

D3.3b Architecture and Interoperability Guidelines for Operational Services of the EOSC-Core





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D3.3b / Architecture and Interoperability Guidelines for Operational Services of the EOSC-Core

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Abstract

This deliverable describes the technical aspects of the model behind the federated EOSC architecture as implemented by EOSC Future. It defines the capabilities on how the systems federate and interact within EOSC. The deliverable describes first the generic technical considerations of a federated system followed by how this has been implemented by EOSC Future.

As for all architectures describing federated systems, the model behind the federated EOSC architecture defines a number of capabilities that are offered at the EOSC level to build the EOSC federated system (for example a common search engine, a single sign-on, common interfaces to share, access and analyse data, etc.). It specifies the technical standards and operating procedures that allow members to connect to the capabilities of the EOSC federated system. Each capability to federate with EOSC is enabled by one or more EOSC Core components. The supporting features to deliver these capabilities over the whole EOSC are captured in the related EOSC Interoperability Guidelines (EOSC IGS) which are defined as the federating interfaces.

An initiative (RIs, e-infrastructures, thematic clusters, national/regional collaborations, etc.) to participate in EOSC should contribute to the delivery of one or more federating capabilities connecting its services with the related EOSC Core Components (technical compliance). The minimum set of capabilities that this initiative should support to join EOSC has to be defined in the EOSC Rules of Participation (policy compliance). Other capabilities can be offered as optional.

After detailing these technical aspects of the EOSC federated system, the document shows the EOSC Future implementation leveraging the concepts of EOSC Interoperability Framework and EOSC Platform. In this implementation, the EOSC Core services (part of the EOSC Platform) are the components that enable the capabilities at EOSC level. Future evolutions of this model, taking into account the introduction of the concept of EOSC Node, are also presented.

Finally, the document introduces the EOSC Platform internals (capabilities, architecture, operations and deployment), the EOSC Profiles and the EOSC Interoperability Guidelines in the scope.



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Glossary

EOSC Future project Glossary is incorporated by reference: https://wiki.eoscfuture.eu/x/JQCK



List of Abbreviations

Acronym	Definition
AAI	Authentication and Authorisation Infrastructure
AARC	Authentication and Authorisation for Research and Collaboration
AI	Artificial Intelligence
API	Application Programming Interface
A/R	Availability/Reliability
CESSDA	Consortium of European Social Science Data Archives
CMS	Configuration Management System
СМТ	Configuration Management Tool
CRIS	Current Research Information System
DIH	Digital Innovation Hub
DMP	Data Management Plan
DOI	Digital Object Identifier
EGI.eu	European Grid Infrastructure Foundation
elDAS	Electronic Identification, Authentication and Trust Services
EIF	EOSC Interoperability Framework
EMSO	European Multidisciplinary Seafloor and Water Column Observatory
EO	Earth Observation
EODC	Earth Observation Data Centre
EOSC	European Open Science Cloud
EPOT	EOSC Portal Onboarding Team
НРС	High-Performance Computing
IdP	Identity Provider
I/O	Input/Output
JNP	JNP Strategy Management Consulting
ML	Machine Learning
MVE	Minimal Viable EOSC
N/A	Not Applicable
OMS	Order Management System
PaaS	Platform as a Service
PID	Persistent Identifier
PSNC	Poznan Supercomputing and Networking Center
RDA	Research Data Alliance
RO	Research Object
RoP	Rules of Participation
SMS	Service Management System



SOMBO	Service Order Management Back Office
TBD	To Be Determined
TF	Task Force
TGB	Technopolis Group Belgium
WeNMR	Worldwide e-Infrastructure for Nuclear Magnetic Resonance
WG	Working Group



1. Executive Summary

EOSC has been conceived as a system of systems where different initiatives (RIs, e-infrastructures, thematic clusters, national/regional collaborations, etc.) collaborate to share services, tools, data and other research resources from hundreds of providers at institutional, national, regional and European level with the aim of improving discovery, access and reuse of research assets from European research communities in order to accelerate time to discovery and boost European excellence in science, supporting Open Science. This document details technical aspects of the **model behind the federated EOSC architecture**, as developed by EOSC Future, that defines how these different systems interact and the capabilities the EOSC federated system delivers. Generic technical considerations on the federated system are initially presented, then the document shows how they have been implemented by EOSC Future.

As for all architectures describing federated systems, the model behind the federated EOSC architecture defines a number of **capabilities that are offered at the EOSC level** to build the EOSC federated system (for example a common search engine, a single sign-on, common interfaces to share, access and analyse data, etc.). Each capability to federate with EOSC is enabled by one or more **EOSC Core components**. The supporting features to deliver these capabilities over the whole EOSC are captured in the related **EOSC Interoperability Framework** Guidelines (EOSC IGs) that define the technical standards and operating procedures (the federating interfaces) that allow members to connect to the capabilities. A capability becomes operational when one or more members are connected to its EOSC Core components and begin to share its information via these interfaces. Depending on the capability in question, this may also mean that access to, and use of the shared resources becomes possible. EOSC IGs also include the metadata schemas that have been adopted in the implementation of a capability to homogeneously describe EOSC Resources (catalogues, services, datasets, etc.) over the whole federated system.

An initiative (RIs, e-infrastructures, thematic clusters, national/regional collaborations, etc.) to participate in the EOSC federated system should contribute to the delivery of one or more capabilities connecting its services with the related EOSC Core components (*technical compliance*). The minimum set of capabilities that this initiative should support to join EOSC has to be defined in the EOSC Rules of Participation (*policy compliance*), other capabilities can be offered as optional.

After detailing these technical aspects, the document presents the EOSC Future implementation leveraging the concepts of EOSC Interoperability Framework and EOSC Platform. The document does not cover governance aspects of the federated system that are not in the scope of EOSC Future.

The EOSC Platform is an integrated operational environment, which is now offered to research communities, that delivers **Core and Horizontal services** as components enabling a number of federating capabilities in EOSC to create a common European portfolio and marketplace of resources (datasets, services, other research products). This vision when realised will see resources federated in EOSC that are accessible via a common delivery channel to guarantee homogeneous user experience (single sign-on, common support channels and quality metrics, common metrics for resource consumption, etc.).

The model implemented by EOSC Future is based on a simple prerequisite: a research organisation or another relevant initiative joins EOSC when it shares/registers one or more of its resources (services, catalogues, research products, etc) in the EOSC Resource Catalogue in compliance with the EOSC Rules of Participation. All the other capabilities are optional.

The document also presents how this model can evolve in the medium-short term, in particular with the introduction of the concept of EOSC Node.

In the second part of the document, the internals of the EOSC Platforms are introduced. EOSC Platform capabilities, architecture, operations and deployment are detailed together with the EOSC Profiles that allow to homogeneously represent resources in EOSC.

Finally, the deliverable shortly describes the EOSC IGs in the scope of the document: Resource Catalogue (Service Catalogue and Research Product Catalogue), Monitoring, Helpdesk, Accounting (for services and research products) and Order Management.



2. Introduction

This deliverable details technical aspects of the model behind the federated EOSC architecture and describes its EOSC Future implementation, leveraging the concepts of EOSC Interoperability Framework and EOSC Platform. It establishes a clear framework and guidance that define the information to be exchanged, together with necessary procedures, to federate communities to EOSC.

The document is structured as follows:

- Section 3 presents technical considerations on the model behind the federated EOSC architecture and details the EOSC Future implementation introducing the concepts of EOSC Interoperability Framework and the EOSC Platform. Future activities are sketched including the inclusion of the concept of EOSC Node in the model.
- Section 4 details the internals of the EOSC Platform providing information on its architecture, operations, interoperability guidelines, and data model. It also introduces the EOSC Profiles, describing their current implementation, the governance and depicting their evolution.
- Section 5 details the EOSC Platform interoperability guidelines in the scope of the deliverable.
- Section 6 draws conclusions and outlines future work.

The following table introduces and defines key terms used in the deliverable¹. It is the output of a process to (1) harmonise the terminology that was adopted by past EOSC projects and (2) align it to the latest advancements on the EOSC Architecture being implemented by EOSC Future. Some old terms were replaced with new terms that better reflect the current implementation.

Terms	Definitions
EOSC Capability	A functionality that is delivered by EOSC for its members (e.g. helpdesk and monitoring in EOSC Future).
EOSC Federating Interfaces	Technical standards and operating procedures that allow members to connect with a specific capability (e.g. the interface defined in the helpdesk interoperability guidelines to connect a community helpdesk to the EOSC helpdesk).
EOSC Federated System	Defines how the different systems participating in EOSC interact and the capabilities the federating system delivers.
EOSC Interoperability Framework	The collection of EOSC Interoperability Guidelines onboarded to the EOSC Platform, visible in the EOSC IF Registry, which can be used to enable interoperability between individual EOSC Resources and EOSC Core services as well as interoperability between EOSC Resources (e.g. enabling data transfer, orchestration, etc.). The Framework includes the governance processes for reviewing, approving and accepting new Interoperability Guidelines into the IF Registry.
EOSC Interoperability Framework Registry	A database of submitted and approved EOSC Interoperability Guidelines, based on an agreed profile of attributes.
EOSC Resources	Services, catalogues, research products, training resources, interoperability guidelines and other resources. In the context of EOSC, these are understood to be both digital and produced or operated by or of potential use to scientists and researchers. Services include data sources, computational resources and data storage resources.

 Table 2-1: Main terms used in the document

¹ Please refer to https://wiki.eoscfuture.eu/display/PUBLIC/EOSC+Future+Glossary for a complete glossary.



