."*

*"$comment": "[RL] For CS subtypes, 19111/Topic 2 has constraints on (i) dimension [number of axes] permitted (for each subtype), (ii) data type for axis unit (for several subtypes). The above enumeration and schema for 'axis' does not include these constraints."*

*"$comment": "[RL] 19111/Topic 2 (and WKT2) has constraints on the type of CS that may be associated with each subtype of CRS. Not clear that the above enumeration allows for these constraints: should each CS subtype be defined?"*

"**crs**": {

"oneOf": [

{ "$ref": "#/definitions/bound\_crs" },

{ "$ref": "#/definitions/compound\_crs" },

{ "$ref": "#/definitions/derived\_engineering\_crs" },

{ "$ref": "#/definitions/derived\_geodetic\_crs" },

{ "$ref": "#/definitions/derived\_geographic\_crs" },

{ "$ref": "#/definitions/derived\_parametric\_crs" },

{ "$ref": "#/definitions/derived\_projected\_crs" },

{ "$ref": "#/definitions/derived\_temporal\_crs" },

{ "$ref": "#/definitions/derived\_vertical\_crs" },

{ "$ref": "#/definitions/engineering\_crs" },

{ "$ref": "#/definitions/geodetic\_crs" },

{ "$ref": "#/definitions/geographic\_crs" },

{ "$ref": "#/definitions/parametric\_crs" },

{ "$ref": "#/definitions/projected\_crs" },

{ "$ref": "#/definitions/temporal\_crs" },

{ "$ref": "#/definitions/vertical\_crs" }

]

},

*"$comment": "[RL] 2x CRS subtypes possibly missing?? See comment under geodetic\_crs."*

*"$comment": "[RL] the concept of bound\_crs is not recognised in* [*Topic 2 (18-005r8)*](https://docs.ogc.org/as/18-005r8/18-005r8.pdf) *but it is defined in* [*CRS WKT (18-010r11)*](https://www.ogc.org/standard/wkt-crs/)*(for backward compatibility of WKT2 with some flavours of WKT1). Should it (and abridged\_transformation) be included in CRS JSON?"*

"**cylindrical\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition should constrain a cylindrical CS to have 3 axes."*

"**datum**": {

"oneOf": [

{ "$ref": "#/definitions/geodetic\_reference\_frame" },

{ "$ref": "#/definitions/vertical\_reference\_frame" },

{ "$ref": "#/definitions/dynamic\_geodetic\_reference\_frame" },

{ "$ref": "#/definitions/dynamic\_vertical\_reference\_frame" },

{ "$ref": "#/definitions/temporal\_datum" },

{ "$ref": "#/definitions/parametric\_datum" },

{ "$ref": "#/definitions/engineering\_datum" }

]

},

*"$comment": "[RL] This datum (member) is not needed if CRSs are constrained to have explicit sub-types of datum."*

"**datum\_ensemble**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["DatumEnsemble"] },

"name": { "type": "string" },

"members": {

"type": "array",

"items": {

"type": "object",

"properties": {

"name": { "type": "string" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

}

},

"ellipsoid": { "$ref": "#/definitions/ellipsoid" },

"accuracy": { "type": "string" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "members", "accuracy" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] this does not seem to define that a member of datum ensemble must be a datum, nor that all members of a datum ensemble must have the same conventionalRS."*

*"$comment": "[RL] The ellipsoid attribute is not included in either 19111/Topic 2 or WKT2. However there are merits in including the attribute - saves having to mine for the information in a member. But the same argument applies to having Usage as an extra attribute - should that be added?"*

"defining\_transformation

"defining\_transformations

*"$comment": "[RL] definition of this association (attribute of a geodetic\_crs, cardinality 0..\*) is missing. Analogous to the geoid model association for vertical\_crs. See comments under vertical\_crs. Schema for both geoid model and defining transformation should be similar."*

"**deformation\_model**": {

"description": "Association to a PointMotionOperation",

"type": "object",

"properties": {

"name": { "type": "string" },

"id": { "$ref": "#/definitions/id" }

},

"required" : [ "name" ],

"additionalProperties": false

},

*"$comment": "[RL] This allows for only the ID of the point motion operation describing the associated deformation model. Should it allow for either full description or name/ID? See comment under vertical\_crs."*

