CRM geo

Spatiotemporal model

Definition of the CRMgeo

An Extension of CIDOC-CRM to link the CIDOC CRM to GeoSPARQL through a Spatiotemporal Refinement

Release Candidate –approved by the CIDOC CRM-SIG

Version 2.0

March 2026

Currently maintained by FORTH

Contributors: Martin Doerr, Gerald Hiebel, Christian-Emil Ore, Øyvind Eide, Wolfgang Schmidle, Mark Fichtner and others

This page is left blank on purpose

Table of Contents

Table of Tables

Table of Figures

Introduction

This document describes work which uses and extends the CIDOC Conceptual Reference Model (CRM, ISO21127). The CIDOC-CRM definition document should be read before this document. References to the CIDOC-CRM in this document are taken from CIDOC-CRM version 7.1.3 maintained by CIDOC.

Scope

This text defines the "Spatiotemporal Model". It is a formal ontology intended to be used as a global schema for integrating spatiotemporal properties of temporal entities and persistent items. Its primary purpose is integrating all kinds of geoinformation that is available in GIS formats into CIDOC CRM representations. In order to do this it links the CIDOC CRM to the OGC standard of GeoSPARQL to make use of the conceptualizations and formal definitions that have been developed in the Geoinformation community.

It uses and extends the CIDOC CRM (ISO21127) as a general ontology of human activity, things and events happening in spacetime. It uses the same encoding-neutral formalism of knowledge representation ("data model" in the sense of computer science) as the CIDOC CRM, which can be implemented in RDFS, OWL, on RDBMS and in other forms of encoding. Since the model reuses, wherever appropriate, parts of CIDOC Conceptual Reference Model, we provide in this document also a comprehensive list of all constructs used from the CIDOC CRM 7.1.3 version, together with their definitions.

The background of the development of this model lies in a rising interest to enrich cultural heritage data with precise and well identified descriptions of location and geometry of sites of historical events or remains, objects and natural features. On one side there is already a tradition of more than 2 decades of using GIS systems for representing cultural-historical and archaeological data and reasoning on properties of spatial distribution, vicinity, accessibility and others. These systems tended to be closed and focused more on representing feature categories by visual symbols at different scales than integrating rich object descriptions. Cultural heritage is only a marginal application case for these systems, they have been extremely successful in all kinds of "geosciences", resource management and public administration.

On the other side, archives, libraries and museums keep detailed historical records of things with very poor spatial determination – frequently in the language of the source or local context, in which at their time of creation there was few ambiguity about their meaning, and frequently only wider geopolitical units, such as "Parthenon in Athens". They rather focus on typologies, individual objects, people, kinds of events, precise dates and periods. This practice comes into conflict when users want to integrate city plans, tourism guides, detailed excavation or restoration records, where the fact that "people know quite well where the Parthenon lies" or "you'll see it when you go to Athens" is not helpful for advanced IT systems. But, the two traditions, the "GIS community" and the "cultural heritage community" have developed standards which precisely reflect the two different foci – the OGC/ISO Standards for Geographic Information which are the building blocks of the GeoSPARQL ontology [OGC 2012] and the ontology of the CIDOC CRM [Le Boeff et. al 2015] which is the ISO standard for representing cultural heritage information.

In an attempt to combine these two standards, we experienced a surprise: Both standards do not really match at any concepts "in between", even though the CRM was explicitly intended to interface with OGC (Open Geospatial Consortium) Standards. Also they do not allow to express objectively the location of something in a way which is robust against any change of spatial scale and time. For instance, the CRM allows for specifying a "P…has former or current location", without declaring if the location is or was the extent of the object, was within the extent of the object or included its extent. GeoSPARQL, on the other hand, allows for assigning one or more precise "geometries" to a "feature", but does not say how the real matter of the thing with its smaller irregularities relates to those. So, for any "feature" there is a spatial scale at which a "geometry" of a detail cannot be compared any more to the geometry of the whole, nor is the temporal validity range explicitly stated although OGC Standards provide mechanisms for doing that.

What is needed is an "articulation" (linkage) of the two ontologies, i.e. a more detailed model of the overlap of both models, which allows for covering the underdetermined concepts and properties of both sides by shared specializations rather than generalizations. Therefore, we took a great step back and developed a model from the analysis of the epistemological processes of defining, using and determining places. This means that we analyzed how a question, such as "is this the place of the Varus Battle" or "is this the place where Lord Nelson died", can be verified or falsified, including geometric specifications. For this all kinds of sources of errors needed to be identified, including questioning the truth of the very historical record.

Consequently, we reached a surprisingly detailed model which seems to give a complete account of all practical components necessary to verify such a question, in agreement with the laws of physics, the practice of geometric measurement and archaeological reasoning. This model indeed appears to have the capability to link both ontologies and shows how to correctly reconcile data at any scale and time – not by inventing precision or truth that cannot be acquired, but by quantifying or delimiting the immanent indeterminacies, as it is good practice in natural sciences.

For the proposed classes the criteria for substance, identity, existence and unity are explicitly stated because we came to the conclusion that the key to defining good ontological classes is to constrain a class to:

a) Substance criteria: What is the essential substance a thing is made of? [Wiggins 2001]

b) Identity criteria: how to distinguish instances of a class. [Guarino 2001]

c) Existence criteria: how to decide when an instance of a class comes into being and when it ceases to exist.

d) Unity criteria: How to decide what is in the extent of the substance of an item?

The following questions may help for the practical application of the criteria:

Substance (S): What is the essential substance a thing is made of? This should not be mistaken with physical matter, for instance the substance of a text is characters and spaces. What are the substantial traits necessary for something to be an instance of a particular class?

Identity (I): How to recognize manifestations of individual instances in the world (at different times or places) as being the same? Does this amount of substance of a class represent one or more instances of this class? How to recognize if two references to instances of a class existing at the same time refer to the same or different instances?

Existence (E): Through which kind of process does an instance of a class begin to exist (e.g. through birth, creation, production) and by what does its existence end (e.g. through death, destruction, dissolution or transformation)?

Unity (U): How do I recognize all parts of an instance? What are the temporal or spatial boundaries of an instance? What is in or out of an instance? Note that it is not necessary that for all potential parts of a thing we can decide if they are a part or not of it [Wiggins 2001]. E.g. , a mountain may be well defined even though we don't know precisely where its boundaries are. Within the scope notes of the classes the abbreviations (E,U,I,S) of the criteria are used within a sentence to mark up the use of these criteria.

Basic concepts

The main purpose of CRMgeo is to relate CIDOC CRM with OGC GeoSPARQL. This is realised through

1. Making E4 Period and E18 Physical Thing a subclass of geo:Feature

2. Introducing the ontological distinction between phenomenal and declarative spatiotemporal concepts as distinct subclasses of E53 Place, E92 Spacetime Volume and E52 Time Span correspondingly. Here the phenomenal classes represent the real world spatiotemporal manifestations of phenomena, such as E4 Periods or E18 Physical Things, which cannot exactly be measured. The declarative classes represent the human-made approximations either for describing measurement results or other theoretical statements about spatiotemporal manifestations, such as an "exclusive economic zone" in the sea.

3. Making SP6 Declarative Places and SP7 Declarative Spacetime Volumes a subclass of geo:Geometry

Figure 1 shows the classes of GeoSPARQL in magenta and the classes of CRMgeo in the respective colors of CIDOC CRM that they belong to.

Figure 1 shows the classes of GeoSPARQL in magenta and the classes of CRMgeo in the respective colors of CRMbase that they belong to.