EOSC Providers	An organisation operating an onboarded resource, whether operating a service or providing access to research artefacts for use or access by users not affiliated with the organisation itself.
EOSC Services	Services onboarded in EOSC as part of the EOSC- Exchange.
EOSC Research Products	Datasets, publications, software and other types of scientific artefact A scientific or research output (classified as publication (literature), research data, research software, and "other kinds of products"), accessible or linked from an EOSC Data Source (e.g. repository, scientific database, publisher archive aggregator, CRIS system), whose metadata might be "harvested from" the linking EOSC Data Source using a defined protocol (e.g. OAI-PMH).
EOSC Data Sources	A service that links to collections of research products (see Research Product) as well as services that provide data in response to queries.
EOSC Service Catalogue	A catalogue containing all the Services onboarded in EOSC, together with their Providers.
EOSC Research Product Catalogue	A catalogue containing all the Research Products (datasets, software, etc.) onboarded in EOSC, together with their context in the scholarly communication infrastructure, e.g. creators, organisations, funders, projects.
EOSC Resource Catalogue	A catalogue of all EOSC Resources, the result of integrating the EOSC Service Catalogue and the EOSC Research Product Catalogue.
EOSC Marketplace/Front-end platform	A web-based interface to search, discover, access, order and use the resources available through the EOSC Exchange, exploiting a range of filtering options, leveraging the relationships available through the Interoperability Framework, and taking advantage of integrations with EOSC Core Services and among other compatible services in the EOSC Exchange.
EOSC Profiles	Metadata schema for the description of services, research products or other research artefacts that their providers choose to share with the EOSC user community through the EOSC-Exchange, as well as for describing the organisations offering to provide these resources to EOSC. EOSC Profiles are specified by the EOSC Profile Interoperability Guideline, which defines the entities for which Profiles have been defined and their logical relationships as part of a larger data model.
EOSC Platform	The EOSC Platform delivers the EOSC Core and EOSC services as an integrated operational environment that enables EOSC research communities to take advantage of this suite of services. Exploiting EOSC Platform capabilities, research communities can add value to their own services in the Exchange and make them more useful and attractive to a wider range of science users. Furthermore, the EOSC Platform, with its extensible architecture, facilitates the addition of new capabilities (Core or Exchange - e.g. horizontal services such as the data transfer) to satisfy emerging user's requirements. The EOSC Platform currently consists of services such as the comprehensive Resource Catalogues, the



	Marketplace, the EOSC Infrastructure Proxy for the EOSC Core services, the EOSC AAI Federation, the Helpdesk, the Monitoring, the Accounting, the Order Management, the Execution Framework and the EOSC Interoperability Framework registry.
Community Platform	A Community Platform is a platform operated by a community to serve its users. It can be made of multiple services (support services such as AAI, Helpdesk, etc and services for the research) and should contain at least an inventory (e.g. in form of a catalogue) of its assets (services, datasets and other research resources).
Community Catalogue	A Community catalogue complying with EOSC Exchange community resource catalogue inclusion criteria and including several resources. It is an external catalogue that can be onboarded into the EOSC Exchange by a Catalogue Operator Representative on behalf of the Community Catalogue Operator.

3. Technical aspects of the model behind the federated EOSC architecture as implemented by EOSC Future

EOSC has been conceived as a system of systems where different initiatives (RIs, e-infrastructures, thematic clusters, national/regional collaborations, etc.) collaborate to share services, tools, data and other research resources from hundreds of providers at institutional, national, regional and European level with the aim of increasing discovery, access and reuse of those assets in order to accelerate time to discovery and boost European excellence in science, supporting Open Science. To achieve this vision, the EOSC has to define a **model for its federated architecture** that specifies how these different systems interact and the capabilities the federated system delivers.

EOSC Future implemented an initial version of this model, currently in operation and under validation by the user communities, with the aim to enable the sharing of resources in EOSC and create a common European portfolio and marketplace of resources (*datasets, services, other research products*). Through this model resources are accessible via a common delivery channel to guarantee **homogeneous user experience** (*single sign-on, common support channels and quality metrics, common metrics for resource consumption, etc.*). The model does not cover governance aspects of the EOSC federated system that are not in the scope of EOSC Future.

It is important to note that the model implemented by EOSC Future cannot be considered final but it is expected to be further evolved in follow-up initiatives (EOSC Procurement, EOSC Beyond project, etc.) with the direct involvement of the EOSC Governance and stakeholders (e.g. user communities).

In this section, after some generic technical considerations on the model, we describe its implementation in the project leveraging the concepts of the EOSC Interoperability Framework and EOSC Platform.

3.1. Technical considerations on the model behind the federated EOSC architecture

As for all architectures describing federated systems, the model behind the federated EOSC architecture defines a number of capabilities that are offered at the EOSC level (**EOSC capabilities**) to build the EOSC federated system (for example a common search engine, a single sign-on, common interfaces to share, access and analyse data, etc.). It specifies the technical standards and operating procedures that allow members to connect to the capabilities of the EOSC federated system. Each capability to federate with EOSC is enabled by one or more **EOSC Core components**. The supporting features to deliver these capabilities over the whole EOSC are captured in the related **EOSC Interoperability Guidelines** (EOSC IGs, see section 3.2) which are defined as the **federating interfaces**. The members of the system can connect their services to the EOSC Core components and participate in the delivery of the capabilities. The EOSC IGs also include the metadata schemas that have been adopted in the implementation of a capability to homogeneously describe EOSC resources



(catalogues, services, datasets, etc.) over the whole federated system. The EOSC Core components are operated by EOSC members or other providers selected by the EOSC Governance.

The **EOSC capabilities** include the diverse functionalities that are offered by the federated system such as a common search engine, a single sign-on (AAI), common interfaces to share, access and analyse data, etc. The minimum set of capabilities that an organisation should support to join the EOSC has to be defined in the **Rules of Participation** (*policy compliance*). EOSC can offer other capabilities as optional.

As an example of EOSC capability, consider an *EOSC federated search service* able to perform distributed queries across catalogues from the EOSC members. To enable this capability in EOSC, the following activities must be performed:

- EOSC Core Components: such capability requires two federating components to operate, namely (1) a catalogue registry to manage information and metadata about all the catalogues participating on the federated search (e.g. their API end-points) and (2) a web application offering a UI that allows users to submit queries and a back-end capable of fetching catalogue information from the registry, brokering queries to the federated search engines, and merging the results to feed the UI.
- EOSC Interoperability Framework: such capability requires the definition of EOSC IF guidelines that define the interfaces (e.g. API) and the metadata schemas (structure of the data that should be provided) that EOSC members must implement to connect their catalogues to the EOSC federated search service.
- EOSC Members: to contribute and benefit (e.g. increased findability and visibility of local resources) from this capability, members must implement APIs as specified by the EOSC IF guidelines for this capability and onboard (i.e. register) their catalogues to the registry, i.e. complete a profile where API end-points, metadata format info, etc. are described for the web application to find and reuse.
- *EOSC Users:* after this process, researchers can find and request resources from the EOSC members made available through EOSC via the EOSC federated search engine.

The following diagram depicts a possible architecture of a common EOSC search engine showing how the EOSC members can connect their catalogues to the federated search service via the interfaces defined in the EOSC IF.



Figure 3.1: Example of the logical architecture of an EOSC federated search service. This capability requires two federating components, the registry of the EOSC catalogues and a web application exposing the search service to the users. EOSC members connect to this capability by publishing catalogue metadata into the registry via the interfaces defined in the related IG.



Note that the model does not define how those components that enable the EOSC capabilities must be operated and deployed. Indeed, these can be operated by multiple providers in different locations but require that providers are selected for each of the components and that the behaviour of all components is properly coordinated assuring their quality delivery. Appropriate service levels for each component need to be defined by the governance of the EOSC. Furthermore, for the specific service in the example, multiple providers can decide to provide customised federated search services choosing different groups of members & search engines (e.g. per domain or country), all based on the service metadata available in the central catalogue provider registry, delivering a dedicated federated search web application configured for this aim.

Generalising this example, we can state that the delivery of an EOSC capability requires:

- *EOSC federating components:* enable the capability in EOSC providing supporting features and are operated by selected EOSC members or other providers;
- Interfaces/APIs/Protocols/Profiles described in Interoperability Guidelines part of the EOSC IF: define how
 the EOSC members have to communicate with the federating components and between them. These
 Interfaces/APIs/Protocols/Profiles are defined in the EOSC IF interoperability guidelines of the related
 capability;
- EOSC members participating in the delivery of the EOSC capability: contribute to the capability enabling it.



Figure 3.2: The components to enable the federated search service can be operated by multiple providers.

An EOSC Capability starts to be operational when one or more EOSC members are connected to its federating components and start to share its information via these interfaces. Depending on the capability in question, this may also mean that access and use to the shared resources becomes possible.

After these steps are completed, the EOSC capability becomes available in EOSC and the researchers can start to use it.

The following diagram shows the architecture of a generic EOSC capability.





Figure 3.3: Example of a generic EOSC capability. The capability is enabled by the federating components and interfaces. EOSC members can contribute to the capability connecting via the defined interfaces. The components are deployed on EOSC members' or other providers' premises selected by the EOSC governance.

3.2. The EOSC Interoperability Framework and the Interoperability Guidelines

The **EOSC Interoperability Framework** (EOSC IF) is designed to provide an extensible framework of guidelines (the EOSC Interoperability Guidelines) that acts as the glue to support the interoperability and composability of EOSC Resources (services, data, other research products, training materials, etc.) made available through the EOSC Exchange between themselves and with EOSC Core services. The EOSC IF is defined as a reference framework to promote standards and best practices but offers the freedom to providers to develop and operate provider specific implementations while conforming to the EOSC IF guidelines and standards.

The **EOSC Interoperability Guidelines** (EOSC IGs) are the basic elements of the EOSC IF, and they provide the instructions needed to make use and interoperate with a Service. They are not just a collection of references to standards and best practices, but describe in detail the APIs, the metadata format of the exchanged data and the processes required to really make specific resources interoperable.

EOSC IGs allow:

- providers to understand how to design and configure services to interoperate with a wider community of users;
- software developers, system engineers and solution architects to understand detailed technical requirements needed to implement code to interoperate with such specific services and resources.

Interoperability guidelines can be classified in two main classes:

- Interoperability Guidelines for the EOSC Core services: These describe the high-level architecture of the EOSC Core services and the interfaces to integrate EOSC Exchange resources with each EOSC Core service (Resource Catalogue, AAI Federation, Helpdesk, Monitoring, Accounting, Order Management, etc.). As much as possible, these interfaces take advantage of existing standards and well-known best-practises in order to facilitate the integration process.
- Interoperability Guidelines for the EOSC Exchange resources: This class of EOSC IGs describes the
 interfaces and processes based on standards and best practices needed to interconnect and combine
 various types of EOSC Exchange resources so as to create new tools and solutions for research. They
 embrace the whole research data lifecycle (discovery and reuse, processing and analysis, curation and
 preservation, access and sharing) addressing interoperability of both services/infrastructure and
 research products (e.g. datasets).