"**derived\_engineering\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["DerivedEngineeringCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/engineering\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/engineering\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] An engineering CRS should be constrained to having an engineering\_cs."*

"**derived\_geodetic\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["DerivedGeodeticCRS",

"DerivedGeographicCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/geodetic\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/geodetic\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] Although not supported by the Topic 2 data model, EPSG includes geodetic datum as a component of derived geodetic CRSs, this to negate the need to data mine for the information."*

*"$comment": "[RL] A geodetic CRS should be constrained to having a geodetic\_cs."*

"**derived\_parametric\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["DerivedParametricCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/parametric\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/parametric\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A parametric CRS should be constrained to having a parametric\_cs."*

"**derived\_projected\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["DerivedProjectedCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/projected\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },

"coordinate\_system": { "$ref": "#/definitions/derived\_projected\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A derived projected CRS should be constrained to having a derived\_projected\_cs."*

"**derived\_projected\_cs**": {

"type": "object",

"properties": {

"oneOf": [

{ "$ref": "#/definitions/affine\_cs" },

{ "$ref": "#/definitions/Cartesian\_cs" }

{ "$ref": "#/definitions/cylindrical\_cs" }

{ "$ref": "#/definitions/ordinal\_cs" }

{ "$ref": "#/definitions/polar\_cs" }

{ "$ref": "#/definitions/spherical\_cs" }

]

"additionalProperties": false

},

"**derived\_temporal\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["DerivedTemporalCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/temporal\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/temporal\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A temporal CRS should be constrained to having a temporal\_cs."*

"**derived\_vertical\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["DerivedVerticalCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/vertical\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/vertical\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A vertical CRS should be constrained to having a vertical\_cs."*

"**dynamic\_geodetic\_reference\_frame**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["DynamicGeodeticReferenceFrame"] },

"name": { "type": "string" },

"anchor": { "type": "string" },

"anchor\_epoch": { "type": "number" },

"conventional\_RS: {}

"publication\_date: { "type": date }

"ellipsoid": { "$ref": "#/definitions/ellipsoid" },

"prime\_meridian": { "$ref": "#/definitions/prime\_meridian" },

"frame\_reference\_epoch": { "type": "number" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "ellipsoid", "prime\_meridian", "frame\_reference\_epoch" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] 2x missing attributes and 3x missing data type."*

*"$comment": "[RL] In 19111/Topic2, ellipsoid is optional. This is because a geodetic geocentric frame/CRS does not require an ellipsoid (or indeed in theory can be associated with any ellipsoid). Because in practice few if any frames do not have a defined or recommended ellipsoid, EPSG makes the ellipsoid attribute mandatory."*

*"$comment": "In 19111/Topic2, prime meridian is a mandatory attribute. In WKT2, for reasons of brevity, prime meridian is conditional [mandatory if not Greenwich, else optional]."*

"**dynamic\_vertical\_reference\_frame**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["DynamicVerticalReferenceFrame"] },

"name": { "type": "string" },

"anchor": { "type": "string" },

"anchor\_epoch": { "type": "number" },

"conventional\_RS: { "type": "string" }

"publication\_date: { "type": date }

"realization\_method": { "$ref": "#/definitions/realization\_method" }

"frame\_reference\_epoch": { "type": "number" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "frame\_reference\_epoch" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] 3x missing attributes and 2x missing data type."*

"**ellipsoid**": {

"type": "object",

"oneOf":[

{

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Ellipsoid"] },

"name": { "type": "string" },

"semi\_major\_axis": { "$ref": "#/definitions/value\_in\_metre\_or\_value\_and\_unit" },

"semi\_minor\_axis": { "$ref": "#/definitions/value\_in\_metre\_or\_value\_and\_unit" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "semi\_major\_axis", "semi\_minor\_axis" ],

"additionalProperties": false

},

{

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Ellipsoid"] },

"name": { "type": "string" },

"semi\_major\_axis": { "$ref": "#/definitions/value\_in\_metre\_or\_value\_and\_unit" },

"inverse\_flattening": { "type": "number" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "semi\_major\_axis", "inverse\_flattening" ],

"additionalProperties": false

},

{

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Ellipsoid"] },

"name": { "type": "string" },

"radius": { "$ref": "#/definitions/value\_in\_metre\_or\_value\_and\_unit" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "radius" ],

"additionalProperties": false

}

],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

]