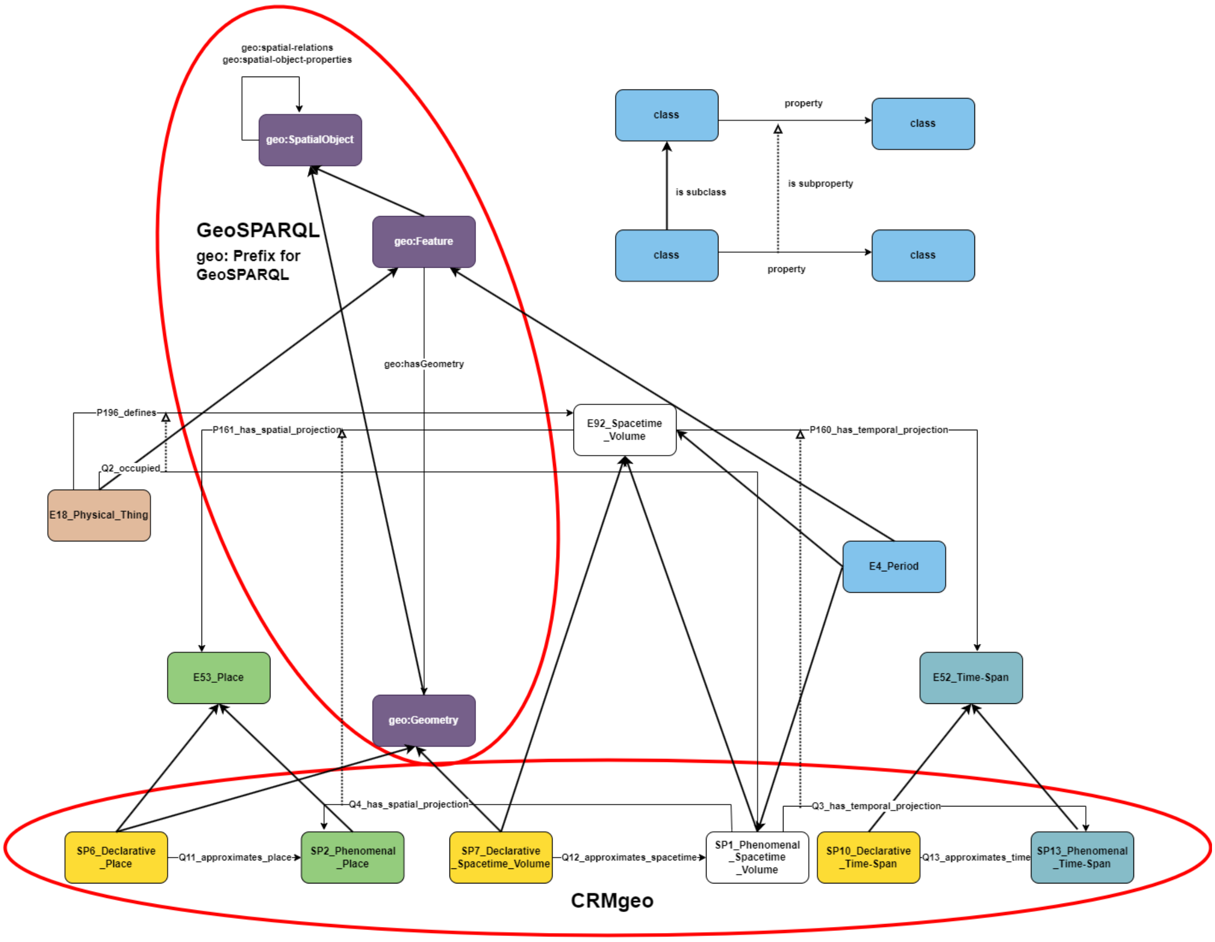

Figure 1: Subclass relations of GeoSPARQL, CRMbase and CRMgeo classes with main properties

Figure 2 shows the complete diagram of CRMgeo with all classes, properties and literals. CRMgeo further introduces classes for spatial and temporal reference systems and relates classes and properties of the CRM to the literals defined in GeoSPARQL. Making wgs84:Point (from the Basic Geo Vocabulary, WGS84 lat/long) a subclass of SP6 Declarative Place allows the use of the wg84 properties "lat" and "long".

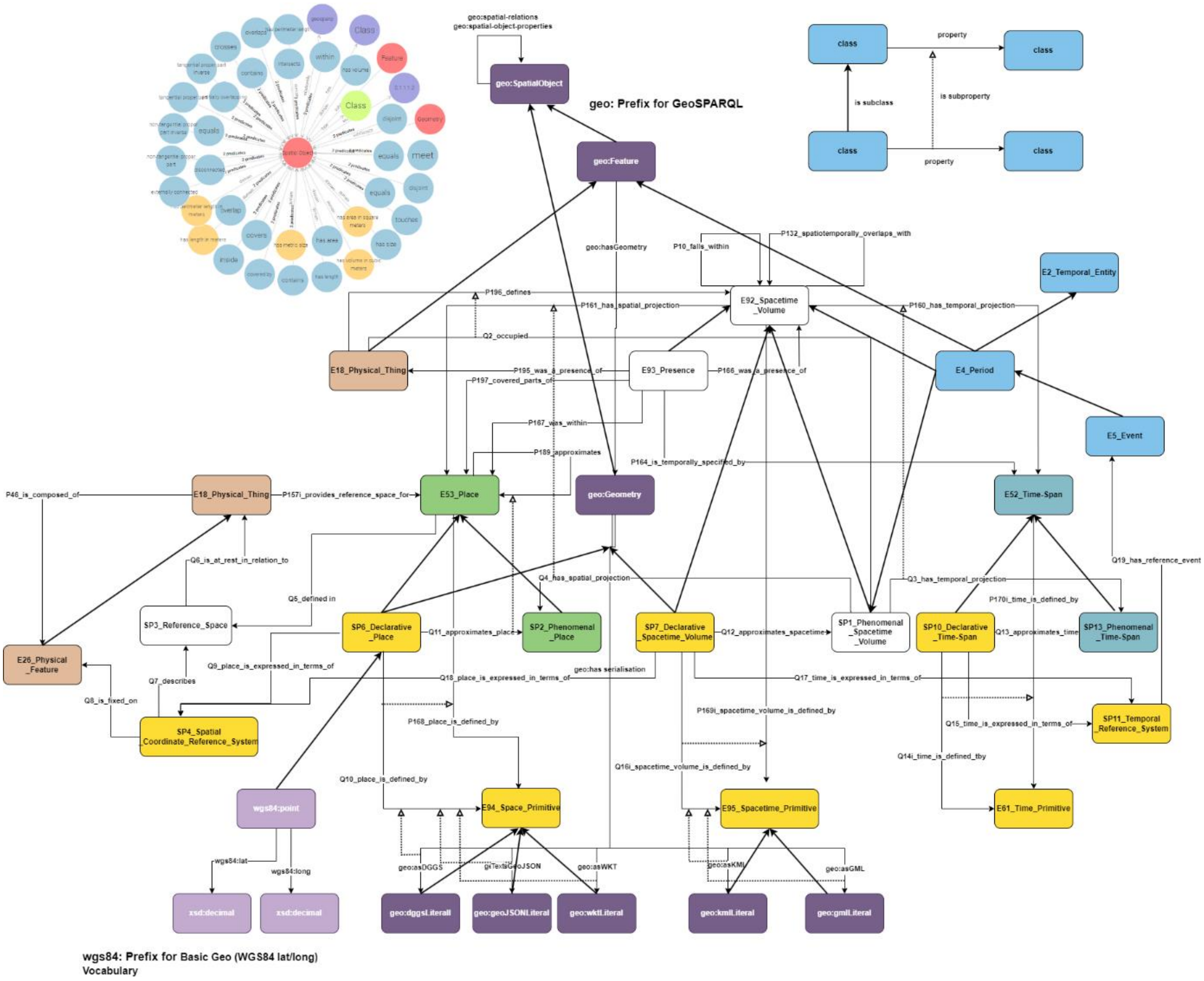

Figure 2: Complete diagram of CRMgeo with all properties and literals

Status

The version 2.0 presented in this document is the new version of the model CRMgeo taking into account the new GeoSPARQL Standard 1.1 published in 2024 which made an (informative) alignment to CRMgeom classes in its OGC Standard. CRMgeo Version 1.2 incorporated the changes realised in CIDOC CRM 6.2. The introduction of the E92 Spacetime Volume replaced the SP8 Spacetime Volume. In version 2.0 the construct E4 Period *Q1 occupied* SP1 Phenomenal Spacetime Volume is replaced by making SP1 Phenomenal Spacetime Volume a superclass of E4 Period and thus introducing an intermediate class between E92 Spacetime Volume and E4 Period. geo:Feature of GeoSPARQL stays superclass of E4 and E18. They inherit the properties of geo: Feature, in particular the elaborated topology relations that can be applied between geo:Feature and geo:Geometry. wgs84:Point from the Basic Geo Vocabulary (WGS84 lat/long) was introduced as a subclass of SP6 Declarative Place.

CRMgeo, version 1.2 was based on the FORTH Technical Report 435 CRMgeo, version 1.0 (Doerr and Hiebel 2013). CRMgeo version 2.0 deprecates the SP15 Geometry class in favour of making SP7 Declarative Place a subclass of geo:Geometry, thus inheriting all spatial relation properties from geo:Geometry and all properties to the serialisations of space and time. SP 5 Geometric Place Expression and SP14 Time expression were deprecated in favor of E94 Space Primitive and E61 Time Primitive respectively. See the appendix for migration paths.