EOSC Exchange Interoperability Guidelines are further classified into:

- Horizontal IGs: IGs for general capabilities that deliver functions useful to multiple scientific domains, called Horizontal Resources. IGs for Horizontal Resources can be associated with metadata, data storage and processing, scientific publishing and discovery, and a number of other functions of value to many scientific domains.
- Community/Thematic IGs: IGs specific to one thematic area or community. They refer to either the context where thematic or community services and resources interoperate with each other, usually at a domain (e.g. life science, earth science, etc.) level or where services and resources interoperate with each other across communities and infrastructures. EOSC Exchange IGs are created by experts in the scientific community to provide guidance to their communities, highlight the importance of their interoperability efforts at the Europe-wide EOSC level, and increase awareness of thematic and community accomplishments to facilitate/increase interoperability within and across domains.

3.3. Technical Implementation of the EOSC Federated System in EOSC Future

EOSC Future has implemented the technical aspects of the model behind the federated EOSC architecture leveraging the concepts of EOSC Interoperability Framework and EOSC Platform in line with the technical consideration described in section 3.1. This section details this implementation introducing the EOSC Platform and its federating capabilities, the EOSC IF IGs defined by the project and describes the process that allows the research communities to federate to EOSC.

3.3.1. The EOSC Platform

The project created an integrated operational environment that is now offered to research communities, the **EOSC Platform**, integrating and further enhancing EOSC Core services developed by past EOSC Projects (EOSC-hub, OpenAIRE Advance, EOSC Enhance, etc.). According to the technical considerations presented in section 3.1, Core services part of the EOSC Platform are the components enabling a number of capabilities to federate with EOSC that are offered to the research communities. Exploiting these capabilities, the research communities can add value to their own services in the Exchange and make them more useful and attractive to a wider range of science users. Currently, the EOSC Platform services delivering federating capabilities are the Resource Catalogue, the Marketplace, the EOSC Infrastructure Proxy, the AAI Registry supporting the EOSC AAI Federation, the Helpdesk, the Monitoring, the Accounting, the Order Management, and the EOSC Interoperability Framework registry is a special core service where all the IGs (core/horizontal/thematic) of the EOSC IF are recorded. Furthermore, the EOSC Platform has an extensible architecture that facilitates the addition of new capabilities to satisfy emerging user requirements.

In addition to enabling the EOSC federated system via its Core services, the EOSC Platform also delivers capabilities for horizontal/cross-disciplinary services via another internal component, the Execution Framework. These horizontal capabilities are those that have been identified as particularly relevant for research communities in Europe in the D2.5b *Inventory of Core Functions and Inclusion Criteria* and D2.9 *Co-designed Architecture Description*. They include services such as data transfer, secure and cloud-based access to IT resources (such as computing power, data and storage), deployment tools & workflow management tools, etc. Currently, the Execution Framework offers only a data transfer service, but it is expected to be further populated in follow-up actions (EOSC Procurement, EOSC Beyond and other EOSC projects).

It is worth mentioning that the EOSC Platform, although it is logically a unique operational environment, is *fully distributed*. Its components are operated by multiple providers in different hosting sites according to the EOSC Service Management System (SMS) that guarantees homogeneous behaviour and quality delivery in a federated environment.

The following table details the capabilities offered by the EOSC platform via its Core and Horizontal services.

Table 3-1: EOSC Platform services and related federating capabilities.

EOSC Platform Services	Federating Capabilities
Resource Catalogue & Marketplace	EOSC Resource Catalogue (services, datasets and other



	 research products) exposed to the end-user via the Marketplace Advanced search engine Research communities can publish (push) and retrieve (pull) resources to/from the federated catalogue
ΑΑΙ	 Single sign-on over federated infrastructures
Helpdesk	 EOSC Helpdesk as entry point to request support for all EOSC services
Monitoring	 Provide information about availability and quality for EOSC services (Core and Exchange)
Accounting	 Provide information about usage of services and resources in EOSC (Core and Exchange)
Order Management	 Offer a framework for providers to define offers and a unique interface for end-users to request access to resources
Execution Framework	 Currently, only the data transfer feature is implemented. Data repositories can connect to the data transfer service exposing standard interfaces. Providers of data transfer services can connect their services to the EOSC Data Transfer.

The description of the capabilities offered by the EOSC Platform and the definition of the interfaces that allow research communities to participate in such capabilities are included in related EOSC Interoperability Guidelines. These are recorded in the EOSC Interoperability Framework registry together with the other guidelines of the EOSC IF.

The following diagram shows the main classes of components of the EOSC Platform: (1) federating capabilities enabled by Core Services, (2) federating capabilities enabled by the Execution Framework (horizontal services), (3) EOSC IF registry and its interoperability guidelines and, (4) the EOSC Exchange, including references to all the services onboarded in EOSC.



Figure 3.4: The EOSC Platform delivers federating capabilities via Core and Horizontal (via the Execution Framework) services. It exposes interfaces to interconnect participating initiatives to the capabilities; these interfaces are described in related interoperability guidelines that are part of the EOSC IF.



3.3.2. The EOSC Platform Interoperability Guidelines

EOSC Future defined interoperability guidelines for all the Core and Horizontal services that are composing the EOSC Platform and are offering federating capabilities.

The following table lists such guidelines and provides references to the related entries in the EOSC IF registry.

Table 3-2: EOSC Platform services and related interoperability guidelines.

EOSC Platform Services	Interoperability Guidelines	
Resource Catalogue & Marketplace	 EOSC Service Catalogue: <u>https://zenodo.org/record/8333871²</u> EOSC Research Product Catalogue: https://doi.org/10.5281/zenodo.8362321³ AI/ML Recommender System: https://doi.org/10.5281/zenodo.7849178⁴ 	
AAI	Several AARC guidelines available in the EOSC IF Registry ⁵	
Helpdesk	https://doi.org/10.5281/zenodo.7308617 ⁶	
Monitoring	https://doi.org/10.5281/zenodo.83339267	
Accounting	 Research Products Accounting: https://doi.org/10.5281/zenodo.8362353⁸ Service Accounting: in publication 	
Order Management	https://doi.org/10.5281/zenodo.83753239	
Execution Framework	 Data Transfer: https://doi.org/10.5281/zenodo.7925514¹⁰ 	

3.3.3. Federating to EOSC according to EOSC Future

The EOSC Federated system implemented in EOSC Future and powered by the EOSC Platform aims to enable a common European portfolio and marketplace of resources (*datasets, services, other research products*) by federating resources from community platforms. This vision when realised will see resources in EOSC that are accessible via a common delivery channel to guarantee **homogeneous user experience** (*single sign-on, common support channels and quality metrics, common metrics for resource consumption, etc.*). Furthermore, **integration of services,** research **tools, datasets**, etc. from community platforms participating in the EOSC is facilitated by the multilateral adoption of common interfaces/APIs, standards and best practices.

The model implemented by EOSC Future is based on a simple prerequisite: a research organisation or another relevant initiative joins EOSC when it shares/registers one or more of its resources (services, catalogues, research products, etc) in the EOSC Resource Catalogue in compliance with the EOSC Rules of Participation¹¹. Contributing to the EOSC Resource Catalogue is the only mandatory capability that is requested to federate with. All the other capabilities are optional.

As a first step, a community has to register itself as a provider in EOSC and, after that, it can start to onboard resources such as services, data sources and its research products, catalogues, training materials, etc. The provider should describe all these resources with common metadata schemas named EOSC Profiles (see section

²https://search.marketplace.eosc-portal.eu/guidelines/eosc.4b877037ed3f1354271ec4d17061447d ³https://search.marketplace.eosc-portal.eu/guidelines/eosc.85412df68dd1171538a8609913fb6c71 ⁴https://search.marketplace.eosc-portal.eu/guidelines/eosc.2ocfa85315219f9151a280966d6fffff

⁵ https://search.marketplace.eosc-portal.eu/search/quideline?q=*

⁶https://search.marketplace.eosc-portal.eu/guidelines/eosc.fa941127b3ace6ad9ob2695db8do7531 7https://search.marketplace.eosc-portal.eu/guidelines/eosc.4of7b33103fdaa1d384a477358acedcc ⁸https://search.marketplace.eosc-portal.eu/guidelines/eosc.8a79fbaf2492ac4df3433c9288d3a8b7 ⁹https://search.marketplace.eosc-portal.eu/guidelines/eosc.c1efa7ced166o2193efe8o952ab3a6c7 ¹⁰https://search.marketplace.eosc-portal.eu/guidelines/eosc.5ec6cc329c858o6fd7234634d863e150 ¹¹EOSC Rules of Participation: https://op.europa.eu/en/publication-detail/-/publication/a96d6233-554e-11ebb59f-01aa75ed71a1/language-en/format-PDF/source-294684379



4.5 for more details). All the information that have been provided are validated by the EOSC Portal Onboarding Team (EPOT¹²) against the EOSC Exchange Inclusion Criteria¹³. This validation ensures that onboarded providers and resources fulfil a set of requirements based on the EOSC Rules of Participation.

After an initiative is officially onboarded in EOSC, it can decide to participate in the delivery of other capabilities. For this aim, the community has to connect its infrastructure/platform to the EOSC Platform where the Core and Horizontal services enabling these capabilities are operated. To make this possible, the platform has to operate *homologous services* that expose interfaces compliant with the related interoperability guidelines of the EOSC IF. After the integration is completed, the community platform can share its information via these interfaces. Depending on the service in question, this may also mean that access and use to the shared resources becomes possible.

Figure 3.5 shows the high-level architecture of a community infrastructure/platform (regional, national or thematic) joining EOSC. It operates homologous services, related to the capabilities the infrastructure/platform is participating in, exposing interfaces compliant with the EOSC IF. The community services in the platform are split in two sets: (1) Community Exchange: it includes all the services, datasets and other research products pushed to/pulled from the EOSC Exchange, (2) other services, datasets and resources relevant for the community operating the infrastructure/platform.



Figure 3.5: High-level architecture of a community infrastructure/platform (regional/national/thematic/institutional) joining EOSC.

