

Heritage Digital Twin Ontology for the European Collaborative Cloud for Cultural Heritage

V1.1

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all ECHOES' project partners contributing to the discussions in WP7, T7.1



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ECHOES is building a federated Knowledge Graph (RDF triple store) to allow for high level integration of all the different elements of the project and the ecosystem, while it will also serve as a point of entry for all queries and requests related to any kind of information potentially available within the Cultural Heritage Cloud. This Knowledge Graph will use the **Heritage Digital Twin Ontology (HDTO)** to unify descriptions and facilitate query and navigation.

The **Heritage Digital Twin** is defined as “the complex of digital information about a real-world heritage asset, with its tangible and intangible components, capturing the entirety of its space-time-culture identity and formally organized in a semantic framework, and described by the CRM-based **Heritage Digital Twin Ontology (HDTO)**”.

It is compliant and harmonised with CIDOC CRM version 7.1.3 and its compatible models CRMdig v5.0, CRMsci v3.0, CRMinf v1.2, LRMoo v1.0 and Narrative Ontology v2.0

https://isl.ics.forth.gr/ontology/echoes/html/HDT_v1.1.html

<https://github.com/ECHOES-ECCCH/HDTO-Heritage-Digital-Twin-Ontology/blob/main/ECHOES-HDTO-v0.2.pdf>



Heritage Digital Twin Ontology

HDTO

The HDTO specializes three epistemological areas and connects them into a functionally complete whole:

Heritage Valuation: How some specific items or traditions are defined to constitute a unit of cultural heritage, i.e., which current social groupings claim historically justified social or spiritual ties of whatever kind to one or more related heritage items, and which (typically wider) identifiable current social groupings explicitly value these items as cultural heritage and respect their specific local ties. This provides the definition of one identity - one HDT.

Digital Twin Maintenance: How a HDT is defined and maintained by some organized collaborative framework, i.e., how the knowledge in the HDT is maintained, updated and kept up-to-date by the responsible consortium, caring for the authenticity, relevance and scientific quality of its content.

Study: Processes of creating studies and the representation of their findings about specific disciplinary aspects of a heritage entity or its parts, by ethnographic, archaeological or natural science methods, detailing the empirical-observational level, or by the analysis of historical sources and their authenticity.

