CRM sci
Scientific observation model

Definition of the CRMsci
An Extension of CIDOC CRM to support scientific observation

Approved by the CIDOC CRM-SIG

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Currently maintained by FORTH

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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 "Scientific Observation Model" (CRMsci), a formal ontology intended to be used as a global schema for integrating metadata about scientific observation, measurements and processed data in descriptive and empirical sciences such as life sciences, geology, geography, archaeology, cultural heritage conservation and others in research IT environments and research data libraries. Its primary purpose is facilitating the management, integration, mediation, interchange and access to research data by describing semantic relationships, in particular causal ones. It is not primarily a model for processing data in order to produce new research results, even though its representations can be used for processing.

The Scientific Observation Model has been developed bottom up from specific metadata examples from life sciences, geology, archaeology, cultural heritage conservation and clinical studies, such as water sampling in aquifer systems, earthquake shock recordings, landslides, excavation processes, species occurrence and detection of new species, tissue sampling in cancer research, 3D digitization, based on communication with the domain experts and the implementation and validation in concrete applications. It takes into account relevant standards, such as INSPIRE, OBOE, national archaeological standards for excavation, Digital Provenance models and others. For each application, another set of extensions is needed in order to describe those data at an adequate level of specificity, such as semantics of excavation layers or specimen capture in biology. However, the model presented here describes, together with the CIDOC CRM, a discipline neutral level of genericity, which can be used to implement effective management functions and powerful queries for related data. It aims at providing superclasses and superproperties for any application-specific extension, such that any entity referred to by a compatible extension can be reached with a more general query based on this model.

Besides application-specific extensions, this model is intended to be complemented by CRMgeo, a more detailed model and extension of the CIDOC CRM of generic spatiotemporal topology and geometric description, also currently available in a first stable version [CRMgeo, version 1.0 - Doerr, M. and Hiebel, G. 2013]. Details of spatial properties of observable entities should be modelled in CRMgeo. As CRMgeo links CIDOC CRM to the OGC standard of GeoSPARQL it makes available all constructs of GML of specific spatial and temporal relationships. Still to be developed are models of the structures for describing quantities, such as IHS colours, volumes, velocities etc.

This is an attempt to maintain a modular structure of multiple ontologies related and layered in a specialization – generalization relationship, and into relatively self-contained units with few cross-correlations into other modules, such as describing quantities. This model aims at staying harmonized with the CIDOC CRM, i.e., its maintainers submit proposals for modifying the CIDOC CRM wherever adequate to guarantee the overall consistency, disciplinary adequacy and modularity of CRM-based ontology modules.

Basic concepts

Figure 1 and figure 2 summarise the classes that CRMsci introduces (in orange) and their relations with CIDOC CRM classes (in blue) & CRMsci (in yellow).

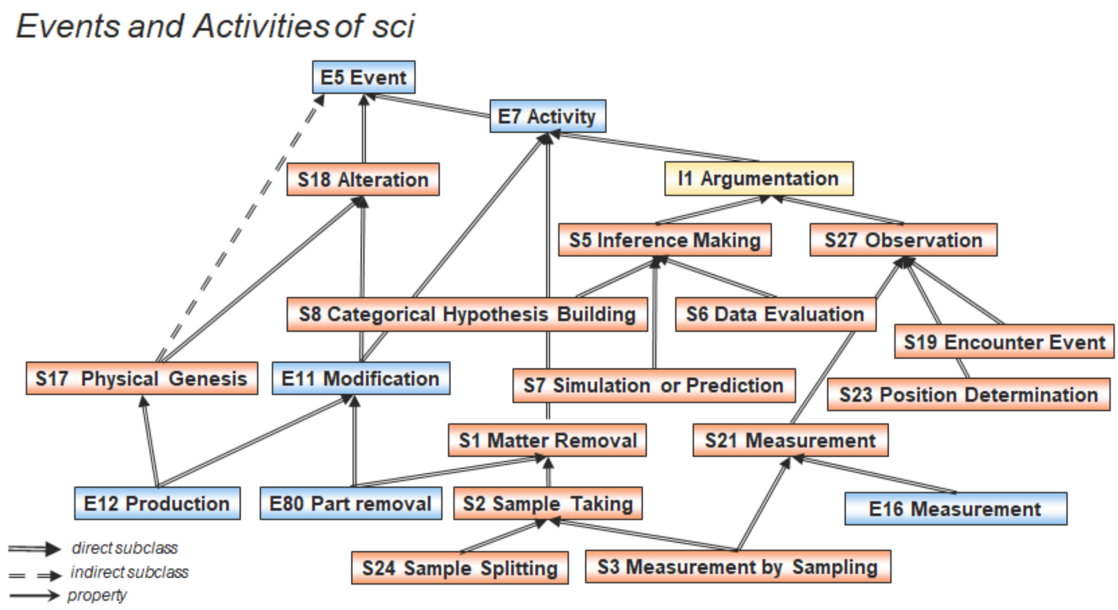

Figure 1: Subclass relations between temporal classes of the CRMsci and the CIDOC CRM **<Draft figure; pending formal approval>**

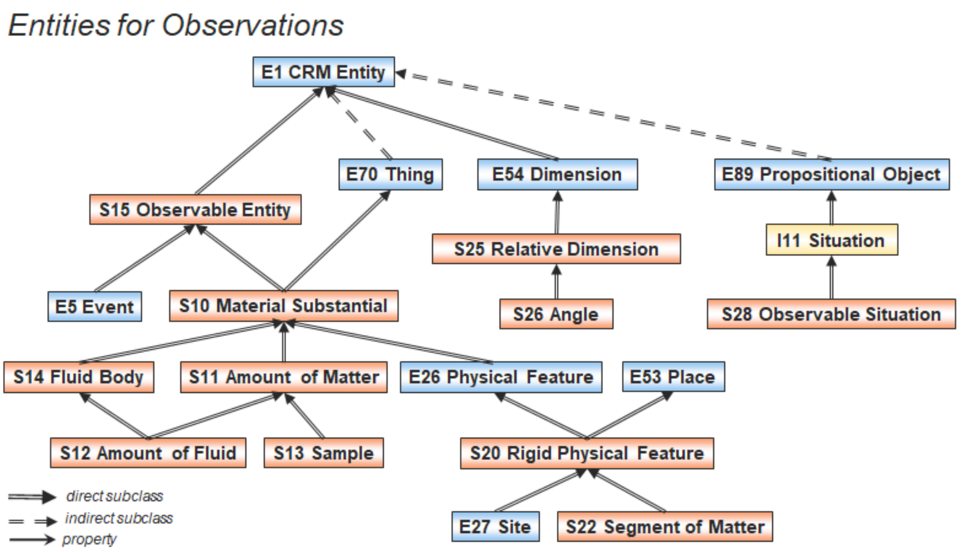

Figure 2: S15 Observable Entity and subclasses describing substance **<Draft figure; pending formal approval>**

The class S10 Material Substantial describes instances of matter which can be identified and therefore recorded. While the material things that the CIDOC CRM describes are primarily considered solid, the CRMsci can also describe material things which are not solid, such as identifiable instances of fluids and piles of earth. The class S10 Material Substantial and its subclasses S14 Fluid Body and S11 Amount of Matter can be used to describe such instances respectively.

Sampling

The process of taking a sample can be described by the class S2 Sample Taking, a specialisation of the more general class S1 Matter Removal, as shown in figure 3. The activity of sampling removes matter from something and creates a new identifiable entity which can be described as an instance of the class S13 Sample. This is similar to the CIDOC CRM construct of removing parts from solid things through the class E80 Part Removal. CRMsci generalises this construct allowing sampling of fluids and other non-solid things. During sampling it is important to record the location on the sampled thing from where the sample was taken (e.g. collecting a pigment sample from the area of a canvas where an apple was painted). This can be described using the property O4 sampled at. This is distinct to the location that the sampling activity was taking place in general (e.g. the conservation studio where the sampling was done). The location of the sampling activity contains the location from where the sample was taken. In contrast, during instances of S19 Encounter Event the two locations are the same. Partitive relationships between instances of S10 Material Substantial can be described using the property O25 contains, which generalises the CIDOC CRM property P46 is composed of used for solid things.

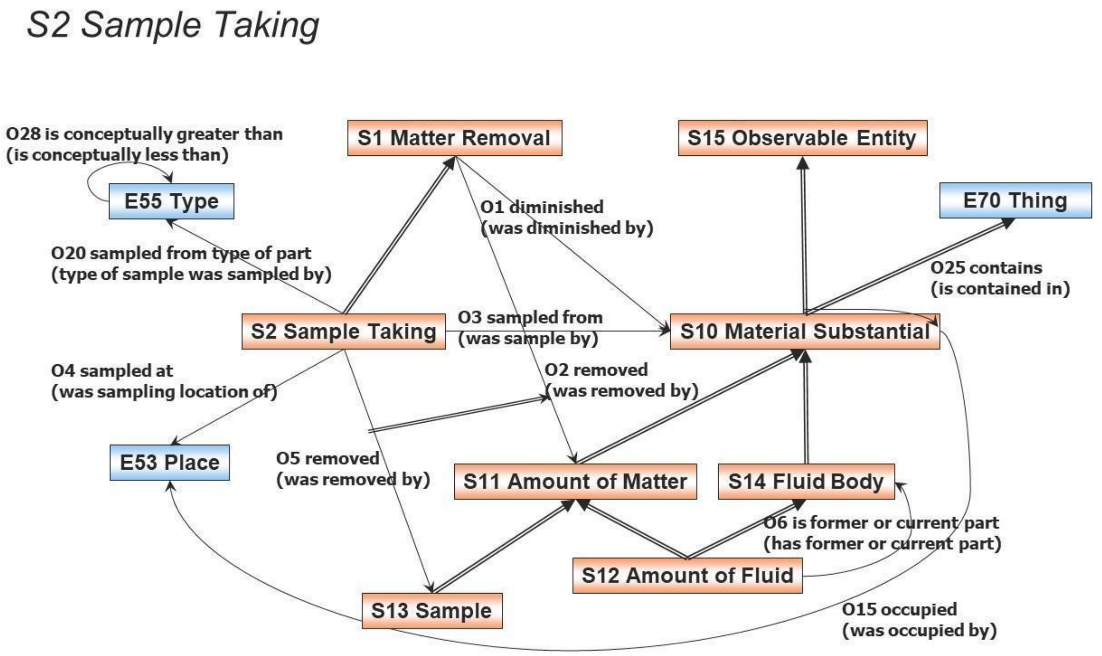

Figure 3: Classes and properties for describing the process of sampling

A special case of sampling is when a sample is split, for example, when taking a blood sample from a patient and then splitting it to use in different diagnostic tests. This can be considered as a sub-sampling activity and can be described using class S24 Sample Splitting with its subproperties mirroring the main sampling process as shown in figure 4.

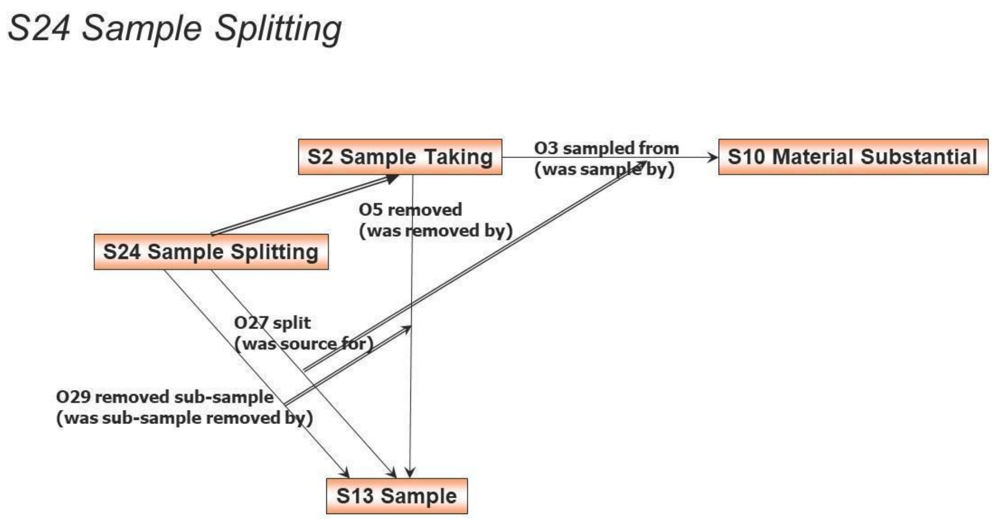

Figure 4: Classes and properties describing sample splitting

Samples are often preserved after analysis is done. In some cases, this is not possible, for example when the sample is destroyed as part of the analysis process. The class S3 Measurement by Sampling can be used to describe such cases. This class is a subclass of both S2 Sample Taking and of S21 Measurement, therefore it inherits the properties and intention of both classes, making this activity of taking a sample also a measurement (figure 5).

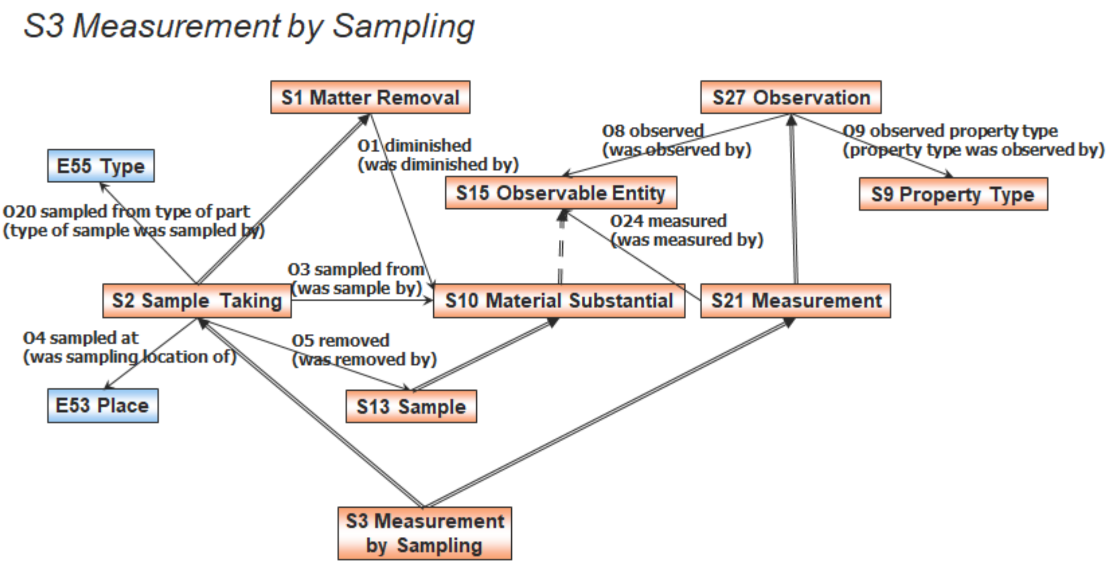

Figure 5: Extending the sampling activity for the special case of samples used solely for measurements **<Draft figure; pending formal approval>**

Alteration

In the CIDOC CRM the making of things is associated with an activity undertaken by an agent as indicated by the construct of the class E12 Production with a) its associated property P108 produced and b) its inherited property P14 carried out. The CRMsci provides classes that describe the making of things without any agents being involved. The class S17 Physical Genesis (figure 7) generalises the class E12 Production for things which materialise through natural processes, such as the making of stalactites. The class S17 Physical Genesis is a subclass of E5 Event but not E7 Activity to make clear that there is no agency associated with the event. The class S18 Alteration (figure 7) is a generalisation of the CIDOC CRM class E11 Modification, therefore it cannot be used for instances of events which generate things but only for instances of events which alter things without agency (e.g. in the case of corrosion layers appearing on a metal surface due to acidic environment).

The CIDOC CRM avoids providing constructs to imply causality of events and instead describes influence and sequence of events. The CRMsci introduces the property O13 triggered (figure 7) which can be used to describe one event being the cause for another event. The triggering event may be the last of a series of events which trigger the triggered event. The association of the two events is based on their temporal proximity, i.e. the triggering event ends when the triggered event starts. This property does not indicate overall causality between events and it should not be used for analysis of social or historical causes of events.

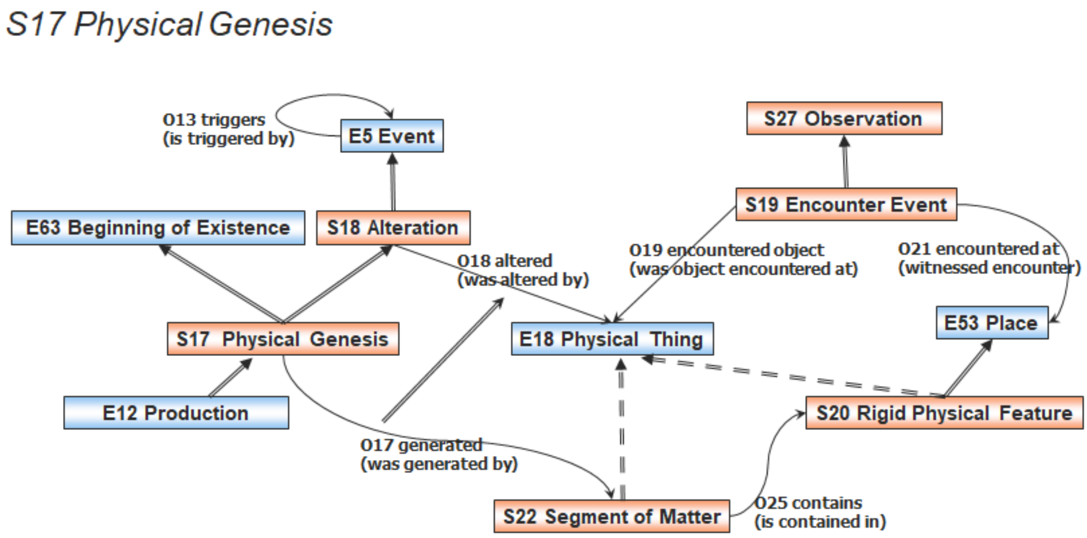

Figure 6: Events generating things without agency and causal relationships of events **<Draft figure; pending formal approval>**

Observation <TO BE UPDATED>

CRMsci offers classes and properties for describing scientific observation (figure 7). Class S4 Observation can be used for all instances of activities which provide additional evidence to add knowledge, regardless of how valuable that is considered. During an instance of S4 Observation an entity is observed and a value is assigned to a type of property that is relevant to the study. This is a specialisation of E13 Attribute Assignment from the CIDOC CRM with a parallel construct which is more generalised. The class S15 Observable Entity is superclass to both E5 Event and S10 Material Substantial to indicate that an instance of S4 Observation can observe both perdurants and endurants with a material substance or interaction.