For example, a research community can decide to directly connect its resource catalogue (containing services and/or data and/or other research products) to the EOSC catalogue to publish in EOSC a certain number of resources without the need to onboard them one by one. In such a case, the research community has to operate its own local resource catalogues (the homologous service for this particular capability) and connect it to the EOSC catalogue in the EOSC Platform. This interconnection has to be implemented via the EOSC catalogue API described in the interoperability guidelines of the EOSC Resource Catalogue part of the EOSC IF. In this way the

¹³ EOSC Exchange Inclusion Criteria:

¹² https://eosc-portal.eu/eosc-providers-hub/how-become-eosc-provider/instructions-onboard-providers-and-resources-eosc

https://wiki.eoscfuture.eu/display/PUBLIC/EOSC+Exchange+inclusion+criteria



research community catalogue can publish (push) or retrieve (pull) resources (services, datasets, etc.) to/from the EOSC Resource Catalogue.



Figure 3.6: EOSC Resource Catalogue as an example of EOSC capability to federate with. The EOSC Platform hosts the EOSC Resource Catalogue. Thematic and Regional Platforms can participate in the EOSC Resource Catalogue publishing (push) or retrieving (pull) resources (services, datasets, etc.) to/from it. EOSC IF defines the API to publish & pull resources to/from the EOSC Resource Catalogue catalogue.

Another example is when a research community decides to contribute to the EOSC Accounting for Service capability. In such a case, the research community infrastructure/platform should operate its accounting for service system (the homologous service) that has to be connected to the accounting core service operated in the EOSC Platform. Each infrastructure/platform can adopt their preferred technology to set up its accounting service, however this service should support the interface to connect to the EOSC Accounting for Service capabilities as defined in the EOSC IF (EOSC Accounting for Service IG). For this specific example, the EOSC IF should define the format of the accounting records and the API to publish these records in the EOSC Accounting Data Store.

Generalising this concept, a research community has to operate homologous services to connect to EOSC Platform services for each capability they want to federate with. This is shown in the figure below.



Figure 3.7: A research community connect homologous services to the EOSC Platform services for each capability they want to federate with.



3.3.4. EOSC Core and Horizontal services as reference implementations

According to the model just depicted, mature initiatives that are already operating their own infrastructure/platform can, if they so choose, reuse their own solutions to connect to the EOSC capabilities. They only need to add the support of the EOSC IF interfaces in their homologous services. Considering that these interfaces take advantage, as much as possible, of existing standards and well-known best-practices, the cost to expose them is usually not high because many communities already support them, or existing open-source implementations are available.

However, this can be more complicated for less structured collaborations that do not own the services to connect to the capabilities offered by the EOSC Platform. EOSC Future offers the EOSC Core and Horizontal services of the EOSC Platform as reference implementations that can be adopted (with a dedicated instance or, in some cases, as a service) by this kind of community. In this way, EOSC can both facilitate less structured collaborations to (1) create their own infrastructure filling gaps on their service offer (e.g. set up a dedicated helpdesk) and (2) join EOSC contributing to the delivery of the EOSC capabilities.

3.4. Model behind the federated EOSC architecture - Future evolutions

This section describes how the EOSC Federated system implemented by EOSC Future can evolve in the medium-short term. In particular, it presents:

- A possible extension of the model presented in this document to re-use EOSC IF guidelines to allow user communities to create their own federated systems. This extension, which is based on the concept of the EOSC IF, could be implemented by EOSC Future following up actions.
- How the model can evolve taking into account the introduction of the concept of EOSC Node in the context of the procurement procedure *Managed Services for the European Open Science Cloud (EOSC) Platform*¹⁴.

3.4.1. Reusing EOSC IF in community context

The definition of the EOSC interfaces in the EOSC IF can also enable two or more infrastructures/platforms to set up their own dedicated federated system. Indeed, a subset of community infrastructures/platforms participating in EOSC might decide to establish a stricter collaboration and leverage EOSC interfaces to connect their infrastructures.

For example, two research communities can decide to share more resources between them than those shared with EOSC because they are specifically relevant to their collaboration (and not generically for EOSC). In such a case, these communities can connect their catalogues reusing the interfaces defined in the EOSC Resource Catalogue IG. The choice of reusing EOSC Resource Catalogue interfaces can be beneficial for multiple reasons. First, their catalogues might already support the EOSC Resource Catalogue interfaces because they have been already connected to the EOSC Resource Catalogue. Furthermore, the interfaces defined in the guidelines are already well established and validated by multiple research communities.

This example is depicted in Figure 3.8.

¹⁴ https://etendering.ted.europa.eu/cft/cft-display.html?cftId=12087







According to this model, the EOSC IF can become a source of interface specifications to set up any kind of federated system, each of one offering a different set of capabilities. The diagram below shows this concept.



Figure 3.9: EOSC Platform and other platforms are interconnected via the interfaces defined in the EOSC Interoperability Framework according to the scope of their collaboration.

While the model as implemented in EOSC Future supports this scenario, the IGs for EOSC Platform services that have been developed by the project provide only instruction on how to connect another platform to the EOSC Platform. So, to make this scenario real, relevant IGs should be properly extended to describe how to set up a federated system for one or more of the EOSC Platform capabilities.



In addition to those defined in the EOSC Platform, research communities can specify other capabilities to federate with and develop related IGs for the EOSC IF to build new federated systems. This is particularly interesting for research communities sharing interests in the same scientific areas that can define thematic capabilities and IGs.

3.4.2. EOSC Platform and the concept of EOSC Node

In December 2022, taking into account the EOSC Future work on the EOSC Architecture (see EOSC Future D2.9 and D3.3a) and the EOSC Platforms definition, the EC introduced the concept of EOSC Node in the descriptive document (DD) of the EOSC Procurement. According to the DD, EOSC will be made up of a **network of EOSC Nodes** able to interoperate to share resources and facilitate their discovery, access and composability. Each node of this network will be "*a particular implementation of the EOSC Platform concept*" with its autonomy, an own governance model and a well-defined offer in terms of services and resources (a subset of the EOSC Exchange).

With the EOSC procurement procedure, the EC is going to set up the first node of the EOSC network, the EOSC Node at European level (the *EOSC EU Node*). Similarly, to the current EOSC Platform, the EOSC EU Node will deliver capabilities to federate with via EOSC Core and horizontal services and defines the interfaces to interconnect the participating initiatives as a part of the EOSC Interoperability Framework (EOSC IF). The EOSC EU Node will also directly deliver horizontal services to end-users such as virtual machines, containers, bulk and large data transfers, notebooks, etc. The EOSC EU Node is expected to replace the current EOSC Platform after the end of EOSC Future.



Figure 3.10: The EOSC EU Node¹⁵.

In the EOSC Procurement DD, the EC envisaged EOSC as a network of federated EOSC Nodes as depicted in the following diagram.

¹⁵ Gustav Kalbe - Acting Director of DG Connect C "Digital Excellence and Science Infrastructure": https://symposium23.eoscfuture.eu/wp-content/uploads/2023/09/1.-Kalbe_EOSC-EU-Node-Value-Proposition_EOSCSymposium_final.pdf





Figure 3.11: EOSC as a network of federated EOSC Nodes.

To contribute to one or more EOSC Capabilities, an EOSC Node should implement and deliver homologous capabilities to connect to the EOSC capabilities in a similar way as community platforms connected to the current EOSC Platform (see section 3.3). These capabilities, which can be implemented with a technology of choice or reusing EOSC EU Node technologies, must support the interfaces as defined by the EOSC IF guidelines for the Core and Horizontal services of the EOSC EU Node.

The model implemented in EOSC Future matches quite well with the concept of EOSC Node. The EOSC Future Platform currently plays the role of the EOSC Node at EC level, while research infrastructures and regional and national nodes can join as an EOSC Node within the EOSC. However, work is still in progress to better define what an EOSC Node is. When this is better clarified, the model implemented by EOSC Future shall be evolved accordingly.

4. Inside the EOSC Platform

This section details the EOSC Platform with information on its internal architecture and operations. It also describes the EOSC Profiles, the metadata schemas for entities in the EOSC Data Model. It is followed by sections describing the EOSC Core services in scope of the deliverable: EOSC Resource Catalogue, Helpdesk, Monitoring, Accounting and Order Management.

4.1. The EOSC Platform and its capabilities

The EOSC Platform is an integrated operational environment that delivers Core services to enable EOSC capabilities that are offered to the research communities to federate with. It includes services such as the Resource Catalogue, the Marketplace, the EOSC Infrastructure Proxy, the AAI Registry supporting the EOSC AAI Federation, the Helpdesk, the Monitoring, the Accounting, the Order Management, and the EOSC Interoperability Framework registry. Through the Execution Framework, the EOSC Platform also delivers capabilities for horizontal/cross-disciplinary services. The architecture of the EOSC Platform is extensible, new capabilities can be easily integrated to satisfy emerging user requirements.

The technical capabilities of the platform are complemented by a series of coordination and support functions that ensure a harmonised delivery of the EOSC Core (e.g. common procedures and policies for the management of all Core Services) and support the interactions with providers and community platforms (e.g. the onboarding process to manage the registration and validation of service onboarding request, the coordination of security incident response activities, etc.).

The EOSC Future *D2.9 Co-Designed Architecture Description* lists all the capabilities of the EOSC Platform and, for each of them, identifies the IT tools and the coordination and support activities needed for their delivery. A description of the requirements each Core service has to comply with is also provided.



4.2. Architecture

The creation of the EOSC Platform required extensive work to design its architecture, in particular focused on the integration of the different Core components. This activity included the definition of the interactions and interfaces between components and towards the external world to implement the use cases that the platform should support, as described in the project High Level Roadmap (HLR). User communities have been directly involved in this effort in line with the co-design principles.

The architecture of the EOSC Platform has been described using the C4 Model¹⁶, a methodology for visualising software architecture. Based on the C4 methodology, a software system is made up of one or more containers (web applications, mobile apps, desktop applications, databases, file systems, etc), each of which contains one or more components, which in turn are implemented by one or more code elements (e.g. classes, interfaces, objects, functions, etc).

A technical overview of the EOSC Platform developed with the C4 Model is shown in Figure 4.1, more details are available in D_{3.2}b *EOSC Architecture and Interoperability Framework*.



Figure 4.1: Technical overview of the EOSC Platform presented using the C4 Model methodology. More details are available in D3.2b

4.3. Operations and deployment

The EOSC Platform, although it is logically a unique operational environment, is fully distributed. Its components are operated by multiple providers in different hosting sites. However, all the aspects of both the operation and maintenance of services within the EOSC Platform are under the control of the Service Management System (SMS) based on the FitSM standard that was specifically designed to support federated service scenarios.