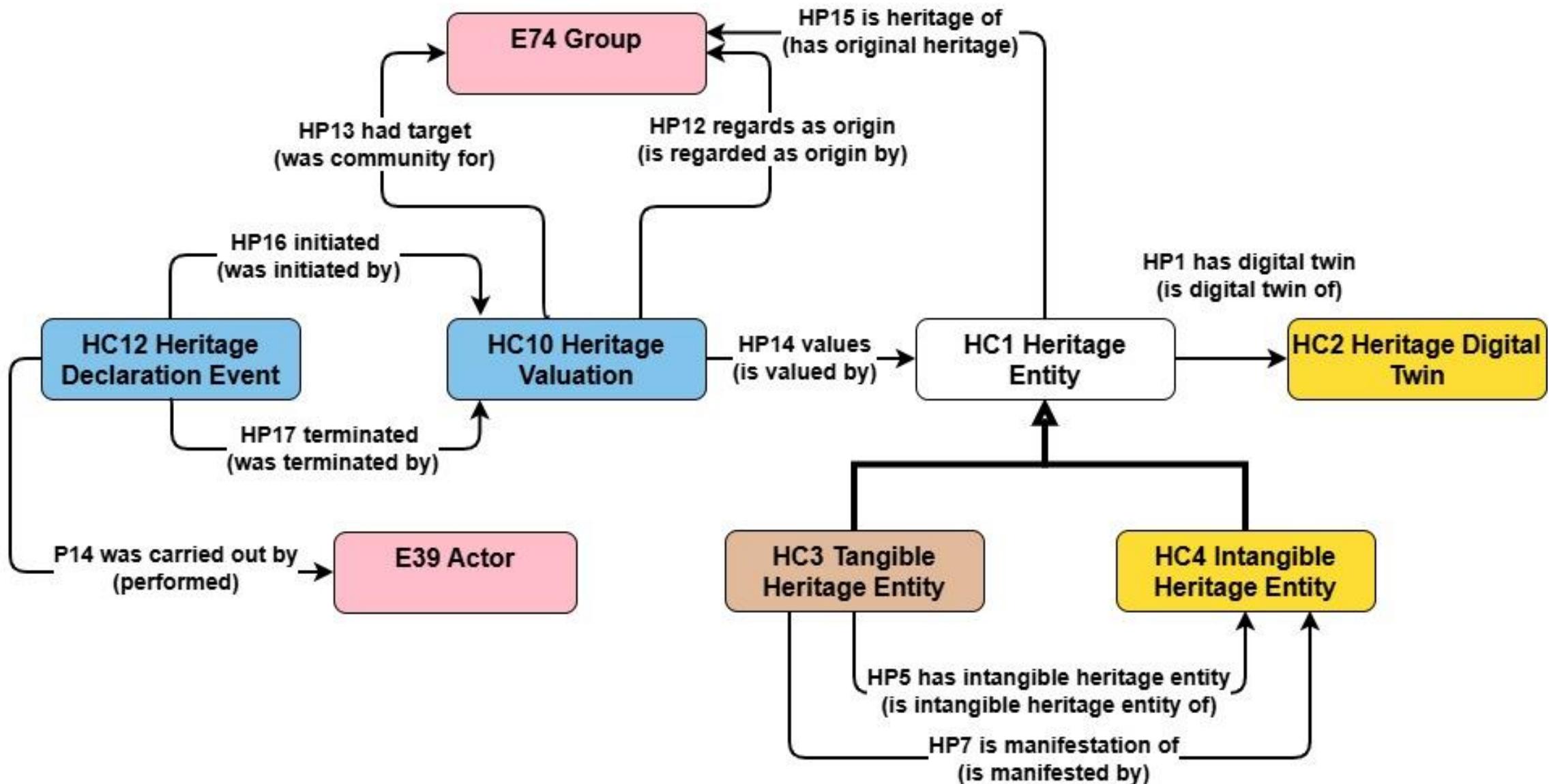


Heritage Valuation

Heritage Valuation

- How some specific items or traditions are defined to constitute a unit of cultural heritage, i.e., which current social groupings claim historically justified social or spiritual ties of whatever kind to one or more related heritage items, and which (typically wider) identifiable current social groupings explicitly value these items as cultural heritage and respect their specific local ties. This provides the definition of one identity - one HDT.
- Implemented by the classes **HC1 Heritage Entity** and subclasses, **HC10 Heritage Valuation**, **HC12 Heritage Declaration Event** and their respective properties, as well as by related CRM concepts.