},

*"$comment": "[RL] This is based on the WKT2 definition which was constrained to be backward-compatible to WKT1 in allowing the ellipsoid unit to be omitted and assumed to be metre. 19111/Topic 2 requires the unit to be explicitly stated and need not be metre."*

*"$comment": "[RL] ProjJSON v0.7 schema omits the definition of a triaxial ellipsoid (this is noted). In 19111/Topic 2 this is provided for by an additional optional semi-median axis attribute. In WKT2 this has a different keyword and (as in 19111/Topic 2) requires unit to be given."*

"**ellipsoidal\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition should constrain an ellipsoidal CS to have 2 or 3 axes. 19111/Topic 2 constrains axis names to "*geodetic latitude, geodetic longitude, [ellipsoidal height (if 3D)]*". WKT2 constrains these to be 'latitude', 'longitude' [and 'ellipsoidal height'. WKT2 requires that axis abbreviations be from the Latin character set and recommends that conventionally-used axis abbreviations φ and θ are be replaced by 'lat' and 'lon' or by 'B' and 'L' (conventional in German)*. *In the 3D case, WKT2 constrains the abbreviation for ellipsoidal height (if given) to be 'h'.*

*See vertical\_cs below for a possible template for adding these constraints."*

"**engineering\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["EngineeringCRS"] },

"name": { "type": "string" },

"datum": { "$ref": "#/definitions/engineering\_datum" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/engineering\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "datum", "coordinate system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] An engineering CRS should be constrained to having an angineering\_cs."*

*"$comment": "[RL] In 19111/Topic 2, an engineering CRS may have a datum ensemble rather than a datum. Not likely to be relevant for an engineering CRS so 19162/WKT2 spec does not offer the option. Should CRS JSON follow Topic 2 or WKT?"*

*"$comment": "[RL] An engineering CRS must have a datum (or a datum\_ensemble, see previous comment). The schema would be clearer if this was included in the required list."*

"**engineering\_cs**": {

"type": "object",

"properties": {

"oneOf": [

{ "$ref": "#/definitions/affine\_cs" },

{ "$ref": "#/definitions/Cartesian\_cs" }

{ "$ref": "#/definitions/cylindrical\_cs" }

{ "$ref": "#/definitions/linear\_cs" }

{ "$ref": "#/definitions/ordinal\_cs" }

{ "$ref": "#/definitions/polar\_cs" }

{ "$ref": "#/definitions/spherical\_cs" }

]

"additionalProperties": false

},

"**engineering\_datum**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["EngineeringDatum"] },

"name": { "type": "string" },

"anchor": { "type": "string" },

"conventional\_RS: { "type": "string" }

"publication\_date: { "type": date }

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] 2x attributes missing."*

"**formula**": {

*"$comment": "[RL] 19111/Topic 2 requires a formula (string) or a formula\_citation (using 19115 Metadata CI\_Citation syntax). For brevity WKT2 relies on a method ID."*

"**geodetic\_crs**": {

"type": "object",

"properties": {

"type": { "type": "string", "enum": ["GeodeticCRS", "GeographicCRS"] },

"name": { "type": "string" },

"datum": {

"oneOf": [

{ "$ref": "#/definitions/geodetic\_reference\_frame" },

{ "$ref": "#/definitions/dynamic\_geodetic\_reference\_frame" }

{ "$ref": "#/definitions/datum\_ensemble" }

]

},

~~"datum\_ensemble": { "$ref": "#/definitions/datum\_ensemble" },~~

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/geodetic\_cs" },

"deformation\_models": {

"type": "array",

"items": { "$ref": "#/definitions/deformation\_model" }

},

"defining\_transformation": { "$ref": "#/definitions/defining\_transformation" },

"defining\_transformations": {

"type": "array",

"items": { "$ref": "#/definitions/defining\_transformation" }

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "datum", "coordinate\_system" ],

"description": "One and only one of datum and datum\_ensemble must be provided",

"allOf": [

{ "$ref": "#/definitions/object\_usage" },

{ "$ref": "#/definitions/one\_and\_only\_one\_of\_datum\_or\_datum\_ensemble" }

],

"additionalProperties": false

},

*"$comment": "[RL] why does this subtype of CRS not include "allOf": [{ "$ref": "#/definitions/object\_usage" }],?"*