The SMS supports the federation approach *by design* and caters for the proper delegation of responsibilities for service delivery via a framework of service level management and using its operations processes. The functions of the SMS ensures that end-to-end Service Level Requirements (SLRs), defined as part of Service Level Management, can be consistently achieved and customer experience is continually improved, the platform is operated according to well-known quality standards, efficient security measures are implemented and EOSC Core and Horizontal Services are properly maintained and supported.

¹⁶ https://c4model.com/



In the daily operations, the SMS processes and procedures are translated into concrete actions by respective Operations Manager and Maintenance Engineers defined for each Core service. This includes for example identifying issues (Incident and Service Request), performing root cause analysis (Problem Management), assigning responsibility for software updates (Change Management), deploying new releases (Release Management), CSIRT procedure to deal with security incidents (ISM), etc. The SMS will keep track of all of these actions to facilitate the creation of reports.

4.4. Interoperability guidelines

EOSC Future has developed IGs for all the components of the EOSC Platform (Helpdesk, Monitoring, Accounting, etc.). These IGs, now publicly available in the EOSC IF registry¹⁷, have been constantly improved during the project life-time following feedback from user communities which acted as early adopters, and they have been adapted to the Interoperability Guideline data model defined to build the EOSC Interoperability Framework registry (see D_{3.2}b).

Each IG of the EOSC Platform describes (1) the capability and its main features, (2) the high-level architecture of the service enabling the capability and, (3) the related interoperability guidelines including adopted standards and integration options. In relation to the latter point, IGs include two main information types, the description of the interfaces/APIs and the format of the data that should be used by other services to interact with the EOSC Platform services.

The EOSC Platform IGs go further than defining a single interface for interoperation but also describe varying levels of integration, the integration options, from which a provider (seeking to onboard services or research products in EOSC) can select the option that best fits its needs. Integration options can specify various ways to integrate resources to an EOSC Platform service, from the tightest option, which allows providers to benefit from a greater number of federation features but requires more integration effort, to the loosest option, which enables a more limited feature set but with a lower complexity in terms of integration. This approach leaves each provider free to benefit from the added value federated functions delivered by EOSC Platform at the level it prefers without raising the cost of the basic integration with EOSC and, without creating a barrier that may hinder some providers to onboard their resources.

As an example, a community platform integrating into EOSC can decide to be federated with the EOSC central Helpdesk choosing one of the following options: (a) full integration - the community decides to use the EOSC central Helpdesk as its own helpdesk, (b) integration through the helpdesk API - the community programmatically connects its helpdesk to the EOSC central Helpdesk so that a ticket created in the EOSC central Helpdesk is automatically forwarded to its own helpdesk, (c) integration through e-mail - the community is notified by the EOSC central Helpdesk via e-mail when a ticket for its Services is created in the EOSC central Helpdesk, (d) no integration - the community decides to not integrate its Services with the EOSC Helpdesk.

Similarly, for a community onboarding Research Products multiple options are available. When a community has onboarded its Data Source, it may choose to onboard the related Research Products according to a selection of metadata profiles, i.e. OpenAIRE guidelines for data archives, institutional and thematic repositories, CRIS systems, and bioschema.org. Communities can also verify the compliance of the metadata of these Research Products, hence the compliance of the Data Source as a whole, to RDA FAIR (data) maturity guidelines.

4.5. EOSC Profiles

The EOSC Profiles are metadata schemas for the description of services, research products or other research artefacts that their providers choose to share with the EOSC user community through the EOSC Exchange, as well as for describing the organisations offering to provide these resources to EOSC. Any provider or other responsible party (the "Provider" or the "Catalogue Operator"/"Community Platform Operator") that intends to include one or more research resources ("Resources") in EOSC must use the appropriate EOSC Profile to describe both themselves and those resources in the machine-readable digital formats described in this IG (see

¹⁷ EOSC Platform IGs in the EOSC IF Registry: https://search.marketplace.eosc-

portal.eu/search/guideline?q=*&fq=eosc_guideline_type:(%22ir_eosc_guideline_type%5Ceosc_core_interoperability_guideline%22)



Section 3). Once described, the Provider or Catalogue Operator submits EOSC Profile records for validation. If the processing is successful, the subject of each approved EOSC Profile will be listed, findable and accessible in the EOSC Marketplace and can be integrated with other EOSC Core Services, pursuant to the respective EOSC IGs for those services.

EOSC Profiles have several functions:

- 1. **Onboarding to EOSC**: EOSC Profiles include information needed to assess the compliance of a specific Provider, Catalogue Operator and/or Resource with the Rules of Participation of EOSC, as well as the specific Inclusion Criteria used by those responsible for onboarding such entities into the EOSC Exchange and monitoring their continued compliance with the Rules of Participation.
- Search and Display within EOSC: EOSC Profiles include information needed to include the Provider and/or Resource in the EOSC Resource Catalogue (combining the EOSC Service Catalogue and EOSC Research Product Catalogue) and the EOSC Marketplace. Generally, a Provider or Resource is included (displayed) automatically in the EOSC Marketplace once it has been included in the EOSC Resource Catalogue.
- 3. Integration with EOSC Core Services: EOSC Profiles act as a reference to support integration of any Resource with one or more EOSC Core Services, including EOSC Monitoring, EOSC Accounting, EOSC Helpdesk and EOSC Order Management. Specific integrations are detailed in various "extensions", which are themselves described in the relevant IG for the EOSC Core Service that uses an extension (see Section 5). Extensions are not part of the EOSC Profile but refer to the identifier of the corresponding EOSC Profile. (Note that, in the abstract, function 2 above represents integration of a resource with the EOSC Resource Catalogue and the EOSC Marketplace, both of which are Core Services but no specific "extension" is required for this, and this integration is the implicit purpose of the EOSC Profile itself.)
- 4. Anchoring of capabilities in EOSC: Certain EOSC Profiles describe a range of possible resources, and specific Subprofiles are defined to enhance the 3 functions described above for a specific type of resource. At the time of writing, one Subprofile, for a Data Source, has been defined, enhancing the generic Service Profile. Other subprofiles are planned for future implementation, particularly for Services that describe computational resources, and for Services that describe data storage resources.

EOSC Profiles specified in version 5.0 (v5.0) represents the "state of the art" of EOSC Profiles, and the final instance of the Profiles as implemented by the EOSC Future project. EOSC Profiles v5.0 were released into production in November 2023. They are documented in GitHub¹⁸.

The EOSC Profiles together with all their extensions related to other EOSC Platform components made up the EOSC Platform Data Model.

4.5.1. EOSC Profiles V5.0

The EOSC Profiles V5.0 includes the following EOSC Profile "types":

- *Provider:* An organisation operating a resource, whether operating a service or providing access to research artefacts for use or access by users not affiliated with the organisation itself.
- Catalogue:
 - Catalogue Operator: An organisation operating an EOSC-compliant community catalogue and responsible for the onboarding and validating selected resources from that community catalogue into the EOSC Exchange.
 - Community Catalogue: A Community catalogue complying with EOSC Exchange community resource catalogue inclusion criteria and including several resources. It is an external catalogue that can be onboarded into the EOSC Exchange by a Catalogue Operator Representative on behalf of the Community Catalogue Operator.
- Service: Digital system that allows a user either to interact with the system, entering data or other inputs, executing instructions through commands or other interfaces, or to issue machine-to-machine commands using a protocol such as an API that allows information or data to be supplied to the system, and that allows results to be received by the user through graphical interfaces and/or production of output data files.

¹⁸ https://eosc-profiles.readthedocs.io/en/latest/



- Data Source, as a Subprofile of Service: A service that links to collections of research products (see Research Product) as well as services that provide data in response to queries.
- Research Product: A scientific or research output (classified as publication (literature), research data, research software, and "other kinds of products"), accessible or linked from an EOSC Data Source (e.g. repository, scientific database, publisher archive aggregator, CRIS system), whose metadata might be "harvested from" the linking EOSC Data Source using a defined protocol (e.g. OAI-PMH)
- *Training Material:* Any resource including print and non-print materials and online/open-access resources which supports and enhances, directly or indirectly, learning and teaching. If a training resource is used in a training environment, for training activities that are part of a training plan and involve instructors, facilitators and students, then we speak of training materials.
- Interoperability Guideline: Version-controlled document(s) that describe standards to enable
 interoperability and explain how Providers can make their resources compatible with them. They
 outline the high-level protocols (such as REST) and low-level protocols (such as OAI-PMH), data models
 (e.g. DCAT model), and schemas (e.g. DCAT JSON schema) that need to be implemented or
 customised to ensure compatibility with each guideline. Guidelines specify the essential technical
 requirements and configurations that providers should follow in order to make their services
 compatible with the interoperability guidelines. EOSC Interoperability Guidelines pass a validation
 process, after which they are onboarded (registered) into the EOSC IF registry.

The Provider and Catalogue Profiles are specific instances of a more general "organisational" entity. The other Profiles, as well as to some extent also the Catalogue Profile, are specific instances of a more general "Resource" entity. These relationships are illustrated in Figure 4.2 below.



Figure 4.2: Logical Relationships Among Profiles and Subprofiles

Detailed specifications of the EOSC Profile types can be found at the GItHub link referenced above.

4.5.2. **Profiles Governance**

EOSC Profile Governance is managed by the EOSC Profile Governance Group (EPGG), which in EOSC Future is identified as the team assigned to Task 3.2.1 in WP3. Candidates for this activity include the EOSC Association, the successful proponent for the Lot 1 Managed Services of EOSC Procurement (https://etendering.ted.europa.eu/cft/cft-display.html?cftld=12087), the EOSC BEYOND Consortium (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-infra-2023-eosc-01-04), or some combination of these groups.

Profile governance includes the following activities:



- Establishing and maintaining a version-controlled, publicly available specification of the EOSC Profiles.
- Collection of possible changes to the EOSC Profiles, proposed both by those involved in delivering the EOSC Platform and those in the communities using the Platform.
- Decision-making about proposed changes,
- Documentation of approved changes.
- Changes to software, procedures or documentation in order to implement the approved Profile changes.
- Validation of all software, procedures or documentation changes to confirm that they implement the changes to the Profile that were approved.
- Updating of formal Profile specifications, including this Interoperability Guideline.

These activities are described below.

4.5.3. Establishing and maintaining a version-controlled, publicly available specification of the EOSC Profiles

Over the course of multiple EU-funded projects that have been building components of EOSC and working to integrate these components into the EOSC Platform, various technologies have been used to document the EOSC Profiles, most recently a public "wiki" created for the EOSC Future project, using Confluence software hosted by EGI Foundation. Although this technology provided an appropriately public platform for disseminating the specifications, it did not offer suitable version-control capabilities or the ability to formally track proposed changes in a granular way.