The class S21 Measurement is a specialisation of S4 Observation and a superclass of CIDOC CRM class E16 Measurement. The class E16 Measurement can be used to measure dimensions of physical things but cannot be used for dimensions of instances of classes such as E5 Event. Class S21 Measurement is broader in scope (also see figure 1) and can be used for other instances than instances of E18 Physical Thing.

Similarly, the property O12 has dimension is equivalent to CIDOC CRM property P43 has dimension only when the observed entity is an instance of class E18 Physical Thing.

The class S19 Encounter Event can be used to describe the observation of entities of particular interest relevant to the research study. This can be used in species surveys or finds in archaeological excavations. It serves documenting the fact that someone has seen the entity of interest as existing at the particular place and time. Figure shows the relevant properties and includes a set of instances as examples from the field of ecology.

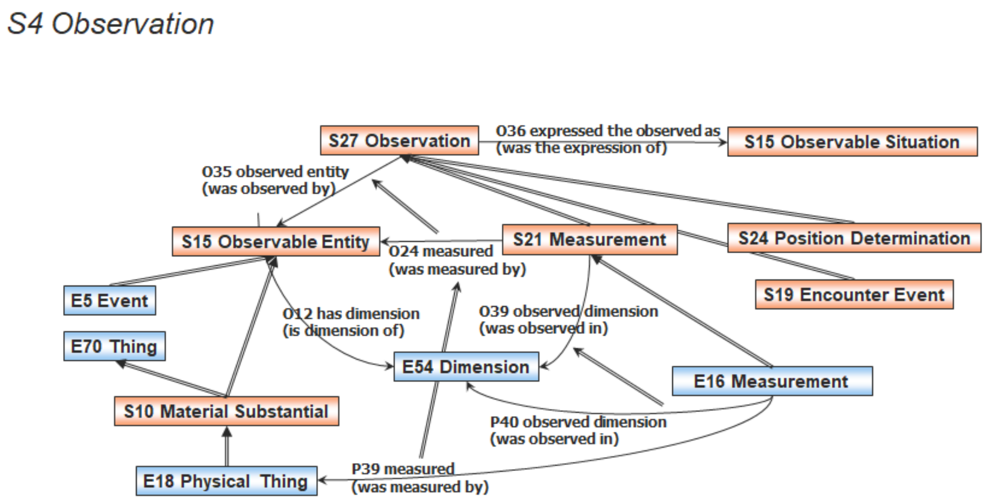

Figure 7: Classes and properties for describing scientific observation **<Draft figure; pending formal approval>**

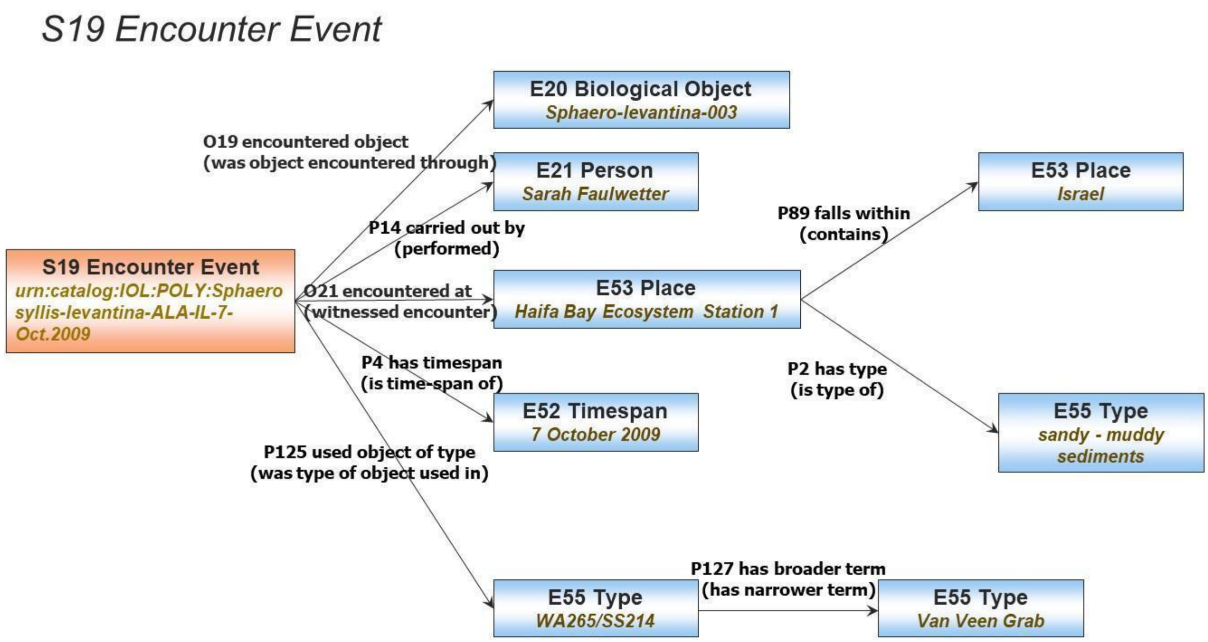

Figure 8: Classes and properties for describing the observation of an entity at a particular place and time

Determining positions <TO BE UPDATED>

A specialisation of the class S4 Observation is the class S32 Position Determination. It allows the modelling of the process of determining the position of entities based on them being observed at a location in a given time-span. The properties connecting the observable entity with time and location are shown in Figure 9.

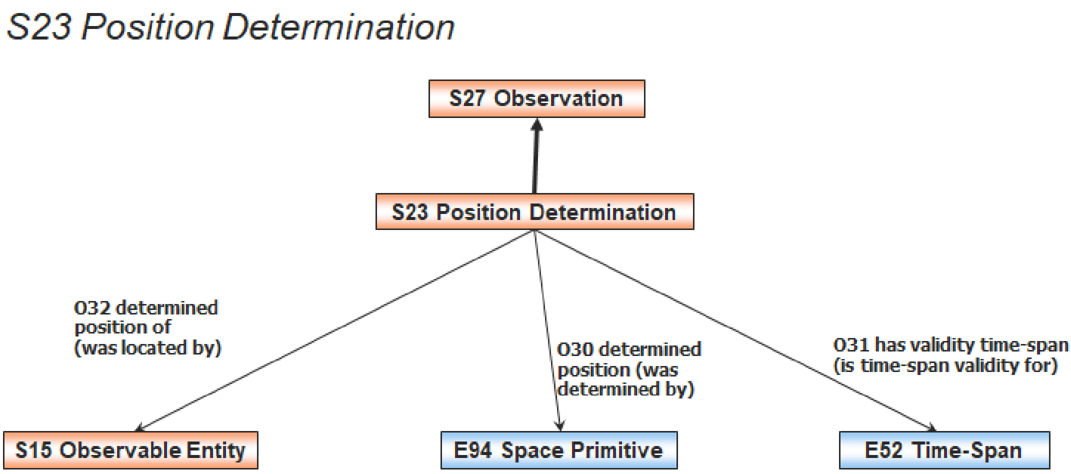

Figure 9: Classes and properties for describing determining the positions of things **<Draft figure; pending formal approval>**

Figure 10 shows an example of determining the position of the Titanic after it hit an iceberg. Before issuing a distress signal, Titanic's captain Smith determined the position of the ship based on the distance travelled from the last known position, but this determination was inaccurate. The Titanic is an instance of S15 Observable Entity and more specifically an instance of E18 Physical Thing and its spatio-temporal extent during the determination is an instance of E93 Presence. The spatial projection of this instance of E93 Presence is the actual place where the Titanic was after hitting the iceberg. Captain Smith's determination was inaccurate and the resulting latitude and longitude coordinates determined (instance of E94 Space Primitive) defined the assumed place of the ship and not the actual place. The assumed place is a separate instance of E53 Place which can only approximate the actual place. The two are connected with the property 'P189 approximates' which allows reasoning on different views of the location of things by comparing instances of E53 Place with their corresponding provenance.

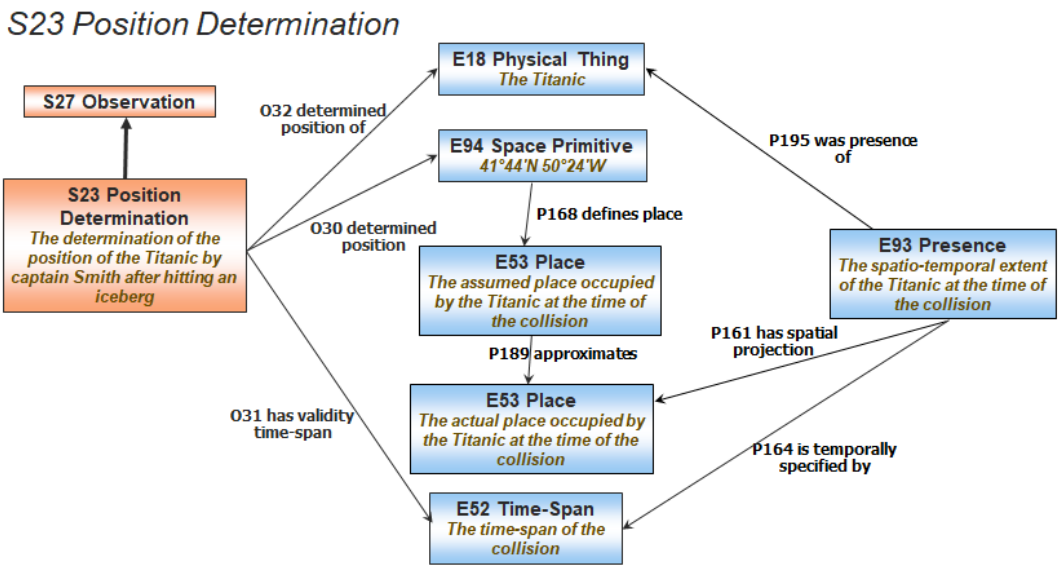

Figure 10: Example of position determination of the Titanic after it hit an iceberg **<Draft figure; pending formal approval>**

Inference making <TO BE UPDATED>

In addition to a model for scientific observation the CRMsci provides classes and properties which allow the description of processing observations to produce new knowledge. This includes inferences made during data analysis, simulation or categorisation with specialised classes as shown in figure 11. Instances of S8 Categorical Hypothesis Building are activities where the definition of categories (similar to instances of CIDOC CRM E55 Type) are created based on the current observations of the instances of these categories (inductive reasoning). Through class S5 Inference Making, it is possible to connect and take advantage of the extended model for argumentation CRMinf from version 1.2.1 (Doerr et al., 2026).

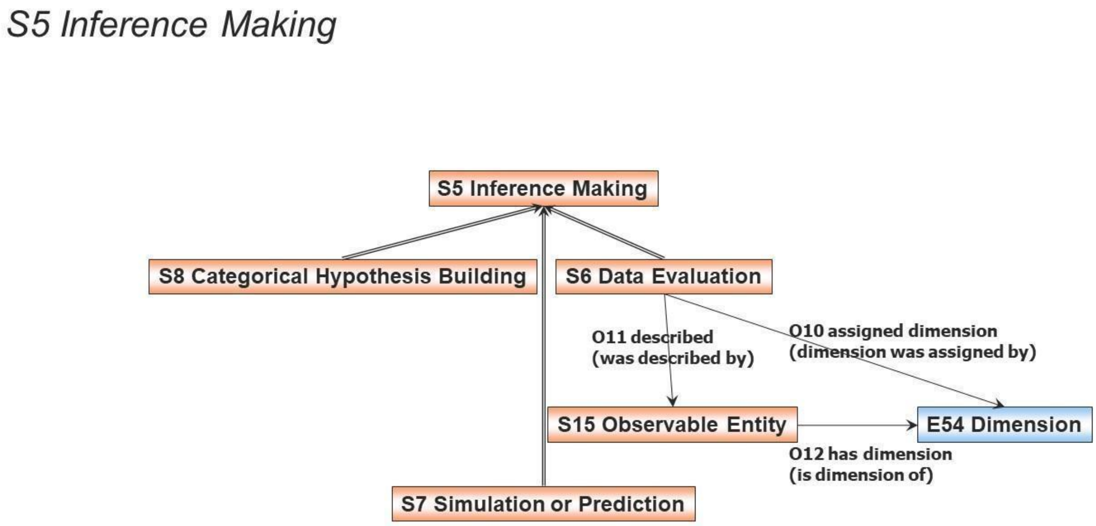

Figure 11: CRMsci classes for inference making

Status

The model presented in this document has been validated in several national and international projects, through implementations of slightly different versions together with application-specific extensions and through mapping to and from related standards. These projects include:

- InGeoCloudS - Inspired GEOdata CLOUD Services 01/02/2012 - 31/07/2014 EU FP7 PSP
- ARIADNE - Advanced Research Infrastructure for Archaeological Dataset Networking in Europe 01/02/2013 - 31/01/2017 EU FP7-INFRASTRUCTURES-2012-1
- Geosemantics for Cultural Heritage Documentation - Domain specific ontological modelling and implementation of a Cultural Geosemantic Information System based on ISO specifications 01/09/2012 - 31/08/2014 European Commission / FP7-PEOPLE-2011-IEF
- iMarine - Data e-Infrastructure Initiative for Fisheries Management and Conservation of Marine Living Resources 01/11/2011 - 30/04/2014 EU - FP7 - CP & CSA
- Standards for cultural documentation and support technologies for the integration of digital cultural repositories and systems interoperability: Studies, Prototypes and Best-practices guides14/2/2004 - 15/3/2005 EU - Op. Pr. Information Society

This document describes a consolidated version from this experience, with the aim to present it for review and further adoption. The model is not “finished”, some parts such as the subclasses of inference making are not fully developed in terms of properties, and all constructs and scope notes are open to further elaboration

CRMsci class hierarchy, aligned with portions from the CIDOC-CRM class hierarchies

This class hierarchy lists:

- all classes declared in CRMsci
- all classes declared in CRMinf version 1.2.1 and CIDOC-CRM version 7.1.3 that are declared as superclasses of classes declared in the CRMsci,
- all classes declared in CIDOC-CRM version 7.1.3 that are either domain or range for a property declared in the CRMsci,
- all classes declared in CRMinf version 1.2.1 and CIDOC-CRM version 7.1.3 that are either domain or range for a property declared in CRMinf version 1.2.1 or CIDOC CRM version 7.1.3 that is declared as superproperty of a property declared in the CRMsci,
- all classes declared in CRMinf version 1.2.1 and CIDOC-CRM version 7.1.3 that are either domain or range for a property that is part of a complete path of which a property declared in CRMsci is declared to be a shortcut.