Heritage Valuation





Digital Twin Maintenance

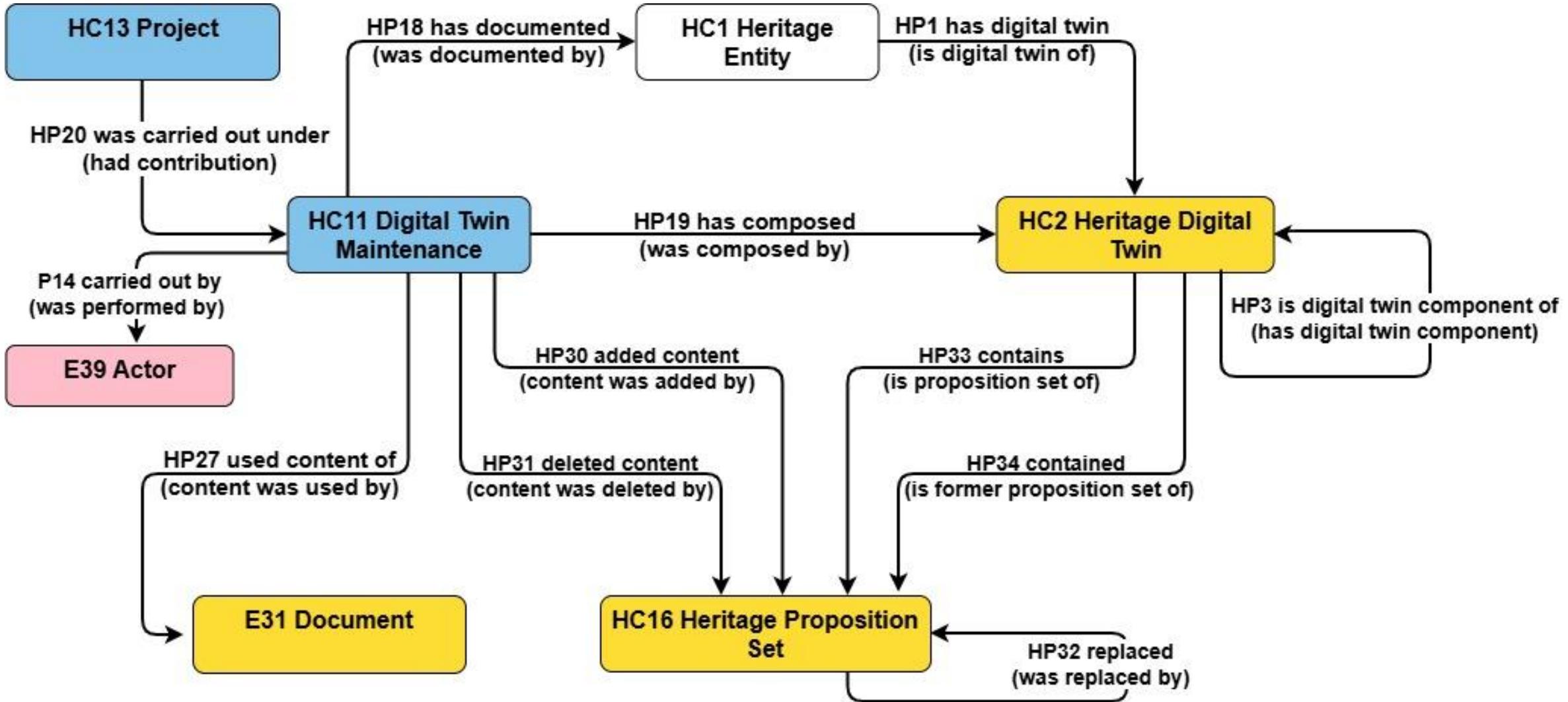
Digital Twin Maintenance

- How a HDT is defined and maintained by some organized collaborative framework, i.e., maintained, updated and kept up-to-date by the responsible consortium, caring for the authenticity, relevance and scientific quality of its content.
- Distinction between “volatile” and “persistent” digital content for connecting the content of the HDT with the citable scholarly publications and their provenance, that make or had made it up.
- Properties for explicating part-whole relations to HDTs of other heritage entity units and to potentially competing projects.
- However, the main purpose of this function is to systematically organize and monitor the completion of a HDT into a cumulative and comprehensive set of documentations of relevant disciplinary aspects.
- It may be also combined with a more detailed workflow model, adequate for scholarly collaboration.
- It can be considered as the administrative framework for eliciting or selecting the studies or documents with specific disciplinary focus on the respective heritage entity.

Digital Twin Maintenance

This functionality is implemented by the classes **HC13 Project**, **HC11 Digital Twin Maintenance** (the update event), **HC2 Heritage Digital Twin** (subclass of HC14 Volatile Digital Object), **HC16 Heritage Proposition Set** (the persistent content parts, subclass of HC15 Persistent Digital Object) and their respective properties, in particular those to **HC9 Study** and **crm:E31 Document**, as well as to other related CRM-based concepts.