CRMgeo class hierarchy, aligned with GeoSPARQL, Basic Geo (WGS84 lat/long) Vocabulary and the CIDOC-CRM class hierarchies

This class hierarchy lists:

- all classes declared in CRMgeo
- all classes declared in GeoSPARQL version 1.1, Basic Geo (WGS84 lat/long) Vocabulary and CIDOC-CRM version 7.1.3. that are declared as superclasses of classes declared in CRMgeo

Table 1: Class Hierarchy of CRMgeo

E1	CRM Entity					
E53	-	Place				
SP2	-	-	Phenomenal Place			
geo: Geometry	-	-	geo:Geometry			
SP6	-	-	-	Declarative Place		
wgs84:Point	-	-	-	-	wgs84:Point	
E92	-	Spacetime Volume				
SP1	-	-	Phenomenal Spacetime Volume			
E4	-	-	-	Period		
geo: Geometry	-	-	geo:Geometry			
SP7	-	-	-	Declarative Spacetime Volume		
E52	-	Time-Span				
SP13	-	-	Phenomenal Time-Span			
SP10	-	-	Declarative Time-Span			
E73	-	Information Object				
SP5	-		Geometric Place Expression			
SP12	-		Spacetime Volume Expression			
SP14	-		Time Expression			
E29	-		Design or Procedure			
SP4	-	-	-	Spatial Coordinate Reference System		
SP11	-	-	-	Temporal Reference System		
SP3	-	Reference Space				
geo:Spatial object	geo:Spatial object					
geo:Feature	-	geo:Feature				
E4	-	-	Period			
E18	-	-	Physical Thing			
geo: Geometry	-	geo:Geometry				
SP6	-	-	-	Declarative Place		
SP7	-	-	-	Declarative Spacetime Volume		
wgs84:Point	-	-	-	-		wgs84:Point

List of external classes used in CRMgeo

Table 2: List of external classes grouped by model and ordered by model (exception: CRMbase always goes first) and then by class identifier.

Class identifier	Class name	Model	Version
E4	Period	CIDOC-CRM	7.1.3
E5	Event	CIDOC-CRM	7.1.3
E18	Physical Thing	CIDOC-CRM	7.1.3
E26	Physical Feature	CIDOC-CRM	7.1.3
E52	Time-Span	CIDOC_CRM	7.1.3
E53	Place	CIDOC-CRM	7.1.3
E59	Primitive Value	CIDOC_CRM	7.1.3
E61	Time Primitive	CIDOC-CRM	7.1.3
E92	Spacetime Volume	CIDOC-CRM	7.1.3
E94	Space Primitive	CIDOC-CRM	7.1.3
E95	Spacetime Primitive	CIDOC-CRM	7.1.3

CRMgeo property hierarchy, aligned with the GeoSPARQL and the CIDOC-CRM property hierarchies

This property hierarchy lists:

- all properties declared in CRMgeo and properties used from GeoSPARQL and Basic Geo (WGS84 lat/long) Vocabulary
- all properties declared in GeoSPARQL version 2.0, and CIDOC-CRM version 7.1.3 that are declared as superproperties of properties declared in CRMgeo,
- all properties declared in GeoSPARQL version 2.0 and CIDOC-CRM version 7.1.3 that are part of a complete path of which a property declared in CRMgeo, is declared to be a shortcut.

Table 3: Property Hierarchy

Property id	Property Name	Entity – Domain	Entity - Range
P1	is identified by (identifies)	E1 CRM Entity	E41 Appellation
P168	- place is defined by (defines place)	E53 Place	E94 Space primitive
Q10	- - place is defined by (defines place)	SP6 Declarative Place	E94 Space primitive
geo:wktLiteral	- - - geo:asWKT	geo:Geometry	geo:wktLiteral
geo:asGeoJSON	- - - geo:asGeoJSON	geo:Geometry	geo:geoJSONLiteral
geo:asDGGS	- - - geo:asDGGS	geo:Geometry	geo:dggsLiterall
wgs84:lat	- - - wgs84:lat	wgs84:Point	xsd:decimal
wgs84:long	- - - wgs84:long	wgs84:Point	xsd:decimal
P170i	- time is defined by (defines time)	E52 Time-Span	E61 Time Primitive
Q14i	- - time is defined by (defines time)	SP10 Declarative Time-Span	E61 Time Primitive
P169i	- spacetime volume is defined by (defines spacetime volume)	E92 Spacetime Volume	E95 Spacetime Primitive
Q16	- - spacetime volume is defined by (defines spacetime volume)	SP7 Declarative Spacetime Volume	E95 Spacetime Primitive
geo:asKML	- - - geo:asKML	geo:Geometry	geo:kmlLiteral
geo:asGML	- - - geo:asGML	geo:Geometry	geo:gmlLiteral
P196	defines (is defined by)	E18 Physical Thing	E92 Spacetime Volume
Q2	- occupied (is occupied by)	E18 Physical Thing	SP1 Phenomenal Spacetime Volume
P160	has temporal projection (is temporal projection of)	E92 Spacetime Volume	E52 Time-Span
Q3	- has temporal projection (is temporal projection of)	SP1 Phenomenal Spacetime Volume	SP13 Phenomenal Time-Span
P161	has spatial projection (is spatial projection of)	E92 Spacetime Volume	E53 Place
Q4	- has spatial projection (is spatial projection of)	SP1 Phenomenal Spacetime Volume	SP2 Phenomenal Place
Q5	defined in (is reference space for)	E53 Place	SP3 Reference Space
Q6	is at rest in relation to (rests in relation to)	SP3 Reference Space	E18 Physical Thing
Q7	describes (is described by)	SP4 Spatial Coordinate Reference System	SP3 Reference Space

Property id	Property Name	Entity – Domain	Entity - Range
Q8	is fixed on (fixes)	SP4 Spatial Coordinate Reference System	E26 Physical Feature
Q9	place is expressed in terms of (expresses place)	E94 Space Primitive	SP4 Spatial Coordinate Reference System
P189	approximates (is approximated by)	E53 Place	E53 Place
Q11	- approximates place (place is approximated by)	SP6 Declarative Place	SP2 Phenomenal Place
Q12	approximates (spacetime is approximated by)	SP7 Declarative Spacetime Volume	SP1 Phenomenal Spacetime Volume
Q13	approximates time (time is approximated by)	SP10 Declarative Time-Span	SP13 Phenomenal Time Span
Q14	defines time (time is defined by)	E61 Time Primitive	SP10 Declarative Time-Span
Q15	time is expressed in terms of (expresses time)	SP10 Declarative Time-Span	SP11 Temporal Reference System
Q16	defines spacetime volume (spacetime volume is defined by)	E95 Spacetime Primitive	SP7 Declarative Spacetime Volume
Q17	time is expressed in terms of (expresses time)	E95 Spacetime Primitive	SP11 Temporal Reference System
Q18	place is expressed in terms of (expresses place)	E95 Spacetime Primitive	SP4 Spatial Coordinate Reference System
Q19	has reference event (is reference event of)	SP11 Temporal Reference System	E5 Event

List of external properties used in CRMgeo

Table 4: List of external properties grouped by model and ordered by model (exception: CRMbase always goes first) and then by property identifier.

Property identifier	**Property name**	**Model**	**Version**

This page is left blank on purpose

CRMgeo Class Declarations

The classes are comprehensively declared in this section using the following format:

- Class names are presented as headings in bold face, preceded by the class's unique identifier;
- The line "Subclass of:" declares the superclass of the class from which it inherits properties;
- The line "Superclass of:" is a cross-reference to the subclasses of this class;
- The line "Scope note:" contains the textual definition of the concept the class represents;
- The line "Examples:" contains a bulleted list of examples of instances of this class. If the example is also an instance of a subclass of this class, the unique identifier of the subclass is added in parenthesis. If the example instantiates two classes, the unique identifiers of both classes are added in parenthesis. Non-fictitious examples may be followed by an explanation in brackets.
- The line "In first-order logic:" expresses the formal constraints of the class in terms of logical axioms in a First-Order Logic notation.
- The line "Properties:" declares the list of the class' properties;
- Each property is represented by its unique identifier, its forward name, and the range class that it links to, separated by colons;
- Inherited properties are not represented;
- Properties of properties are provided indented and in parentheses beneath their respective domain property.

SP1 Phenomenal Spacetime Volume

Subclass of:

E92 Spacetime volume

Superclass of:

E4 Period

Scope note:

This class comprises the 4 dimensional point sets (volumes) (S) which material phenomena (I) occupy in Space-Time (S). An instance of S1 Space Time Volume represents the true (I) extent of an instance of E4 Period in spacetime or the true (I) extent of the trajectory of an instance of E18 Physical Thing during the course of its existence, from production to destruction. A fuzziness of the extent lies in the very nature of the phenomenon, and not in the shortcomings of observation (U). The degree of fuzziness with respect to the scale of the phenomenon may vary widely, but the extent is never exact in a mathematical sense. According to modern physics, points in space-time are absolute with respect to the physical phenomena happening at them, regardless of the so-called Galilean relativity of spatial or temporal reference systems in terms of which an observer may describe them. Following the theory, points relative to different spatial or temporal reference systems can be related if common points of phenomena in space-time are known in different systems. Instances of SP1 Phenomenal Space-Time Volume are sets of such absolute space-time points of phenomena (I). The (Einstein) relativity of spatial and temporal distances is of no concern for the scales of things in the cultural-historical discourse, but does not alter the above principles. The temporal projection of an instance of SP1 Phenomenal Space-Time Volume defines an E52 Time-Span while its spatial projection defines an SP2 Phenomenal Place. The true location of an instance of E18 Physical Thing during some time-span can be regarded as the spatial projection of the restriction of its trajectory to the respective time-span.