Table 1: Class Hierarchy

E1	CRM Entity							
–	E52	Time-Span						
–	E54	Dimension						
–	–	S25	Relative Dimension					
–	–	–	S26	Angle				
–	S15	Observable Entity						
–	–	E5	Event					
–	–	–	S18	Alteration				
–	–	–	–	S17	Physical Genesis			
–	–	–	–	–	E12	Production		
–	–	–	–	E11	Modification			
–	–	–	–	–	*E12*	*Production*		
–	–	–	–	–	E80	Part Removal		
–	–	–	E63	Beginning of Existence				
–	–	–	–	*S17*	*Physical Genesis*			
–	–	–	–	–	*E12*	*Production*		
–	–	–	E7	Activity				
–	–	–	–	S1	Matter Removal			
–	–	–	–	–	S2	Sample Taking		
–	–	–	–	–	–	S3	Measurement by Sampling	
–	–	–	–	–	–	S24	Sample Splitting	
–	–	–	–	–	*E12*	*Production*		
–	–	–	–	–	*E80*	*Part Removal*		
–	–	–	–	I1	Argumentation			
–	–	–	–	–	S27	Observation		
–	–	–	–	–	–	S4	Single Observation	
–	–	–	–	–	–	–	E16	Measurement
–	–	–	–	–	–	S19	Encounter Event	
–	–	–	–	–	–	S21	Measurement	
–	–	–	–	–	–	–	*S3*	*Measurement by Sampling*
–	–	–	–	–	–	–	*E16*	*Measurement*
–	–	–	–	–	–	S23	Position Determination	
–	–	–	–	–	E13	Attribute Assignment		
–	–	–	–	–	–	*S4*	*Single Observation*	
–	–	–	–	–	–	–	*E16*	*Measurement*

– – – – – S5 Inference Making (= I5 Inference Making)
– – – – – – S6 Data Evaluation
– – – – – – S7 Simulation or Prediction
– – – – – – S8 Categorical Hypothesis Building
– – – – – *E11 Modification*
– – – – – – *E12 Production*
– – – – – – *E80 Part Removal*
– – S10 Material Substantial
– – – S11 Amount of Matter
– – – – S12 Amount of Fluid
– – – – S13 Sample
– – – S14 Fluid Body
– – – – *S12 Amount of Fluid*
– – – E18 Physical Thing
– – – – E26 Physical Feature
– – – – – S20 Rigid Physical Feature
– – – – – – S22 Segment of Matter
– – – – – – E27 Site
– *E77 Persistent Item*
– – *E70 Thing*
– – – *S10 Material Substantial*
– – – – *S11 Amount of Matter*
– – – – – *S12 Amount of Fluid*
– – – – – *S13 Sample*
– – – – *S14 Amount of Fluid*
– – – – – *S12 Amount of Fluid*
– – – – *E18 Physical Thing*
– – – – – *E26 Physical Feature*
– – – – – – *S20 Rigid Physical Feature*
– – – – – – – *S22 Segment of Matter*
– – – – – – – *E27 Site*
– – – – E71 Human-Made Thing
– – – – – E28 Conceptual Object
– – – – – – E55 Type
– – – – – – – S9 Property Type
– – – – – – E89 Propositional Object
– – – – – – – I4 Proposition Set
– – – – – – – – I11 Situation
– – – – – – – – – S28 Observable Situation
– – – – – – – – – – S29 Observable Proposition
– – – – – – – – – I17 One-Proposition Set
– – – – – – – – – – *S29 Observable Proposition*
– – – – – – E90 Symbolic Object
– – – – – – – E41 Appellation
– – – – – – – – E94 Space Primitive
– E53 Place
– – *S20 Rigid Physical Feature*
– – – *S22 Segment of Matter*
– – – *E27 Site*
– E59 Primitive Value
– – *E94 Space Primitive*

List of external classes used in CRMsci

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
E1	CRM-Entity	CIDOC CRM	7.1.3
E5	Event	CIDOC CRM	7.1.3
E7	Activity	CIDOC CRM	7.1.3
E11	Modification	CIDOC CRM	7.1.3
E12	Production	CIDOC CRM	7.1.3
E13	Attribute Assignment	CIDOC CRM	7.1.3
E16	Measurement	CIDOC CRM	7.1.3
E18	Physical Thing	CIDOC CRM	7.1.3
E26	Physical Feature	CIDOC CRM	7.1.3
E27	Site	CIDOC CRM	7.1.3
E28	Conceptual Object	CIDOC CRM	7.1.3
E41	Appellation	CIDOC CRM	7.1.3
E52	Time-Span	CIDOC CRM	7.1.3
E53	Place	CIDOC CRM	7.1.3
E54	Dimension	CIDOC CRM	7.1.3
E55	Type	CIDOC CRM	7.1.3
E59	Primitive Value	CIDOC CRM	7.1.3
E63	Beginning of Existence	CIDOC CRM	7.1.3
E70	Thing	CIDOC CRM	7.1.3
E71	Human-Made Thing	CIDOC CRM	7.1.3
E80	Part Removal	CIDOC CRM	7.1.3
E89	Propositional Object	CIDOC CRM	7.1.3
E90	Symbolic Object	CIDOC CRM	7.1.3
E94	Space Primitive	CIDOC CRM	7.1.3
I1	Argumentation	CRMinf	1.2.1
I4	Proposition Set	CRMinf	1.2.1
I11	Situation	CRMinf	1.2.1
I17	One-Proposition Set	CRMinf	1.2.1

CRMsci property hierarchy, aligned with portions from the CRMinf and the CIDOC-CRM property hierarchies

This property hierarchy lists:

- all properties declared in CRMsci,
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- all properties declared in CRMinf version 1.2.1, and CIDOC-CRM version 7.1.3 that are part of a complete path of which a property declared in CRMsci, is declared to be a shortcut.

Table 3: Property Hierarchy

Property id	**Property Name**	**Entity – Domain**	**Entity - Range**
O1	diminished (was diminished by)	S1 Matter Removal	S10 Material Substantial
P112	- diminished (was diminished by)	E80 Part Removal	E18 Physical Thing
O2	removed (was removed by)	S1 Matter Removal	S11 Amount of Matter
O5	- removed (was removed by)	S2 Sample Taking	S13 Sample
O29	- - removed sub-sample (was sub-sample removed by)	S24 Sample Splitting	S13 Sample
O3	sampled from (was sample by)	S2 Sample Taking	S10 Material Substantial
O27	- split (was source for)	S24 Sample Splitting	S13 Sample
O4	sampled at (was sampling location of)	S2 Sample Taking	E53 Place
O7	confines (is confined by)	S20 Rigid Physical Feature	S10 Material Substantial
P140	assigned attribute to (was attributed by)	E13 Attribute Assignment	E1 CRM Entity
O8	- observed (was observed by)	S4 Single Observation	S15 Observable Entity
P39	- - measured (was measured by)	E16 Measurement	E18 Physical Thing
O35	observed entity (was observed by)	S27 Observation	S15 Observable Entity
O8	*- observed (was observed by)*	*S4 Single Observation*	*S15 Observable Entity*
P39	*- - measured (was measured by)*	*E16 Measurement*	*E18 Physical Thing*
O24	- measured (was measured by)	S21 Measurement	S15 Observable Entity
P39	- - measured (was measured by)	E16 Measurement	E18 Physical Thing
O32	- determined position of (was located by)	S23 Position Determination	S15 Observable Entity
P177	assigned property of type (is type of property assigned)	E13 Attribute Assignment	E55 Type
O9	- observed property type (property type was observed by)	S4 Single Observation	S9 Property Type
P141	assigned (was assigned by)	E13 Attribute Assignment	E1 CRM Entity
O10	- assigned dimension (dimension was assigned by)	S6 Data Evaluation	E54 Dimension
O16	- observed value (value was observed by)	S4 Single Observation	E1 CRM Entity
P40	- - observed dimension (was observed in)	E16 Measurement	E54 Dimension
O11	described (was described by)	S6 Data Evaluation	S15 Observable Entity
O12	has dimension (is dimension of)	S15 Observable Entity	E54 Dimension
O33i	-. has relative dimension (is relative to)	S15 Observable Entity	S25 Relative Dimension
O34i	- - is vertex of (has vertex)	S15 Observable Entity	S26 Angle
O13	triggered (was triggered by)	E5 Event	E5 Event
O15	occupied (was occupied by)	S10 Material Substantial	E53 Place
P156	- occupies (is occupied by)	E18 Physical Thing	E53 Place
P141	*assigned (was assigned by)*	*E13 Attribute Assignment*	*E1 CRM Entity*
O16	*- observed value (value was observed*	*S4 Single Observation*	*E1 CRM Entity*

	by)		
P40	*- - observed dimension (was observed in)*	*E16 Measurement*	*E54 Dimension*
O18	altered (was altered by)	S18 Alteration	E18 Physical Thing
O17	- generated (was generated by)	S17 Physical Genesis	E18 Physical Thing
P108	- - has produced (was produced by)	E12 Production	E24 Physical Human-Made Thing
P31	- has modified (was modified by)	E11 Modification	E18 Physical Thing
P12	occurred in the presence of (was present at)	E5 Event	E77 Persistent Item
O19	- encountered object (was object encountered through)	S19 Encounter Event	E18 Physical Thing
O20	sampled from type of part (type of part was sampled by)	S2 Sample Taking	E55 Type
O21	encountered at (witnessed encounter)	S19 Encounter Event	E53 Place
O23	is defined by (defines)	S22 Segment of Matter	E92 Spacetime Volume
O25	contains (is contained in)	S10 Material Substantial	S10 Material Substantial
O6	- is former or current part of (has former or current part)	S12 Amount of Fluid	S14 Fluid Body
P46	- is composed of (forms part of)	E18 Physical Thing	E18 Physical Thing
O28	is conceptually greater than (is conceptually less than)	E55 Type	E55 Type
O30	determined position (was determined by)	S23 Position Determination	E94 Space Primitive
P4	has time-span (is time-span of)	E2 Temporal Entity	E52 Time-Span
O31	- has validity time-span (is time-span validity for)	S23 Position Determination	E52 Time-Span
O36	expressed the observed as (was the expression of)	S27 Observation	S28 Observable Situation
O37	- expressed the observed as observable proposition (was observable proposition)	S4 Single Observation	S29 Observable Proposition
P67	refers to (is referred to by)	E89 Proposition Object	E1 CRM Entity
J28	- contains entity reference (is referred to in)	I4 Proposition Set	E1 CRM Entity
O40	- - refers to observable entity (is referred to in)	S28 Observable Situation	S15 Observable Entity
O38	- - - has domain (is domain of)	S29 Observable Proposition	S15 Observable Entity
O39	observed dimension (was observed in)	S21 Measurement	E54 Dimension
P40	*- observed dimension (was observed in)*	*E16 Measurement*	*E54 Dimension*
O41	measured dimension (was measured in)	S23 Position Determination	S25 Relative Dimension
O42	used result of (results contributed to)	S23 Position Determination	S27 Observation

List of external properties used in CRMsci

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
P4	has time-span (is time-span of)	CIDOC CRM	7.1.3
P12	occurred in the presence of (was present at)	CIDOC CRM	7.1.3
P31	has modified (was modified by)	CIDOC CRM	7.1.3
P39	measured (was measured by)	CIDOC CRM	7.1.3
P40	observed dimension (was observed in)	CIDOC CRM	7.1.3
P108	has produced (was produced by)	CIDOC CRM	7.1.3
P112	diminished (was diminished by)	CIDOC CRM	7.1.3
P140	assigned attribute to (was attributed by)	CIDOC CRM	7.1.3
P141	assigned (was assigned by)	CIDOC CRM	7.1.3
P156	occupies (is occupied by)	CIDOC CRM	7.1.3
P177	assigned property of type (is type of property assigned)	CIDOC CRM	7.1.3
J28	contains entity reference (is referred to in)	CRMinf	1.2.1

Compatibility note for CRMsci version 3.2

CRMsci v3.2 is compatible with the RDF implementation of CIDOC CRM v7.1.3.

However, CRMsci is not compatible with the quantification "(1,n:0,n)" of the CIDOC CRM v7.1.3 property:

- P40 observed dimension (was observed in),

when this property is used more than once for the same instance of E16 Measurement, because the shortcut property O39 measured (was measured by) is declared with the quantification "(1,1:0,n)". Consequently, querying via S21 Measurement may create ambiguities regarding the correspondence between the instance of E16 Measurement and the respective observed dimensions.

The resulting RDF expressions may create ambiguity regarding the relation between the instance of E18 Physical Thing measured and the observed instance of E54 Dimension, when queried via S21. Such ambiguity, however, is intrinsic to CIDOC CRM v7.1.3 itself due to the cardinality of O39 measured (was measured by), and is not introduced specifically by CRMsci v3.2.

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CRMsci Class Declarations

S1 Matter Removal

Subclass of:

E7 Activity

Superclass of:

S2 Sample Taking
E80 Part Removal

Scope note:

This class comprises the activities that result in an instance of S10 Material Substantial being decreased by the removal of an amount of matter.

Typical scenarios include the removal of a component or piece of a physical object, removal of an archaeological or geological layer, taking a tissue sample from a body or a sample of fluid from a body of water. The removed matter may acquire a persistent identity of different nature beyond the act of its removal, such as becoming a physical object in the narrower sense. Such cases should be modelled by using multiple instantiation with adequate concepts of creating the respective items.

Examples:

- the removal of the layer of black overpainting that covered the background of 'La Gioconda of the Prado' between 2011 and 2012 by the Prado Museum in Madrid (Museo del Prado, 2012)

In first-order logic:

S1(x) ⇒ E7(x)
E80(x) ⇒ S1(x)

Properties:

O1 diminished (was diminished by): S10 Material Substantial
O2 removed (was removed by): S11 Amount of Matter

S2 Sample Taking

Subclass of:

S1 Matter Removal

Superclass of:

S3 Measurement by Sampling
S24 Sample Splitting

Scope note:

This class comprises the activity that results in taking an amount of matter as sample for further analysis from a material substantial such as a body of water, a geological formation, or an archaeological object. The removed matter may acquire a persistent identity of different nature beyond the act of its removal, such as becoming a physical object in the narrower sense. The sample is typically removed from a physical feature which is used as a frame of reference, the place of sampling. In case of a non-rigid Material Substantial, the source of sampling need not be modified by the activity of sample taking.

Examples:

- the water sampling carried out by IGME, sampled from borehole 10/G5 at 419058.03, 4506565, 95.7 Mygdonia basin on 28/6/2005 (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- the collection of specimen 'FHO – Benth. - 1055' from a plant of the species 'spiciformis' in Zambia by Bullock, A.A. in 1939)
- the collection of micro-sample 7, from the paint layer on the area of the apple shown on the painting 'Cupid complaining to Venus' (Cranach) by Joyce Plesters in June 1963 (The National Gallery, London, 1963)

In first-order logic:

S2(x) ⇒ S1(x)

Properties:

O3 sampled from (was sample by): S10 Material Substantial
O4 sampled at (was sampling location of): E53 Place
O5 removed (was removed by): S13 Sample
O20 sampled from type of part (type of part was sampled by): E55 Type

S3 Measurement by Sampling

Subclass of:

S2 Sample Taking
S21 Measurement

Superclass of:

Scope note:

This class comprises activities of taking a sample and measuring or analysing it as one unit of activity, in which the sample is typically not identified and preserved beyond the context of this activity. Instances of this class describe the taking of one or more samples regardless whether they are explicitly identified in documentation or preserved beyond this activity. The dimensions observed by the respective measurement of this particular sample are regarded as dimensions of the instance of S10 Material Substantial at the place from which the samples were taken. Therefore, the class S3 Measurement by Sampling inherits the properties of S2 Sample Taking *O3 sampled from (was sample by)*: S10 Material Substantial and *O4 sampled at (was sampling location of)*: E53 Place, and the properties of S21 Measurement *O24 measured (was measured by)*: S15 Observable Entity.

It needs not instantiate the properties *O5 removed (was removed by)*: S13 Sample and *O24 measured (was measured by)*: S15 Observable Entity, if the sample is not documented beyond the context of the activity.

Examples:

- the chemical analysis 1 on 20/4/2004 which sampled from layer 50501 and observed 70 mg of Ca (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- the Sphaerosyllislevantina specimen length measurement on 12/3/1999 (Bekiari et al., 2014)
- the measurement of retention times during Gas Chromatography analysis of a paint sample 'mid-blue paint for the sky' which identified Linseed oil as the paint medium (Foister, 2015)

In first-order logic:

S3(x) ⇒ S2(x)
S3(x) ⇒ S21(x)

Properties:

S4 Single Observation

Subclass of:

S27 Observation
E13 Attribute Assignment

Superclass of:

E16 Measurement

Scope note:

This class comprises the activity of gaining scientific knowledge about particular states of physical reality through empirical evidence, experiments, or measurements, for cases in which the observed knowledge can be described by a single binary proposition relating one instance of S15 Observable Entity to some instance of E1 CRM Entity.

Examples:

- the observation of the density of the X-Ray image of cupid's head from the painting ‘Cupid complaining to Venus’ as ‘high density’, on the 19th of March 1963 (The National Gallery, London, 1963)
- the observation of visible light absorption of the painting ‘Cupid complaining to Venus’ as ‘having red pigment’ in 2015 (Foister, 2015)

In first-order logic:

S4(x) ⇒ S27(x)
S4(x) ⇒ E13(x)
E16(x) ⇒ S4(x)

Properties:

O8 observed (was observed by): S15 Observable Entity
O9 observed property type (was property type observed): S9 Property Type
O16 observed value (value was observed by): E1 CRM Entity
O37 expressed the observed as observable proposition (was observable proposition observed by): S29 Observable Proposition

S5 Inference Making (same as I5 Inference Making)

Subclass of:

I1 Argumentation

Superclass of:

S6 Data Evaluation
S7 Simulation or Prediction
S8 Categorical Hypothesis Building

Scope note:

This class comprises the action of making propositions and statements about particular states of affairs, in reality or in possible realities, or categorical descriptions of reality by using inferences from other statements based on hypotheses and any form of formal or informal logic. It includes evaluations, calculations, and interpretations based on mathematical formulations and propositions.

Examples:

- the inference made by Sakellarakis in 1980 about the sacrifice of a young man in the Minoan temple of Anemospilia based on the skeleton found (and 2 more) in the west room of the temple and the ritual bronze knife on it and the hypothesis that he died from loss of blood [the evidence was that his bones remained white in contrast to the others] (Sakellarakis and Sapouna-Sakellaraki, 1981)
- the inference that the underdrawing of the painting ‘Cupid complaining to Venus’ was done with red pigment, based on the observation that red pigment lines appear under the top paint layers (Foister, 2015)

In first-order logic:

S5(x) ⇔ I1(x)

Properties:

S6 Data Evaluation

Subclass of:

S5 Inference Making

Superclass of:

Scope note:

This class comprises the action of concluding propositions on a respective reality from observational data by making evaluations based on mathematical inference rules and calculations using established hypotheses, such as the calculation of an earthquake epicentre. S6 Data Evaluation is distinct from both S21 Measurement and E16 Measurement; Secondary derivations of dimensions of an object from data measured by different processes are regarded as S6 Data Evaluation and not determining instances of Measurement in its own right. For instance, the volume of a statue concluded from a 3D model is an instance of S6 Data Evaluation and not of Measurement.

