CRMsci In Progress since [22/3/2017] ver 1.2.4, September 2017

# Introduction

## Scope

This text defines the “Scientific Observation Model”, 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.

It uses and extends the CIDOC Conceptual Reference Model (CRM, ISO21127) as a general ontology of human activity, things and events happening in spacetime. It uses the same encoding-neutral formalism of knowledge representation (“data model” in the sense of computer science) as the CIDOC CRM, which can be implemented in RDFS, OWL, on RDBMS and in other forms of encoding. Since the model reuses, wherever appropriate, parts of CIDOC CRM, we provide in this document also a comprehensive list of all constructs used from ISO21127, together with their definitions following the version 6.2 maintained by CIDOC.

The Scientific Observation Model has been developed bottom up from specific metadata examples from life sciences, geology, archeology, 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 colors, 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.

## Status

The model presented in this document has been validated in several national and international projects[[1]](#footnote-2), through implementations of slightly different versions together with application-specific extensions and through mapping to and from related standards. 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.

## Naming Conventions

All classes and properties declared were given both a name and an identifier constructed according to the conventions used in the CIDOC CRM model. For classes, that identifier consists of the letter S followed by a number. For propertiesthat identifier consists of the letter O followed by a number, which in turn is followed by the letter “i” every time the property is mentioned “backwards”, i.e., from target to domain (inverse link). “S” and “O” do not have any other meaning. They correspond respectively to letters “E” and “P” in the CIDOC CRM naming conventions, where “E” originally meant “entity” (although the CIDOC CRM “entities” are now consistently called “classes”), and “P” means “property”. Whenever CIDOC CRM classes are used in our model, they are named by the name they have in the original CIDOC CRM.

Letters in red colour in CRM Classes and properties are additions/extensions defined in the scientific observation model.

## Class and property hierarchies

The CIDOC CRM model declares no “attributes” at all (except implicitly in its “scope notes” for classes), but regards any information element as a “property” (or “relationship”) between two classes. The semantics are therefore rendered as properties, according to the same principles as the CIDOC CRM model.

Although they do not provide comprehensive definitions, compact monohierarchical presentations of the class and property IsA hierarchies have been found to aid in the comprehension and navigation of the model significantly, and are therefore provided below.

The class hierarchy presented below has the following format:

* Each line begins with a unique class identifier, consisting of a number preceded by the letter “S”, or “E”.
* A series of hyphens (“-”) follows the unique class identifier, indicating the hierarchical position of the class in the IsA hierarchy.
* The English name of the class appears to the right of the hyphens.
* The index is ordered by hierarchical level, in a “depth first” manner, from the smaller to the larger sub hierarchies.
* Classes that appear in more than one position in the class hierarchy as a result of multiple inheritance are shown in an *italic typeface*.

The property hierarchy presented below has the following format:

* Each line begins with a unique property identifier, consisting of a number preceded by the letter “O”.
* A series of hyphens (“-”) follows the unique property identifier, indicating the hierarchical position of the property in the IsA hierarchy.
* The English name of the property appears to the right of the hyphens.
* The domain class for which the property is declared.

# Scientific Observation Model Class Declaration

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

* Class names are presented as headings in bold face, preceded by the class’s unique identifier;
* The line “Subclass of:” declares the superclass of the class from which it inherits properties;
* The line “Superclass of:” is a cross-reference to the subclasses of this class;
* The line “Scope note:” contains the textual definition of the concept the class represents;
* The line “Examples:” contains a bulleted list of examples of instances of this class.
* The line “Properties:” declares the list of the class’s properties;
* Each property is represented by its unique identifier, its forward name, and the range class that it links to, separated by colons;
* Inherited properties are not represented;
* Properties of properties, if they exist, are provided indented and in parentheses beneath their respective domain property.

## Classes

### S1 Matter Removal

Subclass of: [E7](#_E7_Activity) Activity

Superclass of: [E80](#_E80_Part_Removal) Part Removal

[S2](#_S2_Sample_Taking) Sample Taking

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 modeled 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[[2]](#footnote-3).

Decision: accepted.

In First Order Logic:

S1(x) ⊃ E7(x)

Properties:

[O1](#_O1_diminished) diminished (was diminished by): [S10](#_S10_Material_Substantial) Material Substantial

[O2](#_O2_removed) removed (was removed by): [S11](#_S11_Amount_of) Amount of Matter

### S2 Sample Taking

Subclass of: [S1](#_S1_Matter_Removal) Matter Removal

Superclass of [S3](#_S3_Sample_Taking) Measurement by Sampling

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 non-rigid Material Substantials, the source of sampling may regarded not to be modified by the activity of sample taking.