Several alternative approaches and technologies were considered, and after assessment, GitHub was chosen as a widely accessible tool well suited to this requirement. GitHub was primarily created as a "website and cloud-based service that helps developers store and manage their code, as well as track and control changes to their code", but is also well suited to managing formal specifications such as the EOSC Profiles. For the EOSC Profiles, a repository ("https://github.com/EOSC-PLATFORM") has been created to hold the technical specifications of the Profiles.

To implement the specifications using GitHub, the EOSC Future project translated the specifications assembled in the EOSC Future "Wiki" into text files structured using the "RST" ("ReStructured Text") format, which is widely used for technical documentation. This format is also compatible with a range of document generation tools, such as "ReadTheDocs", which is used to translate the RST-formatted specifications into human-readable pages, which can in turn be converted into PDFs for documentation, reporting and archiving purposes.

Specifically, each EOSC Profile has a corresponding RST file representing the Profile's specification. In addition, each controlled vocabulary used by any field of the Profile schema has a specific RST file to represent the controlled vocabulary. These RST files are complemented with explanatory text for each profile in an "Introduction.RST" file.

The primary component of the EOSC Platform that implements the EOSC Profiles is the EOSC Service Catalogue, specifically the "Providers Portal", which has the ability to generate XML Schema Descriptions (XSD) that reflect the "as is" state of the Profiles implementation. The developers of the Providers Portal have enhanced the schema details generated by this software to include all documented aspects of each implemented Profile and each field of that Profile. The resulting XSD can be compared to the specification to validate correct implementation.

4.5.4. Collection of possible changes to the EOSC Profiles, proposed both by those involved in delivering the EOSC Platform and those in the communities using the Platform

GitHub provides specific tools for its users to propose changes to the contents of a repository. The process requires the user to have an account on GitHub, so that the source of any changes can be identified. Certain authorised users working with EOSC have rights that allow them to accept, reject or defer decision-making about proposed changes. Other identified users are not allowed to change the "main" contents of the repository but can create their own "branches" of the main contents, reflecting all that content and allowing the user to edit the contents in the way that they propose. Each proposed change must be "committed" by the user (who is proposing the change) to their own branch of the contents. Once the user is satisfied with the changes that



they have proposed, then can make a "pull request" to request that these changes should be "pulled" back into the main repository contents. At this point, other users can review and discuss the proposed changes, allowing them to be debated by a larger group of interested individuals. If this discussion leads to approval, the Pull Request is accepted, is tagged to link the Pull Request with a release candidate (the next version of the documentation) and merged into the main content of that documentation. GitHub allows different versions of the documentation to be maintained so that past and planned releases are clearly documented.

For the EOSC Profiles, this generic capability of GitHub is used to manage the governance process as follows:

- The EOSC Profile Governance Group is identified and has the ability to comment on changes of others.
- The leader of the EPGG will receive rights in GitHub to accept Pull Requests and manage versions of the EOSC Profile specifications.
- Individuals interested in EOSC Profiles, e.g. representatives from linked EOSC Communities, can create accounts on GitHub and request the ability to create new branches in the EOSC Platform repository. This will allow them to make and commit changes to their branches, and then make Pull Requests for those changes, signaling their request for changes to the specifications.
- Other parties, such as members of the EOSC Portal Onboarding Team (EPOT) can make similar requests. In particular, EPOT is notified when Providers suggest new entries for controlled vocabularies, and e.g. one EPOT member could transcribe these requests into GitHub.

4.5.5. Decision-making about proposed changes

Periodically and/or in response to operational pressures, the EPGG reviews Pull Requests submitted to the GitHub repository. The EPGG would then engage in dialog with requesting individuals to weigh the pros and cons of the requested change. The EPGG would decide whether to accept any requests and would assign them to specific release candidates in order to manage the implementation process.

4.5.6. Documentation of approved changes

GitHub would be used to document approved changes in each release, and depending on tools used by development teams, approved changes would be converted into Jira tickets or similar artefacts to support management and control of the change process.

4.5.6.1. Changes to software, procedures or documentation in order to implement the approved Profile changes

Documented changes, which might apply to software, procedures as well as documentation for Providers and other stakeholders, would be implemented. E.g. new software would be developed and deployed to a beta instance for testing.

The primary component of the EOSC Platform that implements the EOSC Profiles is the EOSC Service Catalogue, specifically the "Providers Portal". As an additional documentation artefact, the Providers Portal has the ability to generate XML Schema Description (XSD) files that reflect the "as is" state of the Profiles implementation. The developer of the Providers Portal has enhanced the programmatically generated schema details generated by the Providers Portal software with additional information, e.g. descriptions, cardinalities, optional/mandatory, etc. to ensure a complete representation of each implemented Profile and each field of that Profile.

When the Providers Portal is modified through the change management process and is deployed on beta, the updated XSD files generated by the Providers Portal can be compared to the change documentation in GitHub to ensure correct implementation of approved changes.

4.5.6.2. Validation of all software, procedures or documentation changes to confirm that they implement the changes to the Profile that were approved

New artefacts (software in beta, revised procedure documentation, other documentation, as well as the XSD generated by the EOSC Providers Portal) would be reviewed by the EPGG to confirm correct behaviour of any new capabilities related to revised Profiles.



If new behaviour matches the new requirements, the EPGG would advise that the Profile-related changes are ready for release into production. If not, developers and those responsible for other artefacts would be asked for additional effort to align the new "as is" behaviour with the approved "to be" specification.

4.5.6.3. Updating of formal Profile specifications, including this Interoperability Guideline

Once revised Profile implementations are deployed to production, the corresponding candidate release in GitHub can be updated to reflect that it is live.

Note that external references and URLs for the GitHub instance of the specifications should be sure to refer to the 'latest" release so that these references will remain valid after each release.

4.5.7. Evolution and Development

This version of the EOSC Profiles has been developed and implemented by the EOSC Future project, which will finish in March 2024. A follow-up technical development project, EOSC BEYOND will start in April 2024 and run through March 2027. In parallel, managed services to operate the EOSC Platform, using the EOSC Profiles and related governance procedures, are now being procured by the European Commission under tender (https://etendering.ted.europa.eu/cft/cft-display.html?cftld=12087), with services expected to be available from early 2024 through early 2027. These initiatives will have to take over and may decide to advance at least some of the operational aspects described in these guidelines. Overall governance of the development of the EOSC profiles beyond the EOSC Future project has to be decided outside the scope of the project.

The EOSC Profiles are a mechanism to describe the diversity of research artefacts and resources onboarded into EOSC Federation ensuring their findability and accessibility throughout the entire ecosystem. The EOSC Profiles themselves shall evolve to reflect the expanding universe of such artefacts and resources, adapting to the changes of architectural concepts of the EOSC architecture, as well as developments among the specific EOSC community of practice (including regional and thematic catalogues, RIs, and other entities, e.g. industrial research). At the same time EOSC Profiles must always be clear and practical to enable findability and accessibility.

Future evolution and development will be driven by the necessity to fulfil the purpose of the EOSC Profiles in the evolving environment of the EOSC Architecture and EOSC Federation. Specific developments can be expected in several areas:

- Refining profiles to remove or simplify data requested that is not used or used fully;
- Adding data that would improve usability (in connection with the four functions listed above):
 - E.g. adding fields to enable automated assessment of inclusion criteria vs. requiring additional information from providers and/or manual review of data included in Profiles.
 - Adding fields to enable automated ordering, management of access and use for resources.
- Exposing catalogue operators and their catalogues in the Marketplace to allow direct access;
- Creating subprofiles of services to model:
 - computational services and infrastructure
 - data storage services and infrastructure
 - entire community catalogues
- Extending the catalogue operator profile to more completely represent communities and "portals", which in turn are linked to one or more specific community catalogues;
- Better alignment of EOSC Profile standards with other standards such as:
 - Resource Description Framework (RDF)
 - Web-Services Description Language (WSDL)
 - Compound standards developed by initiatives such as Gaia-X for services
 - Catalogue standards (e.g. DCAT, DCAT-AP, GeoDCAT, OGC standards)
 - Discipline specific standards such as those developed by the Global Alliance for Genomes and Health (GA4GH)
 - Access and Use Policies (ODRL)

Some of these evolutionary aspects are illustrated in Figure 4.3 below:





Figure 4.3: Possible Future Profile Entities and Relationships

5. Architecture Specifications and Interoperability Guidelines for EOSC Platform components

This section shortly presents the Architecture Specifications and Interoperability Guidelines for the EOSC Platform components in the scope of this deliverable:

- EOSC Resource Catalogue
 - EOSC Service Catalogue
 - EOSC Research Product Catalogue
- EOSC Monitoring
- EOSC Helpdesk
- EOSC Accounting
 - Accounting for services
 - Accounting for research products
- EOSC Order Management

These IGs are available in the EOSC IF registry¹⁹ for consultation.

5.1. EOSC Resource Catalogue

The EOSC Resource Catalogue is a catalogue of all EOSC Resources, that is the result of integrating the EOSC Service Catalogue and the EOSC Research Product Catalogue. Architecture and Interoperability guidelines have been developed for these 2 components and are presented in the following sections.

¹⁹ EOSC Platform IGs in the EOSC IF Registry: https://search.marketplace.eosc-

portal.eu/search/guideline?q=*&fq=eosc_guideline_type:(%22ir_eosc_guideline_type%5Ceosc_core_interoperability_guideline%22)



5.1.1. EOSC Service Catalogue

The **EOSC Service Catalogue**, as part of the *EOSC Resource Catalogue*, is the heart of the EOSC Future ecosystem. It provides both data and functionalities to register, maintain, administer and share resources onboarded by various providers. Moreover, it is the point of reference for all EOSC Core components that provide added value to the EOSC resources and help in making all these data and services searchable and accessible using various tools.

Regarding resource onboarding and management, the EOSC Service Catalogue provides functionality for:

- Providers, to register to the EOSC and become eligible for the onboarding of Resources and Interoperability Guidelines.
- Providers, to onboard their services into the EOSC Service Catalogue.
- Providers, to view the list of services registered in the Service Catalogue and perform a variety of actions such as activate, deactivate, view usage statistics.
- EOSC Portal Onboarding Team (EPOT) members, to manage the onboarding process (approve, reject an application), manage the catalogue of providers and services and audit the validity of the catalogue entries.
- Providers of Catalogues, to add regional or thematic catalogues to the EOSC ecosystem.