Digital Twin Maintenance





Study

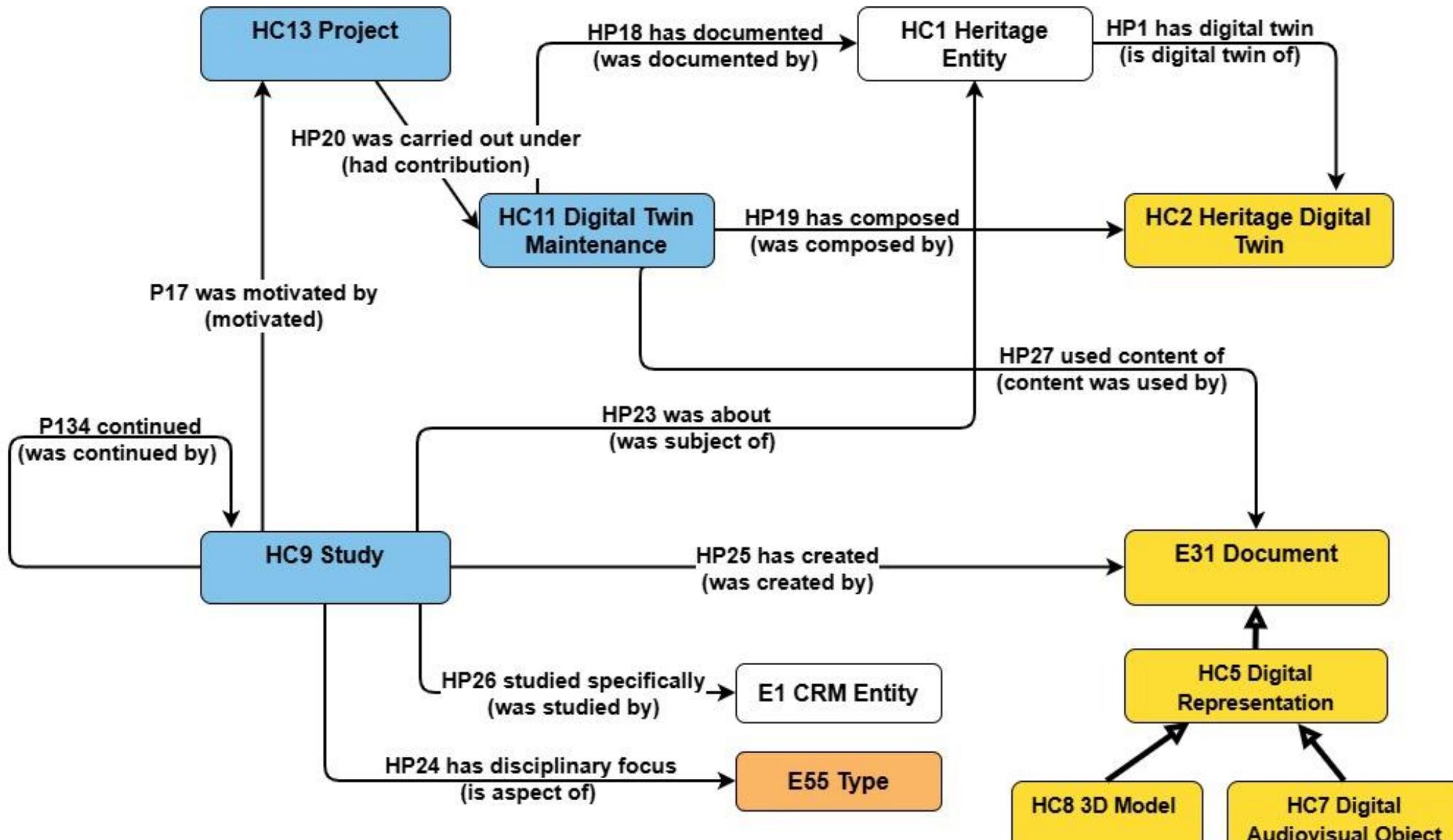
Study

- The processes of creating studies and the representation of their findings about specific disciplinary aspects of a heritage entity or its parts, by ethnographic, archaeological or natural science methods, detailing the empirical-observational level, or by the analysis of historical sources and their authenticity. It further comprises cross-disciplinary studies and annotated literature. The studies may have been carried out or not on behalf of the specific consortium maintaining the HDT. A factual representation of the findings together with metadata and the data provenance should be provided in digital knowledge representation encoding, to be embedded in the knowledge graph of a corresponding **HC16 Heritage Proposition Set**, and thus becoming globally accessible to digital processing in all detail. They should include primary digital visual or audio-visual representations with all their metadata. Beyond that, they should always be accompanied by a comprehensive, citable and open access scholarly publication for complete description of the context and interpretations, keeping in mind the dangers of format obsolescence.

Study

This functionality is implemented by the classes **HC9 Study**, in particular explicating the disciplinary focus and part of the heritage entity investigated for understanding and managing the cross-disciplinary coverage of the HDT. The study, being legacy or current, always results in a **crm:E31 Document**, regardless format. By inheritance, the latter includes the classes **HC5 Digital Representation** and subclasses, using and specializing the CRM extension CRMdig. Via inclusion in the knowledge graph, the data analysis process in a study is captured by a description of the reasoning, through the CRMinf and CRMsci, pairing between observations and their derivative statements, in order to formally express the knowledge acquired through the analyses performed. The argumentation model also applies to the passing on of information.

Study



HC1 Heritage Entity

The **HC1 Heritage Entity** comprises **tangible** and **intangible** entities of the real-world declared as valuable because of their contribution to society, knowledge and/or culture. The value that a heritage entity acquires is relative to the society and culture that assigns it each time. Instances of HC1 may constitute real assets of any nature: physical, both movable and immovable, immaterial, or born digital. They may also constitute types or patterns of cultural events, traditions and practices, typical of the intangible heritage that should be documented with their features and their extent in space and time. Individual events are not considered instances of HC1. Rather, they can be related via their types or patterns to an instance of HC1. An instance of HC1 can be considered as the focal item for aggregating the content of its corresponding HC2 Digital Twin instance.

Parts of an instance of HC1 Heritage Entity may or may not constitute Heritage Entities in their own right, such as a shop in a historical building.



the Knossos Palace, part of the Knossos WH archaeological site



the “Palio di Siena”



the Stonehenge Complex, a WH site

HC2 Heritage Digital Twin

The **HC2 Heritage Digital Twin** class comprises collections of sets of formal propositions more or less directly related to an instance of HC1 Heritage Entity that are documented as single units and serve as topic of discourse about the latter.

Characteristically, the collected sets of propositions may relate information available in a given system including digital visual representations (e.g. 3D models, images, videos), textual descriptions (e.g. digital documents, narrations or stories), information of the effects or images of events that influenced or/and are related in any way to the state of the respective Heritage Entity (e.g. earthquakes, floods etc.) and of activities (e.g. restorations, conservations etc.) carried out on it.

In the context of the defining project or authority, every instance of HC2 Heritage Digital Twin should be linked to one instance of HC1 Heritage Entity being valid for a specific time-span. It aims at providing an archive of the documented history, traits and social relationships of the corresponding HC1 Heritage Entity. However, there may be multiple instances of HC2, created by different projects, that may overlap or include each other as they are related to the same HC1. The creation of an instance of HC2 depends on the valuation of a heritage entity, since the classification of an item as heritage entity itself primarily depends on the valuation.

HC2 Heritage Digital Twin (cont'd)

Instances of HC2 are defined in the context of a project or authority and are valid for a specific time-span. The identity of an instance of HC2 is determined by its content (set of statements) and the creating authority group. The identity of an instance of HC2 is determined by the creating authority group by associating its identifier with one unique content at any point in time and maintained, updated etc. by its content (set of statements) which is subject to continuous change (HC14 Volatile Digital Object). In general, the content of these propositions refers to an information object in an immaterial propositional form.

An instance HC2, being a subclass of HC14 Volatile Digital Object (in the sense of the Parthenos Entity Model), is composed of a set of (persistent) instances of HC16 Heritage Proposition Set, which may be added to, deleted from or replaced in the Digital Twin at any point in time via distinct actions that are each one an instance of HC11 Digital Twin Maintenance. Care should be taken that all information referred to in the content units having constituted a Digital Twin at any point in time can be traced back to persistent ("fixed"), citable or at least permanently accessible documents, which the respective studies should anyhow independently have provided according to scientific practice.

Since instances of HC2 are volatile objects in the sense of the Parthenos Entity Model, care should be taken that all information in the Digital Twin can be traced back to persistent ("fixed"), citable or at least permanently accessible documents, which the respective studies should anyhow independently have provided according to scientific practice.