*"$comment": "[RL] Can the choice of datum v datum ensemble be simplified by including datum ensemble in the datum one of list? (Description would then not be necessary)."*

*"$comment": "[RL] A geodetic CRS must have a datum or a datum\_ensemble. The schema would be clearer if this was included in the required list."*

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] (i) A geodetic CRS should be constrained to having a geodetic\_cs. (ii) A geographic CRS should be constrained to having an ellipsoidal\_cs. To make these constraints clearer, should geographic\_crs be defined separately?"*

*"$comment": "[RL] Defining transformation(s) attribute (0..\*) missing. Equivalent of geoid\_model(s) in vertical CRS. See comments below under vertical\_crs."*

*"$comment": "[RL] Is the geoid model(s) attribute correctly modelled? A geoid model is usually described as a transformation. If this were done here then is the geoid\_model member definition above needed in the schema? However, although 19111/Topic 2 has the association to transformation, implying that the full definition is required, for brevity WKT2 requires only the geoid model name. Should the CRS JSON schema give option for either full definition or just name (or ID)?"*

*"$comment": "[RL] Same question about full definition or name/ID for deformation model."*

"**geodetic\_cs**": {

"type": "object",

"properties": {

"oneOf": [

{ "$ref": "#/definitions/Cartesian\_cs" }

{ "$ref": "#/definitions/ellipsoidal\_cs" }

{ "$ref": "#/definitions/spherical\_cs" }

]

"additionalProperties": false

},

"**geodetic\_reference\_frame**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["GeodeticReferenceFrame"] },

"name": { "type": "string" },

"anchor": { "type": "string" },

"anchor\_epoch": { "type": "number" },

"conventional\_RS: { "type": "string" }

"publication\_date: { "type": date }

"ellipsoid": { "$ref": "#/definitions/ellipsoid" },

"prime\_meridian": { "$ref": "#/definitions/prime\_meridian" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "ellipsoid", "prime\_meridian" ],

"additionalProperties": false

},

*"$comment": "[RL] 2x attributes missing."*

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] Topic 2 requires prime meridian as an attribute of geodetic reference frame but WKT2 makes it optional on the condition that value = the international reference meridian (Greenwich).*

*Note: WKT2 has prime meridian as a direct attribute of a geodetic CRS (for backward compatibility with WKT1) but the modelling here of prime meridian being an attribute of a geodetic reference frame follows 19111/Topic 2."*

*"$comment": "[RL] In 19111/Topic 2 ellipsoid is an optional attribute of geodetic reference frame (because an ellipsoid is not necessary if working exclusively in geocentric Cartesian coordinates) but WKT2 makes it mandatory (to ensure it is available for conversion to ellipsoidal coordinates)."*

"**geoid\_model**": {

"type": "object",

"properties": {

"name": { "type": "string" },

"~~interpolation\_crs": { "$ref": "#/definitions/crs" },~~

"transformation": { "$ref": "#/definitions/transformation" },

"id": { "$ref": "#/definitions/id" }

},

"required" : [ "name" ],

"additionalProperties": false

},

*"$comment": "[RL] Is the geoid model(s) attribute correctly modelled? A geoid model is usually described as a transformation."*

*"$comment": "[RL] If its use in vertical\_crs were changed as suggested below, is this geoid model member actually needed in the schema?"*

"**id**": {

"type": "object",

"properties": {

"authority": { "type": "string" },

"code": {

"oneOf": [ { "type": "string" }, { "type": "integer" } ]

},

"version": {

"oneOf": [ { "type": "string" }, { "type": "number" } ]

},

"authority\_citation": { "type": "string" },

"uri": { "type": "string" }

},

"required" : [ "authority", "code" ],

"additionalProperties": false

},

"**ids**": {

"type": "array",

"items": { "$ref": "#/definitions/id" }

},

"**id\_ids\_mutually\_exclusive**": {

"not": {

"type": "object",

"required": [ "id", "ids" ]

}

},

*"$comment": "[RL] In ProjJSON schema this follows method. Moved here to be ordered alphabetically."*

"**linear\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition should constrain a linear CS to have 1 axis."*

"**meridian**": {

"description": "Supplementary attribute for an axis direction in a polar aspect azimuthal projection. Not to be confused with prime\_meridian.",

