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European Cloud
for Heritage OpEn Science

How to be part of the Cultural Heritage Cloud?

ECHOES Integration framework
Building the Cultural Heritage Cloud



Funded by
the European Union



UK Research
and Innovation

ECHOES is a project funded by the European Commission under Grant Agreement n.101157364, with the support of UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee n.10110142 & n.10110466.

March 2026

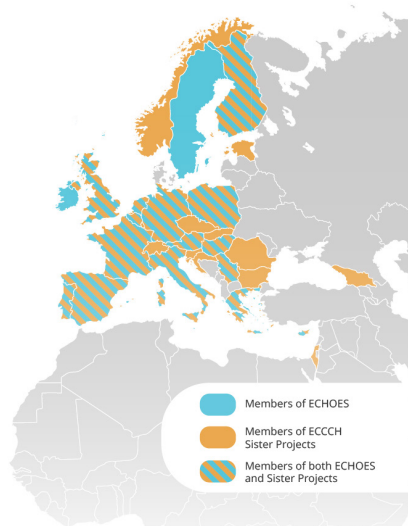
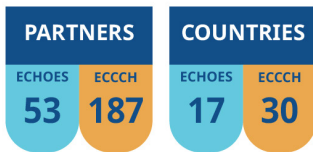
How to be part of the Cultural Heritage Cloud?

ECHOES Integration framework Building the Cultural Heritage Cloud

The Cultural Heritage Cloud (or European Collaborative Cloud on Cultural Heritage - ECCCH) is Europe's collaborative digital infrastructure for research, science, and innovation in cultural heritage. It aims to offer access to data, advanced digital tools and state-of-the-art workflows for the creation and analysis of a new generation of semantically rich and collectively produced heritage assets. In doing so, it facilitates collaboration among researchers and other heritage professionals, enabling them to modernise their workflows and create a cohesive community focused on the Digital Commons. The Cloud is funded through Horizon Europe, the EU's framework programme for research and innovation.

The ECHOES project (2024-2029) is currently designing and implementing the Cloud's architecture, data model and governance, and assembling together its community of users. At the same time, Horizon Europe is funding additional projects in the ECCCH initiative aiming at developing additional tools and functionalities and testing them through real-world use cases. As such, the Cloud is currently under active construction.

This booklet presents the context in which the ECHOES project proposes its Cloud Architecture, its Data Model and its Integration Framework and explains how institutions, projects and stakeholders can take part in building the Cultural Heritage Cloud by integrating their resources into this emerging European Digital Commons. The framework draws on the ECHOES project deliverables [D3.1 Integration Strategy](#), [D3.2 Integration Roadmap](#), [D6.1 Data Strategy for the Cultural Heritage Knowledge Base](#), and [D6.2 Interoperability Guidelines](#).



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1. The Cultural Heritage Cloud

The Cultural Heritage Cloud (ECCCH), being implemented through the ECHOES project, establishes a federated, semantically interoperable infrastructure designed to overcome the fragmentation of data across institutions and regions. It functions as a hub where cultural heritage assets come together into a connected “Digital Commons”. This environment enables the formal organization of digitized heritage assets, their properties and their space-time-culture identity within a shared semantic framework.

The ECCCH infrastructure is fundamentally built upon the FAIR principles to ensure that cultural heritage data is not only preserved but remains actively usable within a global research ecosystem. To achieve **Findability**, the cloud utilizes persistent identifiers (PIDs) and rich metadata that allows both humans and machines to discover assets. **Accessibility** ensures that while data is retrievable via standardized protocols, institutional assets remain available under clear governance and licensing frameworks. **Interoperability** is achieved by mapping diverse datasets to the Heritage Digital Twin Ontology (HDTO) and CIDOC CRM, which allows fragmented silos to function as a unified knowledge graph. Finally, **Reusability** is guaranteed by the systematic collection of paradata and provenance information, which documents the “how” and “why” behind data creation, allowing future researchers to validate and build upon existing digital heritage wisdom.

Digital Commons definition

Digital Commons as a distributed knowledge ecosystem enable the co-creation and reuse of digital heritage across borders and govern the production, sharing, and stewardship of digital resources through collaborative and interdisciplinary processes. These resources are shaped by interrelated legal, socio-cultural, and economic dimensions and function within a sustainability-oriented framework.