HC3 Tangible Aspect

The **HC3 Tangible Aspect** class comprises tangible, material entities of the real-world, both movable (e.g. archaeological, artistic and cultural objects) and immovable (e.g., built heritage like monuments, buildings, cities and other complexes), regarded as valuable because of their contribution to society, knowledge and/or culture. The “tangible” term in the name of this class does not exclude that its instances also possess an intangible aspect, which is specified through the HP5 has intangible aspect property.

Subclass of: HC1 Heritage Entity and crm:E18 Physical Thing



the Knossos Palace, part of the Knossos WH archaeological site



The Derynia icon

HC4 Intangible Aspect

The **HC4 Intangible Aspect** class comprises expressions and declarations of cultural events, traditions and practices having particular social, historical and cultural significance, including practices and expressions, memories and oral traditions about events, things, people. An Intangible Aspect is identified by a society or by evidence or other kind of manifestations. The identity of an Intangible Aspect results from an agreement and a validation made by a group of people for a specific time-span.



the “Palio di Siena”

Subclass of: HC1 Heritage Entity and crm:E89 Propositional Object

HC9 Study

The class **HC9 Study**, comprises **activities of analysing heritage entities or other material and immaterial items or events related to heritage entities and studying their relevant contexts throughout the past**, with the purpose of revealing and documenting their nature and significance for past, current and future societies, as well as preserving themselves and the knowledge about them for future generations. The results of an instance of HC9 Study may be in the form of a scientific or scholarly publication or a dataset. Characteristically, instances of HC9 Study occur in units given by different disciplinary aspects or skills, such as history of art, conservation history, C14 dating and many others. Ideally, the study of the different disciplinary aspects should inform and provide arguments for each other. For instance, techniques or materials identified by conservation science may allow for narrowing down time and area of production in for a history of art study. On the other side, historical knowledge may help excluding certain materials during the interpretation of chemical analysis. **Instances HC9 Study may directly be related to the execution of a particular scholarly workflow aiming at systematically planning, finding or initiating studies and collecting their results until they cover all disciplinary aspects intended by a respective project.** The results of an instance of HC9 Study should be documented in a persistent ("fixed"), citable or at least permanently accessible form according to scholarly and scientific practice, independently from being represented partially or completely within an instance of HC2 Digital Twin. If an instance of HC9 Study occurs in the framework of an instance of HC13 Project, the relationship should be documented with the property crm: P9 consists of (forms part of), such as "The creation of the 3D reconstitution of the Tour de Choeur of Notre-Dame de Chartres cathedral (HC9) forms part of The ChArtRes project (HC13)"

Use Case: The Derynia icon



The Derynia icon

The icon originates from the church of the Birth of the Virgin, built in the 15th / 16th century in Deryneia, Cyprus. The white frame delineates the XRF scanning area.

Heritage science-based art historical investigation of the Derynia icon

Objective: Understand the material composition of the icon, the painting techniques and its history of conservation

Requirement: non-invasive / non-destructive analysis methods.

Authors: R. Moreau, S. Hermon, N. Bakirtzis, T. Calligaro, L. Pichon, I. Reiche, Svetlana Gasanova, Ropertos Georgiou, Valentina Vassallo, Nicolette Levy

Communities: Heritage Science, Conservation, Art History, Museology



Art Characterisation

Biography

Genre
History
Visual analysis
Intangible aspects
Related artworks

Physical properties

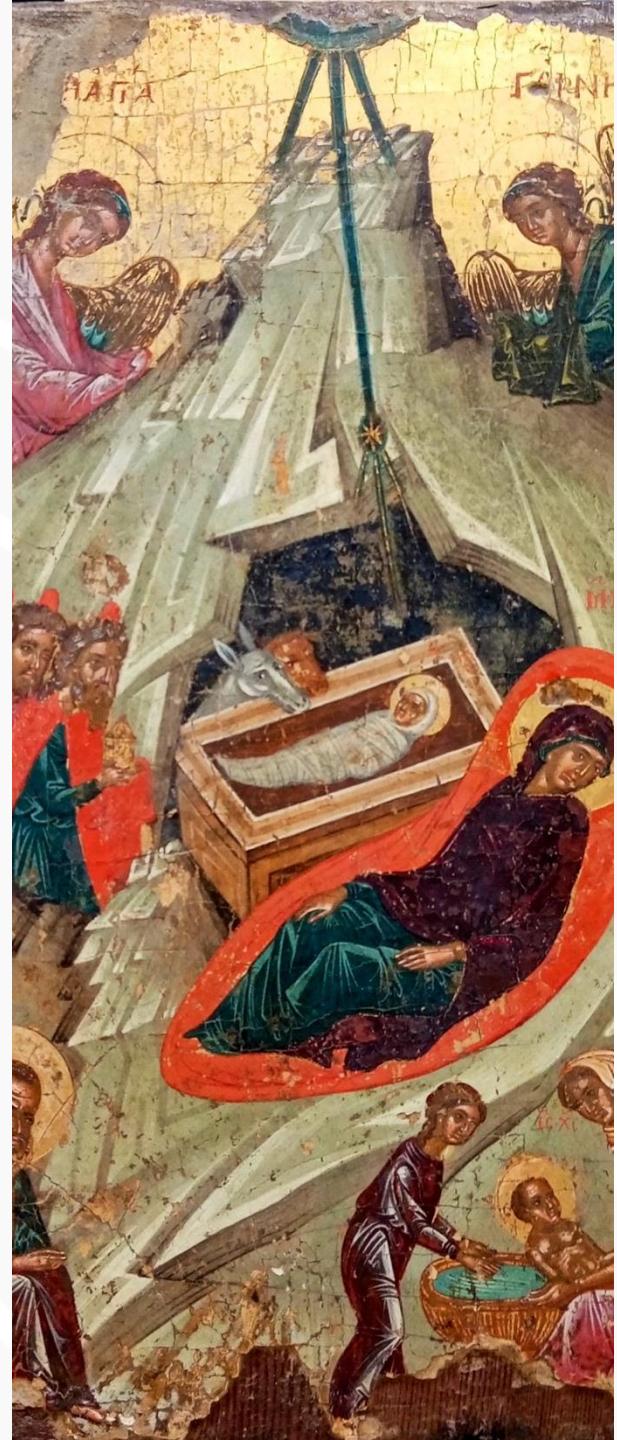
Structure
Dimensions
Materiality
Technique
Preservation