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["Meridian"] },

"longitude": { "$ref": "#/definitions/value\_in\_degree\_or\_value\_and\_unit" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "longitude" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] In ProjJSON schema this follows object\_usage. Moved here to be ordered alphabetically."*

"**method**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["OperationMethod"]},

"name": { "type": "string" },

"formula": { "type": ""#/definitions/formula" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] In 19111/Topic 2, operation method requires one of a formula or a formula citation. In WKT2 for reasons of brevity it was decided to rely on an identifier (authority reference) to a method in a registry such as EPSG, although this is optional. If CRS JSON is to be capable of carrying the full definition of a coordinate operation (transformation, conversion or point motion operation) then method will need to require one of ID, formula or formula citation."*

"**object\_usage**": {

"anyOf": [

{

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"scope": { "type": "string" },

"area": { "type": "string" },

"bbox": { "$ref": "#/definitions/bbox" },

"vertical\_extent": { "$ref": "#/definitions/vertical\_extent" },

"temporal\_extent": { "$ref": "#/definitions/temporal\_extent" },

"remarks": { "type": "string" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

]

},

{

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"usages": { "$ref": "#/definitions/usages" },

"remarks": { "type": "string" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

]

}

]

},

*"$comment": "[RL] See comments regarding usage under compound\_crs and usages."*

"**one\_and\_only\_one\_of\_datum\_or\_datum\_ensemble**": {

"allOf": [

{

"not": {

"type": "object",

"required": [ "datum", "datum\_ensemble" ]

}

},

{

"oneOf": [

{ "type": "object", "required": ["datum"] },

{ "type": "object", "required": ["datum\_ensemble"] }

]

}

]

},

*"$comment": "[RL] Why is the structure different to that of one of ID or IDs?"*

"**ordinal\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain an ordinal CS to have axes with integer coordinates (so no units)."*

"**parameter\_value**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["ParameterValue"] },

"name": { "type": "string" },

"value": {

"oneOf": [

{ "type": "string" },

{ "type": "number" }

]

},

"unit": { "$ref": "#/definitions/unit" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "value" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

"**parametric\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["ParametricCRS"] },

"name": { "type": "string" },

"datum": { "$ref": "#/definitions/parametric\_datum" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/parametric\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "datum", "coordinate system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A parametric CRS should be constrained to having a parametric\_cs."*

*"$comment": "[RL] In 19111/Topic 2, a parametric CRS may have a datum ensemble rather than a datum. 19162/WKT2 spec does not offer the option. Should CRS JSON?"*

*"$comment": "[RL] A parametric CRS must have a datum (or a datum\_ensemble, see previous comment). The schema would be clearer if this was included in the required list."*

"**parametric\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain a parametric CS to have 1 axis."*

"**parametric\_datum**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["ParametricDatum"] },

"name": { "type": "string" },

"anchor": { "type": "string" },

"anchor\_epoch": { "type": "number" }

"conventional\_RS": { "type": "string" }

"publication\_date": { "type": date }

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] 3x attributes missing."*

"**point\_motion\_operation**": {

"$comment": "Not implemented in PROJ (at least as of PROJ 9.1)",

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["PointMotionOperation"] },

"name": { "type": "string" },

"source\_crs": { "$ref": "#/definitions/crs" },

"method": { "$ref": "#/definitions/method" },

"parameters": {

"type": "array",

"items": { "$ref": "#/definitions/parameter\_value" }

},

"accuracy": { "type": "string" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "source\_crs", "method", "parameters" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] See comment under method."*

"**polar\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain a polar CS to have 2 axes. Requires a reference direction ()."*

"**prime\_meridian**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["PrimeMeridian"] },

"name": { "type": "string" },

"longitude": { "$ref": "#/definitions/value\_in\_degree\_or\_value\_and\_unit" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] Topic 2 requires this as an attribute of geodetic reference frame but WKT2 makes it optional on the condition that value = the international reference meridian (Greenwich)."*

"**projected\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string",

"enum": ["ProjectedCRS"] },

"name": { "type": "string" },

"base\_crs": { "$ref": "#/definitions/geodetic\_crs" },

"conversion": { "$ref": "#/definitions/conversion" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/affine\_cs" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "base\_crs", "conversion", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A projected CRS should be constrained to having an affine\_cs. Most projected CRSs will have a Cartesian CS. A Cartesian CS is a subtype of affine CS."*