Examples:

- the calculation of the earthquake epicentre of Lokris area in 1989 by IGME (Ganas et al., 2006)
- the calculation of the intensity distance and assignment of PGA_N using the gcf2sac software from the EPPO shock wave recording of 2/2/1990 in Athens (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- the calculation of the overall height of the statue of Hercules in the Temple of Hercules in Amman from the measurement of the size of the fragment of the fingers (‘Temple of Hercules (Amman)’, 2025)
- Samuel Halpern’s 2007 determination of the position of the Titanic at the time of the collision (S6) [based on the position of the ship-wreck] (Halpern, 2007)

In first-order logic:

S6(x) ⇒ S5(x)

Properties:

O10 assigned dimension (dimension was assigned by): E54 Dimension
O11 described (was described by): S15 Observable Entity

S7 Simulation or Prediction

Subclass of:

S5 Inference Making

Superclass of:

Scope note:

This class comprises activities of executing algorithms or software for simulating the behaviour and the properties of a system of interacting components that form part of reality or not by using a mathematical model of the respective interactions. In particular, it implies making predictions about the future behaviours of a system of interacting components of reality by starting simulation from an actually observed state, such as weather forecasts. Simulations may also be used to understand the effects of a theory, to compare theoretical predictions with reality, or to show differences with another theory.

Examples:

- the forecasting of the imminent flooding of Venice in November 2012 by the Hellenic Centre for Marine Research using the Poseidon Sea Level Forecast System, 72 hours before its actual occurrence (slide 18 in Kores et al., 2013)
- predicting the required temperature to maintain a target RH (%) of 50, based on monthly average temperature and RH in Birmingham, UK [using the 'Calculator for conservation heating'] (Padfield, no date)

In first-order logic:

S7(x) ⇒ S5(x)

Properties:

S8 Categorical Hypothesis Building

Subclass of:

S5 Inference Making

Superclass of:

Scope note:

This class comprises the action of making categorical hypotheses based on inference rules and theories; By categorical hypotheses we mean assumptions about the kinds of interactions and related kinds of structures of a domain that have the character of "laws" of nature or human behaviour, be it necessary or probabilistic. Categorical hypotheses are developed by "induction" from finite numbers of observations and the absence of observations of some particular kind. As such, categorical hypotheses are always subject to falsification by new evidence. Instances of S8 Categorical Hypothesis Building include making and questioning categorical hypotheses.

Examples:

- hypothesising that "no binding before the 9th century is made with spine supports" by Szirmai [documented in section 7.1 and 7.2 of "The Archaeology of Medieval bookbinding"] (Szirmai, 1999)

In first-order logic:

S8(x) ⇒ S5(x)

Properties:

S9 Property Type

Subclass of:

E55 Type

Superclass of:

Scope note:

This class comprises properties. Typically, instances of S9 Property Type would be taken from an ontology or terminological system. In particular, instances of this class can be used to describe in a parametric way what kind of properties the values in scientific data sets are about. By virtue of such descriptions, numeric data can be interpreted as sets of propositions in terms of a formal ontology, such as "concentration of nitrate", observed in the ground water from a certain borehole.

Examples:

- the velocity (of a station that is observed, meaning a share-wave velocity over the first 30 m). (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- the retention time [in gas chromatography, meaning the time it takes for a component to pass through the chromatographer's column] ('Gas chromatography', 2025)

In first-order logic:

$S9(x) \Rightarrow E55(x)$

Properties:

S10 Material Substantial

Subclass of:

S15 Observable Entity
E70 Thing

Superclass of:

S11 Amount of Matter
S14 Fluid Body
E18 Physical Thing

Scope note:

This class comprises constellations of matter with a relative stability of any form sufficient to associate them with a persistent identity, such as being confined to certain extent, having a relative stability of form or structure, or containing a fixed amount of matter. In particular, it comprises physical things in the narrower sense and fluid bodies. It is an abstraction of physical substance for solid and non-solid things of matter.

Examples:

- the groundwater of the 5-22 basin of Central Macedonia (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- the Mesozoic carbonate sequence with flysch extracted from the area of Nafplion that was mapped and studied by Tattaris in 1970 (Photiades, 2010)
- Parnassos, the limestone mountain (Strid, 1986)

In first-order logic:

S10(x) ⇒ E70(x)
S10(x) ⇒ S15(x)
E18(x) ⇒ S10(x)

Properties:

O25 contains (is contained in): S10 Material Substantial
O15 occupied (was occupied by): E53 Place

S11 Amount of Matter

Subclass of:

S10 Material Substantial

Superclass of:

S12 Amount of Fluid
S13 Sample

Scope note:

This class comprises fixed amounts of matter specified as some air, some water, some soil, etc., defined by the total and integrity of their material content. In order to be able to identify and recognize in practice one instance of S11 Amount of Matter, some sort of confinement is needed that serves as a constraint for the enclosed matter and the integrity of the content, such as a bottle. In contrast to instances of E18 Physical Thing, no stability of form is required. The content may be put into another bottle without losing its identity. Subclasses may define very different identity conditions for the integrity of the content, such as chemical composition, or the sequence of layers of a bore core. Whereas an instance of E18 Physical Thing may gradually change form and chemical composition while preserving its identity, such as living beings, an instance of S11 Amount of Matter may lose its identifying features by such processes. What matters for the identity of an instance of S1 Amount of Matter is the preservation of a relevant composition from the initial state of definition onwards.

Examples:

- the mass of soil that was removed from sections 1, 2, 3 and 4 of the central building of Zominthos in order to be sieved, during the excavation in 2006 (Archaeological Institute of America, 2006)
- the amount of natural cement that was added in a proportion of 5% in 2016 for the development of the sample of mortar in the laboratory of Ceramic, in Boumerdes University (Kelouaz et al., 2016)

In first-order logic:

S11(x) ⇒ S10(x)

Properties:

S12 Amount of Fluid

Subclass of:

S11 Amount of Matter
S14 Fluid Body

Superclass of:

Scope note:

This class comprises fixed amounts of fluid (be they gas or liquid) defined by the total of its material content, typically molecules. They frequently acquire identity in laboratory practice by the fact of being kept or handled together within some adequate containers.

Examples:

- J.K.'s blood sample 0019FCF5 for the measurement of the cholesterol blood level (fictitious)
- the ground water sample with ID 105293 that was extracted from the top level of the intake No32 under terrain (S12, S13) (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)

In first-order logic:

S12(x) ⇒ S11(x)
S12(x) ⇒ S14(x)

Properties:

O6 is former or current part (has former or current part): S14 Fluid Body

S13 Sample

Subclass of:

S11 Amount of Matter

Superclass of:

Scope note:

This class comprises instances of S11 Amount of Matter taken from some instance of S10 Material Substantial with the intention to be representative for some material qualities of the instance of S10 Material Substantial or part of it was taken for further analysis. We typically regard a sample as ceasing to exist when the respective representative qualities become corrupted, such as the purity of a water sample or the layering of a bore core.

Examples:

- the ground water sample with ID 105293 that was extracted from the top level of the intake No32 under terrain (S13, S12) (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- the micro-sample 7, taken from the painting 'Cupid complaining to Venus' (Cranach) by Joyce Plesters in June, 1963 (The National Gallery, London, 1963)

In first-order logic:

S13(x) ⇒ S11(x)

Properties:

S14 Fluid Body

Subclass of:

S10 Material Substantial

Superclass of:

S12 Amount of Fluid

Scope note:

This class comprises a mass of matter in fluid form environmentally constraint in some persistent form allowing for identifying it for the management or research of material phenomena, such as a part of the sea, a river, the atmosphere or the milk in a bottle. Fluids are generally defined by the continuity criterion which is characteristic of their substance: their amorphous matter is continuous and tends to flow. Therefore, contiguous amounts of matter within a fluid body may stay contiguous or at least be locally spatially confined for a sufficiently long time in order to be temporarily identified and traced. This is a much weaker concept of stability of form than the one we would apply to what one would call a physical object. In general, an instance of Fluid Body may gain or lose matter over time through so-called sources or sinks in its surface, in contrast to physical things, which may lose or gain matter by exchange of pieces such as spare parts or corrosion.

Examples:

- the Rhine River

In first-order logic:

$S14(x) \Rightarrow S10(x)$

Properties:

S15 Observable Entity

Subclass of:

E1 CRM Entity

Superclass of:

S10 Material Substantial
E5 Event

Scope note:

This class comprises instances of E5 Event or S10 Material Substantial (i.e. items or phenomena, such as physical things, their behaviour, states and interactions or events), that can be observed by measurement or detection devices or by human sensory impression including when enhanced by tools.

In order to be observable, instances of E5 Event must consist of some interaction or action of material substance. In some cases, the spatiotemporal confinement of the event itself, such as a flash, a car stopping etc. marks the limits of a documented observation of an event. In other cases, such as the situation of a car passing by a certain object, the spatiotemporal limits of the event of observing itself, as well as the direction of attention or the orientation of used instruments, may constrain the observed detail of a larger process, e.g., noticing the sight of a car passing by; a light emission, etc.

Conceptual objects manifest through their carriers such as books, digital media, or even human memory. Attributes of conceptual objects, such as number of words, can be observed on their carriers. If the respective properties between carriers differ, either they carry different instances of conceptual objects or the difference can be attributed to accidental deficiencies in one of the carriers. In that sense, even immaterial objects are observable. By this model we address the fact that frequently, the actually observed carriers of conceptual objects are not explicitly identified in documentation, i.e., they are assumed to have existed but they are unknown as individuals.

Examples:

- the domestic goose from Guangdong/1/1996 (H5N1) that was identified in 1996 in farmed geese in southern China as circulating highly pathogenic H5N1 (E20) (Wan, 2012)
- the flight of a male Bearded Vulture observed near Loukia, Heraklion, Crete in the morning of the 24th of October 2020 (E5) [The Bearded Vulture (Gypaetus Barbatus) is a threatened species in Crete] (Claes, 2020)
- the eruption of Krakatoa volcano at Indonesia in 1883 (E5) (Symons et al., 1888)
- the cupid head area in the X-Ray of the painting ‘Cupid complaining to Venus’ (E25) (The National Gallery, London, 1963)
- Earth's magnetic field (S15) [a magnetic field is neither S10 nor E5]

In first-order logic:

S15(x) ⇒ E1(x)
E5(x) ⇒ S15(x)

Properties:

O12 has dimension (is dimension of): E54 Dimension

S17 Physical Genesis

Subclass of:

E63 Beginning of Existence
S18 Alteration

Superclass of:

E12 Production

Scope note:

This class comprises events or processes that result in (generate) physical things, man-made or natural, coming into being in the form by which they are later identified. The creation of a new physical item, at the same time, can be a result of an alteration (modification) – it can become a new thing due to an alteration activity.

Examples:

- the desertification process affecting my copper samples in the artificial aging salt-spray apparatus after 10 cycles which produced layers of cuprite and malachite (E12)
- the corrosion process affecting my copper samples in the artificial aging salt-spray apparatus after 10 cycles which produced layers of cuprite and malachite (E12)

In first-order logic:

S17(x) ⇒ S18(x)
S17(x) ⇒ E63(x)
E12(x) ⇒ S17(x)

Properties:

O17 generated (was generated by): E18 Physical Thing

S18 Alteration

Subclass of:

E5 Event

Superclass of:

S17 Physical Genesis
E11 Modification

Scope note:

This class comprises natural events or man-made processes that create, alter or change physical things, by affecting permanently their form or consistency without changing their identity. Examples include alterations on depositional features-layers by natural factors or disturbance by roots or insects, organic alterations, petrification, etc.

Examples:

- the petrification process of the Lesvos forest related to the intense volcanic activity in Lesvos island during late Oligocene - middle Miocene period (Marinos, 1997)
- the flattening of the Lanhydrock Pedigree parchment after humidification (E11) (Pickwoad, 2016)

In first-order logic:

S18(x) ⇒ E5(x)
E11(x) ⇒ S18(x)

Properties:

O18 altered (was altered by): E18 Physical Thing

S19 Encounter Event

Subclass of:

S27 Observation

Superclass of:

Scope note:

This class comprises activities of Observation (S27) (substance) where an Actor (E39) encounters an instance of E18 Physical Thing, of a kind relevant for the mission of the observation or regarded as potentially relevant for some community (identity). This observation produces knowledge about the existence of the respective thing at particular place in, or on, surrounding matter. This knowledge may be new to the group of people the actor belongs to. In that case, we would talk about discovery. The observer may recognize or assign an individual identity of the thing encountered, or regard only the type as noteworthy in the associated documentation or report.

In Archaeology, there is a particular interest if an object is found "in situ", i.e., if its embedding in the surrounding matter supports the assumption that the object was not moved since the archaeologically relevant deposition event. The surrounding matter with the relative position of the object in it, as well as the absolute position and time of the observation may be recorded to enable inferences about the history of the object.

In Biology, additional parameters may be recorded – like the kind of ecosystem, if the biological individual survives the observation, what detection or catching devices have been used, or if the encounter event supported the detection of a new biological kind ("taxon").

Examples:

- the finding, by Nikolaos Stampolidis, of a complete skeleton, in situ, at the site of Eleutherna during the archaeological excavation carried out by the University of Crete in 2007 (Bonn-Muller, 2010)
- the detection of *Lagocephalos_Sceleratus* was carried out with the trawler 419 in the Mediteranean sea, during the first week of August 2014 (S19) (Bekiari et al., 2014)
- the encounter of the marble floor of the Villa of the Papyri in Herculaneum during the digging of a well in 1750 (Sider, 1990)

- the encounter of oak planks from a ship during a dig in a mound at the farm Lille Oseberg in Norway in 1908 (Ferguson, 2009, 2012)

In first-order logic:

S19(x) ⇒ S27(x)

Properties:

O19 encountered object (was object encountered through): E18 Physical Thing
O21 encountered at (witnessed encounter): E53 Place

S20 Rigid Physical Feature

Subclass of:

E26 Physical Feature
E53 Place

Superclass of:

S22 Segment of Matter
E27 Site

Scope note:

Any instance of this class is a physical feature with sufficient stability of form, in itself and with respect to the physical object bearing it, in order to associate a permanent reference space within which its form is invariant and at rest. The maximum volume in space that an instance of S20 Rigid Physical Feature occupies defines uniquely a place for the feature with respect to its surrounding matter.

Therefore, we model S20 Rigid Physical Feature as a subclass of E26 Physical Feature and of E53 Place. The latter is intended as a phenomenal place as defined in CRMgeo (Doerr and Hiebel 2013). By virtue of this multiple inheritance, we can discuss positions relative to the extent of an instance of S20 Rigid Physical Feature without representing each instance of it together with an instance of its associated place. However, since the identity and existence of this place depends uniquely on the identity of the instance of S20 Rigid Physical Feature as matter, this multiple inheritance is unambiguous and effective and furthermore corresponds to the intuitions of natural language. It shortcuts an implicit self-referential path from E26 Physical Feature through *P156 occupies (is occupied by)*, E53 Place*, P157 is at rest relative to (provides reference space for)*, to E26 Physical Feature.

In cases of instances of S20 Rigid Physical Feature on or in the surface of earth, the default reference is typically fixed to the closer environment of the tectonic plate or sea floor. In cases of features on mobile objects, the reference space is typically fixed to the geometry of the bearing object. Note that the reference space associated with the instance of S20 Rigid Physical Feature may quite well be deformed over time, as long the continuity of its topology does not become unclear, such as the compression of dinosaur bones in geological layers, or the distortions of the hull of a ship by the waves of the sea. Defined in this way, the reference space can be used as a means to infer from current topological relationships past topological relationships of interest.

Examples:

- the temple in Abu Simbel before its removal, which was carved out of solid rock (‘Abu Simbel’, 2025)
- Albrecht Duerer’s signature on his painting of Charles the Great (Germanisches Nationalmuseum, 2022)
- the damaged form of the nose of the Great Sphinx in Giza (‘Great Sphinx of Giza’, 2025)

- the ‘Central Orygma’ (pit-house) which dominates the central part of the excavated area of the settlement of Mavropigi, representing phases I-III (Karamitrou-Mentessidi et al., 2015)
- the top surface of the clay floor A11 [Heterogeneous, yellow to grey silty clay; clear, wavy lower boundary] (illu p. 1601, Croix et al, 2019)

In first-order logic:

S20(x) ⇒ E26(x)
S20(x) ⇒ E53(x)
E11(x) ⇒ S18(x)

Properties:

O7 confines (is confined by): S10 Material Substantial

S21 Measurement

Subclass of:

S27 Observation

Superclass of:

S3 Measurement by Sampling
E16 Measurement

Scope note:

This class comprises actions measuring instances of S15 Observable Entity, properties of physical things, or phenomena, states and interactions or events, that can be determined by a systematic procedure. Primary data from measurement devices are regarded to be results of an observation process.