Examples:

* The water sampling (S2) carried out by IGME, sampled from borehole 10/G5 at 419058.03, 4506565 , 95.7 Mygdonia basin on 28/6/2005[[3]](#footnote-4)
* The collection (S2) of specimen “FHO – Benth. - 1055” (S13) from a plant (E20) of the species “spiciformis” (E55) in Zambia by Bullock, A.A. in 1939.
* The collection (S2) of micro-sample 7 (S13), from the paint layer (S10) on the area of the apple (E53, E25) shown on the painting (E22) “Cupid complaining to Venus” (Cranach) by Joyce Plesters in June 1963.

Decision: examples accepted. Put in. Thanais provide biblio if possible.

In First Order Logic:

S1(x) ⊃ S3(x)

Properties:

[O3](#_O3_sampled_from) sampled from (was sample by): [S10](#_S10_Material_Substantial) Material Substantial

[O4](#_O4_sampled_at) sampled at (was sampling location of): [E53](#_E53_Place) Place

[O5](#_O5_removed) removed (was removed by): [S13](#_S13_Sample) Sample

[O20](#_O20_sampled_from) sampled from type of part (type of part was sampled by): [E55](#_E55_Type) Type

### S3 Measurement by Sampling

Subclass of: [S2](#_S2_Sample_Taking) Sample Taking

[S21](#_S21_Measurement_(equivalent) Measurement

Scope note: This class comprises activities of taking a sample and measuring or analyzing 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 are constrained to describe the taking of exactly one sample and the dimensions observed by the respective measurement are implicitly understood to describe this particular sample as representative of the place on the instance of S10 Material Substantial from which the sample was taken. Therefore the class S3 Measurement by Sampling inherits the properties of S2 Sample Taking. *O3 sampled from:* S10 Material Substantial and *O4 sampled at:* E53 Place, and the properties of S21(E16) Measurement. *P40 observed dimension:* E54 Dimension, due to multiple inheritance. It needs not instantiate the properties *O5 removed:* [S13](#_S13_Sample) Sample and *O24 measured*: S15 Observable Entity, if the sample is not documented beyond the context of the activity.

Examples:

* The chemical Analysis 1 on 20/4/2004 sampled from layer50501 and observed 70 mg of Ca[[4]](#footnote-5)
* The Sphaerosyllislevantina specimen length measurement on 12/3/1999[[5]](#footnote-6).
* Measurement (S3) of retention times during Gas Chromatography analysis of a paint sample (S13) which identified Linseed oil as the paint medium.

In First Order Logic:

S3(x) ⊃ S2(x)

S3(x) ⊃ S21(x)

Decision: add identifiying infromation for the particular measurement in gas chromotography example. MD to revise phrase in yellow.

### S4 Observation

Subclass of: [E13](#_E13_Attribute_Assignment_1) Attribute Assignment

Superclass of: [S21](#_S21_Measurement_(equivalent) Measurement

[S19](#_S19_Encounter_Event) Encounter Event

Scope note: This class comprises the 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 behavior and interactions are observed by human sensory impression, and often enhanced by tools and measurement devices.

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. Manual recordings may serve as additional evidence. Measurements and witnessing of events are special cases of observations. Observations result in a belief about certain propositions. 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, or by reification of the property *O16 observed value*.

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.

Observations represent the transition between reality and propositions in the form of instances of a formal ontology, and can be subject to data evaluation from this point on. For instance, detecting an archaeological site on satellite images is not regarded as an instance of S4 Observation, but as an instance of S6 Data Evaluation. Rather, only the production of the images is regarded as an instance of S4 Observation.

Examples:

* The excavation of unit XI by the Archaeological Institute of Crete in 2004.
* The observation (S4) of the density (S9) of the X-Ray image of cupid's head from the painting “Cupid complaining to Venus” (S15) as “high density” (E1), on the 19th of March 1963.
* The observation (S4) of visible light absorption (S9) of the painting “Cupid complaining to Venus” (S15) as “having red pigment”, in 2016.

.

In First Order Logic:

S4(x) ⊃ E13(x)

Properties:

[O8](#_O8_observed_(was) observed (was observed by): [S15](#_S15_Observable_Entity) Observable Entity

[O9](#_O9_observed_property) observed property type (property type was observed by): [S9](#_S9_Property_Type) Property Type

[O16](#_O16_observed_value)observed value (value was observed by): [E1](#_E1_CRM_Entity) CRM Entity

O?observed: Situation?