*"$comment": "[RL] Does this permit a projected CRS to have a derived geodetic CRS as its base CRS?"*

"**realization\_method**": {

"description": "definition to be completed"

*"$comment": "[RL] The definition of this attribute of a vertical and dynamic vertical reference frame is missing. In Topic 2 it is a code list with three entries. EPSG has extended that list by adding 'local'."*

"**single\_operation**": {

"oneOf": [

{ "$ref": "#/definitions/conversion" },

{ "$ref": "#/definitions/transformation" },

{ "$ref": "#/definitions/point\_motion\_operation" }

]

},

*"$comment": "[RL] In ProjJSON schema this follows prime\_meridian. Moved here to be ordered alphabetically."*

"**spherical\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition should constrain a spherical CS to have 2 or 3 axes.*

*When a spherical CS is used within a geodetic CRS, 19111/Topic2 constrains axis names (see Topic 2 Table 27). WKT2 requires that axis abbreviations be from the Latin character set and recommends that axis abbreviations φ and θ are be replaced by U and V*.*"*

"**temporal\_crs**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["TemporalCRS"] },

"name": { "type": "string" },

"datum": { "$ref": "#/definitions/temporal\_datum" },

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": {

"oneOf": [

{ "$ref": "#/definitions/temporalCount\_cs" },

{ "$ref": "#/definitions/temporalDateTime\_cs" }

{ "$ref": "#/definitions/temporalMeasure\_cs" }

]

},

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "datum", "coordinate\_system" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A temporal CRS should be constrained to having a temporal\_cs (one of temporalCount\_cs, temporalDateTime\_cs, or temporalMeasure\_cs."*

*"$comment": "[RL] In 19111/Topic 2, a temporal CRS may have a datum ensemble rather than a datum. Not likely to be relevant for a tempral CRS so 19162/WKT2 spec does not offer the option. Should CRS JSON?"*

"**temporal\_datum**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["TemporalDatum"] },

"name": { "type": "string" },

"conventional\_RS": { "type": "string" }

"publication\_date": { "type": date }

"calendar": { "type": "string" },

"time\_origin": { "type": "string" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "calendar", "time\_origin" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] Calendar default is proleptic Gregorian."*

*"$comment": "[RL] 19111/Topic 2 model has conventionalRS as an optional attribute but unlikely to be relevant to temporal datum."*

"**temporal\_extent**": {

"type": "object",

"properties": {

"start": { "type": "string" },

"end": { "type": "string" }

},

"required" : [ "start", "end" ],

"additionalProperties": false

},

*"$comment": "[RL] If both start and end are required, how does one express a continuing time period e.g. 'after start = t' or 'before end = t' ?"*

"**temporalCount\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain a vertical CS to have 1 axis and integer coordinates (so no units)."*

*"$comment": "[RL] Is use of upper camel case as member name ok?."*

"**temporalDateTime\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain a temporal dateTime CS to have 1 axis and data type of dateTime."*

*"$comment": "[RL] Is use of upper camel case as member name ok?."*

"**temporalMeasure\_cs**": {

*"$comment": "[RL] Definition to be completed. The definition would constrain a temporalMeasure CS to have 1 axis and units to be real numbers."*

*"$comment": "[RL] Is use of upper camel case as member name ok?."*

"**transformation**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["Transformation"] },

"name": { "type": "string" },

"source\_crs": { "$ref": "#/definitions/crs" },

"target\_crs": { "$ref": "#/definitions/crs" },

"interpolation\_crs": { "$ref": "#/definitions/crs" },

"method": { "$ref": "#/definitions/method" },

"parameters": {

"type": "array",

"items": { "$ref": "#/definitions/parameter\_value" }

},

"accuracy": { "type": "string" },

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "source\_crs", "target\_crs", "method", "parameters" ],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] See comment under method."*

"**unit**": {

"oneOf": [

{

"type": "string",

"enum": ["metre", "degree", "unity"]

},

{

"type": "object",

"properties": {

"type": { "type": "string",

"enum": ["LinearUnit", "AngularUnit", "ScaleUnit",

"TimeUnit", "ParametricUnit", "Unit"] },

"name": { "type": "string" },

"conversion\_factor": { "type": "number" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "type", "name" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

}

]