Examples:

- the magnitude measurement of the earthquake of Mexico City in 2017. [It had the magnitude 6.2 Richter] (Mindock, 2017)
- the sensor measurement by IGME in 1999 which measured the landslide displacement in the area of Parnitha, Greece (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- The measurement of the angle between the Sun and Moon with a half-moon at daylight by Aristarchus of Samos on an unknown day around 280 B.C. [The measurement of the angle between the Sun and Half-Moon at daylight was used by Aristarchus of Samos circa 280 B.C to calculate (S6) the ratio of the distances of the Sun and the Moon from the Earth, using the fact that the Half-Moon itself is the vertex of an angle of exactly 90 degrees between the observer and the Sun. Since he measured an angle of 87 degrees instead of 89° 50', he underestimated the distance to the Sun.] (Berggren and Sidoli, 2007) (Bonpland and Humboldt, 1815)
- The measurement of the angle between the summit of the Pico del Teide, Tenerife and a horizontal level by Alexander von Humboldt in the harbour of Orotava in Tenerife on the 19th of June 1799. [Alexander von Humboldt measured the elevation angle under which the Pico del Teide appears on the 19th of June 1799 from the harbour of Orotava in Tenerife, to be 16 ½ degrees, and previously from Santa Cruz to be 4º 36’. We can assume he used an instrument with a built-in level for the horizontal. He estimated the distance of the summit from Orotava to be 8600 toise (= 16,8km) and from Santa Cruz to be 22500 toise. He measured the angle for estimating the height of the mountain, an important landmark, now referred to as 3,715 m. (Remark by Martin Doerr: The value of 16 ½ degrees may be a later transcription error, it should have been around 11½ degrees)] (Humboldt, 1859)

In first-order logic:

S21(x) ⇒ S27(x)
E16(x) ⇒ S21(x)

Properties:

O24 measured (was measured by): S15 Observable Entity
O39 observed dimension (was observed in): E54 Dimension

S22 Segment of Matter

Subclass of:

S20 Rigid Physical Feature

Superclass of:

Scope note:

This class comprises physical features with relative stability of form and structure within a declared spatial volume of interest. The spatial extent of an instance of S22 Segment of Matter may be declared or defined by a researcher or observer usually because the arrangement and composition of substance is characteristic for the surrounding matter or can be interpreted as traces of its genesis and subsequent internal and external processes it was exposed to. The defining spatial extent is typically declared on a continuous matter by means of geometric determination without observable boundaries on all sides or any side. It may however be extracted at some point in time along the declared boundaries.

An instance of S22 Segment of Matter is regarded to be existing from the time on it completely solidified with a structure that is still preserved in a recognizable way at the time of its spatial definition. Its existence is regarded to end when its respective integrity is partially or completely corrupted. Uncorrupted subsections of an instance of S22 Segment of Matter may continue to exist as segments of matter in their own right beyond the existence of the containing instance, and may have solidified before it.

Typical examples are segments of archaeological or geological layers. They are regarded as uncorrupted even if they have undergone conformal deformations, such as compressions or shifts, as long as the effects of these deformations do not destroy the relevant structures of interest. This means that the defining spatial volume may be only geometrically valid for an instant of time for which it was declared, and undergo before and after deformations. In some cases, it may be possible to calculate the initial volume at the time of solidification, for instance for petrified bones compressed in Jurassic layers.

Examples:

- the clay floor A11 [Heterogeneous, yellow to grey silty clay; clear, wavy lower boundary] (illu p. 1601, Croix et al, 2019)

In first-order logic:

S22(x) ⇒ S20(x)

Properties:

O23 is defined by (defines): E92 Spacetime Volume

S23 Position Determination

Subclass of:

S27 Observation

Superclass of:

Scope note:

This class comprises activities of determining the actual position of some instance of S15 Observable Entity in space and time by measuring the necessary parameters sufficient for calculating this position. In the case of a material item, the determined position is intended to approximate a part or all of the extent of the presence (instance of E93 Presence) of an instance of the S15 Observable Entity of interest, such as the outer walls of an excavated settlement, the position of a ship sailing or the start and/or end of an athlete's run in a competition. Characteristically, a theodolite or GPS device may be positioned on some persistent feature. Determining the position of the device will yield an approximation of the position of the feature of interest at that time. Alternatively, some material item may be observed moving through a previously determined position at a given time. In case of determining the position of an Event, the approximated position pertains to areas in the spatiotemporal extent of the Event.

This class is not a subclass of S21 Measurement because a position determination normally has to measure more than one dimension. Typically, a position determination consists of a combination of measurements of multiple associated distances and/or angles (instances of E54 Dimension) from a particular spot to certain reference points with previously known position in the same reference space. In some cases, a constituting spatial distance is given by a directed speed and the temporal distance measured from starting from a known position to the actual position, for instance what is registered in a standard log book entry. A particular role is played by the Earth's magnetic field and rotational axis as reference for an angle or direction. Often, the constituting dimensions observed within the context of an instance of S23 Position Determination are not explicitly documented, or hidden in an electronic device**'s** software. Nevertheless, they constitute parts of this activity, which can be documented for future reference by the property *O41 measured dimension (was measured in):* S25 Relative Dimension, or, if they are taken from a previous context, by *O42 used result of (results contributed to):* O27 Observation. Measurements carried out within the course of the instance of S23 Position Determination for part of the latter and can be documented via the property *P9 consists of (forms part of)*: S21 Measurement. Devices used can be documented via *P16 used specific object (was used for)*.

The actual calculation of a position is typically executed following standardized methods as part of the same activity carrying out the necessary observations, in particular by using a GPS device. If the calculation is done later in another context, it should be regarded as a distinct instance of S6 Data Evaluation, with its own history of assumptions and accuracies. Even in this case, it is the results of instance of S23 Position Determination which are determinative for the obtained position. In the simplest case of an item being observed to meet an immobile feature of known position (i.e., at a distance as close to 0 as adequate in the particular context), no calculation is needed.

The determined position may be given as an E94 Space Primitive, which constitutes a declarative place in the sense of CRMgeo (2013). Note that an instance of E94 Space Primitive itself constitutes an area, often implicit by the given digits, and not an infinitesimally small point. Together with the measured time-span covering the time-critical part of the constituting observations it forms a spacetime volume, which ideally should overlap with the spatiotemporal extent of the thing or phenomenon of interest, if adequate error margins are given. Otherwise, the determined position is regarded to approximate the actual one with deviations characteristic for the measurement methods applied. However, instances of this class are regarded as historical facts, which means that they represent the opinion of the actor executing the determination with all its errors and inaccuracies.

Examples:

- the determination of the position of the Titanic for the initial distress call after hitting an iceberg [The iceberg was hit on 14 April 1912 at 23:40 ship's time. The subsequent position determination was likely done by Capt. Edward Smith and was transmitted 15 April 1912 at 00:27.] (Halpern, 2011)
- the determination of the position of the Titanic by officer Joseph G. Boxhall after the initial distress signal was sent [done between 00:27 and 00:35, when Boxhall showed the coordinates to Smith] (Halpern, 2011)
- the determination of the position of the Titanic by Robert Ballard's team after the Titanic ship-wreck was found (Ballard et al., 1987)
- Edmund Hillary and Tenzing Norgay finding themselves on the 29th of May 1953 at 11:30 am at the summit of Mount Everest.
- the determination of the position of Messner and Habeler in May 8, 1978 (Messner 1978, Roberts 2003)

In first-order logic:

S23(x) ⇒ S27(x)

Properties:

O30 determined position (was determined by): E94 Space Primitive
O31 has validity time-span (is time-span validity for): E52 Time-Span
O32 determined position of (was located by): S15 Observable Entity
O41 measured dimension (was measured in): S25 Relative Dimension
O42 used result of (results contributed to): S27 Observation

S24 Sample Splitting

Subclass of:

S2 Sample Taking

Superclass of:

Scope note:

This class comprises the activity of dividing an instance of S13 Sample into new instances of S13 Sample. This activity describes cases of sub-sampling where the resulting instance maintains the characteristic qualities of the original instance. Any observations of these qualities made on the new instance also apply to the original one. This class should be used to model cases of splitting a homogenous sample into multiple ones.

Examples:

- the activity of removing a part from the sample, which was originally taken from the tusk fragment GT993 by Godfrey et al. in 2000, in order to analyse it through ICP-AES analysis to reveal the composition of the original sample
  [A sample from a section of the tusk fragment GT993 which was originally found in the ship-wreck of Vergulde Draeck in Western Australia was taken. This sample was homogenous (ground to fine powder). Part of the sample was then removed for elemental analysis using inductively coupled plasma atomic emission spectrometry (ICP-AES). Another part was removed for carbon/nitrogen analysis using a LECO analyser.] (Godfrey et al., 2002)

In first-order logic:

S24(x) ⇒ S2(x)

Properties:

O27 split (was split by): S13 Sample
O29 removed sub-sample (was sub-sample removed by): S13 Sample

S25 Relative Dimension

Subclass of:

E54 Dimension

Superclass of:

S26 Angle

Scope note:

This class comprises quantifiable properties that can be measured by some calibrated means and were holding between two or more distinct instances of S15 Observable Entity for some time.

Typical examples include relative distances between physical things or temporal distances between events such as athletes arriving at a goal or the time elapsed from production in thermoluninescence dating.

Generally, all kinds of quantifiable properties holding for a single item in isolation can be compared relative to the same of another item. Depending on the methods, such relative dimensions often constitute important primary observational data for calculating absolute values rather than being computational results from absolute values, an example being relative barometric measurements of altitude during expeditions.

Examples:

- the distance of the Moon from Earth (P2 has type: 'spatial distances') [The distance to the Moon can be measured with millimetre precision.] ('Lunar Laser Ranging experiments', 2024)
- the distance of the epicentre of the 2017 Puebla earthquake, also known as 19S at 13:14 CDT (18:14 UTC) on 19 September 2017 from the city of Puebla, Mexico (P2 has type: 'spatial distances')
  [The 2017 Puebla earthquake, also known as 19S, struck at 13:14 CDT (18:14 UTC) on 19 September 2017 with an estimated magnitude of 7.1 Mw and strong shaking for about 20 seconds. Its epicentre was about 55 km (34 mi) south of the city of Puebla, Mexico. The earthquake caused damage in the Mexican states of Puebla and Morelos and in the Greater Mexico City area, including the collapse of more than 40 buildings.[5][6][7] 370 people were killed by the earthquake and related building collapses, including 228 in Mexico City,[8][9] and more than 6,000 were injured.[10] ('2017 Puebla earthquake', 2025)
- the determination of the position of Messner and Habeler in May 8, 1978 (Messner 1978, Roberts 2003)

In first-order logic:

S25(x) ⇒ E54(x)

Properties:

O33 is relative to (has relative dimension): S15 Observable Entity

S26 Angle

Subclass of:

S25 Relative Dimension

Superclass of:

Scope note:

This class comprises quantifiable angles that can be measured by some calibrated means and held between a spot on some instance of S15 Observable Entity forming the geometric vertex and two directions to the position of some other instances of S15 Observable Entity.

Typical examples include results of measurements with theodolites, sextants or compasses.

Examples:

- The angle between the Sun and Moon with a half-moon at daylight as measured by Aristarchus of Samos on an unknown day around 280 B.C. [87 degrees instead of the current value of 89° 50'] (Berggren and Sidoli, 2007)
- The angle between the summit of the Pico del Teide, Tenerife and a horizontal level as measured by Alexander von Humboldt in the harbour of Orotava in Tenerife on the 19th of June 1799. [16 ½ degrees] (Humboldt, 1859)

In first-order logic:

S26(x) ⇒ S25(x)

Properties:

O34 has vertex (is vertex of): S15 Observable Entity

S27 Observation

Subclass of:

I1 Argumentation

Superclass of:

S4 Single Observation
S19 Encounter Event
S21 Measurement
S23 Position Determination

Scope note:

This class comprises activity of gaining scientific knowledge about particular states of physical reality through empirical evidence, experiments and measurements.

We define observation in the sense of natural sciences, as a kind of human activity: at some place and within some time-span, certain physical things and their behaviour and interactions are observed by human sensory impression, and often enhanced by tools and measurement devices.

Observed situations or dimensions may pertain to properties confined to a single instance of S15 Observable Entity or pertain to constellations of multiple instances and relations between them, in particular distances between them.

The output of the internal processes of measurement devices that do not require additional human interaction are in general regarded as part of the observation and not as additional inference. Primary data from measurement devices are regarded in this model to be results of observation and can be interpreted as propositions believed to be true within the (known) tolerances and degree of reliability of the device.

Measurements and witnessing of events are special cases of observations. Observations result in a belief that certain propositions held at a time within the time-span of the observation. In this model, the degree of confidence in the observed properties is regarded to be “true” by default, but could be described differently by adding a property *P3 has note* to an instance of S4 Observation.

Examples:

- the excavation of unit XI by the Archaeological Institute of Crete in 2004
- the excavation in the NE section of the central court of the Knossos palace by the Ephorate of Antiquities of Heraklion in 1997 (Επιστημονική Επιτροπή Κνωσού, 2008)
- the observation of the density of the X-Ray image of cupid's head from the painting ‘Cupid complaining to Venus’ as ‘high density’, on the 19th of March 1963 (S4) (The National Gallery, London, 1963)
- the observation of visible light absorption of the painting ‘Cupid complaining to Venus’ as ‘having red pigment’, in 2015 (S4)
- the inspection of the interior of La Tomba dell'Aryballos sospeso, at Doganaccia di Tarquinia, in Tuscany, Italy, by Alessandro Mandolesi on the 21st of September 2013 (Mandolesi 2013)

In first-order logic:

S27(x) ⇒ I1(x)

Properties:

O35 observed entity (was observed by): S15 Observable Entity
O36 expressed the observed as (was the expression of): S28 Observable Situation

S28 Observable Situation

Subclass of:

I11 Situation

Superclass of:

S29 Observable Proposition

Scope note:

An instance of S28 Observable Situation can be perceived as a set of formal propositions deriving from an observation event on a constellation, an interaction or a dynamic behaviour of instances of S15 Observable Entity, or sections of these instances within a particular time-span and spatial extent that lie in the past. The observation event in question either relies on human senses, or it has been enhanced or mediated by technical instruments.

The observer may be directly involved themselves, or they may be receiving signals from each observation. The focus of the observer determines the model they overlay on the observed reality, in order to describe it in terms of distinct properties and value ranges of parameters. The latter selection and projection from reality constitutes the content of a particular instance of S28 Observable Situation. Multiple observers may select different models, details and value systems to the same spatiotemporal area (i.e., views they pay attention to). Consequently, the observed situations may differ, but should, in principle, be comparable to a common reality in their overlaps.

Examples:

- the proposition set with content:

{The burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object) *is composed of* the spear found in La Tomba dell' Aryballos sospeso (E22 Human-Made Object)
The skeleton in La Tomba dell'Aryballos sospeso on the left bench (E20 Biological Object) forms part of the burial arrangement on La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object).} (Mandolesi, 2013)

- the proposition set with content:
  {The content of the La Tomba dell'Aryballos sospeso at the time of its opening (E24 Physical Human-Made Thing) *is composed of* the burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object).
  The burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object) *is composed of* the spear found in La Tomba dell'Aryballos sospeso (E22 Human-Made Object).
  The skeleton in La Tomba dell'Aryballos sospeso on the left bench (E20 Biological Object) *forms part of* the burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object).
  The skeleton in La Tomba dell'Aryballos sospeso on the right bench (E20 Biological Object) *forms part of* the content of the La Tomba dell'Aryballos sospeso at the time of its opening (E24 Physical Human-Made Thing).
  The content of the La Tomba dell'Aryballos sospeso at the time of its opening (E24 Physical Human-Made Thing) *has condition* the condition of the content of the La Tomba dell'Aryballos sospeso from its sealing to its opening (E3 Condition State).
  The condition of the content of the La Tomba dell'Aryballos sospeso from its sealing to its opening (E3 Condition State) *has type* 'intact' (E55 Type). (Mandolesi 2013)

[The abovementioned examples form part of a scientific knowledge revision, where the original belief was formed based on a simple inference, and following a thorough scientific analysis, underwent revision.
The skeleton found on the left bench of La Tomba dell'Aryballos sospeso, at Doganaccia di Tarquinia, in Tuscany, Italy, by Prof. Alessandro Mandolesi on the 21st September 2013, was initially estimated to be the remains of a male person, due to a spear found lying next to it. In fact, the initial press release mentioned there being a skeleton of a male person in the tomb. Soon after, osteological analysis carried out by Mandolesi's team, revealed that the skeleton had belonged to a female person, a piece of information included in all scientific publications that followed the osteological analysis.
We refer to this skeleton in the examples found throughout the text as "The skeleton on the left bench in La Tomba dell'Aryballos sospeso", and to the burial arrangement as "The burial arrangement on the left bench in La Tomba dell'Aryballos sospeso", respectively.]

- a triple-braided clasp strap being detached at the survey of Sinai MS GREEK 418 (Honey and Pickwoad, 2010).

In first-order logic:

$S28(x) \Rightarrow I11(x)$

$S28(x) \Rightarrow (\exists y) [S15(y) \wedge J28(x,y)]$

Properties:

O40 refers to observable entity (is referred to in): S15 Observable Entity

S29 Observable Proposition

Subclass of:

S28 Observable Situation
I17 One-Proposition Set

Superclass of:

Scope note:

This class comprises proposition sets containing exactly one binary proposition which is, or could, in principle, be, encoded in a knowledge representation language, and which characterizes an observable phenomenon, regardless of whether it has happened or not. For example, it could refer to the intended meaning of a text about an observable phenomenon, where the belief value concerning its reality has not been asserted, or to the question of whether a certain situation has ever happened. The identity of an instance of S29 Observable Proposition is given by the totality of its content, whatever its encoding.

The class S29 Observable Proposition plays the role of an important logical interface between observing single propositions and more generally observable situations. It is particularly relevant for implementing effective queries. For documentation, the use of the simpler shortcut properties of S4 Single Observation, i.e. O35 observed entity (was observed by), O9 observed property type (property type was observed by) and O16 observed value (value was observed by) will, typically, be the preferred approach.