Heritage Digital Twin (HDT)

The HDT is the state-of-the-art digital representation of a real-world heritage asset, encompassing both tangible and intangible components. It formally organizes an asset's properties and its space-time-culture identity within a semantic framework based on the CIDOC CRM-based Heritage Digital Twin Ontology (HDTO). Heritage Digital Twins (HDTs) enable access to data, their interpretation, and the specific workflows that generated them, effectively serving as the backbone of digital representations and associated interpretations.

Three strategic axes

The development of the Cultural Heritage Cloud is guided by three strategic axes that structure its architecture, its integration model, and its collaborative dimension.

1. Federated Open Infrastructure

The Cultural Heritage Cloud is built as a federated and open infrastructure. Rather than centralising all resources in a single system, it connects distributed data, services, and infrastructures across institutions. This approach ensures scalability, institutional autonomy, and long-term sustainability.

2. Integration of EU-funded results

The Cultural Heritage Cloud aims to capitalise on the results of past, ongoing and future European projects. Datasets, tools, services and knowledge models developed through EU funding can progressively be integrated into the ecosystem, ensuring continuity and reuse of digital heritage investments.

3. Collaborative Knowledge Co-creation

The Cultural Heritage Cloud enables researchers, cultural heritage institutions and communities to collaborate around shared data, tools and workflows. By connecting resources and expertise across domains, the Cloud supports new forms of interdisciplinary research and collective knowledge production.

What we are building

Federated Data Infrastructure

Rather than a centralized database, the Cloud connects distributed resources, allowing institutions to maintain local autonomy while participating in a global network.

Modular Cloud infrastructure

A flexible architecture composed of interoperable services that support data storage, processing, authentication, monitoring and integration of workflows.

Heritage Digital Twin (HDT) as semantic backbone

The Heritage Digital Twin provides a structured, semantically modelled representation of cultural heritage assets. It connects heterogeneous data, metadata and interpretations within a shared knowledge framework.

Open-by-design ecosystem

The Cultural Heritage Cloud is designed around openness, interoperability and community participation. Open standards and shared practices enable institutions and projects to progressively contribute resources and services to the ecosystem.



2. The Cultural Heritage Cloud ecosystem

The Cultural Heritage Cloud develops within a multi-layered ecosystem of actors, projects, and initiatives. It is conceived as an open and federated environment where different communities can contribute resources and collaborate around shared cultural heritage knowledge.

Institutions and initiatives may engage with the Cloud at different levels depending on their objectives, technical maturity, and available resources. What matters is that all actors can participate and progressively connect their resources to the ecosystem.

The ecosystem is structured around several groups of actors:

- **ECHOES consortium:** at the core of the ecosystem, responsible for developing the Cultural Heritage Cloud infrastructure and the integration framework.
- **ECHOES Cascading grant projects:** funding up to 50 projects across three calls to encourage cultural heritage institutions to engage with the Cultural Heritage Cloud, contribute datasets, develop applications and expand the community.
- **ECCCH sister projects:** 13 ECCCH-funded projects (21 expected in total) representing 187 partners across 30 countries, contributing complementary research, technologies, datasets and tools. In addition to their activities, these ECCCH sister projects will also fund more than 80 projects under their Cascading Grants programmes.
- **National and European initiatives:** including research infrastructures, digital heritage platforms and programmes supporting cultural heritage digitisation.
- **External stakeholders:** museums, libraries, archives, universities, research institutions, technology providers and cultural heritage professionals contributing expertise, resources and use cases.



Fig. 1 - The Cultural Heritage Cloud ecosystem

Because the Cultural Heritage Cloud is designed as a federated infrastructure, participation does not require the same level of integration for all actors. Instead, organisations can engage with the Cloud at different levels of integration, depending on their needs and capacities:

- **At Level 1: Tactical Integration.** The primary objective at this level is critical mass and visibility. We aim to lower the entry barrier for institutions to bring their assets onto the Cloud. Strategically, this phase focuses on ingestion and storage efficiency rather than deep computational interoperability.
- **At Level 2: Strategic Integration.** The objective shifts to meaning and connection. We move from pointing to the data, to understanding what it represents. Strategically, this level enforces the adoption of the Heritage Digital Twin Ontology



(HDTO), ensuring that a dataset from Italy can be semantically aligned with a dataset from France, as well as implementation of unified APIs to access the distributed datasets.