},

"**usages**": {

"type": "array",

"items": {

"type": "object",

"properties": {

"scope": { "type": "string" },

"area": { "type": "string" },

"bbox": { "$ref": "#/definitions/bbox" },

"vertical\_extent": { "$ref": "#/definitions/vertical\_extent" },

"temporal\_extent": { "$ref": "#/definitions/temporal\_extent" }

},

"additionalProperties": false

}

},

*"$comment": "[RL] In ISO 19111 a usage must contain one scope and one extent. (See below for extent). The main geodetic entities (CRS, datum, all types of coordinate operation) should have at least one and may have many usages. Should the schema be something like* Usage *below?"*

"**usage**": {

"type": "array",

"items": {

"type": "object",

"properties": {

"scope": { "type": "string" },

"extent": { "$ref": "#/definitions/extent" },

},

"required" : [ "scope", "extent" ],

"additionalProperties": false

}

},

*"$comment": "[RL]In ISO 19111 a usage is optional but (in §8.1.4) at least one usage is recommended. If this is considered best practice for geodetic registries, should the cardinality of Usage in CRS JSON be 1:\* ?"*

"**extent**": {

"type": "array",

"items": {

"type": "object",

"properties": {

"extent\_description": { "type": "string" },

"bbox": { "$ref": "#/definitions/bbox" },

"extent\_polygon": { "type": "array" },

"vertical\_extent": { "$ref": "#/definitions/vertical\_extent" },

"temporal\_extent": { "$ref": "#/definitions/temporal\_extent" }

},

"required" : [ "extent\_description", "bbox" ],

"additionalProperties": false

}

},

*"$comment": "[RL] In ISO 19111 [OGC Abstract Spec Topic 2](from ISO 19115 [OGC Abstract Spec Topic 11]) an extent must contain at least one of the above properties; it may contain any or all of these properties. In ISO 19127 (geodetic registry) this is specialised: a description and a bbox are made mandatory, the remaining properties are optional. If this is considered best practice for geodetic registries, should it be considered as appropriate for CRS JSON?"*

"**value\_and\_unit**": {

"type": "object",

"properties": {

"value": { "type": "number" },

"unit": { "$ref": "#/definitions/unit" }

},

"required" : [ "value", "unit" ],

"additionalProperties": false

},

"**value\_in\_degree\_or\_value\_and\_unit**": {

"oneOf": [

{ "type": "number" },

{ "$ref": "#/definitions/value\_and\_unit" }

]

},

"**value\_in\_metre\_or\_value\_and\_unit**": {

"oneOf": [

{ "type": "number" },

{ "$ref": "#/definitions/value\_and\_unit" }

]

},

*"$comment": "[RL] This option to have default units is from WKT2, included for backward compatibility with WKT1. In Topic 2 there is no option to have default units."*

"**vertical\_crs**": {

"type": "object",

"properties": {

"type": { "type": "string", "enum": ["VerticalCRS"] },

"name": { "type": "string" },

"datum": {

"oneOf": [

{ "$ref": "#/definitions/vertical\_reference\_frame" },

{ "$ref": "#/definitions/dynamic\_vertical\_reference\_frame" }

{ "$ref": "#/definitions/datum\_ensemble" }

]

},

~~"datum\_ensemble": { "$ref": "#/definitions/datum\_ensemble" },~~

~~"coordinate\_system": { "$ref": "#/definitions/coordinate\_system" },~~

"coordinate\_system": { "$ref": "#/definitions/vertical\_cs" },

~~"geoid\_model": { "$ref": "#/definitions/geoid\_model" },~~

"geoid\_model": { "$ref": "#/definitions/transformation" },

"geoid\_models": {

"type": "array",

~~"items": { "$ref": "#/definitions/geoid\_model" }~~

"items": { "$ref": "#/definitions/transformation" }

},

"deformation\_models": {

"type": "array",

"items": { "$ref": "#/definitions/deformation\_model" }

},

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name", "datum", "coordinate\_system" ],

"description": "One and only one of datum and datum\_ensemble must be provided",

"allOf": [

{ "$ref": "#/definitions/object\_usage" },

{ "$ref": "#/definitions/one\_and\_only\_one\_of\_datum\_or\_datum\_ensemble" },

{

"not": {

"type": "object",

"required": [ "geoid\_model", "geoid\_models" ]