Examples:

- the proposition set with content:
  {The burial arrangement (E22 Human-Made Object) in La Tomba dell'Aryballos sospeso on the left bench *is composed of* the spear (E22 Human-Made Object) found in La Tomba dell'Aryballos sospeso.} (Mandolesi, 2013)
- the proposition set with content:
  {The skeleton (E20 Biological Object) in La Tomba dell'Aryballos sospeso on the right bench *forms part of* the burial arrangement (E22 Human-Made Object) in La Tomba dell'Aryballos sospeso on the left bench.} (Mandolesi, 2013)
- the proposition set with content:
  {The skeleton (E20 Biological Object) in La Tomba dell'Aryballos sospeso on the left bench *P2 has type* 'female' (E55 Type).} (Mandolesi, 2013)

[The abovementioned examples form part of a scientific knowledge revision, where the original belief was formed based on a simple inference, and following a thorough scientific analysis, underwent revision.
The skeleton found on the left bench of La Tomba dell'Aryballos sospeso, at Doganaccia di Tarquinia, in Tuscany, Italy, by Prof. Alessandro Mandolesi on the 21st September 2013, was initially estimated to be the remains of a male person, due to a spear found lying next to it. In fact, the initial press release mentioned there being a skeleton of a male person in the tomb. Soon after, osteological analysis carried out by Mandolesi's team, revealed that the skeleton had belonged to a female person, a piece of information included in all scientific publications that followed the osteological analysis.
We refer to this skeleton in the examples found throughout the text as "The skeleton on the left bench in La Tomba dell'Aryballos sospeso", and to the burial arrangement as "The burial arrangement on the left bench in La Tomba dell'Aryballos sospeso", respectively.]

In first-order logic:

$S29(x) \Rightarrow S28(x)$

$S29(x) \Rightarrow I17(x)$

Properties:

O38 has domain (is domain of): S15 Observable Entity

CRMsci Property Declarations

O1 diminished (was diminished by)

Domain:

S1 Matter Removal

Range:

S10 Material Substantial

Subproperty of:

Superproperty of:

E80 Part Removal. P112 diminished (was diminished by): E18 Physical Thing

Quantification:

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

Scope note:

This property associates an instance of S1 Matter Removal with the instance of S10 Material Substantial that this activity diminished.

Although an instance of S1 Matter Removal activity normally concerns only one item of S10 Material Substantial, it is possible to imagine circumstances under which more than one item might be diminished by a single Matter Removal activity.

An instance S1 Matter Removal activity requires to diminish at least one item of S10 Material Substantial. This may be documented by any of the subproperties of *O1 diminished (was diminished by)*. Therefore, the instantiation of a particular subproperty of *O1 diminished (was diminished by)* is not necessary.

Full path:

Examples:

- The removal of the fill from the interior of the ‘tomb of Lagadas’ at Derveni Thessaloniki by the excavators in 1995 (S1) *diminished* the width of the cross-section of the burial chamber and the fill of the façade (S10). (Papasotiriou et al., 2010)

In first-order logic:

O1(x,y) ⇒ S1(x)
O1(x,y) ⇒ S10(y)

O2 removed (was removed by)

Domain:

S1 Matter Removal

Range:

S11 Amount of Mater

Subproperty of:

Superproperty of:

S2 Sample Taking. O5 removed (was removed by): S13 Sample

Quantification:

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

Scope note:

This property associates an instance of S1 Matter Removal with the instance of S11 Amount of Matter that it has removed.

Full path:

Examples:

- The ‘La Gioconda of the Prado’ layer removal by the conservators of Prado Museum in Madrid (S1) *removed* the layer of black overpainting (S11) that covered the background of it (Museo del Prado, 2012)

In first-order logic:

O2(x,y) ⇒ S1(x)
O2(x,y) ⇒ S10(y)

O3 sampled from (was sample by)

Domain:

S2 Sample Taking

Range:

S10 Material Substantial

Subproperty of:

Superproperty of:

S24 Sample Splitting. O27 split (was source for): S13 Sample

Quantification:

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

Scope note:

This property associates an instance of S2 Sample Taking with the instance S10 Material Substantial from which a sample was taken. In particular, it may be a feature or a fluid body from which a sample was removed.

Full path:

Examples:

- Water Sample Taking 74001 (S2) *sampled from* the aquifer (S10) that overlaps with borehole 10/G5. (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- Collecting micro-sample 7 (S2) *sampled from* the painting ‘Cupid complaining to Venus’ (Cranach) (S10) by Joyce Plesters, in June 1963. (The National Gallery, London, 1963)

In first-order logic:

O3(x,y) ⇒ S2(x)
O3(x,y) ⇒ S10(y)

O4 sampled at (was sampling location of)

Domain:

S2 Sample Taking

Range:

E53 Place

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S2 Sample Taking with the instance of E53 Place ("spot") at which this activity sampled. It identifies the narrowest relevant area on the material substantial from which the sample was taken. This may be known or given in absolute terms or relative to an instance of the material substantial from which it was taken. If samples are taken from more than one spot, the sample taking activity must be documented by separate instances for each spot.

The property *P7 took place at (witnessed)*, inherited from E4 Period, describes the position of the area in which the sampling activity occurred; this latter comprises the space within which operators and instruments were contained during the activity, and the sample taking spot.

Full path:

Examples:

- Water Sample Taking 74001 (S2) *sampled at* borehole 10/G5 at depth 0, which falls within the water district 10/G5 in Central Macedonia (E53). (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- Collecting micro-sample 7 (S2) *sampled at* the area of the apple (E53), shown on the painting ‘Cupid complaining to Venus’ (Cranach) (The National Gallery, London, 1963)

In first-order logic:

O4(x,y) ⇒ S2(x)
O4(x,y) ⇒ E53(y)
O4(x,y) ∧ P7(x,z) ⇒ P89(y,z)

O5 removed (was removed by)

Domain:

S2 Sample Taking

Range:

S13 Sample

Subproperty of:

S1 Matter Removal. O2 removed (was removed by): S11 Amount of Matter

Superproperty of:

S24 Sample Splitting. O29 removed sub-sample (was sub-sample removed): S13 Sample

Quantification:

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

Scope note:

This property associates an instance of S2 Sample Taking with the instance of S13 Sample that was taken during the activity.

Full path:

Examples:

- Lithology Sample Taking 201 (S2) *removed* sample 2B (S113). (Lucchese et al, 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- The sampling (S2) undertaken by Joyce Plesters in June 1963, while she was working on the painting 'Cupid complaining to Venus' (Cranach), *removed* micro-sample 7 (S13). (The National Gallery, London, 1963)

In first-order logic:

O5(x,y) ⇒ S2(x)
O5(x,y) ⇒ S13(y)
O5(x,y) ⇒ O2(x,y)

O6 is former or current part of (has former or current part)

Domain:

S12 Amount of Fluid

Range:

S14 Fluid Body

Subproperty of:

S10 Material Substantial. O25 contains (is contained in): S10 Material Substantial

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S12 Amount of Fluid with an instance of S14 Fluid Body which formed or forms part of it. It allows instances of S14 Fluid Body to be analysed into elements of S12 Amount of Fluid.

Full path:

Examples:

- J.K.'s blood sample 0019FCF5 (S12) *is former or current part of* J.K.'s blood (S14). (fictitious)

In first-order logic:

O6(x,y) ⇒ S12(x)
O6(x,y) ⇒ S14(y)
O6(x,y) ⇒ O25(x,y)

O7 confines (is confined by)

Domain:

S20 Rigid Physical Feature

Range:

S10 Material Substantial

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S20 Rigid Physical Feature with an instance of S10 Material Substantial that it partially or completely confines. It describes cases in which rigid features such as stratigraphic layers, walls, dams, riverbeds, etc. form the boundaries of some item such as another stratigraphic layer or the waters of a river.

Full path:

Examples:

- The Stavros – Farsala artesian aquifer (S20) *confines* the overexploited groundwater of the area (S10). (Rozos et al., 2017)
- The posthole (S20) *confines* the organic material (S10) identified in the 1997 analysis of the post holes of the structure 2 in the Tutu archaeological village site. (Righter, 2002)
- Borehole No1234 *confines* intake No5 (S10). (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)

In first-order logic:

O7(x,y) ⇒ S20(x)
O7(x,y) ⇒ S10(y)

O8 observed (was observed by)

Domain:

S4 Single Observation

Range:

S15 Observable Entity

Subproperty of:

S27 Observation. O35 observed entity (was observed by): S15 Observable Entity
E13 Attribute Assignment. P140 assigned attribute to (was attributed by): E1 CRM Entity

Superproperty of:

E16 Measurement. P39 measured (was measured by): E18 Physical Thing

Quantification:

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

Scope note:

This property associates an instance of S4 Single Observation with one instance of S15 Observable Entity that was observed. Specifically, it describes that a thing, a feature, a phenomenon or some process is observed by an activity of Observation.

This property is a strong shortcut of the fully developed path from S4 Single Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *O38 has domain (is domain of)*, to S15 Observable Entity.

Full path:

S4 Single Observation. *O37 expressed the observed as observable proposition (was observable proposition characterized by)*: S29 Observable Proposition. *O38 has domain (is domain of)*: S15 Observable Entity

Examples:

- The engineers' observation (S4) on the slope of Panagopoula coastal site, near Patras, on the 3rd May 1971 *observed* the rotational landslide at the same site (E4). (Tavoularis et al., 2017)
- The survey (S4) of Sinai MS GREEK 418 *observed* a detached triple-braided clasp strap (S15). (Honey and Pickwoad, 2010)

In first-order logic:

O8(x,y) ⇒ S4(x)
O8(x,y) ⇒ S15(y)
O8(x,y) ⇒ O35(x,y)
O8(x,y) ⇒ P140(x,y)
P39(x,y) ⇒ O8(x,y)
O8(x,y) ⇔ (∃z) [S29(z) ∧ O37(x,z) ∧ O38(z,y)]

O9 observed property type (property type was observed by)

Domain:

S4 Single Observation

Range:

S9 Property Type

Subproperty of:

E13 Attribute Assignment. P177 assigned property type (is property type assigned): E55 Type

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S1 Matter Removal with the instance of S10 Material Substantial that this activity diminished.

Although an instance of S4 Single Observation with the instance of S9 Property Type for which the observation provides a value or evidence, such as 'concentration of nitrate' observed in the water from a particular borehole. Encoding the observed property by type, observed entity and value (namely, properties O9, O37, and O16, respectively), is a method to circumscribe the reification of the observed property by the respective instance of S4 Single Observation.

In an RDFS encoding, this circumscription can be transformed into an explicit representation of the observed property in terms of a formal ontology, either by the use of a reification construct or a Named Graph containing the observed property. The latter representation allows for more formal reasoning with the model, the former is more flexible about the kinds of observations.

This property is a strong shortcut of the fully developed path from S4 Single Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *J32 has property type (is property type of)*, to S9 Property Type.

Full path:

S4 Single Observation. *O37 expressed the observed as observable proposition (was observable proposition characterized by)*: S29 Observable Proposition. *J32 has property type (is property type of)*: S9 Property Type

Examples:

- The seismic hazard analysis and recording by EPPO in 1990 (S4), in the area of Attica *observed property type* share wave velocity (S9) and recorded it. (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- The Gas Chromatography analysis (S4) of the sample 'mid-blue paint from the sky' *observed property type* retention time (S9). (Foister, 2015)

In first-order logic:

O9(x,y) ⇒ S4(x)
O9(x,y) ⇒ S9(y)
O9(x,y) ⇒ P177(x,y)
O9(x,y) ⇔ (∃z) [S29(z) ∧ O37(x,z) ∧ J32(z,y)]

O10 assigned dimension (dimension was assigned by)

Domain:

S6 Data Evaluation

Range:

E54 Dimension

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S6 Data Evaluation with an instance of E54 Dimension that a data evaluation activity has assigned. In that case, dimensions may be determined by making evaluations on observational data based on mathematical inference rules and calculations.

Full path:

Examples:

- The shock wave recording (S6) carried out by EPPO in 1999 *assigned dimension* PSA_10 (E54). [The dimension had value 0.0008.] (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)

In first-order logic:

O10(x,y) ⇒ S6(x)
O10(x,y) ⇒ E54(y)

O11 described (was described by)

Domain:

S6 Data Evaluation

Range:

S15 Observable Entity

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S6 Data Evaluation with an instance of S15 Observable Entity for which a data evaluation activity provides a description. This description of any Observable Entity is based on data evaluations.

Full path:

Examples:

- The quantitative analysis of Munsell colour data (S6), carried out by C.T. Brown in 1999 in Yucatán, Mexico, *described* the slipped sherds of Mayapán period ceramics (S15). (Ruck and Brown, 2015)
- The linear extrapolation of overall figure height from the size of the fingers (S6) *described* the statue of Hercules (S15). [The statue is located in Amman.] (‘Temple of Hercules (Amman)’, 2025)

In first-order logic:

O11(x,y) ⇒ S6(x)
O11(x,y) ⇒ S15(y)

O12 has dimension (is dimension of)

Domain:

S15 Observable Entity

Range:

E54 Dimension

Subproperty of:

Superproperty of:

S15 Observable Entity. O33i has relative dimension (is relative to): S25 Relative Dimension

Quantification:

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

Scope note:

This property associates an instance of S15 Observable Entity with an instance of E54 Dimension that the observable entity has. It offers no information about how and when an E54 Dimension was established.

Most instances of E54 Dimension pertain to one item only. An instance of E54 Dimension referred to by more than one item via this property or a specialization of it is more specifically an instance of S25 Relative Dimension, such as a distance between two physical objects.

In the case of S25 Relative Dimension the property is equivalent to *O33i has relative dimension (is relative to)*.

In case the instance of S15 Observable Entity is more specifically an instance of S10 Material Substantial and the instance of E54 Dimension is not an instance of S25 Relative Dimension, using the property *O12 has dimension (is dimension of)* is equivalent to using the property *P43 has dimension (is dimension of)*. In other words, using the one implies the other.

This property is a shortcut of the fully developed path from S15 Observable Entity through *O24i was measured by (measured)*, S21 Measurement, *O39 observed dimension (was observed in)*, to E54 Dimension.

Referring to an instance of E54 Dimension by this property is mutually exclusive to using either property *P191 had duration (was duration of)* or *P179 had sales price (was sales price)* to refer to the same instance of E54 Dimension. This broadens the same rule for*P43 has dimension (is dimension of)*.

Full path:

S15 Observable Entity. *O24i was measured by (measured)*: S21 Measurement: *O39 observed dimension (was observed in)*: E54 Dimension

Examples:

- The earthquake of Mexico City in 2017 (E7) has dimension Mexico City 2017 earthquake magnitude (E54) [which *has type* seismic magnitude (E55), has unit Richter (E58) and has value 6.2 (E60)]. (Mindock, 2017)
- The landslide that was activated in Parnitha in 1999 after the earthquake (E26) *has dimension* Parnitha 1999 landslide crest length (E54) [which *has type* landslide crest length (E55), *has unit* meters (E58) and *has value* (70, ∞) (E60). For the interval interpretation of the value ">70" in the source see notation: https://www.math.net/interval-notation]. (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)

In first-order logic:

O12(x,y) ⇒ S15(x)
O12(x,y) ⇒ E54(y)
(∃xz)[O12(x,y) ∧ O12(z,y) ∧ (x≠z)] ⇒ S25(y) –this follows from the quantification (2,n:0,n) of its subproperty O33)

$O12(x,y) \Leftarrow (\exists z)\ [S21(z) \wedge O24i(x,z) \wedge O39(z,y)]$

Both O12 and P43 can be used with S10(x). With the restriction that P43 can pertain to one item only and thus cannot be used with S25(y), they are in fact equivalent there:
$[S10(x) \wedge \neg S25(y)] \Rightarrow [O12(x,y) \Leftrightarrow P43(x,y)]$

Exclusion statements (broadening the statements of P43):
$[O12(x,y) \wedge P179(z,w)] \Rightarrow w \neq y$
$[O12(x,y) \wedge P191(z,w)] \Rightarrow w \neq y$

O13 triggered (was triggered by)

Domain:

E5 Event

Range:

E5 Event

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of E5 Event that triggered another instance of E5 Event with the latter. It identifies the interaction between events: an event can activate (trigger) other events in a target system that is in a situation of sustained tension, such as a trap or an unstable mountain slope giving way to a land slide after a rain or earthquake

The distinction of a triggering event A from the triggered event B lies in their difference of nature. The starting of B is the result of an interaction of material constituents of A with material constituents of B. However, B does not necessarily continue the kinds of processes of A. Therefore, the triggering event A must spatiotemporally overlap with the initial time and area of the triggered event B. Any subsequent phenomena must initiate from this area and time and not from multiple independent areas.

Full path:

Examples:

- The earthquake of Parnitha in 1999 (E5) *triggered* the rotational landslide that was observed along the road on the same day (E5). (fictitious)
- The explosion at the Montserrat massif in 2007 (E5) (near Barcelona, Spain) *triggered* the rock fall event (E5) which happened on 2007-02-14. (Vilajosana et al., 2008)
- The 1966 flood in Florence (E5) *triggered* mould growth on books (E5) stored in flooded library rooms. (Rubinstein, 1966)

In first-order logic:

$O13(x,y) \Rightarrow E5(x)$
$O13(x,y) \Rightarrow E5(y)$

O15 occupied (was occupied by)

Domain:

S10 Material Substantial

Range:

E53 Place

Subproperty of:

Superproperty of:

E18 Physical Thing. P156 occupies (is occupied by): E53 Place

Quantification:

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

Scope note:

This property associates an instance of S10 Material Substantial with the instance of E53 Place that this substance occupied. It describes the space filled (occupied) by a physical matter. This property is the development of the shortcut expressed in the proposition of classification: "S20 Physical Feature" isA "E53 Place". This property is equivalent to *P156 occupies (is occupied by)* with domain E18 Physical Thing and range E53 Place.