Examples:

- The Space Time Volume (SP1) of the Event (E7) of Ceasar's (E21) murdering
- The Space Time Volume (SP1) where and when the carbon 14 dating (E16) of the "Schoeninger Speer II" (E22) in 1996 took place
- The spatio-temporal trajectory (SP1) of the H.M.S. Victory (E22) from its launching (E12) to its actual location (E9)
- The Space Time Volume (SP1) of the temple in Abu Simbel (E25) before its removal (E6)

In first-order logic:

SP1(x) ⇒ E92(x)

Properties:

Q3 has temporal projection: SP13 Phenomenal Time-Span

Q4 has spatial projection: SP2 Phenomenal Place

SP2 Phenomenal Place

Subclass of:

E53 Place

Scope note:

This class comprises instances of E53 Place (S) whose extent (U) and position is defined by the spatial projection of the spatiotemporal extent of a real world phenomenon that can be observed or measured. The spatial projection depends on the instance of S3 Reference Space onto which the extent of the phenomenon is projected. In general, there are no limitations to the number of Reference Spaces one could regard, but only few choices are relevant for the cultural-historical discourse. Typical for the archaeological discourse is to choose a reference space with respect to which the remains of some events would stay at the same place, for instance, relative to the bedrock of a continental plate. On the other hand, for the citizenship of babies born in aeroplanes, the space in which the boundaries of the overflown state are defined may be relevant (I). Instances of SP2 Phenomenal Place exist as long as the respective reference space is defined. Note that we can talk in particular about what was at a place in a country before a city was built there, i.e., before the time the event occurred by which the place is defined, but we cannot talk about the place of earth before it came into existence due to lack of a reasonable reference space (E).

Examples:

- The place (SP2) where the murder (E7) of Caesar (E21) happened
- Place (SP2) on H.M.S. Victory (E22) at which Nelson (E21) died
- The Place (SP2) of the Varus Battle (E7)

- The volume in space (SP2) of my vine glass (E22)
- The place (SP2) the H.M.S Victory (E22) occupied over the seafloor when Nelson (E21) died
- The space (SP2) enclosed by this room (E22)
- The space (SP2) in borehole Nr. 405 (E25)

In first-order logic:

SP2(x) ⇒ E53(x)

SP3 Reference Space

Subclass of:

E1 CRM Entity

Scope note:

This class comprises the (typically Euclidean) Space (S) that is at rest (I) in relation to an instance of E18 Physical Thing and extends (U) infinitely beyond it. It is the space in which we typically expect things to stay in place if no particular natural or human distortion processes occur. This definition requires that at least essential parts of the respective physical thing have a stability of form. The degree of this stability (e.g., elastic deformation of a ship on sea, landslides, geological deformations) limits the precision to which an instance of SP3 Reference Space is defined. It is possible to construct types of (non Euclidean) reference spaces which adapt to elastic deformations or have other geometric and dynamic properties to adapt to changes of form of the reference object, but they are of rare utility in the cultural-historical discourse.

An instance of SP3 Reference Space begins to exist with the largest thing that is at rest in it and ceases to exist with its E6 Destruction. If other things are at rest in the same space and their time-span of existence falls within the one of the reference objects, they share the same reference space (I). It has therefore the same temporal extent (time-span of existence) as the whole of the E18 Physical Things it is at rest with (E).

Examples:

- The Space (SP3) inside and around H.M.S. Victory (E22) while it is moving through the Atlantic Ocean (E26)
- The Space (SP3) inside and around the Eurasian Continental Plate (E26)
- The Space (SP3) inside and around the Earth (E26)
- The Space (SP3) inside and around the Solar system (E26)

In first-order logic:

SP3(x) ⇒ E1(x)

Properties:

Q6 is at rest in relation to: **E18** Physical Thing

SP4 Spatial Coordinate Reference System

Subclass of:

E29 Design or Procedure

Scope note:

This class comprises systems that are used to describe locations in a SP3 Reference Space (S). An instance of SP4 Spatial Coordinate Reference System is composed of two parts: The first is a Coordinate System which is a set of coordinate axes with specified units of measurement and axis directions. The second part is a set of reference features at rest in the Reference Space it describes in the real world that relate the Coordinate System to real world locations (U) and fix it with respect to the reference object of its Reference Space .

In surveying and geodesy, instances of SP4 Spatial Coordinate Reference System are called a datum. In the case of spatial coordinate reference systems for the earth the datum consists of the reference points and an ellipsoid that approximates the shape of the earth. National systems often use ellipsoids that approximate their territory best and shift them in an appropriate position relative to the earth while WGS84 is an ellipsoid for the whole earth and used in GPS receivers. In engineering a datum is a reference feature of an object used to create a reference system for measurement.The set of reference features in the real world are subset of E26 Physical Feature that are within the described reference space at rest and pertain to the E18 Physical Thing the reference space is at rest with.

SP4 Spatial Coordinate Reference Systems have a validity for a certain spatial extent of the SP3 Reference Space and in addition a temporal validity. The combination of coordinate reference system and datum provides a unique identity (I). SP4 Spatial Coordinate Reference Systems may be defined for the earth, moving objects like planes or ships, linear features like boreholes or local systems. If there is a standardised identifier system available, such as EPSG codes, it should be used.

Examples:

- Longitude-Latitude(ellipsoidal Coordinate System) in WGS84 (Datum)
- EPSG 3241
- the coordinate system to describe locations on H.M.S. Victory (E22) taking the deck foundation of the middle mast (E26) as origin, the mast as z axis, the line at right angle to the bow line as x axis and a right angle to both as y axis.
- The printed lines of the millimeter paper on which an archaeological site (E27) is drawn

In first-order logic:

$SP4(x) \Rightarrow E29(x)$

Properties:

Q7 describes: SP3 Reference Space

SP6 Declarative Place

Subclass of: E53 Place
geo:Geometry

Superclass of:

wgs84:Point

Scope note:

This class comprises instances of E53 Place (S) whose extent (U) and position is defined by an E94 Space Primitive (S). There is one implicit or explicit SP3 Reference Space in which the E94 Space Primitive describes the intended place. Even though E94 Space Primitives have an unlimited precision, measurement devices and the precision of the position of reference features relating the SP4 Spatial Coordinate Reference System to a SP3 Reference Space impose limitations to the determination of a SP6 Declarative Place in the real world (U).
Several E94 Space Primitives may denote the same SP6 Declarative Place if their precision falls within the same range (I).
Instances of SP6 Declarative Places may be used to approximate instances of E53 Places or parts of them. They may as well be used to define the location and spatial extent of property rights or national borders.Instances of SP6 Declarative Places may be used to approximate instances of E53 Places or parts of them. They may as well be used to define the location and spatial extent of property rights or national borders.

Examples:

- the place (SP6) defined by <gml:Point gml:id="p21" srsName="http://www.opengis.net/def/crs/EPSG/0/4326"> <gml:coordinates>45.67, 88.56</gml:coordinates> </gml:Point>
- the place (SP6) defined by a line approximating the Danube river (E27)
- the place (SP6) of the Orinoco river (E27) defined in the map (E22) of Diego Ribeiro (E21) in 1529
- the place (SP6) defined through a polygon that represents the boundaries of the Germanisches Nationalmuseum (E25)
- the extent of the United Kingdom (E25) in the year 2003

In first-order logic:

SP6 (x) ⇒ E53(x)
SP6 (x) ⇒ geo:Geometry

Properties:

Q11 approximates: **E53** Place

SP7 Declarative Spacetime Volume

Subclass of:

E92 Spacetime Volume
geo:Geometry

Scope note:

This class comprises instances of E92 Spacetime Volumes (S) whose temporal and spatial extent (U) and position is defined by a E95 Spacetime Primitive. There is one implicit or explicit SP3 Reference Space in which the E95 Spacetime Primitive describes the intended Spacetime Volume. As we restrict the model to Galilean physics and explicitly exclude systems with velocities close to the speed of light we do not model a “Reference Time” as it would be necessary for relativistic physics. This implies that there is only one Reference Time.
Even though E95 Spacetime Primitives have an unlimited precision, measurement devices and the precision of the position of reference features relating the SP4 Spatial Coordinate Reference System to a SP3 Reference Space impose limitations to the

determination of the spatial part of a SP7 Declarative Spacetime Volume in the real world (U).
The same limitation to precision is true for the temporal part of a SP7 Declarative Spacetime Volume due to precision of time measurement devices and of the determination of the reference event of a SP11 Temporal Reference System.
Several SP12 Spacetime Volume Expressions may denote the same SP7 Declarative Spacetime Volume if their precision falls within the same range (I).
Instances of SP7 Declarative Spacetime Volumes may be used to approximate instances of SP8 Spacetime Volumes or parts of them. They may as well be used to define the spatial and temporal extent of property rights or national borders.