- **At Level 3: Transformational integration.** The ultimate goal is automation, autonomy, and distributed trust. We transition from a repository to a Distributed Data Fabric where applications, services, data and workflows are dynamically federated, scaled, and actioned or used. Strategically, this level enables Federated Compute, moving algorithms to the data or if needed, moving data to the algorithms.

Together, these different levels of engagement enable the Cultural Heritage Cloud to grow progressively as a shared European infrastructure for cultural heritage knowledge, bringing together a diverse community of actors around common standards and collaborative practices.

3. Why integration matters for ECHOES and the Cultural Heritage Cloud

The establishment of the Cultural Heritage Cloud is driven by the urgent need to transition from a landscape of isolated digital repositories to a unified, functional ecosystem.

The Current Landscape: Challenges and Obstacles

The cultural heritage sector currently faces several systemic barriers that hinder the full potential of digital transformation:

- **Fragmented Digital Heritage Landscape:** Digital assets are currently scattered across thousands of institutions and regions, existing as “silos” that lack a common point of entry or discovery.
- **Disciplinary Silos:** Professional practices in archaeology, conservation, and art history often operate in isolation, preventing the interdisciplinary synthesis required for advanced heritage interpretation.
- **Heterogeneous Standards:** The use of diverse and often incompatible metadata schemas, data formats, and protocols make it technically difficult to exchange or aggregate data across different platforms.
- **Limited Reuse of Results:** High-quality outputs from various EU-funded projects often remain underutilized because they lack the technical infrastructure needed for long-term accessibility and integration into broader research workflows.
- **Sustainability Risks:** Without a shared infrastructure, digital resources face significant risks of obsolescence or loss once individual project funding ends, as institutions struggle to maintain specialized software and storage systems independently.

The Solution: A Unified Digital Commons

Integration within the ECCCH offers a transformative shift from isolated data management to Digital Commons - a collaborative, open, and federated environment. This integration provides:



- **Semantic Interoperability:** By adopting shared ontologies like the Heritage **Digital Twin Ontology (HDTO)** and **CIDOC CRM**, the Cloud ensures that data from different sources can be meaningfully combined and searched as a single knowledge graph.
- **The Heritage Digital Twin (HDT) Backbone:** HDTs serve as the nexus for all digital representations, workflows, and interpretations, allowing researchers to access the full history and provenance of an asset in one place.
- **Enhanced Collaboration Potential:** The use of **Collaborative Research Scenarios (CRS)** ensures that the technical integration directly supports real-world research needs, fostering interdisciplinary and intersectoral cooperation.

By overcoming current fragmentations, the ECCCH transforms cultural heritage data from raw digital files into a sustainable, machine-actionable resource that serves the collective wisdom of the European research community.

A resource-oriented integration model

The Cultural Heritage Cloud follows a resource-oriented integration model. Rather than integrating entire projects or initiatives, the Cloud focuses on integrating the resources they produce and maintain. This approach allows the infrastructure to remain flexible, scalable, and sustainable over time.

What gets integrated?

The integration framework targets several types of resources that can contribute to the Cultural Heritage Cloud ecosystem:

- Datasets
- Metadata
- Applications and Services
- Workflows

Each integration activity is organised around an integration unit, defined as the interaction between a specific resource and one of the Cloud components.

By structuring integration in this way, the Cultural Heritage Cloud can progressively incorporate diverse resources while maintaining coherence across the infrastructure. This modular approach allows new datasets, services and knowledge models to be integrated incrementally, supporting the continuous growth of the ecosystem.

From principles to action

The integration of resources into the Cultural Heritage Cloud is guided by a set of principles that translate the project's strategic vision into practical criteria. Rather than integrating projects as a whole, the Cloud focuses on integrating specific resources, such as datasets, services, tools or knowledge models, that can contribute to the shared infrastructure.

Each integration will therefore be assessed according to several criteria that ensure both relevance for the community and long-term sustainability:

Community relevance

Integration priorities are driven by the needs of the cultural heritage community. Resources that support widely recognised research challenges, collaborative use cases or shared data infrastructures are prioritised.