Full path:

Examples:

- The layer of pink plaster that occupied the block 30 floor of the area X. on 2009-02-03. [The plaster covered the floor.] (fictitious)

In first-order logic:

O15(x,y) ⇒ S10(x)
O15(x,y) ⇒ E53(y)
P156(x,y) ⇒ O15(x,y)
P156(x,y) ⇔ O15(x,y) ∧ E18(x)

O16 observed value (value was observed by)

Domain:

S4 Single Observation

Range:

E1 CRM Entity

Subproperty of:

E13 Attribute Assignment. P141 assigned (was assigned by): E1 CRM Entity

Superproperty of:

E16 Measurement. P40 observed dimension (was observed in): E54 Dimension

Quantification:

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

Scope note:

This property associates a value assigned to an entity observed by S4 Single Observation.

This property is a strong shortcut of the fully developed path from S4 Single Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *J31 has range (is range of)*, to E1 CRM Entity.

Full path:

S4 Single Observation. *O37 expressed the observed as observable proposition (was observable proposition characterized by)*: S29 Observable Proposition. *J31 has range (is range of)*: E1 CRM Entity

Examples:

- The surface survey at the bronze age site of Mitrou in East Lokris (S4), carried out by Cornell University in 1989, *observed* value 600 (of sherds) (E1). (Kramer-Hajos and O'Neill, 2008)

In first-order logic:

O16(x,y) ⇒ S4(x)
O16(x,y) ⇒ E1(y)
O16(x,y) ⇒ P141(x,y)
P40(x,y) ⇒ O16(x,y)
O16(x,y) ⇔ (∃z) [S29(z) ∧ O37(x,z) ∧ J31(z,y)]

O17 generated (was generated by)

Domain:

S17 Physical Genesis

Range:

E18 Physical Thing

Subproperty of:

S18 Alteration. O18 altered (was altered by): E18 Physical Thing

Superproperty of:

E12 Production. P108 has produced (was produces by): E24 Physical Human-Made Thing

Quantification:

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

Scope note:

This property associates an instance of S17 Physical Genesis event with an instance of E18 Physical Thing that the event generated.

Full path:

Examples:

- The landslide of Parnitha in 1999 (S17) *generated* the head of the landslide feature (E18). (fictitious)
- The mud flow in the western region of Thessaly million years ago (S17) *generated* the deposits of solidified mud with irregular surface in the area (E18). (fictitious)
- The introduction of my copper samples in the salt-spray apparatus (S17) *generated* new corrosion layers of cuprite and malachite (E18). (Velios, 1998)

In first-order logic:

O17(x,y) ⇒ S17(x)
O17(x,y) ⇒ E18(y)

O17(x,y) ⇒ O18(x,y)
P108(x,y) ⇒ O17(x,y)

O18 altered (was altered by)

Domain:
S18 Alteration

Range:
E18 Physical Thing

Subproperty of:

Superproperty of:
E11 Modification. P31 has modified (was modified by): E18 Physical Thing
S17 Physical Genesis. O17 generated (was generated by): E18 Physical Thing

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

Scope note:
This property associates an instance of S18 Alteration process with an instance of E18 Physical Thing which was altered by this activity.

Full path:

Examples:

- The death of the trees (S18), caused by beetle infestation in 1995, *altered* the Brazilian forest (E18). (Paine, 2008)
- The application of tension (S18) *altered* the humidified parchment of the Lanhydrock Pedigree (E18) (Pickwoad, 2010)

In first-order logic:
O18(x,y) ⇒ S18(x)
O18(x,y) ⇒ E18(y)
O18(x,y) ⇒ P12(x,y)
P31(x,y) ⇒ O18(x,y)

O19 encountered object (was object encountered through)

Domain:
S19 Encounter Event

Range:
E18 Physical Thing

Subproperty of:
E5 Event. P12 occurred in the presence of (was present at): E77 Persistent Item

Superproperty of:

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

Scope note:

This property associates an instance of S19 Encounter Event with an instance of E18 Physical Thing that was encountered or observed as present during the event.

Full path:

Examples:

- The encounter of a marble floor during the digging of a well in 1750 (S19) *encountered object* the Villa of the Papyri in Herculaneum (E18). (Sider, 1990, p. 536)
- The encounter of oak planks from a ship during a dig in a mound at the farm Lille Oseberg in Norway, in 1904 (S19) *encountered object* the Oseberg Ship (E18). (Ferguson, 2009, p.10-11)

In first-order logic:

O19(x,y) ⇒ S19(x)
O19(x,y) ⇒ E18(y)

O20 sampled from type of part (type of part was sampled by)

Domain:

S2 Sample Taking

Range:

E55 Type

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates the activity of a Sample Taking with the type of the location part from which a sample was taken. It is a shortcut of the property *O4 sampled at (was sampling location of)*, and it is used as an alternative property, identifying features and material substantial as types of parts of sampling positions.

Full path:

S2 Sample Taking. *O4 sampled at (was sampling location of)*: E53 Place. *P2 has type (is type of)*: E55 Type

Examples:

- The sampling (S2) of tissue for DNA analysis of human remains in an archaeological site, *sampled from type of part* molar tooth (E55). (fictitious)
- The sampling (S2) undertaken by Joyce Plesters in June 1963 while she was working on the painting 'Cupid complaining to Venus' (Cranach), *sampled from type of part* paint (E55). (The National Gallery, London, 1963)

In first-order logic:

O20(x,y) ⇒ S2(x)
O20(x,y) ⇒ E55(y)

O21 encountered at (witnessed encounter)

Domain:

S19 Encounter Event

Range:

E53 Place

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S19 Encounter Event with an instance of E53 Place at which the things, which were encountered, were observed to be present. This may be given in absolute terms or in terms relative to the observed thing. The associated place must be within the boundaries of the E53 Place at which the S19 Encounter Event took place, if that has been given.

Note, that the encountered object may be larger and extend beyond the place of encounter, such as a corner of a building being excavated.

Full path:

Examples:

- The encounter of the Oseberg Ship in 1904 (S19) *encountered at* the farm Lille Oseberg in Norway (E53). (Ferguson, 2009, p.10-11)

In first-order logic:

$O21(x,y) \Rightarrow S19(x)$

$O21(x,y) \Rightarrow E53(y)$

$O21(x,y) \Rightarrow \exists z[E53(z) \land P161(x,z) \land P89(y,z)]$

$O21(x,y) \Rightarrow (\exists z,v,w) [E93(w) \land E18(z) \land E52(v) \land O19(x,z) \land P195(w,z) \land P4(x,v) \land P164(w,v) \land P197(w,y)]$

O23 is defined by (defines)

Domain:

S22 Segment of Matter

Range:

E92 Spacetime Volume

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property identifies the E92 Spacetime Volume that defines a S22 Segment of Matter. The spatial boundaries of the E92 Spacetime Volume are defined through S4 Single Observation or declaration while the temporal boundaries are confined by S18 Alteration events.

Full path:

Examples:

- The accumulation zone (S22) of the landslide *is defined* by the evolution of the landslide of Santomerion village in 2008 (E92) (Litoseliti et al., 2014)

In first-order logic:

O23(x,y) ⇒ S22(x)
O23(x,y) ⇒ E92(y)

O24 measured (was measured by)

Domain:

S21 Measurement

Range:

S15 Observable Entity

Subproperty of:

S27 Observation. O35 observed entity (was observed by): S15 Observable Entity

Superproperty of:

E16 Measurement. P39 measured (was measured by): E18 Physical Thing

Quantification:

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

Scope note:

This property associates an instance of S21 Measurement with an instance of S15 Observable Entity to which it applied. An instance of S15 Observable Entity may be measured more than once. Material things and processes may be measured, e.g. the number of words in a copy of a text, or the duration of an event. An instance of S21 Measurement may measure a specific constellation of distinct instances of S15 Observable Entity at some time, to determine a dimension holding between the latter, i.e. an instance of S25 Relative Dimension.

This property is part of the fully developed path from S15 Observable Entity through *O24i was measured by (measured)*, S21 Measurement, *O39 observed dimension (was observed in)*, to E54 Dimension, which is shortcut by *O12 has dimension (is dimension of)*.

Full path:

Examples:

- The sensor measurement by IGME in 1999 (S21) *measured* the landslide displacement (S15) in the area of Parnitha. (Lucchese et al., 2013; Kritikos et al., 2013; InGeoCloudS, 2012; InGeoCloudS, 2013)
- The measurement of the angle between the Sun and Moon with a half-moon at daylight as by Aristarchus of Samos on an unknown day around 280 B.C. *measured* the Moon (E19). (Berggren and Sidoli 2007)
- The measurement of the angle between the Sun and Moon with a half-moon at daylight as by Aristarchus of Samos on an unknown day around 280 B.C. *measured* the Sun (E19). (Berggren and Sidoli 2007)

- The measurement of the angle between the summit of the Pico del Teide, Tenerife and a horizontal level by Alexander von Humboldt in the harbour of Orotava in Tenerife on the 19th of June 1799 *measured* the Pico del Teide, Tenerife (E26). (Humboldt, 1859)

In first-order logic:

O24(x,y) ⇒ S21(x)
O24(x,y) ⇒ S15(y)
O24(x,y) ⇒ O35(x,y)
P39(x,y) ⇒ O24(x,y)

P39(x,y) ⇔ O24(x,y) ∧ E18(x) ∧ ¬S25(y)
O24(x,y) ∧ E5(y) ⇒ P132(x,y)
O24(x,y) ∧ E18(y) ∧ E92(z) ∧ P196(y,z) ⇒ P132(x,z)
(reminder: E18(y) ⇒ (∃z) [E92(z) ∧ P196(y,z)] and z is unique)

O25 contains (is contained in)

Domain:

S10 Material Substantial

Range:

S10 Material Substantial

Subproperty of:

Superproperty of:

S12 Amount of Fluid. O6 is former or current part of (has former or current part): S14 Fluid Body
E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

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

Scope note:

This property describes that an instance of S10 Material Substantial was or is contained in another instance of S10 Material Substantial regardless of whether the identity of the involved instances is based on the persistence of the form of material or on material substance that may change form.

Full path:

Examples:

- The opal specimen from Jalisco in Mexico (E18) *contains* the fluid inclusion of the specimen (S14). (Rentro, 2019)

In first-order logic:

O25(x,y) ⇒ S10(x)
O25(x,y) ⇒ S10(y)
P46(x,y) ⇒ O25(x,y)

O27 split (was source for)

Domain:

S24 Sample Splitting

Range:

S13 Sample

Subproperty of:

S2 Sample Taking. O3 sampled from (was sample by): S10 Material Substantial

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S24 Sample Splitting with the instance of S13 Sample which is the original sample being split.

Full path:

Examples:

- The subsampling activity by Godfrey et al. in 2000 (S24) *split* the homogenous Sample (S13). [Part of the finely ground sample from fragment GT993 was taken to be used in ICP-AES analysis.] (Godfrey et al., 2002)

In first-order logic:

O27(x,y) ⇒ S24(x)
O27(x,y) ⇒ S13(y)
O27(x,y) ⇒ O3(x,y)

O28 is conceptually greater than (is conceptually less than)

Domain:

E55 Type

Range:

E55 Type

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of E55 Type from a particular concept scheme or vocabulary to be declared as having an order relative to other instances of E55 Type in the same or other concept schemes, without necessarily having a specific value associated with either instance. This allows, for example, for an E55 Type instance representing the concept of "good" in a conservation report vocabulary to be greater than the E55 Type instance representing the concept of "average" in the same vocabulary. This property is transitive, and thus if "average" is greater than "poor", then "good" is also greater than "poor". In the domain of statistics, types that participate in this kind of relationship are called "Ordinal Variables"; as opposed to those without order which are called "Nominal Variables". This property allows for queries that select based on the relative position of participating E55 Types.

Full path:

Examples:

- In the condition survey of the manuscripts of the library of the Saint Catherine Monastery, the option ‘supple’ (E55) *is conceptually greater* than the option ‘stiff’ (E55).
  [These options are used for assessing parchment on page 2, section 2 of the survey form and within the context of the dry conditions of the Sinai desert where the Monastery is, ‘supple’ is considered better because it is less brittle] (Pickwoad, 2004)

In first-order logic:

O28(x,y) ⇒ E55(x)
O28(x,y) ⇒ E55(y)

O29 removed sub-sample (was sub-sample removed by)

Domain:

S24 Sample Splitting

Range:

S13 Sample

Subproperty of:

S2 Sample Taking. O5 removed (was removed by): S13 Sample

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S24 Sample Splitting with the resulting instance of S13 Sample that has been removed from the original sample. The new sample (i.e. the sub-sample) maintains the characteristic qualities of the original.

Full path:

Examples:

- The subsampling activity by Godfrey et al. in 2000 (S24) *removed sub-sample* the ICP-AES subsample (S13).
  [This sub-sample was used for elemental analysis using inductively coupled plasma atomic emission spectrometry (ICP-AES) to reveal the composition of the original sample.] (Godfrey et al., 2002)

In first-order logic:

O29(x,y) ⇒ S24(x)
O29(x,y) ⇒ S13(y)
O29(x,y) ⇒ O5(x,y)

O30 determined position (was determined by)

Domain:

S23 Position Determination

Range:

E94 Space Primitive

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S23 Position Determination with an instance of E94 Space Primitive that is the result of calculating or concluding an actual position as an integral part of the activity of determining the position. In case the calculation is done later in another context, it should be regarded as the result of a distinct instance of S6 Data Evaluation. The instance of E94 Space Primitive approximates the place occupied by the entity whose position is being determined by the constituting observations.

Full path:

Examples:

- The determination of the position of the Titanic for the initial distress call after hitting an iceberg (S23) *determined position* 41°44′N 50°24′W (E94).
  [This was quickly determined via ‘dead reckoning’, i.e. based on the distance travelled since the previous known location, extrapolating a previous dead reckoning for 14 April 1912 20:00] (Halpern, 2011; Boxhall, 1962)
- The determination of the position of the Titanic by officer Joseph G. Boxhall after the initial distress signal was sent (S23) *determined position* 41°46′N 50°14′W (E94).
  [This was again determined via dead reckoning but extrapolating Boxhall's own determination shortly after 20:00, and revised the original position.] (Halpern, 2011; Boxhall, 1962)
- The calculation of the position of the Titanic by Robert Ballard's team after the Titanic ship-wreck was found (S23) *determined position* 41°43′32″N 49°56′49″W (E94).
  [This was the position of the centre of the ‘boiler field’, part of the Titanic debris] (Ballard et al., 1987)
- The determination of the position of the Titanic at the time of the collision (S23), by Samuel Halpern in 2007, *determined position* 41°45.5′N 49°55′W (E94).
  [This was based on the position of the boiler field and the ocean drift at the time.] (Halpern, 2007)

In first-order logic:

O30(x,y) ⇒ S23(x)
O30(x,y) ⇒ E94(y)

O31 has validity time-span (is time-span validity for)

Domain:

S23 Position Determination

Range:

E52 Time-Span

Subproperty of:

E2 Temporal Entity: P4 has time-span (is time-span of): E52 Time-Span

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S23 Position Determination with the instance of E52 Time-Span for which the determination is valid according to the observer at the time of the observation. No inferences can be made in relation to the validity of the determination outside this time-span, despite the fact that some entities are relatively stable, and their positions may remain the same after the determination within the relevant precision.

The time-span of validity should fall within the overall time-span of the process of determination. This property should be instantiated if the overall time-span of the process of determination is not sufficiently precise for the purpose and precision of the determination. An example would be the time that a ship reached an assumed position after running for a measured temporal duration with a measured speed and direction from a known position.

Full path:

S23 Position Determination. *O36 expressed the observed as (was observed by)*: S28 Observable Situation. *J24 held at least for (is at least validity of)*: E52 Time-Span

Examples:

- The determination of the position of the Titanic for the initial distress call after hitting an iceberg (S23) *has validity time-span* the time of the collision (E52).
  [This is a plausible guess based on Boxhall's account; the collision was on 14 April 1912 23:40 ship's time.] (Halpern, 2011; Boxhall, 1962)
- The determination of the position of the Titanic by officer Joseph G. Boxhall after the initial distress signal was sent (S23) *has validity time-span* the time of the collision (E52).
  [Boxhall was convinced of the correctness of his position determination until his death.] (Halpern, 2011; Boxhall, 1962)
- The determination of the position of the Titanic by Robert Ballard's team after the Titanic ship-wreck was found (S23) *has validity time-span* the time of the position determination (E52).
  [This period falls within the 1st of September 1985 00:48, i.e. the first encounter of a piece of Titanic debris and 1987] (Ballard et al., 1987)
- The determination of the position of Messner and Habeler in May 8, 1978 (S23) *has validity time-span* 8.5.1978 noon (E52). (Messner 1978, Roberts 2003)

In first-order logic:

$O31(x,y) \Rightarrow S23(x)$

$O31(x,y) \Rightarrow E52(y)$

$O31(x,y) \wedge E52(z) \wedge P4(x,z) \Rightarrow P86(y,z))$

O32 determined position of (was located by)

Domain:

S23 Position Determination

Range:

S15 Observable Entity

Subproperty of:

S27 Observation. O35 observed entity (was observed by): S15 Observable Entity

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S23 Position Determination with the instance of S15 Observable Entity whose position is being determined.