Provenance

Ownership
Bibliography
Access
Attestations

Conservation

Treatment
Restoration
Prevention



Technical metadata of the in-house built MA-XRF, RIS, LIS scanner

- Experimental conditions
 - Data acquisition: 365-nm;
 - Size area: 25 x 17 cm²;
 - Step size: 500-μm step size / 80-ms of dwell time per pixel;
 - Time of scan: 3h30 min;
 - XRF - X-Ray generator operated at 40 kV and 500 μA
 - RIS - reflectance spectroscopy range 470-820 nm (UV-Vis-NIR)
 - LIS - luminescence excitation wavelength - 365 nm, 655 nm
- Raw data:
 - Raw datacube size: 498 pixels (h) by 340 pixels (w);
 - Total channels 2600: CXRF=512 CRIF=1044 and CLIS=1044
- Processing software: PyMCA
- RIS:
 - Python library pysptools 0.15.0 and SPECTRONON software.
 - Endmembers extracted using NFInder algorithm implemented in the pysptools library.
 - Spectral Angle Mapper (SAM) was performed with SPECTRONON software.
- LIS: LIS datacube processed with PyMCA software

Lead white

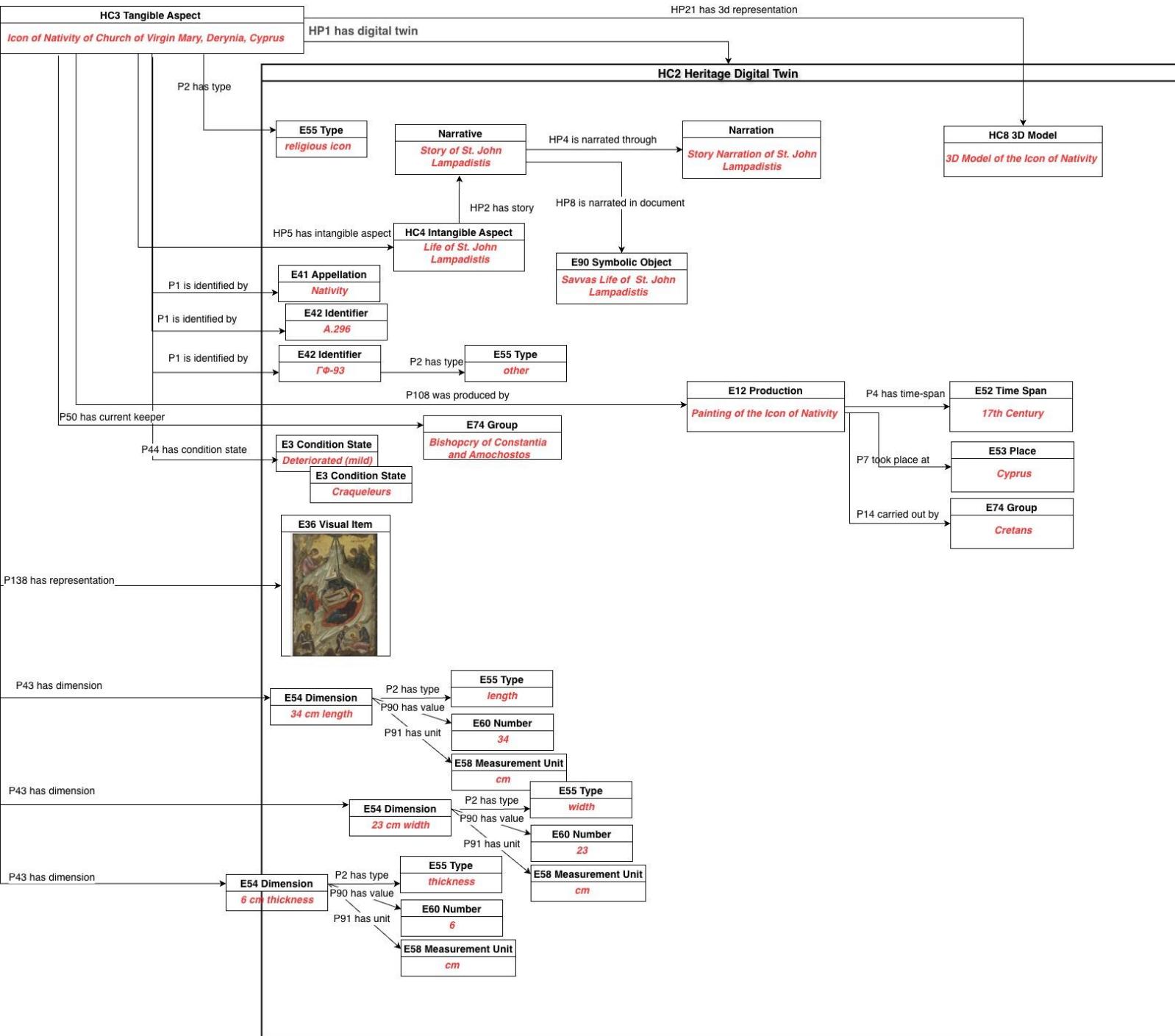
Observations

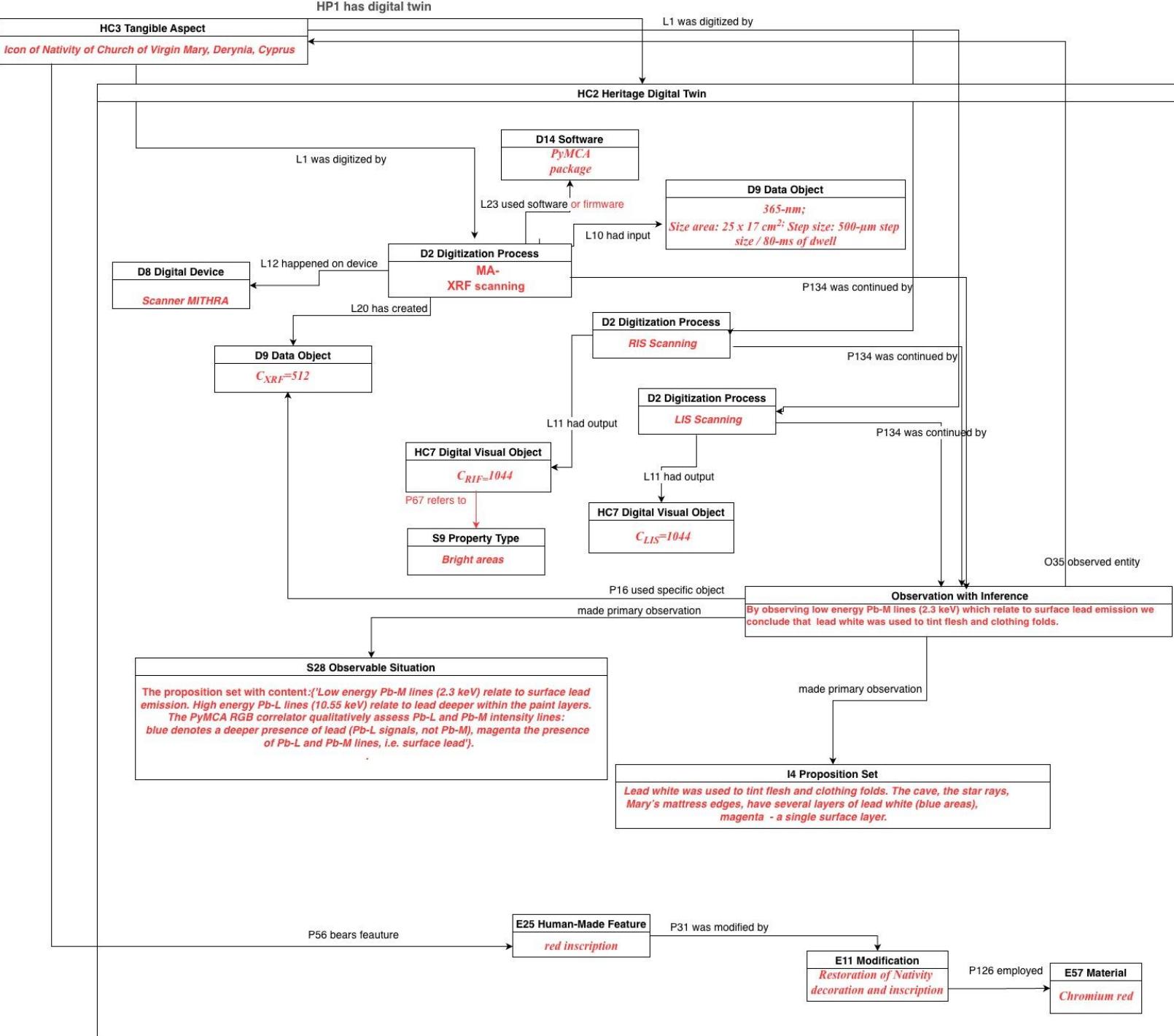
Low energy Pb-M lines (2.3 keV) relate to surface lead emission. High energy Pb-L lines (10.55 keV) relate to lead deeper within the paint layers. The PyMCA RGB correlator qualitatively assess Pb-L and Pb-M intensity lines: blue denotes a deeper presence of lead (Pb-L signals, not Pb-M), magenta the presence of Pb-L and Pb-M lines, *i.e.* surface lead.