Examples:

- the spacetime volume (SP7) defined by a polygon (E94) approximating the Danube river flood in Austria (E27) between 6th and 9th of August 2002 (E52)
- the spacetime volume (E94) of the Orinoco river (E27) defined in the map (E22) of Diego Ribeiro (E21) in 1529
- the spacetime volume (SP7) representing the boundaries (E94) of the United Kingdom (E25) from 1900-1950 (E52)

In first-order logic:

SP7 (x) ⇒ E92(x)
SP7 (x) ⇒ geo:Geometry

Properties:

Q12 approximates: **E92** Spacetime Volume

SP10 DeclarativeTime-Span

Subclass of:

E52 Time-Span

Scope note:

This class comprises instances of E52 Time-Spans that represent the Time Span defined by a SP 14 Time Expression. Thus they derive their identity through an expression defining an extent in time. Even though SP10 Declarative Time Spans have an unlimited precision, measurement devices and the possible precision within the SP11 Temporal Reference System impose limitations to the determination of a SP10 Declarative Time Span. The accuracy of a SP10 Declarative Time Spans depends upon the documentation and measurement method.
SP10 Declarative Time Spans may be used to approximate actual (phenomenal) Time-Spans of temporal entities.

Examples:

- Extent in time defined by the expression “1961”
- Extent in time defined by the expression “From 12-17-1993 to 12-8-1996”
- Extent in time defined by the expression “14h30 – 16h22 4th July 1945”

In first-order logic:

SP10 (x) ⇒ E52(x)

Properties:

Q13 approximates: E52 Time-Span

SP11 Temporal Reference System

Subclass of:

E29 Design or Procedure

Scope note:

This class comprises systems (S) that are used to describe positions and extents in a Reference Time. If relativistic effects are negligible in the wider spacetime area of interest and the speeds of associated things, then there is only one unique global reference time. The typical way to measure time is to count the cycles of a periodic process for which we have a hypothesis of constant frequency, such as oscillations of a crystal, molecular arrangement, rotation of earth around itself or around the sun. The origin for a Temporal Reference System is fixed on a reference event. As long as the number of cycles passed from that reference event until now are known, the temporal reference system exists (E) and expressions in this Reference System can be interpreted with respect to the Reference Time.

A temporal reference system represents time as a continuous linear interpolation over the infinite series of cycles extended from the reference event to the past and the future, regardless of the temporal position of the mathematical point zero of an instance of SP14 Time Expression. For instance the proleptic Gregorian calendar begins with the event at an arbitrary position, the point zero being the date of the „Birth of Christ". The actual date of the birth of Christ is regarded as unknown and therefore is not the reference event.

The identity of a Temporal Reference System is defined through the type of periodic process it is based on, the reference event and the distance of the reference event to the position of the mathematical point zero (I).

A value in the Reference Time is a temporal position measured relative to a temporal reference system. For dates after 1582, ISO 8601 specifies the use of the Gregorian Calendar and 24 hour local or Coordinated Universal Time (UTC) for information interchange.

In ISO 19108 three common types of temporal reference systems are explicitly stated: calendars (used with clocks for greater resolution), temporal coordinate systems, and ordinal temporal reference systems.

Calendars and clocks are both based on interval scales. A calendar is a discrete temporal reference system that provides a basis for defining temporal position to a resolution of one day. A clock provides a basis for defining temporal position within a day. A clock must be used with a calendar in order to provide a complete description of a temporal position within a specific day. Every calendar provides a set of rules for composing a calendar date from a set of elements such as year, month, and day. In every calendar, years are numbered relative to the date of a reference event that defines a calendar era [ISO 19108].

Specifying temporal position in terms of calendar date and time of day complicates the computation of distances between points and the functional description of temporal operations. A temporal coordinate system may be used to support applications of this kind. [ISO 19108].

Ordinal temporal reference systems as specified in ISO 19108 are no instances of SP11 Temporal Reference Systems as they do not define cycles of a periodic process but define a system of time intervals based on reference periods related to certain natural or cultural phenomena.

Examples:

- Gregorian Calendar
- Coordinated Universal Time (UTC)
- Julian date
- Greenwich time
- ISO 8601

In first-order logic:

SP11(x) ⇒ E29(x)

Properties:

Q19 has reference event: E5 Event

SP13 Phenomenal Time-Span

Subclass of:

E52 Time-Span

Scope note:

This class comprises instances of E52 Time-Spans whose extent (U) and position is defined by the temporal projection of the spatiotemporal extent that can be observed or measured. Thus they derive their identity through the extent in time of a real world phenomenon (I).

Examples:

- Duration of the phenomenal temporal extent of the Trafalgar battle (E7)
- The real duration of the Ming Dynasty (E74)
- The real extent of the lifetime of Caesar (E21) starting with his birth (E67) and ending with his death (E69)

In first-order logic:

SP13 (x) ⇒ E52(x)

CRMgeo Property Declarations

The properties are comprehensively declared in this section using the following format:

- Property names are presented as headings in bold face, preceded by unique property identifiers;
- The line “Domain:” declares the class for which the property is defined;
- The line “Range:” declares the class to which the property points, or that provides the values for the property;
- The line “Subproperty of:” is a cross-reference to any superproperties the property may have;
- The line “Superproperty of:” is a cross-reference to any subproperties the property may have;
- The line “Quantification:” declares the possible number of occurrences for domain and range class instances for the property. For a list of possible values, see section “Property Quantifiers” (pp. 24-25) of the CIDOC CRM;
- The line “Scope note:” contains the textual definition of the concept the property represents
- The line “Examples:” contains a bulleted list of examples of instances of this property.
- The line “In first-order logic:” expresses the formal constraints of the property in terms of logical axioms in a first-order logic notation.

Q2 occupied (is occupied by)

Domain:

E18 Physical Thing

Range:

SP1 Phenomenal Spacetime Volume

Subproperty of:

E18 Physical Thing. P196 defines (is defined by): E92 Spacetime Volume

Quantification:

one to one, necessary (1,1:0,1)

Scope note:

This property describes the 4 dimensional point sets (volumes) in spacetime that the trajectory of an instance of E18 Physical Thing occupies in spacetime in the course of its existence. We include in the occupied space the space filled by the matter of the physical thing and all inner spaces not accessible in regular function.

Examples:

- H.M.S. Victory (E22) occupied a spatio-temporal trajectory (SP1) from its launching (E12) to its actual location (E9)

In first-order logic:

$Q2(x,y) \Rightarrow E18(x)$

$Q2(x,y) \Rightarrow SP1(y)$

$Q2(x,y) \Leftrightarrow P196(x,y)$

Q3 has temporal projection (is temporal projection of)

Domain:

SP1 Phenomenal Spacetime Volume

Range:

SP13 Phenomenal Time-Span

Subproperty of:

E92 Spacetime Volume. P160 has temporal projection (is temporal projection of): E52 Time Span

Quantification:

one to one, necessary, dependent (1,1:1,1)

Scope note:

This property describes the temporal projection of an instance of a SP1 Phenomenal Spacetime Volume. The property P4 has time-span is a shortcut of the more fully developed path from E4 Period as a SP1 Phenomenal Spacetime Volume Q3 has temporal projection to E52 Time Span. This property can be extended in a future model to a ternary (3-ary) relationship describing the temporal projection under a spatial constraint.

Examples:

- The spatio-temporal trajectory (SP1) of the H.M.S. Victory (E22) *has temporal projection the* phenomenal temporal extent from its from its launching to its actual location (SP13)

In first-order logic:

Q3(x,y) ⇒ SP1(x)
Q3(x,y) ⇒ SP13(y)

Q4 has spatial projection (is spatial projection of)

Domain:

SP1 Phenomenal Spacetime Volume

Range:

SP2 Phenomenal Place

Subproperty of:

E92 Spacetime Volume. P161 has spatial projection (is spatial projection of): E53 Place

Quantification:

one to many, necessary, dependent (1,n:1,1)

Scope note:

This property describes the spatial projection of an instance of a SP1 Phenomenal Spacetime Volume on an instance of SP2 Phenomenal Place. Even though the projection of a spacetime volume to one instance of SP3 Reference Space is unique, each reference space gives rise to another projection. The projections overlap at the time of the

spacetime volume, the respective instances of SP2 Phenomenal Place may later drift apart, or earlier be yet apart.
The property P7 took place at is a shortcut of the more fully developed path from E4 Period through Q1 occupied, SP1 Phenomenal Spacetime Volume Q4 has spatial projection to SP2 Phenomenal Place. This property can be extended in a future model to a ternary (3-ary) relationship describing the spatial projection under a temporal constraint.

Examples:

- The spatio-temporal trajectory (SP1) of the H.M.S. Victory (E22) *has spatial projection the* phenomenal spatial extent from its from its launching to its actual location (SP2)

In first-order logic:

Q4(x,y) ⇒ SP1(x)
Q4(x,y) ⇒ SP2 (y)

Q5 defined in (is reference space for)

Domain:

E53 Place

Range:

SP3 Reference Space

Quantification:

many to one, necessary (1,1:0,n)

Scope note:

This property associates an instance of E53 Place with the instance of SP3 Reference Space it is defined in.