Regarding resources discovery and access, the EOSC Service Catalogue provides functionality for:

- APIs to search, browse, and navigate the EOSC Providers, Resources and entries in the Interoperability Registry.
- APIs to broker/route metadata information to service providers and any other EOSC Core components that uses such data.

Figure 5.1 explains the general architecture of the EOSC Resource Catalogue and subcomponent interactions:



Figure 5.1: EOSC Resource Catalogue High Level Architecture

There are three main cases regarding interaction with the Service Catalogue:

- Onboarding single Providers and Resources directly to the EOSC Service Catalogue
- Onboarding entire collections of Providers and Resources as parts of third-party external Catalogues (Regional/Thematic catalogues, etc.)
- Interoperations with other EOSC Future Core components



These are detailed below.

5.1.1.1. Provider/Resource or Guideline onboarding and management

EOSC Service Catalogue offers **two** interfaces to enable onboarding and management of providers and resources:

- 1. The EOSC Providers Portal Component: **a web portal** that offers a simple UI to interact with the EOSC Service Catalogue.
- 2. The EOSC Service Catalogue **REST API**.

These interfaces enable the following functionalities:

- Onboarding service, which implements the EOSC portal onboarding process for resources, i.e., the registration of a new Provider and the registration of Resources or Data sources managed by the Providers, as well as the registration of catalogues. Onboarding services will target authenticated users who will be able to onboard either via a web-based step wise process or programmatically by using the EOSC Service Catalogue's APIs.
- Resource Management service: It offers the functionality for authenticated users from providers to
 manage their resource portfolio in the catalogue, i.e., view the list of resources associated with their
 organisation and manage all characteristics of their offerings. Resource management will enable users
 from onboarded providers to add, update a resource, also the ability enable providers to
 "activate"/"deactivate" a resource in the EOSC Portal, to assign it to categories or other classification
 schemes (e.g., scientific domain, TRL, etc), to manage the different versions of a resource and add new
 users who will be responsible for managing the offerings of a provider.
- Providers Dashboard: It serves as the UI entry point for providers. The dashboard offers an overview to the users for the list of the providers and it represents the list of resources and their properties including a history of changes applied to each resource. The dashboard will also give access to a rich set of statistics, which are collected by the EOSC portal and will be associated with resources and providers onboarded in the EOSC Service Catalogue.
- Statistics over the content of the catalogue, organised by resources and providers, such as number of resources per scientific discipline, providers per country, etc. These include usage statistics, such as views and visits for a resource, aggregated views and visits for all resources offered by a provider, search related statistics which are associated with a provider, orders placed for a resource, ratings, recommendations offered to users related to a resource and finally favourites those users add in the EOSC portal.
- Validation/Auditing functionality for recurring quality assurance of resources data and status and for curation of providers changes on resources over time. This functionality is currently used by EPOT Team members, but it also applies to external catalogues administrators.

Summary of functionality offered:

- For providers
 - Onboarding
 - Management of resources
 - Live usage statistics from the EOSC Providers Portal
 - Email notifications
 - Interaction with EPOT team
- For EPOT team members



- Onboarding management
- Auditing and Catalogue management
- Email digest and interaction with providers
- For other users (funders, EOSC profiles management (vocabularies, schema, etc.)
 - Statistics

5.1.1.2. Resource catalogues onboarding and management (Third party, Thematic or Regional)

This functionality facilitates the onboarding of entire collections or **Catalogues** of resources maintained by another organisation or provider. These catalogues could include resources that share a common subject (thematic catalogues) or resources that come from a specific geographical region or consortium/fellowship (regional catalogues). There are three key issues that distinguish resource catalogue registration from a simple resource registration as already described above:

- A service or resource can participate in more than one catalogue.
- A catalogue should be able to synchronise data with the EOSC Resource catalogue (and vice versa).
- A catalogue should be managed by a provider, just as any other resource.

A catalogue can be considered as another kind of EOSC service. Like all other services, it is managed by a Catalogue Owner (the entity registering the catalogue to the EOSC catalogue). This means that:

- The EOSC catalogue has its own entry to itself.
- EOSC is a Provider, managing the EOSC Catalogue.

Resources and Providers onboarded through a third-party catalogue contain a reference to the original hosting catalogue. Those registered directly in the EOSC Catalogue could mention the EOSC Catalogue, while those harvested/aggregated/collected/registered by other catalogues mention the respective catalogue.

5.1.1.3. Interaction with other EOSC Future Core components – Marketplace, Monitoring, Helpdesk, Interoperability Registry

The EOSC Service Catalogue uses a JMS messaging subsystem in order to facilitate a loose coupling communication with the Marketplace. This can be expanded for use with more EOSC components and/or external systems that seek interaction with EOSC Resource Catalogue (for example, external catalogues). JMS messaging can be replaced by AMS messaging for greater scalability, and a more general specification about message format and schema might be necessary to cover more component interactions.

Information for Monitoring or Helpdesk integration can be provided during onboarding or at a later stage, either through the Providers Portal UI or through REST API calls. Users and providers can see monitoring metrics for resource reliability and can benefit from a single helpdesk for any issue across the EOSC ecosystem.

Finally, regarding Interoperability Registry, a REST API is in place to link resources onboarded into the Service Catalogue with entries in the Interoperability Registry. Providers can also facilitate this linking through the Providers Portal UI.





Figure 5.2: EOSC Interoperability Registry and Service Catalogue / Providers Portal interactions

The following table contains a listing of all REST APIs used for Service Catalogue interactions:

Table 5-1: EOS	C Interoperability	/ Registry a	nd Service Catalogue ,	/ Providers Porta	l interactions
----------------	--------------------	--------------	------------------------	-------------------	----------------

Client	API	Resource Profile	Status
Services	 For Service Providers: Provider/Resource/Controlled Vocabulary REST API Onboarding workflow (guide, documentation) For EPOT team members: Auditing and Registry workflow Email digest and interaction with providers 	Service (was Resource) and Provider Profiles (v 3.o, v 4.o)	Ready
Catalogues	 For third party EOSC Federated Catalogues: Catalogue Provider/Resource/Controlled Vocabularies REST API For EPOT team members: Auditing and Registry workflow 	Catalogue Profiles (v.4.o)	Ready
Training Resources	 For Training Resource Providers: REST APIs for Training Resources Providers/Resources/Controlled Vocabularies For EPOT team members Onboarding/Auditing workflow for Training Resources 	Training Resource <u>Profiles</u> (v4.0)	Ready



Interoperability Guidelines	 For Interoperability Guidelines Providers: REST APIs for Interoperability Guidelines/Controlled Vocabularies For EPOT team members Onboarding/Auditing workflow for Interoperability Guidelines 	Interoperability Guidelines Profile	Ready
Profile Extensions (Monitoring Helpdesk)	 For Service Providers: Monitoring/Helpdesk extensions /Controlled Vocabulary REST API For EOSC Core components: Getting Service Catalogue Providers and providing extension functionality 	Not applicable	Ready

5.1.2. EOSC Research Product Catalogue

The EOSC Research Products Provider Dashboard, powered by OpenAIRE PROVIDE (http://provide.openaire.eu), is the tool that enables EOSC Data Source managers (aka service managers/developers acting on behalf of the Data Source provider) to onboard the research products hosted by the data source into the EOSC Research Product catalogue and, in turn, into the EOSC Resource Catalogue. The onboarding of research products occurs via dedicated harvesting and aggregation workflows configured by EOSC data curators, which harvest metadata records describing the research products via Data Source APIs.

To onboard research products, data source providers must follow the EOSC Data Source onboarding procedures from the EOSC Service Catalogue. Once the EOSC Data Source is onboarded in the catalogue, the following Interoperability Guidelines must be implemented:

- The data source implements (at least) one of the APIs listed in the EOSC Data Source protocols for Research Product Onboarding (see Table 5-2: List with references of the protocols/APIs adopted by this service (for an up-to-date list see the <u>dedicated wiki page</u>)
- 2. below for a list at the time of publishing this document)
- 3. The data source exposes (at least) one of metadata record formats listed in the EOSC Research Product Profiles (see Table 5-3 below for a list at the time of publishing this document).

Products are onboarded via the EOSC Research Product Providers Dashboard.

The EOSC Research Products onboarding guidelines define which harvesting protocols and metadata schema should be implemented by data source providers across different disciplines to share and interlink their research products via the EOSC Resource Catalogue. Identifying and implementing such "commons" is key to enabling a cross-disciplinary overlay of interconnected resources. To this aim, the EOSC has adopted a System of Systems approach, which tries to maximise global coverage of research products within the EOSC Resources Catalogue, while minimising the technical effort by providers to comply with the guidelines. The EOSC Governance will establish, in collaboration with the communities, the list of protocols and metadata schemas selected and supported by the onboarding policies described in this document. The EOSC Research Product Provider Dashboard (OpenAIRE PROVIDE) will serve as a gateway for EOSC providers to configure harvesting, validation, and onboarding workflows capable of automatically collecting and onboard research product metadata from their Data Source into the EOSC Resource Catalogue.



5.1.2.1. High-level Service Architecture



Figure 5.3: Harvesting and onboarding workflow with time-frame

5.1.2.2. Integration Procedure

Once the EOSC Data Source adheres to the IF guidelines described in this document, the integration into the EOSC takes place via the EOSC Research Product Providers Dashboard (OpenAIRE PROVIDE). The provider logs into the dashboard and provides the necessary protocols and schema parameters. The Dashboard offers functionality for the validation of guideline compatibility and for the final request of integration, which EOSC data curators follow up.