Decision: postpone all work on this.

### S5 Inference Making

Subclass of: [E13](#_E13_Attribute_Assignment_1) Attribute Assignment

Superclass of: [S6](#_S6_Data_Evaluation) Data Evaluation

[S7](#_S7_Simulation_or) Simulation or Prediction

[S8](#_S8_Categorical_Hypothesis) 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 (E7) 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 (E22) on it and the hypothesis that he died from loss of blood (the evidence was that his bones (E20) remained white in contrast to the others). [[6]](#footnote-8)

The inference that the underdrawing (E25) of the painting “Cupid complaining to Venus” (E22) was done with red pigment (E57), based on the observation (S4) that red pigment lines appear under the top paint layers.

In First Order Logic:

S5(x) ⊃ E13(x)

Properties:

Decision: postpone thought on this until reconsideration of S4 Observation. Consider together with. Thanasis will provide ref for the cupid example.

### S6 Data Evaluation

Subclass of: [S5](#_S5_Inference_Making) Inference Making

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 epicenter. S6 Data Evaluation is not defined as S21/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 epicenter of Lokris area in 1989 by IGME[[7]](#footnote-9).
* 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 (S4). [[8]](#footnote-10)
* The calculation of the overall height (E54) of the heavily fragmented statue of Hercules (S15) in Ancient Messini from the measurement of the size of the fragment of the foot.

In First Order Logic:

S6(x) ⊃ S5(x)

Decision: examples accepted but reference needed for messini example.

NEW ISSUE: formulate the belief conditions for the input data of the data evaluation process. Need to add a link of input data AND this has to be connceted to CRMdig.

HW: TV and MD, take examples from laser department

Properties:

[O10](#_O10_assigned_dimension) assigned dimension (dimension was assigned by): [E54](#_E54_Dimension) Dimension

[O11](#_O11_described_(was) described (was described by): [S15](#_S19_Observable_Entity) Observable Entity

### S7 Simulation or Prediction

Subclass of: [S5](#_S5_Inference_Making) Inference Making

Scope note: This class comprises activities of executing algorithms or software for simulating the behavior 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 behaviors 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).[[9]](#footnote-11)
* Predicting the temperature fluctuation during summer months inside the building of the library of the Saint Catherine Monastery in Sinai, Egypt.

In First Order Logic:

S7(x) ⊃ S5(x)

Decision: accept examples and add ref for st catherine example.

Contiuation of examples: add an example of a what if simultation, inputs and outputs are fictitious but comparable to reality… would be good idea to add agent based model in CH. Or example from Sahara. Assigned OE and/or SS.

Properties:

### S8 Categorical Hypothesis Building

Subclass of: [S5](#_S5_Inference_Making) Inference Making

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 behavior, be it necessary or probabilistic. Categorical hypotheses are developed by “induction” from finite numbers of observation and the absence of observations of particular kinds. 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:

* Hypothessizing that “no binding before the 10th century is made with spine supports” documented in ….

Decision: accept example and add ref.

In First Order Logic:

S8(x) ⊃ S5(x)

Properties:

### S9 Property Type

Subclass of: [E55](#_E55_Type) Type

Scope note: This class comprises types of 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 (S9) (of a station that is observed, meaning a share-wave velocity over the first 30 m).)[[10]](#footnote-12)
* Retention time (S9) (in gas chromatography, meaning the time it takes for a component to pass through the chromatographer's column).

Decision: skip and consider together with issue related to redoing S4

In First Order Logic:

S9(x) ⊃ E55(x)

Properties:

### S10 Material Substantial

Subclass of: [E70](#_E70_Thing) Thing

Superclass of: [S14](#_S14_Fluid_Body) Fluid Body

[S11](#_S11_Amount_of) Amount of Matter

[E18](#_E12_Production_) 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[[11]](#footnote-13).
* The Mesozoic carbonate sequence with **flysch (S10)** extracted from the area of Nafplion that was mapped and studied by Tattaris in 1970[[12]](#footnote-14).

Parnassos, the limestone mountain[[13]](#footnote-15)

Decision: accepted.

In First Order Logic:

S10(x) ⊃ E70(x)

Properties:

[O25](#_O25_is_composed) contains (is contained in): [S10](#_S10_Material_Substantial) Material Substantial

*It has been proposed that P44, P45 and P46 are moved from E18 Physical Thing to E70 Thing. Decision of CRM SIG is pending.*

[O15](#_O15_occupied_(equivalent) occupied (was occupied by): [E53](#_E53_Place) Place

### S11 Amount of Matter

Subclass of: [S10](#_S10_Material_Substantial) Material Substantial

Superclass of: [S12](#_S12_Amount_of) Amount of Fluid

[S13](#_S13_Sample) 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.