Examples:

- The location of Lord Nelson when he died (E53) defined in the Reference Space (SP3) inside and around the H.M.S. Victory (E22)

In first-order logic:

Q5(x,y) ⇒ E53(x)
Q5(x,y) ⇒ SP3 (y)

Q6 is at rest in relation to (rests in relation to)

Domain:

SP3 Reference Space

Range:

E18 Physical Thing

Quantification:

many to many, necessary, dependent (1,n:1,n)

Scope note:

This property associates an instance of SP3 Reference Space with the instance of E18 Physical Thing that is at rest in it. For all instances of E18 Physical Thing exist at least one reference space it is at rest with due to their relative stability of form. Larger constellations of matter may comprise many physical features that are at rest with them.

Examples:

- The Reference Space (SP3) which *is at rest in relation to* the H.M.S. Victory (E22)

In first-order logic:

Q6(x,y) ⇒ SP3 (x)
Q6(x,y) ⇒ E18 (y)

Q7 describes (is described by)

Domain:

SP4 Spatial Coordinate Reference System

Range:

SP3 Reference Space

Quantification:

many to one, necessary (1,1:0,n)

Scope note:

This property associates an instance of SP4 Spatial Coordinate Reference System with the instance of SP3 Reference Space for which it can be used to describe locations.

Examples:

- The Spatial Coordinate Reference System (SP4) which *describes* the Reference Space (SP3) in and around the H.M.S. Victory (E22)

In first-order logic:

Q7(x,y) ⇒ SP4 (x)
Q7(x,y) ⇒ SP3 (y)

Q8 is fixed on (fixes)

Domain:

SP4 Spatial Coordinate Reference System

Range:

E26 Physical Feature

Quantification:

one to many, necessary, dependent (1,n:1,1)

Scope note:

This property defines the physical reference features that ground a spatial coordinate reference system in the real world.
In surveying and geodesy this is part of the datum definition and is often a point identified by a physical feature on earth (sometimes monuments) where the earth approximation ellipsoid touches the earth and one axis of the ellipsoid runs through.

Examples:

- the Spatial Coordinate Reference System (SP4) of the H.M.S. Victory (E22) is fixed on the mast of the H.M.S. Victory (E26)

In first-order logic:

Q8(x,y) ⇒ SP4 (x)
Q8(x,y) ⇒ E26 (y)

Q9 place is expressed in terms of (expresses place)

Domain:

SP6 Declarative Place

Range:

SP4 Spatial Coordinate Reference System

Quantification:

many to many (0,n:0,n)

Scope note:

This property defines the coordinate reference system in terms of which a Space Primitive is formulated.

Examples:

- the Declarative Place the Spatial Coordinate Reference System (SP4) of the H.M.S. Victory (E22) is fixed on the mast of the H.M.S. Victory (E26)

In first-order logic:

Q9(x,y) ⇒ SP6 (x)
Q9(x,y) ⇒ SP4 (y)

Q10 place is defined by (defines place)

Domain:

SP6 Declarative Place

Range:

E94 Space Primitive

Subproperty of:

E53 Place. P168 place is defined by (defines place): E94 Space Primitive

Quantification:

one to many, dependent (0,n:1,1)

Scope note:

This property associates an instance of SP6 Declarative Place with the instance of E94 Space Primitive that defines it. Syntactic variants or use of different scripts may result in multiple instances of E94 Space Primitive defining exactly the same place. Transformations between different reference systems always result in new definitions of places approximating each other and not in alternative definitions.

Examples:

- The centroid from https://sws.geonames.org/735927 (SP6) *place is defined by* 40°31'17.9"N 21°15'48.3"E (E94). [A single point for approximating the centre of the city of Kastoria, Greece]
- Martin's coordinates for Kastoria (SP6) *place is defined by* 40°30'23"N 21°14'53"E, 40°31'40"N 21°16'43"E (E94). [A square covering the built settlement structure of Kastoria, Greece]

In first-order logic:

Q10(x,y) ⇒ SP6 (x)
Q10(x,y) ⇒ E94 (y)
Q10(x,y) ⇔ P168(x,y)

Q11 approximates place (place is approximated by)

Domain:

SP6 Declarative Place

Range:

SP2 Phenomenal Place

Subproperty of:

E53 Place. P189 approximates (is approximated by): E53 Place

Quantification:

many to one (0,1:0,n)

Scope note:

This property approximates a SP2 Phenomenal Place which is defined in the same reference space.
The property does not state the quality or accuracy of the approximation, but states the intention to approximate the place.

Examples:

- [40°31'17.9"N 21°15'48.3"E] (SP6) *approximates place* Kastoria, Greece, TGN ID: 7010880 (SP2). [The declarative place with point shape which is defined in terms of coordinates taken from https://sws.geonames.org/735927 approximates the phenomenal place of Kastoria]
- [40°31'00.1"N 21°16'00.1"E] (SP6) *approximates place* Kastoria, Greece, TGN ID: 7010880 (E53). [The declarative place with point shape which is defined in terms of coordinates taken from http://vocab.getty.edu/page/tgn/7010880 approximates the phenomenal place of Kastoria]

In first-order logic:

Q11(x,y) ⇒ SP6 (x)
Q11(x,y) ⇒ SP2 (y)

Q12 approximates spacetime (spacetime is approximated by)

Domain:

SP7 Declarative Spacetime Volume

Range:

SP1 Phenomenal Spacetime Volume

Quantification:

many to one (0,1:0,n)

Scope note:

This property approximates an E53 Place which is defined in the same reference space. The property does not state the quality or accuracy of the approximation, but states the intention to approximate the place.

Examples:

- <Placemark>
<name> Byzantine Empire </name>
<TimeSpan>
<begin>330</begin><end>1453</end>
</TimeSpan>
<Polygon>
<altitudeMode>clampToGround</altitudeMode>
<outerBoundaryIs>
<LinearRing>
<coordinates>18.452787460,40.85553626,017.2223187,40.589098,....0 17.2223,39.783
</coordinates>
</LinearRing>
</outerBoundaryIs>
</Polygon>
</Placemark> [spatial and temporal information in KML] (E95) defining the maximum extent of the Byzantine Empire (SP7) *approximates spacetime* the phenomenal maximum extent of the Byzantine Empire (SP1)

In first-order logic:

Q12(x,y) ⇒ SP7 (x)
Q12(x,y) ⇒ SP1 (y)

Q13 approximates time (time is approximated by)

Domain:

SP10 Declarative Time-Span

Range:

SP13 Phenomenal Time-Span

Quantification:

many to one (0,1:0,n)

Scope note:

This property approximates a E52 Time-Span. The property does not state the quality or accuracy of the approximation, but states the intention to approximate the time span .

Examples:

- September 1939- September 1945 (SP10) *approximates time* the phenomenal duration of the Second World War (SP13)

In first-order logic:

Q13(x,y) ⇒ SP10 (x)
Q13(x,y) ⇒ SP13 (y)

Q14 defines time (time is defined by)

Domain:

E61 Time Primitive

Range:

SP10 Declarative Time-Span

Subproperty of:

E61 Time Primitive. P170 defines time (time is defined by): E52 Time-Span

Quantification:

many to one (0,1:0,n)

Scope note:

This property associates an instance of E61 Time Primitive with the instance of SP10 Declarative Time Span it defines. Syntactic variants or use of different scripts may result in multiple instances of E61 Time Primitive defining exactly the same time span. Transformations between different temporal reference systems in general result in new definitions of time spans approximating each other.

Examples:

- “1800/1/1 0:00:00 – 1899/31/12 23:59:59” (E61) *defines time* the 19th century (SP10).
- “1968/1/1 – 2018/1/1” (E61) *defines time* 1968/1/1 – 2018/1/1 (SP10). [an arbitrary time-span during which the Saint Titus reliquary was present in the Saint Titus Church in Heraklion, Crete]

In first-order logic:

Q14(x,y) ⇒ E61 (x)
Q14(x,y) ⇒ SP10 (y)
Q14(x,y) ⇔ P170(x,y)

Q15 time is expressed in terms of (expresses time)

Domain:

SP10 Declarative Time-Span

Range:

SP11 Temporal Reference System

Quantification:

many to many (0,n:0,n)

Scope note:

This property defines the temporal reference system in terms of which an E61 Time Primitive is formulated.

Examples:

- The declarative time-span (SP10) defined by "1800/1/1 0:00:00 – 1899/31/12 23:59:59" (E61) *time is expressed in terms of* the Gregorian Calendar (SP11).