Technical maturity

Resources should demonstrate sufficient stability and documentation to ensure reliable integration and long-term usability. This helps guarantee that integrated services and datasets can be maintained and effectively used within the ecosystem.

Interoperability compliance

Resources must align with the technical and semantic standards adopted by the Cultural Heritage Cloud. Interoperability enables data exchange, integration of services and the development of cross-domain research workflows.

Governance alignment

Integrated resources must be consistent with the governance framework of the Cultural Heritage Cloud, including clear



responsibilities for maintenance and alignment with the objectives of the infrastructure.

Legal and licensing clarity

Clear licensing conditions are essential to enable reuse of datasets, tools and services while respecting intellectual property rights and institutional policies. Whenever possible, open licences are encouraged to maximise reuse across the ecosystem.

Integration lifecycle

The integration of resources into the Cultural Heritage Cloud follows a structured and iterative process designed to ensure technical reliability, interoperability and long-term usability. Rather than a one-time operation, integration is conceived as a progressive workflow in which resources are identified, assessed, integrated and evaluated within the Cloud environment.

This process is organised around a six-step integration lifecycle, which provides a common framework for adopters and Cloud component providers.

The 6-step integration lifecycle

1. Resource identification.

The integration process begins with the identification of candidate resources. These may include datasets, services, tools, workflows or semantic artefacts produced by projects, institutions or research infrastructures. At this stage, the resource and the relevant Cloud component are paired to form an integration unit, which defines the scope of the integration activity.

2. Interoperability self-assessment

Once a resource has been identified, adopters perform a preliminary interoperability assessment. This step evaluates the compatibility of the resource with the technical and semantic standards of the Cultural Heritage Cloud, including data formats, metadata structures, and interoperability guidelines.

3. Technical onboarding

During the onboarding phase, the resource is technically connected to the relevant Cloud component. This may involve configuring APIs, aligning metadata models, adapting data structures, or implementing necessary interfaces that enable the resource to interact with the Cloud infrastructure.

4. Validation

After onboarding, the integration is validated through testing and verification procedures. This step ensures that the resource functions correctly within the Cloud environment and complies with interoperability and quality requirements.

5. Release and monitoring

Once validated, the resource becomes accessible within the Cultural Heritage Cloud. Continuous monitoring ensures that the integrated resource remains operational, interoperable and accessible over time.

6. User evaluation

Finally, the integrated resource is evaluated through its use in collaborative research scenarios and community activities. Feedback from users helps assess the effectiveness of the integration and identify potential improvements.

Integration Cycles

Through structured Integration Cycles, the ECHOES Integration Task Force (EITF) and continuous feedback loop, the Cloud provides a repeatable, clear path for projects and institutions to onboard their tools and datasets.

- **Structured 3–6 month cycles:** Integration activities are organised into structured integration cycles, typically lasting three to six months. Each cycle groups together a set of integration activities that are planned, implemented and evaluated within a defined timeframe.
- **Prioritisation via the ECHOES Integration Task Force (EITF):** the EITF plays a key role in coordinating integration cycles. It



helps prioritise candidate resources based on community needs, technical readiness, and strategic relevance for the Cultural Heritage Cloud.

- **Continuous feedback loop:** each cycle produces feedback from adopters, developers and users, which is used to refine the integration framework and improve future cycles. This continuous feedback loop ensures that the Cultural Heritage Cloud evolves progressively while responding to the needs of its growing community.

Architecture foundations and core technological building blocks

This section details the architectural foundations and core technological building blocks of the European Collaborative Cloud for Cultural Heritage (ECCCH), synthesizing the strategic vision of the Data Strategy (D6.1), the technical requirements of the Interoperability Guidelines (D6.2), and the integration path defined in the Roadmap (D3.2).

Architectural Principles

The design of the ECCCH is governed by four fundamental principles that ensure scalability, technical sustainability, and institutional autonomy:

- **Federated Model:** To respect the sovereignty of cultural heritage institutions, the cloud acts as a connecting layer for distributed resources rather than a single centralized silo. This allows providers to maintain local control over their assets while benefiting from a unified discovery layer.
- **Modular Services:** The infrastructure is built as a set of decoupled, microservices (OCI-compliant). This modularity allows individual components to be updated, scaled, or replaced without disrupting the entire ecosystem.
- **API-Based Interaction:** Communication between components is strictly handled through standardized, versioned RESTful APIs documented via OpenAPI Specifications. This ensures that

any third-party tool can interact with the cloud if it meets the technical requirements.