}

}

],

"additionalProperties": false

},

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

*"$comment": "[RL] A vertical CRS should be constrained to having a vertical\_cs."*

*"$comment": "[RL] A vertical CRS must have a datum or a datum\_ensemble. The schema would be clearer if this was included in the required list."*

*"$comment": "[RL] Why two attributes geoid\_model and geoid\_models and only one attribute deformation\_models when both associations in the 19111/Topic 2 data model have 0..\* cardinallity?"*

*"$comment": "[RL] Is the geoid model(s) attribute correctly modelled? A geoid model is usually described as a transformation. If this were done here then is the geoid\_model member definition above needed in the schema? However, although 19111/Topic 2 has the association to transformation, implying that the full definition is required, for brevity WKT2 requires only the geoid model name. Should the CRS JSON schema give option for either full definition or just name (or ID)?"*

*"$comment": "[RL] Same question about full definition or name/ID for deformation model. Schema definition of deformation\_model allows for only ID."*

"**vertical\_cs**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["verticalCS"] },

"name": { "type": "string" },

"vertical\_axis": { "$ref": "#/definitions/vertical\_axis" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "vertical\_axis" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"**vertical\_axis**": {

"type": "object",

"properties": {

"$schema" : { "type": "string" },

"type": { "type": "string", "enum": ["axis"] },

"name": { "type": "string", "enum": ["gravity-related height", "depth" ] },

"abbreviation": { "type": "string"

"not": { "type": "object",

"required": [ "h", ] }

},

"direction": { "type": "string", "enum": ["up", "down" ] },

"unit": { "$ref": "#/definitions/unit" },

"minimum\_value": { "type": "number" },

"maximum\_value": { "type": "number" },

"id": { "$ref": "#/definitions/id" },

"ids": { "$ref": "#/definitions/ids" }

},

"required" : [ "name", "abbreviation", "direction" "unit" ],

"allOf": [

{ "$ref": "#/definitions/id\_ids\_mutually\_exclusive" }

],

"additionalProperties": false

},

*"$comment": "[RL] The definition constrains a vertical CS to have 1 axis, and axis name to be either 'gravity-related height' or 'depth', axis abbreviation to not be 'h', and axis direction to be either 'up' or down'. (This draft schema syntax needs verification)."*

"**vertical\_extent**": {

"type": "object",

"properties": {

"minimum": { "type": "number" },

"maximum": { "type": "number" },

~~"unit": { "$ref": "#/definitions/unit" }~~

"vertical\_extent\_id": { "$ref": "#/definitions/vertical\_crs" }

},

"required" : [ "minimum", "maximum", "vertical\_extent\_id" ],

"additionalProperties": false

},

*"$comment": "In ISO 19115 [OGC Abstract Spec Topic 11] a vertical\_extent must contain at least one of either a vertical CRS full definition or a vertical CRS ID. Above insert allows for only an ID.*

*If vertical CRS [ID] is given, it defines the CRS units and the unit member would conflict with this.*

*ISO 19115 [OGC Abstract Spec Topic 11] also has both minimum and maximum required. This seems odd to me. The absence of one of these would imply that the vertical extent is unlimited in that direction, e.g. height below [maximum =] 500m, so should be allowed as long as at least one of minimum and maximum are present.*

*"$comment": "[RL] If both minimum and maximum are required, how does one express an unboundedg height range e.g. 'above minimum = H' or 'below maximum = H'? (Here 'above' and 'below' are in context of a vertical height CRS, need reversing for a vertical depth CRS)."*

"**vertical\_reference\_frame**": {

"type": "object",

"allOf": [{ "$ref": "#/definitions/object\_usage" }],

"properties": {

"type": { "type": "string", "enum": ["VerticalReferenceFrame"] },

"name": { "type": "string" },

"anchor": { "type": "string" },

"anchor\_epoch": { "type": "number" },

"conventional\_RS": { "type": "string" }

"publication\_date": { "type": date }

"realization\_method": { "$ref": "#/definitions/realization\_method" }

"$schema" : {},

"scope": {},

"area": {},

"bbox": {},

"vertical\_extent": {},

"temporal\_extent": {},

"usages": {},

"remarks": {},

"id": {}, "ids": {}

},

"required" : [ "name" ],

"additionalProperties": false

}

}

*"$comment": "[RL] See comment regarding usage under compound\_crs."*

}