In first-order logic:

Q15(x,y) ⇒ SP10 (x)
Q15(x,y) ⇒ SP11 (y)

Q16 defines spacetime volume (spacetime volume is defined by)

Domain:

E95 Spacetime Primitive

Range:

SP7 Declarative Spacetime Volume

Subproperty of:

E95 Spacetime Primitive. P169 defines spacetime volume (spacetime volume is defined by): E92 Spacetime Volume

Quantification:

many to one, necessary (1,1:0,n)

Scope note:

This property associates an instance of E95 Spacetime Primitive with the instance of SP7 Declarative Spacetime Volume it defines. Syntactic variants or use of different scripts may result in multiple instances of E95 Spacetime Primitive defining exactly the same SP7 Declarative Spacetime Volume. Transformations between different temporal or spatial reference systems in general result in new definitions of Spacetime Volumes approximating each other.

Examples:

- <Placemark>
  <name> Byzantine Empire </name>
  <TimeSpan>
  <begin>330</begin><end>1453</end>
  </TimeSpan>
  <Polygon>
  <altitudeMode>clampToGround</altitudeMode>
  <outerBoundaryIs>
  <LinearRing>
  <coordinates>18.452787460,40.85553626,017.2223187,40 .589098,....0 17.2223,39.783
  </coordinates>
  </LinearRing>
  </outerBoundaryIs>
  </Polygon>
  </Placemark> [spatial and temporal information in KML] (E95) *defines spacetime volume* the declared maximum extent of the Byzantine Empire (SP7)

In first-order logic:

Q16(x,y) ⇒ E95 (x)
Q16(x,y) ⇒ SP7 (y)
Q16(x,y) ⇔ P169(x,y)

Q17 time is expressed in terms of (expresses time)

Domain:

SP7 Declarative Spacetime Volume

Range:

SP11 Temporal Reference System

Quantification:

many to many (0,n:0,n)

Scope note:

This property defines the temporal reference system in terms of which a SP7 Declarative Spacetime Volume is formulated.

Examples:

- The declared maximum extent of the Byzantine Empire (SP7) defined by <Placemark>
  <name> Byzantine Empire </name>

<TimeSpan>
<begin>330</begin><end>1453</end>
</TimeSpan>
<Polygon>
<altitudeMode>clampToGround</altitudeMode>
<outerBoundaryIs>
<LinearRing>
<coordinates>18.452787460,40.85553626,017.2223187,40.589098,....0 17.2223,39.783
</coordinates>
</LinearRing>
</outerBoundaryIs>
</Polygon>
</Placemark> (E95) *time is expressed in terms of* the Gregorian Calendar (SP11).

In first-order logic:

Q17 (x,y) ⇒ SP7 (x)
Q17 (x,y) ⇒ SP11 (y)

Q18 place is expressed in terms of (expresses place)

Domain:

SP7 Declarative Spacetime Volume

Range:

SP4 Spatial Coordinate Reference System

Quantification:

many to many (0,n:0,n)

Scope note:

This property defines the spatial coordinate reference system in terms of which a SP12 Spacetime Volume Expression is formulated.

Examples:

- The declared maximum extent of the Byzantine Empire (SP7) defined by <Placemark>
<name> Byzantine Empire </name>
<TimeSpan>
<begin>330</begin><end>1453</end>
</TimeSpan>
<Polygon>
<altitudeMode>clampToGround</altitudeMode>
<outerBoundaryIs>
<LinearRing>
<coordinates>18.452787460,40.85553626,017.2223187,40.589098,....0 17.2223,39.783
</coordinates>
</LinearRing>
</outerBoundaryIs>
</Polygon>

</Placemark> (E95) *place is expressed in terms of* Longitude-Latitude(ellipsoidal Coordinate System) in WGS84 (Datum) (SP4)

In first-order logic:

Q18 (x,y) ⇒ SP7 (x)
Q18 (x,y) ⇒ SP4 (y)

Q19 has reference event (is reference event of)

Domain:

SP11 Temporal Reference System

Range:

E5 Event

Quantification:

many to one, necessary (1,1:0,n)

Scope note:

This property defines the reference event for a SP11 Temporal Reference System.

Examples:

- the proleptic Gregorian Calendar (SP11) *has reference event* Birth of Christ (E67). [The actual date of the birth of Christ is regarded to be unknown and therefore is not the reference event.]

In first-order logic:

Q18 (x,y) ⇒ SP11 (x)
Q18 (x,y) ⇒ E5 (y)

Referred CIDOC CRM Classes

E4 Period

Subclass of: E2 Temporal Entity,
E92 Spacetime volume
SP1 Phenomenal Spacetime Volume
geo:**Feature**

Superclass of: E5 Event

Scope note: This class comprises sets of coherent phenomena or cultural manifestations occurring in time and space.

It is the social or physical coherence of these phenomena that identify an E4 Period and not the associated spatiotemporal extent. This extent is only the “ground” or space in an abstract physical sense that the actual process of growth, spread and retreat has covered. Consequently, different periods can overlap and coexist in time and space, such as when a nomadic culture exists in the same area and time as a sedentary culture. This also means that overlapping land use rights, common among first nations, amounts to overlapping periods.

Often, this class is used to describe prehistoric or historic periods such as the “Neolithic Period”, the “Ming Dynasty” or the “McCarthy Era”, but also geopolitical units and activities of settlements are regarded as special cases of E4 Period. However, there are no assumptions about the scale of the associated phenomena. In particular all events are seen as synthetic processes consisting of coherent phenomena. Therefore E4 Period is a superclass of E5 Event. For example, a modern clinical E67 Birth can be seen as both an atomic E5 Event and as an E4 Period that consists of multiple activities performed by multiple instances of E39 Actor.

As the actual extent of an E4 Period in spacetime we regard the trajectories of the participating physical things during their participation in an instance of E4 Period. This includes the open spaces via which these things have interacted and the spaces by which they had the potential to interact during that period or event in the way defined by the type of the respective period or event. Examples include the air in a meeting room transferring the voices of the participants. Since these phenomena are fuzzy, we assume the spatiotemporal extent to be contiguous, except for cases of phenomena spreading out over islands or other separated areas, including geopolitical units distributed over disconnected areas such as islands or colonies.

Whether the trajectories necessary for participants to travel between these areas are regarded as part of the spatiotemporal extent or not has to be decided in each case based on a concrete analysis, taking use of the sea for other purposes than travel, such as fishing, into consideration. One may also argue that the activities to govern disconnected areas imply travelling through spaces connecting them and that these areas hence are spatially connected in a way, but it appears counterintuitive to consider for instance travel routes in international waters as extensions of geopolitical units.

Consequently, an instance of E4 Period may occupy a number of disjoint spacetime volumes, however there must not be a discontinuity in the timespan covered by these spacetime volumes. This means that an instance of E4 Period must be contiguous in time. If it has ended in all areas, it has ended as a whole. However it may end in one area before another, such as in the Polynesian migration, and it continues as long as it is ongoing in at least one area.

We model E4 Period as a subclass of E2 Temporal Entity and of E92 Spacetime volume. The latter is intended as a phenomenal spacetime volume as defined in CRMgeo (Doerr and Hiebel 2013). By virtue of this multiple inheritance we can discuss the physical extent of an E4 Period without representing each instance of it together with an instance of its associated spacetime volume. This model combines two quite different kinds of substance: an instance of E4 Period is a phenomena while a spacetime volume is an aggregation of points in spacetime. However, the real spatiotemporal extent of an instance of E4 Period is regarded to be unique to it due to all its details and fuzziness; its identity and existence depends uniquely on the identity of the instance of E4 Period. Therefore this multiple inheritance is unambiguous and effective and furthermore corresponds to the intuitions of natural language.

There are two different conceptualisations of 'artistic style', defined either by physical features or by historical context. For example, "Impressionism" can be viewed as a period lasting from approximately 1870 to 1905 during which paintings with particular characteristics were produced by a group of artists that included (among others) Monet, Renoir, Pissarro, Sisley and Degas. Alternatively, it can be regarded as a style applicable to all paintings sharing the characteristics of the works produced by the Impressionist painters, regardless of historical context. The first interpretation is an instance of E4 Period, and the second defines morphological object types that fall under E55 Type.

Another specific case of an E4 Period is the set of activities and phenomena associated with a settlement, such as the populated period of Nineveh.

Examples:

- Jurassic
- European Bronze Age
- Italian Renaissance
- Thirty Years War
- Sturm und Drang
- Cubism

In First Order Logic:

$E4(x) \supset E2(x)$
$E4(x) \supset E92(x)$

Properties**:**

P7 took place at (witnessed): E53 Place
P8 took place on or within (witnessed): E18 Physical Thing
P9 consists of (forms part of): E4 Period

E18 Physical Thing

Subclass of: E72 Legal Object
Feature

Superclass of: E19 Physical Object
E24 Physical Human-Made Thing
E26 Physical Feature

Scope Note: This class comprises all persistent physical items with a relatively stable form, man-made or natural.