- **Open Standards:** The architecture relies on community-endorsed standards (RDF, SPARQL, JSON-LD, IIIF) to prevent vendor lock-in and ensure the long-term accessibility of heritage data.

Technical building blocks

Authentication and Authorization Infrastructure (AAI): The security cornerstone of the Cloud. It provides a Single Sign-On (SSO) mechanism, allowing users to be recognized by the central portal and all integrated Vertical Applications (VAs) while respecting institutional access policies and GDPR requirements.

Knowledge Base (KB): The semantic heart of the ecosystem. It manages the storage and exposure of Heritage Digital Twins (HDTs) in RDF format. It ensures that data is not merely stored but semantically connected through the Heritage Digital Twin Ontology (HDTO) and CIDOC CRM.

Data Storage (Internal and Federated): The architecture supports a hybrid model. Internal storage handles data closely integrated with core services, while the Federated Node system allows institutions to maintain external databases and object stores while remaining active participants in the ECHOES workflow.

Processing and Vertical Applications (VAs): VAs are specialized software tools (e.g., Virtual Transcription Laboratories, 3D viewers, or annotation tools) that provide a user interface and allow interactions with the Knowledge Base via APIs. They create, interact or change HDTs, allowing them to “close the loop” and write newly generated digital representations or interpretations back into the system.

Service Desk: Acting as the centralized support hub, it facilitates user assistance and technical integration requests (onboarding), ensuring the platform’s usability for the wider community through the Integration Tracking Tool.



Interoperability: The Operational Glue

Interoperability is the functional requirement that enables the reliable exchange and reuse of digital assets within the Cloud. Following the D6.2 guidelines, ECHOES addresses interoperability across four dimensions: **Technical** (APIs and protocols), **Semantic** (HDTO and shared meaning), **Organizational** (standardized workflows), and **Legal** (machine-actionable licensing).

To facilitate a structured onboarding process, the Cloud implements three cumulative Interoperability Levels:

- **L1 - Basic:** Minimum entry level ensuring discoverability, basic access, stable identifiers, clear licensing, and baseline security. No semantic interoperability.
- **L2 - Intermediate:** Adds structured semantics and operational readiness: JSON-LD/RDF metadata, controlled vocabularies, documented/versioned APIs, entitlement-based access, and health/logging support.
- **L3 - Advanced:** Enables full federated participation with formal semantic validation and deep object-level provenance, allowing for automated, high-trust research workflows.

By adhering to these architectural principles, integration processes and interoperability levels, the ECCCH ensures that the “Digital Commons” remains a stable and evolving environment for European cultural heritage. Through this, we aim to achieve a virtuous cycle where enrichment of the HDTs leads to their wider use, creates new knowledge and provides added value to existing users — in turn attracting new users and uses that further enrich the HDTs.



Fig. 2 - The Cultural Heritage Cloud Virtuous Circle

4. Towards long-term sustainability

Establishing a legal entity

Ensuring the long-term sustainability of the Cultural Heritage Cloud requires a stable legal and governance framework. The ECHOES project therefore explores the creation of a dedicated legal entity as a solid base for the long-term coordination, governance and development of the infrastructure. Such a structure would provide continuity beyond individual project cycles and ensure that the Cloud remains a reliable service for the cultural heritage community.

Continuous improvement

The Cultural Heritage Cloud is designed as an evolving infrastructure. Through regular roadmap reviews, integration cycles, and monitoring mechanisms, the ecosystem continuously adapts to new technological developments and research practices. Feedback from users, developers and institutions helps refine integration processes and improve the overall functionality of the Cloud **Sustainability**.

The Cultural Heritage Cloud is built on a federated architecture, where institutions retain control over their resources while contributing to a shared European infrastructure.

This model distributes responsibilities across the ecosystem and enables long-term sustainability by combining shared standards, interoperability frameworks and collaborative governance.



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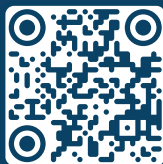
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