Q: what is the difference between S10 and S11

Reasoning is: such an amount of matter, in order to be identifiable individual, requires a sort of confinement that supplies a constraint on the constallation of matter and its stability of form which, in practical terms, could be a bottle.

Decision: need to add a phrase to encapsulate the reasoning above in the S11 scope note. MD to do.

Examples:

* The mass of soil (S11) 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[[14]](#footnote-16).

The amount of natural cement (S11) 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[[15]](#footnote-17).

Decision: accept examples

In First Order Logic:

S11(x) ⊃ S10(x)

### S12 Amount of Fluid

Subclass of: [S11](#_S11_Amount_of) Amount of Matter

[S14](#_S14_Fluid_Body) Fluid Body

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)

In First Order Logic:

S12(x) ⊃ S11(x)

S12(x) ⊃ S14(x)

Properties:

[O6](#_O6_forms_former) forms former or current part (has former or current part ): [S14](#_S14_Fluid_Body) Fluid Body

Decision: current example accepted But to add Armstrong example MD

### S13 Sample

Subclass of: [S11](#_S11_Amount_of) Amount of Matter

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.[[16]](#footnote-18) (S13, S12)
* The micro-sample 7, taken from the painting (S10) “Cupid complaining to Venus” (Cranach) by Joyce Plesters in June, 1963.

In First Order Logic:

S13(x) ⊃ S11(x)

Decision: examples accepted. TV to give example 2 a reference.

### S14 Fluid Body

Subclass of: [S10](#_S10_Material_Substantial) Material Substantial

Superclass of: [S12](#_S12_Amount_of) 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

Decision: rejected the ficitonal example. Added the river. Should add a reference to the geological definition on which this class is modelled.

In First Order Logic:

S14(x) ⊃ S10(x)

### S15 Observable Entity

Subclass of: [E1](#_E1_CRM_Entity) CRM Entity

Superclass of: [E2](#_E2_Temporal_Entity_1) Temporal Entity

[E77](#_E77_Persistent_Item_1) Persistent Item

Scope note:

This class comprises instances of E2 Temporal Entity or E77 Persistent Item, i.e. items or phenomena, such as physical things, their behavior, states and interactions or events, that can be observed by human sensory impression, often enhanced by using tools and measurement devices.

Conceptual objects manifestthrough 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) (S15) that was identified in 1996 in farmed geese in southern China as circulating highly pathogenic H5N1[[17]](#footnote-19) .
* The crow flight he observed over the waters of Minamkeak Lake during the summer. of 2015.
* The eruption of Krakatoa volcano at Indonesia in 1883[[18]](#footnote-20).
* The density of the cupid head area in the X-Ray of the painting “Cupid complaining to Venus”.

Decision: postponed because the whole entity under review.

In First Order Logic:

S15(x) ⊃ E1(x)

Properties:

[O12](#_O12_has_dimension) has dimension (is dimension of): [E54](#_E54_Dimension) Dimension

### S17 Physical Genesis

Subclass of: [E63](#_E63_Beginning_of) Beginning of Existence

[S18](#_S18_Alteration) Alteration

Superclass of: [E12](#_E12_Production_1) 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 that resulted in the spatial ‘tiger bush’ pattern on the gradually sloped terrain in Western Africa, as it was studied in 1994.[[19]](#footnote-21)
* The landslide event, near the epicentre of the 1999 earthquake, along the road leading to the peak of the Parnitha Mountain..

The corrosion process affecting my copper samples (S13) in the artificial aging salt-spray apparatus after 10 cycles which produced layers (E25) of cuprite and malachite. (E12)

Decision: examples accepted. TV to give reference to his sampling example.

In First Order Logic:

S17(x) ⊃ E63(x)

S17(x) ⊃ S18(x)

Properties:

[O17](#_O17_generated_(was) generated (was generated by): [E18](#_E12_Production_) Physical Thing

### S18 Alteration

Subclass of: [E5](#_E2_Temporal_Entity) Event

Superclass of: [S17](#_S17_Physical_Genesis) Physical Genesis

[E11](#_E11_Modification) 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[[20]](#footnote-22).
* The stretching of cockled parchment leaves (E18) after humidification which results in these leaves being flattened.