Full path:

Examples:

- The determination of the position of the Titanic for the initial distress call after hitting an iceberg (S23) *determined position of* the Titanic (E22). (Halpern, 2011)
- The determination of the position of the Titanic by officer Joseph G. Boxhall after the initial distress signal was sent (S23) *determined position of* the Titanic (E22) (Halpern, 2011)
- The determination of the position of the Titanic by Robert Ballard's team after the Titanic ship-wreck was found (S23) *determined position* of the Titanic. [More precisely it determined the position of the centre of the ‘boiler field’ of Titanic’s debris] (E22) (Ballard et al., 1987)
- The determination of the position of the Titanic at the time of the collision (S23) by Samuel Halpern in 2007, *determined position of* the Titanic (E22)
- The determination of the position of Messner and Habeler in May 8, 1978 (S23) *determined position of* Reinhold Messner and Peter Habeler (E20) (Messner 1978)

In first-order logic:

O32(x,y) ⇒ S23(x)

O32(x,y) ⇒ S15(y)

O32(x,y) ⇒ (∃z,u,v,w) [E93(z) ∧ P195(z,y) ∧ E52(w) ∧ O31(x,w) ∧ P164(z,w) ∧ E94(v) ∧ O30(x,v) ∧ E53(u) ∧ P161(z,u) ∧ P121(v,u)]

O33 is relative to (has relative dimension)

Domain:

S25 Relative Dimension

Range:

S15 Observable Entity

Subproperty of:

E54 Dimension: O12i is dimension of (has dimension): S15 Observable Entity

Superproperty of:

E26 Angle. O34 has vertex (is vertex of): S15 Observable Entity

Quantification:

many to many, necessary (2,n:0,n)

Scope note:

This property associates an instance of S25 Relative Dimension with one of the instances of S15 Observable Entity between which it was holding.

Full path:

Examples:

- The distance between the Moon and the Earth *is relative to* the Moon. [The distance to the Moon can be measured with millimetre precision.] (‘Lunar Laser Ranging experiments’, 2024)
- The distance between the Moon and the Earth *is relative to* The Earth (S10). (‘Lunar Laser Ranging experiments’, 2024)
- The angle between the Sun and Moon with a half-moon at daylight as measured by Aristarchus of Samos on an unknown day around 280 B.C. *is relative to* the Moon (E18). (Berggren and Sidoli, 2007)
- The angle between the Sun and Moon with a half-moon at daylight as measured by Aristarchus of Samos on an unknown day around 280 B.C. i*s relative to* the Sun (E18). (Berggren and Sidoli, 2007)
- The angle between the summit of the Pico del Teide, Tenerife and a horizontal level as measured by Alexander von Humboldt in the harbour of Orotava in Tenerife on the 19th of June 1799 *is relative to* the Pico del Teide (E26). (Humboldt, 1859)
- The distance of Reinhold Messner and Peter Habeler from Mount Everest summit 8.5.1978 (S25) *is relative to* Reinhold Messner and Peter Habeler (E20). (Messner 1978, Roberts 2003)
- The distance of Reinhold Messner and Peter Habeler from Mount Everest summit 8.5.1978 (S25) *is relative to* Mount Everest summit (E27). (Messner 1978, Roberts 2003)

In first-order logic:

O33(x,y) ⇒ S25(x)
O33(x,y) ⇒ S15(y)
O33(x,y) ⇒ O12i(x,y)

O34 has vertex (is vertex of)

Domain:

S26 Angle

Range:

S15 Observable Entity

Subproperty of:

S25 Relative Dimension. O33 is relative to (has relative dimension): S15 Observable Entity

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S26 Angle with the instance of S15 Observable Entity that includes in its extent the vertex of the former.

Typical examples are respective marked spots on Earth or a ship where a theodolite ('Theodolite', 2025), a sextant ('Sextant', 2025), or a compass is positioned during a position measurement.

Full path:

Examples:

- The angle between the Sun and Moon with a half-moon at daylight as measured by Aristarchus of Samos on an unknown day around 280 B.C. (S26) *has vertex* Aristarchus of Samos (E21) (Berggren and Sidoli, 2007)
- The angle between the summit of the Pico del Teide, Tenerife and a horizontal level, measured by Alexander von Humboldt on the 19th of June 1799 (S26) has vertex the harbour of Orotava in Tenerife (E25). (Humboldt, 1859)

In first-order logic:

O34(x,y) ⇒ S26(x)
O34(x,y) ⇒ S15(y)
O34(x,y) ⇒ O33(x,y)

O35 observed entity (was observed by)

Domain:

S27 Observation

Range:

S15 Observable Entity

Subproperty of:

Superproperty of:

S4 Single Observation. O8 observed (was observed by): S15 Observed Entity
S21 Measurement. O24 measured (was measured by): S15 Observable Entity
S23 Position Determination. O32 determined position (was located by): S15 Observable Entity

Quantification:

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

Scope note:

This property associates an instance of S27 Observation with one of the instances of S15 Observable Entity that were observed. Specifically, it describes that a thing, a feature, a phenomenon, or some process, is observed by an activity of S27 Observation.

This property is a strong shortcut for the detailed path from S27 Observation through *O36 expressed the observed as (was the expression of)*, S28 Observable Situation, *O40 refers to observable entity (is referred to in),* to S15 Observable Entity.

Full path:

S27 Observation. *O36 expressed the observed as (was the expression of)*: S28 Observable Situation. *O40 refers to observable entity (is referred to in)*: S15 Observable Entity

Examples:

- The engineers' observation on the slope of Panagopoula coastal site, near Patras, on the 25th–26th April 1971 and the 3rd May 1971 (S4) *observed entity* the rotational landslide at the same site (E4). (Tavoularis et al., 2017)

In first-order logic:

O35(x,y) ⇒ S27(x)
O35(x,y) ⇒ S15(y)
O35(x,y) ⇔ (∃z) [S28(z) ∧ O36(x,z) ∧ O40(z,y)]

O36 expressed the observed as (was the expression of)

Domain:

S27 Observation

Range:

S28 Observable Situation

Subproperty of:

Superproperty of:

S4 Single Observation. O37 expressed the observed as observable proposition (was observable proposition observed by): S29 Observable Proposition

Quantification:

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

Scope note:

This property associates an instance of Observation with an instance of S28 Observable Situation that the actors carrying out the observation used to express the observed phenomena of their interests. The alleged time-span of the observed situation must be equal to or within the overall time-span of the domain instance used for this property. A narrower time-span of validity for the observed situation can be documented via the property S28 Observable Situation. *J24 held at least for (is at least validity of)*: E52 Time-Span.

This property is a strong shortcut for the path from S27 Observation through *J2 concluded that (was concluded by)*, I2 Belief, *J4 that (is subject of)*, S28 Observable Situation, *J5 holds to be*, to I6 Belief Value (= “True”).

Full path:

S27 Observation. *J2 concluded that (was concluded by)*: I2 Belief. *J4 that (is subject of)*: S28 Observable Situation. *J5 holds to be*: I6 Belief Value (= “True”)

Examples:

- The observation between April, 25 and May, 3 1971 at the slope of the coastal region of Panagopoula (S27), *expressed the observed as* the rotational landslide on the same site (S15). (Tavoularis et al., 2017)
- The survey of Sinai MS GREEK 418 (S4) *expressed the observed as* a detached triple-braided clasp strap (S15). (Honey and Pickwoad, 2010)

In first-order logic:

O36(x,y) ⇒ S27(x)
O36(x,y) ⇒ S28(y)
O36(x,y) ⇔ S27(x) ∧ S28(y) ∧ (∃u) [I2(u) ∧ J2(x,u) ∧ J4(u,y) ∧ J5(u,‘TRUE’)]

O37 expressed the observed as observable proposition (was observable proposition characterized by)

Domain:

S4 Single Observation

Range:

S29 Observable Proposition

Subproperty of:

S27 Observation. O36 expressed the observed as (was the expression of): S28 Observable Situation
E13 Attribute Assignment. J33 assigned proposition (is assigned by): I17 One-Proposition Set

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S4 Single Observation with the instance of S29 Observable Proposition that the actors carrying out the observation used to express the observed phenomenon of interest. This property forms a logical interface between observing single propositions or more generally observable situations. It is particularly relevant for implementing effective queries. For documentation, the use of the simpler shortcut properties, i.e., *O8 observed (was observed by), O9 observed property type (property type was observed by)*, and *O16 observed value (value was observed by)* will typically be the preferred approach.

The property is part of the fully developed path from S4 Single Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *O38 has domain (is domain of)*, S15 Observable Entity, which is shortcut by *O8 observed (was observed by)*.

The property is part of the fully developed path from S4 Single Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *J31 has range (is range of)*, E1 CRM Entity, which is shortcut by *O16 observed value (value was observed by)*.

The property is part of the fully developed path from S4 Single Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *J32 has property type (is property type of)*, E55 Type, which is shortcut by *O9 observed property type (property type was observed by)*.

Full path:

Examples:

- The inspection of the burial arrangement in La Tomba dell'Aryballos sospeso on the left bench by Prof. Alessandro Mandolesi on the 21st of September 2013 (S4) *expressed the observed as observable proposition* the proposition set with content
{The burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object} (S29). (Mandolesi, 2013)

In first-order logic:

O37(x,y) ⇒ S4(x)
O37(x,y) ⇒ S29(y)
O37(x,y) ⇒ O36(x,y)
O37(x,y) ⇒ J33(x,y)

O38 has domain (is domain of)

Domain:

S29 Observable Proposition

Range:

S15 Observable Entity

Subproperty of:

S28 Observable Situation. O40 refers to observable entity (is referred to in): S15 Observable Entity
I17 One-Proposition Set. J30 has domain (is domain of): E1 CRM Entity

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S29 Observable Proposition with an instance of S15 Observable Entity that must appear as the only domain instance of the proposition in the content of the former.

This property is part of the fully developed path from S4 Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *O38 has domain (is domain of)*, SO15 Observable Entity, which is shortcut by *O8 observed (was observed by)*.

Full path:

Examples:

- The proposition set with content:
  {The burial arrangement on the left bench in La Tomba dell'Aryballos sospeso (E22 Human-Made Object)} (S29) *has domain* the burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object). (Mandolesi, 2013)
- The proposition set with content:
  {The skeleton on the left bench in La Tomba dell'Aryballos sospeso (E20 Biological Object) forms part of the burial arrangement on the left bench in La Tomba dell Aryballos sospeso} (S29) *has domain* the skeleton on the left bench in La Tomba dell'Aryballos sospeso (E20). (Mandolesi, 2013)

In first-order logic:

O38(x,y) ⇒ S29(x)
O38(x,y) ⇒ S15(y)
O38(x,y) ⇒ O40(x,y)
O38(x,y) ⇒ J30(x,y)

O39 observed dimension (was observed in)

Domain:

S21 Measurement

Range:

E54 Dimension

Subproperty of:

Superproperty of:

E16 Measurement. P40 observed dimension (was observed in): E54 Dimension

Quantification:

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

Scope note:

This property records the dimension of an instance of S15 Observable Entity or a specific constellation of such instances that was observed in an instance of S21 Measurement. The observed items should be documented using the property *O24 measured (was measured by)*.

One measurement activity may determine only one dimension of an instance of S15 Observable Entity or a specific constellation of such instances. Such a dimension may be any observable and quantifiable aspect of the latter. Weight, length, spatial or temporal distances are characteristic kinds of dimensions in this sense.

A dimension of one or more instances of S15 Observable Entity may be determined either by direct observation or using recorded evidence. However, determination by measuring requires the presence of the measured items. Other methods may constitute other kinds of instances of I1 Argumentation.

Even though knowledge of the value of a dimension requires measurement, the dimension may be an object of discourse prior to, or even without, any measurement being made.

This property is a part of the fully developed path from S15 Observable Entity through *O24i was measured by (measured)*, S21 Measurement, *O39 observed dimension (was observed in)* to E54 Dimension.

In case the instance of S21 Measurement is more specifically an instance of E16 Measurement, the instance of E54 Dimension cannot be an instance of S25 Relative Dimension and using the property *O39 observed dimension (was observed in)* is equivalent to using the property *P40 observed dimension (was observed in)*. In other words, using the one implies the other.

Referring to an instance of E54 Dimension by this property is mutually exclusive to using either property *P191 had duration (was duration of)* or *P179 had sales price (was sales price)* to refer to the same instance of E54 Dimension. This follows from the same rule as for *O12 has dimension (is dimension of)*, in the same way as for *P40 observed dimension (was observed in)* and *P43 has dimension (is dimension of)*.

Full path:

Examples:

- The measurement of the angle between the Sun and Moon with a half-moon at daylight as by Aristarchus of Samos on an unknown day around 280 B.C. *observed dimension* the angle between the Sun and Moon with a half-moon at daylight (S26). [observed as 87 degrees instead of the current value of 89° 50'] (Berggren and Sidoli 2007)
- The measurement of the angle between the summit of the Pico del Teide, Tenerife and a horizontal level by Alexander von Humboldt in the harbour of Orotava in Tenerife on the 19th of June 1799 *observed dimension* the angle between the summit of the Pico del Teide, Tenerife and a horizontal level by Alexander von Humboldt in the harbour of Orotava in Tenerife. [observed as 16 ½ degrees] (Humboldt, 1859)

In first-order logic:

$O39(x,y) \Rightarrow S21(x)$
$O39(x,y) \Rightarrow E54(y)$
$P40(x,y) \Rightarrow O39(x,y)$

When restricted to E16 Measurement, i.e. to dimensions that pertain to a single physical thing, O39 and P40 are equivalent:
$P40(x,y) \Leftrightarrow O39(x,y) \wedge E16(x) \wedge \neg S25(y)$
$O39(x,y) \wedge E16(x) => \neg S25(y)$

O39 implies a shortcut O12 with the same y:
$O39(x,y) \Rightarrow (\exists z)\ [S15(z) \wedge O24i(z,x) \wedge S21(x) \wedge O39(x,y)] \Rightarrow (\exists z)\ O12(z,y)$

Exclusion statements (by deduction from O12):
$[O39(x,y) \wedge P179(z,w)] \Rightarrow w \neq y$
$[O39(x,y) \wedge P191(z,w)] \Rightarrow w \neq y$

O40 refers to observable entity (is referred to in)

Domain:

S28 Observable Situation

Range:

S15 Observable Entity

Subproperty of:

I4 Proposition Set. J28 contains entity reference (is referred to in): E1 CRM Entity

Superproperty of:

S29 Observable Proposition. O38 has domain (is domain of): S15 Observable Entity

Quantification:

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

Scope note:

This property associates an instance of S28 Observable Situation with an instance of S15 Observable Entity that appears as an element of one or more propositions in the content of the former.

This property serves on one side to relate an instance of S28 Observable Situation to other contexts of interest, in particular when its content is or cannot be represented as a Named Graph in the same knowledge base. On the other hand, it plays a structural role in this model for expressing a minimal formal constraint for the observability of what is referred by an instance of S28 Observable Situation.

This property is part of the fully developed path from S4 Observation through *O37 expressed the observed as observable proposition (was observable proposition characterized by)*, S29 Observable Proposition, *O38 has domain (is domain of)*, to S15 Observable Entity, which is strongly shortcut by *O8 observed (was observed by)*.

Full path:

Examples:

- The proposition set with content:
  {Nero on July 19, 64 AD (E93 Presence)

P164 is temporally specified by: July 19, 64 AD (E52 Timespan)
P195 was a presence of: Nero Claudius Caesar Drusus Germanicus (E21 Person)
P167 was within the settlement of Antium (E27 Site) in 64AD
}
refers to the observable entity Nero Claudius Caesar Drusus Germanicus (E21, S15).

In first-order logic:

O40(x,y) ⇒ S28(x)
O40(x,y) ⇒ S15(y)
O40(x,y) ⇒ J28(x,y)

O41 measured dimension (was measured in)

Domain:

S23 Position Determination

Range:

S25 Relative Dimension

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S23 Position Determination with an instance of S25 Relative Dimension that was the result of a measurement carried out as part of the activity of determining the position in order to obtain or complete the necessary information for determining the position, such the distances of the item to be determined from two immobile items with known position, or the compass directions of two light-houses (angles with the Earth's magnetic field**)** a**s** seen from a boat for determining the boat's position.

Only the time-critical measurements need to be carried out of as part of the actual domain instance of this property, such as the time elapsed at which an athlete meets a goal with a predetermined distance from the starting point.

This property needs not be instantiated in cases in which the actual relative dimensions are not known to the user, such as the distances to the satellites when using GPS devices.

Full path:

Examples:

- The determination of the position of Messner and Habeler in May 8, 1978 (S23) *measured dimension* the distance of Reinhold Messner and Peter Habeler from Mount Everest summit 8.5.1978 (S25) (Messner 1978, Roberts 2003)
- The determination of the position of the Titanic by officer Joseph G. Boxhall after the initial distress signal was sent (S23) *measured dimension* the elapsed time from the last fixed star observation 7:30 to the time of the initial distress signal (S25) (Halpern, 2005) [Boxhall said that he used the star fix position for 7:30pm (Probably 7:38pm) that night as his base and used a speed of 22 knots from there to a time of 11:45pm.]

In First Order Logic:

O41(x,y) ⇒ S23(x)
O41(x,y) ⇒ S25(y)

O42 used result of (results contributed to)

Domain:

S23 Position Determination

Range:

S27 Observation

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of S23 Position Determination with an instance of S27 Observation the results of which were part of the necessary constituting observations of the position determination but carried out earlier, in another context.

Therefore, the observations must not be a critical component of the validity time-span of the position determination, such the measurement of the distance between the start and the finish line in a 100m sprint race competition. In contrast, the measurement of the elapsed time an athlete reaches the finish line needs to fall within the time-span and be part of the domain instance of this property.

Full path:

Examples:

- The determination of the position of the Titanic by officer Joseph G. Boxhall after the initial distress signal was sent (S23) *used results of* the last fixed star observation 7:30 pm (S27) (Halpern, 2005)
  [Boxhall said that he used the star fix position for 7:30pm (Probably 7:38pm) that night as his base and used a speed of 22 knots from there to a time of 11:45pm.]

In First Order Logic:

O42(x,y) ⇒ S23(x)
O42(x,y) ⇒ S25(y)

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