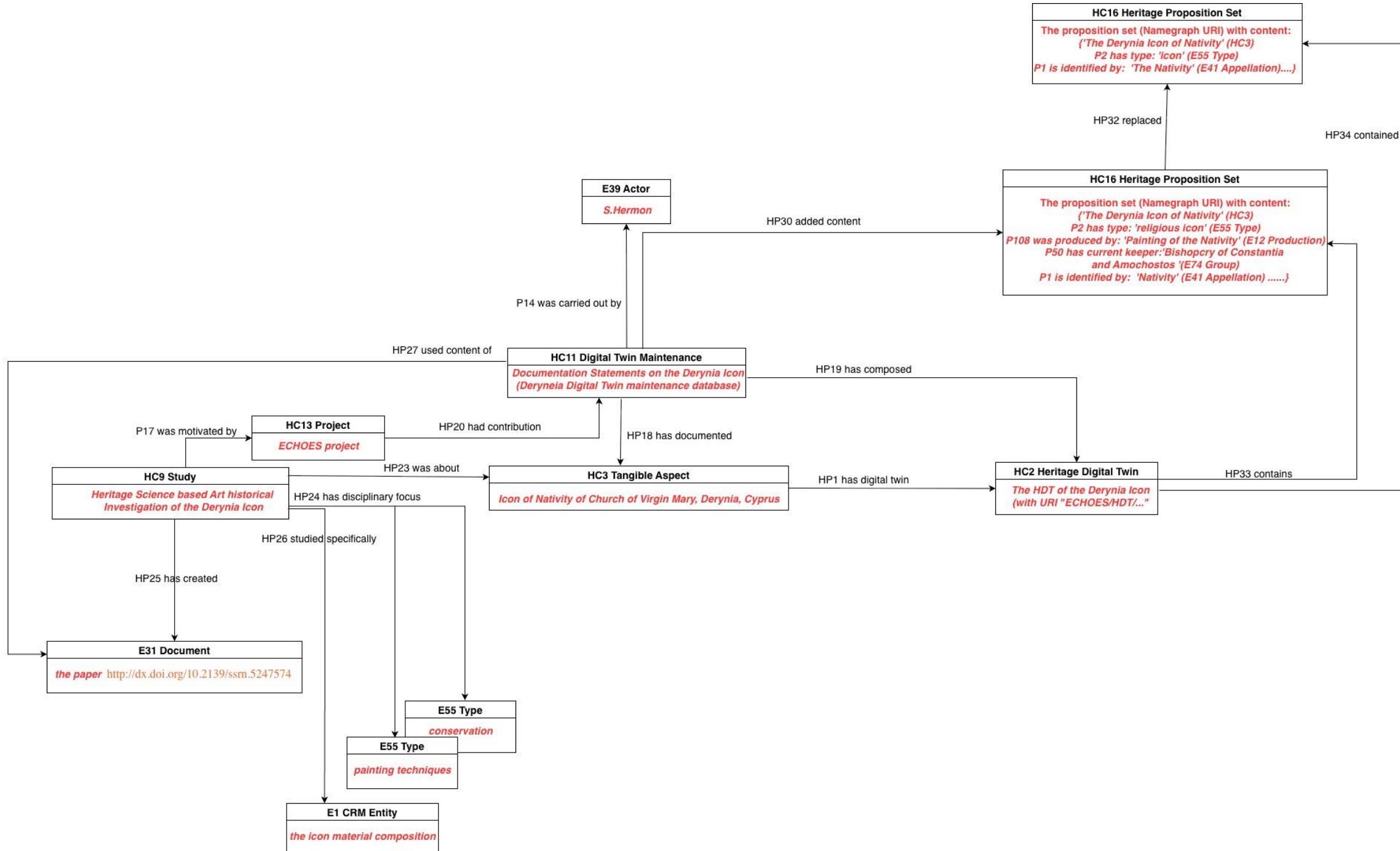
Derivate Statements

Lead white was used to tint flesh and clothing folds. The cave, the star rays, Mary's mattress edges, have several layers of lead white (blue areas), magenta - a single surface layer.









Next Steps

- Provide templates with the minimal required metadata for Valuation, Maintenance and Study
- Provide rdf examples
 - ✓ The Derynia icon
 - ✓ Playbill tickets, OCR enhancement, VTL
 - ✓ Allegory of Despair, 3D scanning, OCRA
 - ✓ Pistoia Pulpit

Thank you for your attention!

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Questions?



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