In First Order Logic:

S18(x) ⊃ E5(x)

Decision: examples good. TV will send ref for example 2

Properties:

[O18](#_O18_altered_(was) altered (was altered by): [E18](#_E12_Production_) Physical Thing

### S19 Encounter Event

Subclass of: [S4](#_S4_Observation) Observation

Scope note: This class comprises activities of S4 Observation (substance) where an E39 Actor 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 a 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 a 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 in order 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 Prof. Stampolidis, of a complete skeleton, *in situ*, at the site of Eleutherna during the archaeological excavation carried out by the University of Crete in 2000.
* The detection of *lagocephalos\_Sceleratus* in the catch of trawler XXX in Mediteranean sea, during the first week of August 2014[[21]](#footnote-23).

Decision: accepted by for adding references and the name of the trawler

In First Order Logic:

S19(x) ⊃ S4(x)

Properties:

[O19](#_O19_has_found) has found object (was object found by): [E18](#_E12_Production_) Physical Thing

[O21](#_O21_has_found)has found at (witnessed): [E53](#_E53_Place) Place

### S20 Rigid Physical Feature

Subclass of: E26 Physical Feature

[E53](imap://bekiari@mailhost.ics.forth.gr:993/fetch%3eUID%3e/INBOX%3e71636#_E53_Place) Place

Superclass of: [E27](imap://bekiari@mailhost.ics.forth.gr:993/fetch%3eUID%3e/INBOX%3e71636#_E26_Physical_Feature) Site

[S22](imap://bekiari@mailhost.ics.forth.gr:993/fetch%3eUID%3e/INBOX%3e71636#_S22_Segment_of) Segment of Matter

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](imap://bekiari@mailhost.ics.forth.gr:993/fetch%3eUID%3e/INBOX%3e71636#_E53_Place) 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,* E53 Place, *P157 is at rest relative 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
* Albrecht Duerer's signature on his painting of Charles the Great
* The damaged form of the nose of the Great Sphinx in Giza
* The “Central Orygma” pit-house that marks the excavated built area of the settlement of Mavropigi., representing phases I-III.[[22]](#footnote-24)
* The surface Surf313 (created by the excavation process on 3/3/2003). (fictitious)

In First Order Logic:

S20(x) ⊃ E18(x)

S20(x) ⊃ E53(x)

Decision: accept examples but phrasing needed to be imprved on 4.

Properties:

O7 confines (is confined by) :[S10](#_S10_Material_Substantial) Material Substantial

### S21 Measurement

Subclass of: [S4](#_S4_Observation) Observation

[E16](#_E16_Measurement) Measurement

Superclass of: [S3](#_S3_Sample_Taking) Measurement by Sampling

Scope note: This class comprises actions measuring instances of E2 Temporal Entity or E77 Persistent Items, 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:

* UOC chemical analysis of pH with ID 1234.

Decision: need examples from laser department. Generic example rejected.

In First Order Logic:

S21(x) ⊃ S4(x)

S21(x) ⊃ E16(x)

Properties:

[O24](#_O24_measured_(was) measured (was measured by): [S15](#_S19_Observable_Entity) Observable Entity

### S22 Segment of Matter

Subclass of: [S20](#_S20_Physical_Feature) Physical Feature

Scope Note: This class comprises physical features in a relative stability of form within a specific spacetime volume. The spatial extent of an instance of S22 Segment of Matter is defined by humans usually because the geometric arrangement of physical features or parts of them on or within it are of interest. It comes into existence as being an object of discourse through an instance of S4 Observation or declaration and is restricted to the time span starting after the last change caused by an instance of S18 Alteration before the observation or declaration and ending with an instance of another S18 Alteration Event.

The history of a S22 Segment of Matter started with a S17 Physical Genesis event that deposited still existing matter within the defined spatial extent. The collection of all S18 Alteration events represent its history. Some of the events will not leave any physical material within the S22 Segment of Matter.

In other words, this is a fiat object (B. Smith sense) that has declarative boundaries in 3 dimensions but natural boundaries in time (the 4th dimension).

Decision: reflect on scope note before next time. SS and MD

Examples:

* The borehole collar 74001 part of the borehole 74001 of GR central Macedonia.[[23]](#footnote-25)

Decision: example rejected. Need example of a ‘baulk’ from an archaeological record.

In First Order Logic:

S22(x) ⊃ S20(x)

Properties:

[O23](#_O23_is_defined)is defined by (defines): [E92](#_E92_Spacetime_Volume) Spacetime Volume

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