Depending on the existence of natural boundaries of such things, the CRM distinguishes the instances of E19 Physical Object from instances of E26 Physical Feature, such as holes, rivers, pieces of land etc. Most instances of E19 Physical Object can be moved (if not too heavy), whereas features are integral to the surrounding matter.

An instance of E18 Physical Thing occupies not only a particular geometric space, but in the course of its existence it also forms a trajectory through spacetime, which occupies a real, that is phenomenal, volume in spacetime. We include in the occupied space the space filled by the matter of the physical thing and all its inner spaces, such as the interior of a box. Physical things consisting of aggregations of physically unconnected objects, such as a set of chessmen, occupy a number of individually contiguous spacetime volumes equal to the number of unconnected objects that constitute the set.

We model E18 Physical Thing to be a subclass of E72 Legal Object and of E92 Spacetime volume. The latter is intended as a phenomenal spacetime volume as defined in CRMgeo

(Doerr and Hiebel 2013). By virtue of this multiple inheritance we can discuss the physical extent of an E18 Physical Thing without representing each instance of it together with an instance of its associated spacetime volume. This model combines two quite different kinds of substance: an instance of E18 Physical Thing is matter while a spacetime volume is an aggregation of points in spacetime. However, the real spatiotemporal extent of an instance of E18 Physical Thing is regarded to be unique to it, due to all its details and fuzziness; its identity and existence depends uniquely on the identity of the instance of E18 Physical Thing. Therefore this multiple inheritance is unambiguous and effective and furthermore corresponds to the intuitions of natural language.

The CIDOC CRM is generally not concerned with amounts of matter in fluid or gaseous states.

Examples:

- the Cullinan Diamond (E19)
- the cave “Ideon Andron” in Crete (E26)
- the Mona Lisa (E22)

In First Order Logic:

E18(x) ⊃ E72(x)
E18(x) ⊃ E92(x)

Properties:

P44 has condition (is condition of): E3 Condition State
P45 consists of (is incorporated in): E57 Material
P46 is composed of (forms part of): E18 Physical Thing
P49 has former or current keeper (is former or current keeper of): E39 Actor
P50 has current keeper (is current keeper of): E39 Actor
P51 has former or current owner (is former or current owner of): E39 Actor
P52 has current owner (is current owner of): E39 Actor
P53 has former or current location (is former or current location of): E53 Place
P58 has section definition (defines section): E46 Section Definition
P59 has section (is located on or within): E53 Place
P128 carries (is carried by): E90 Symbolic Object
P156 occupies (is occupied by): E53 Place

Referred GeoSPARQL Classes

GeoSPARQL (OGC 2012) does not provide scope notes as the CIDOC CRM but extensive descriptions to the semantics of the classes are found in the OGC standards, or respective ISO standards on geographic information. Some descriptions are cited here and the references to the sources are given. For more details on GeoSPARQL and in particular subclasses and properties please refer to the **GeoSPARQL** documentation.

SpatialObject

Superclass of: **Feature**
Geometry

Scope note: The class SpatialObject, superclass of everything feature or geometry that can have a spatial representation.

Feature

Subclass of: **SpatialObject**

Scope note: Feature is defined as superclass of everything feature

Further OGC/ ISO 19100 definitions:

"A feature is an abstraction of a real world phenomenon" [ISO 19101];

A feature is a geographic feature if it is associated with a location relative to the Earth. Vector data consists of geometric and topological primitives used, separately or in combination, to construct objects that express the spatial characteristics of geographic features.

Attributes of (either contained in or associated to) a feature describe measurable or describable properties about this entity. Unlike a data structure description, feature instances derive their semantics and valid use or analysis from the corresponding real world entities' meaning.

Documenting feature instances, types, semantics and their properties is often detailed in an information model. An information model details how to take real world ideas or objects and make them useful to a computer system. In the geospatial world the focus is on depicting things in the real world as points, lines, or polygons (the geometry "primitives" we use to assemble location data about those real world objects) and their attributes (information about those objects). When linked together, a pair (geometry and attributes) representing one or more real world objects, is called a feature.

There are three popular approaches for the modeling of geospatial features.

The first models the spatial extent of a feature with point, lines, polygons, and other geometric primitives that come from a list of well-known types. Features modeled in this fashion are called "Features with Geometry."

The second approach is called a "Feature as Coverage". This technology includes images as a special case.

The third approach is "Feature as Observation". An Observation is an action with a result which has a value describing some phenomenon. The observation is modelled as a Feature within the context of the General Feature Model [ISO 19101, ISO 19109]. An observation feature binds a result to a feature of interest, upon which the observation was made. The observed property is a property of the feature of interest. All these primary Features types are intimately related, yet have distinct concepts (OGC 2009)

Geometry

Subclass of: **SpatialObject**

Scope note: The class Geometry, superclass of everything geometry.

Further OGC/ ISO 19100 definitions:

The Geometry class is based on the specifications in ISO 19107 (ISO 2003) and in particular of the GM_Object. GM_Object is the root class of the geometric object taxonomy and supports interfaces common to all geographically referenced geometric objects. GM_Object instances are sets of direct positions in a particular coordinate reference system. A GM_Object can be regarded as an infinite set of points that satisfies the set operation interfaces for a set of direct positions, TransfiniteSet<DirectPosition>. Since an infinite collection class cannot be implemented directly, a Boolean test for inclusion shall be provided by the GM_Object interface. This International Standard concentrates on vector geometry classes, but future work may use GM_Object as a root class without modification (ISO 2003).

OGC (2012), OGC GeoSPARQL - A Geographic Query Language for RDF Data, http://www.opengeospatial.org/standards/geosparql (**10.9.2015**)

Referred Basic Geo (WGS84 lat/long) Vocabulary

GeoSPARQL (OGC 2012) does not provide scope notes as the CIDOC CRM but extensive descriptions to the semantics of the classes are found in the OGC standards, or respective ISO standards on geographic information. Some descriptions are cited here and the references to the sources are given. For more details on GeoSPARQL and in particular subclasses and properties please refer to the **GeoSPARQL** documentation.

Point

Subclass of: SP6 Declarative Place

Scope note:

This class comprises instances of E53 Place (S) whose extent (U) and position is defined by an E94 Space Primitive (S). There is one implicit or explicit SP3 Reference Space in which the SP5 Geometric Place Expression describes the intended place. Even though SP5 Geometric Place Expressions have an unlimited precision, measurement devices and the precision of the position of reference features relating the SP4 Spatial Coordinate Reference System to a SP3 Reference Space impose limitations to the determination of a SP6 Declarative Place in the real world (U).
Several SP5 Geometric Place Expressions may denote the same SP6 Declarative Place if their precision falls within the same range (I).
Instances of SP6 Declarative Places may be used to approximate instances of E53 Places or parts of them. They may as well be used to define the location and spatial extent of property rights or national borders.

Examples:

- the place defined by <gml:Point gml:id="p21" srsName="http://www.opengis.net/def/crs/EPSG/0/4326"> <gml:coordinates>45.67, 88.56</gml:coordinates> </gml:Point>
- the place defined by a line approximating the Danube river
- The place of the Orinoco river defined in the map of Diego Ribeiro

Properties:

lat: xsd:decimal
long: xsd:decimal

Works Cited

N. Guarino and C. Welty (2002), "Evaluating ontological decisions with OntoClean," Communications of the ACM, 45 (2), pp. 61-65, 2002

OGC (2024), OGC GeoSPARQL 1.1 - A Geographic Query Language for RDF Data, http://www.opengis.net/doc/IS/geosparql/1.1 (**5.3.2025**)

OGC (2009), The OpenGIS® Abstract Specification: Topic 5: Features , https://portal.ogc.org/files/?artifact_id=29536 (**5.3.2025**)

W3C (2003) Basic Geo (WGS84 lat/long) vocabulary https://www.w3.org/2003/01/geo/ (**5.3.2025**)

Wiggins David (2001), Sameness and Substance Renewed, Cambridge University Press

Appendix

Deprecated classes and properties

The following is a list of classes and/or properties that have been deprecated between the version 1.2 of CRMgeo, and this release (2.0). While the CIDOC CRM is developed with the principle of monotonic change, attempting to minimize backwards incompatibility through conservative initial modelling as well as modelling evolution, certain revisions inevitably entail changes to the model which will require an update to knowledge bases based on old versions of the ontology, in order to reconcile instances with the current version. The following tables provide information on which classes or properties have been deprecated and will thus require an update to previous CRMgeo compliant KBs in order to be in accord with the latest version of the extension. The reader will find in the first table, "Deprecated Class Migration Instructions", classes that have been deprecated and the suggested class or primitive replacement for that class.

Deprecated Class Migration Instructions

Table 6: Deprecated Class Migration Instructions

Deprecated Class	**Migration Instruction**
SP5 Geometric Place Expression	use E94 Space Primitive
SP12 Spacetime Volume Expression	use E95 Spacetime Primitive
SP14 Time Expression	use E61 Time Primitive
SP15 Geometry	use SP6 Declarative Place or geo:geometry