5.1.2.3. Related Guidelines

- OpenAIRE Guidelines
- DataCite metadata schema

5.1.2.4. Adopted Standards

Table 5-2: List with references of the protocols/APIs adopted by this service (for an up-to-date list see the dedicated wiki page)

Protocol/API	Short Description	Integration	References
OAI-PMH	The Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) is a low- barrier mechanism for repository interoperability. Data Providers are repositories that expose structured metadata via OAI-PMH. Service Providers then make OAI-PMH service requests to harvest that metadata. OAI-PMH is a set of six verbs or services that are invoked within HTTP.	Data Source Providers can provide the OAI- PMH parameters (end- point, sets, etc.) via the OpenAIRE PROVIDE user interface. Via UIs they can test, validate, and finalize the onboarding	https://www.openarchiv es.org/pmh/



		FTP integration cannot	
		take place via OpenAIRE	
	The File Transfer	PROVIDE UIs and	
	Protocol (FTP) is a	requires interaction with	
	standard communication	the EPOT team for	
ETD	protocol used to transfer	research products.	
FIF	computer files from a	Records should be	
	server to a client on a	contained into one	https://it.wikipedia.org/w
	computer network. FTP	folder, match the	iki/File_Transfer_Protoco
	is built on a client-server	guidelines, and be	I
	model architecture using	accessible from a given	
	separate control and	FTP/SFTP end point. The	
	data connections	EPOT team will finalize	
	between the client and	the configuration of the	
	the server.	harvesting workflow	
		associated with the data	
		source	

 Table 5-3: List with references of the metadata standards adopted by this service (for an up-to-date list see the <u>dedicated wiki</u> page)

Metadata schema	Short Description	References
OpenAIRE Guidelines for Institutional and Thematic Repositories v4.0	Metadata schema entirely inspired from DataCite.org, with extensions required to model scientific articles (e.g. journals, conference, link to PDF), links to funders and grants	https://openaire-guidelines-for- literature-repository- managers.readthedocs.io/en/v4.0. 0 GitHub: https://github.com/openaire/guid elines-literature-repositories
OpenAIRE Guidelines for Literature Repositories v3.0 (for resources onboarded in the OpenAIRE Graph before 1/1/2023)	Previous version of OpenAIRE Guidelines for Institutional and Thematic Repositories, implemented by repository platforms of DSpace and DataVerse, included to ensure EOSC compliance for all Data Sources in the OpenAIRE Graph that are currently matching the schema. Data sources onboarding after 1/1/2023 must comply to version 4.0.	https://guidelines.openaire.eu/en /latest/literature/index_guidelines -lit_v3.html GitHub: https://github.com/openaire/guid elines
OpenAIRE Guidelines for Data Archives v2.0	Metadata schema entirely inspired from DataCite.org, with extensions required to model links to funders and grants	https://guidelines.openaire.eu/en /latest/data/introduction.html GitHub: https://github.com/openaire/guid elines
OpenAIRE Guidelines for CRIS Managers v1.1	Metadata schema defined in collaboration with CERIF to match the essential properties required to export research product metadata frm CRIS systems	https://openaire-guidelines-for- cris- managers.readthedocs.io/en/v1.1. 1/ GitHub: https://github.com/openaire/guid elines-cris-managers



5.1.2.5. Interoperability Guidelines

The guidelines describe the protocols and the metadata schema that should be provided by the data sources to enable the automated and regular harvesting of research product profiles from the EOSC data source endpoint(s).

Table 5-2 and Table 5-3 above describe the current list of standards, which may, however, vary to add new options in the future. Guidelines versions are published in Zenodo and are freely available on GitHub (see Table 5-3), through which communities can provide feedback.

5.2. EOSC Monitoring

The EOSC Monitoring is the key service needed to gain insights into an infrastructure. It needs to be continuous and on-demand to quickly detect, correlate, and analyse data for a fast reaction to anomalous behaviour. The challenge of this type of monitoring is how to quickly identify and correlate problems before they affect endusers and ultimately the productivity of the organisation. Management teams can monitor the availability and reliability of the services from a high level view down to individual system metrics and monitor the conformance of multiple SLAs.

The key functionalities offered by the EOSC Monitoring service are:

- Monitoring of:
 - EOSC Core services
 - EOSC Exchange Services (see Integration Options section)
- Reporting availability and reliability,
- Visualisation of the services status,
- Provide dashboard interfaces that can be target towards both Providers and End Users (e.g. Researchers),
- Sending real-time alerts to Providers (Service operators) and EOSC Core service operators to varying levels of complexity (for example, for the purposes of alerting operators to availability issues, or to alert the EOSC Provider Onboarding Team of issues with Resource Profiles).

The dashboard design should enable easy access and visualisation of data for end-users. APIs are supported to allow third parties to gather monitoring data from the system.

The EOSC Monitoring service was designed to:

- Support multiple entry points (different types of systems can work together),
- Being easily interoperable with other monitoring systems,
- Operate the different components of the systems in High Availability,
- Support for Multiple Tenants, Configurations, Metrics and profiles to add flexibility and ease of customisation.

The EOSC Monitoring service combines two operational monitoring services: the EOSC Core and the EOSC Exchange Monitoring Services, respectively monitoring the EOSC Core services (EOSC Core Monitoring) and the services onboarded to the Marketplace (EOSC Exchange Monitoring).

The EOSC Monitoring services were implemented adopting the ARGO technology.

5.2.1. High-Level Architecture

The EOSC Monitoring service collects status (metrics) results from one or more monitoring engine(s) deployed across distributed infrastructure and delivers daily and/or monthly availability (A) and reliability (R) results for monitored services. Status results and A/R metrics are presented through a Web UI, with the ability for a user to drill-down from the availability of a site to individual test results that contributed to the computed figure.





Figure 5.4: EOSC Monitoring High-Level Architecture.

The main components of the EOSC Monitoring service are depicted in the high-level architecture diagram and described in the following text.

- **Monitoring Engine(s):** this component executes the service checks against the distributed infrastructure and delivers the metric data (probe check results) to the Messaging Service.
- Sources of Truth: The Monitoring system supports a number of connector plugins that are able to fetch topology, metrics and factors from various sources such as the CMDB and the EOSC Resource Catalogue. A Metric and Profile Management Component allows checks (probes) to be defined and associated with specific Services. Each combination of checks and service types forms a profile.
- **Messaging:** The monitoring system uses a Pub/Sub Messaging Service to connect its components.
- **Computations & Analytics:** Computational jobs are defined for ingesting data, calculating status and availability/reliability and a management service automatically configures, deploys and executes those jobs on a distributed processing engine for stateful computations. This component analyses the monitoring results and sends notifications based on a set of rules, to inform the Service Providers about the status of their services.
- WEB API: RESTful HTTP API service that provides access to status and availability/reliability results. It supports token based authentication and authorisation with established roles. Results are provided in JSON Format.
- WEB UI: The Web UI is the component to present the information about the status of the services. The global information from the primary and heterogeneous data sources is retrieved by means of the different plugins. The collected information is structured and organised within configuration files in the service and, finally, made available to the web application without the need for any further computations. This modular architecture is conceived in order to make it easy to add new data sources



and to use cached information if a primary source is unavailable. The resulting data is exposed through a RESTful web service interface.

5.2.2. Integration Options

After a successful onboarding in the EOSC Exchange, EOSC Providers can choose one of five approaches to integrate their services with the EOSC Monitoring service:

- Monitor an Onboarded Service: monitor a single EOSC Service. This option covers the scenario to monitor one EOSC service. The results of this process will become available via the EOSC Exchange Monitoring WebUI;
- 2. Monitor an Infrastructure: monitor a complete infrastructure supporting multiple Services and Resources. This option covers the scenario when an infrastructure (e.g. an e-infrastructure) with multiple services and a custom topology needs to be monitored by the EOSC Monitoring;
- 3. Integrate External Monitoring service: configure the EOSC Monitoring service to accept monitoring data from third-party monitoring engines. This integration option covers the case when a service or an infrastructure provider is already operating its own monitoring system and is willing to publish information about the status of its service(s) in EOSC to, for example, demonstrate their reliability;
- 4. Combine Results of existing ARGO Tenants: allow to combine the topology and the results of multiple tenants in a number of reports. This integration option covers the scenarios where the topology and the results of multiple monitoring instances/tenants need to be combined in a number of reports. It allows the creation of a monitoring report including services coming from multiple infrastructures like, for example, when a research community is using services from more e-infrastructures. Through this option, a research community is able to create a unique monitoring report including all the services it is using regardless of who is operating them;
- 5. Third-party services exploiting EOSC Monitoring data: a customer retrieves results from the EOSC Monitoring Service to use them in an external service/dashboard. This option covers the scenario according to which the Provider needs to use the results of the EOSC Monitoring Service in an external service/dashboard.

These integration options are detailed in the EOSC Monitoring interoperability guidelines (https://zenodo.org/records/8333926).

5.3. EOSC Helpdesk

The EOSC Helpdesk serves as the main gateway and system for reporting issues related to EOSC Services. It handles incident and service requests, facilitating communication between users and IT resource providers. With features like self-service, reporting, and notifications, it helps maintain IT infrastructure integrity and service quality.

5.3.1. High-Level Architecture

Figure 5.4 shows the high-level technical architecture of EOSC Helpdesk currently implemented in the project. The main component is the Helpdesk Back Office that implements the core functionality of the service: ticket management, user role management, management of the support groups, etc. The Helpdesk main portal provides the UI for both users and helpdesk agents²⁰, search functionality based on Elasticsearch engine, reporting and statistics dashboards. It also provides self-service functions like a knowledge base and a search engine for common and resolved known issues and problems.

²⁰ A Helpdesk agent is the person responsible for providing helpdesk support and resolution of the incidents, service requests, queries submitted to the helpdesk, ensuring high level of customer satisfaction.





Figure 5.5: High-level architecture and integrations of the EOSC Helpdesk

5.3.2. Integration Options

The EOSC Helpdesk implements multiple options for the ticket submission. One of them offered for EOSC Services is the submission via webform. This option implies the simple addition of the helpdesk ready-to-use webform script on any webpage or portal. Each webform can be connected with different support groups, which allows it to implement a distributed support structure of the helpdesk with multiple entry points for different providers and their services.

The EOSC Helpdesk interoperability guidelines provide the detailed specification of the main integration scenarios for EOSC Providers for integration of their services, processes and workflows with EOSC Helpdesk.

For new EOSC Providers and communities onboarding services, three levels of interoperability with EOSC Helpdesk will be offered, corresponding to the three integration paths:

- Full integration: this path corresponds to the integration of community helpdesks with the EOSC Helpdesk, which implies full synchronisation between EOSC Helpdesk and community helpdesk. This integration can be achieved by application of a set of the EOSC Helpdesk REST APIs²¹. The exact integration guidelines will be defined based on the specifications agreed with the community.
- 2. Ticket redirection: in this integration the EOSC Helpdesk is used only as an initial contact point to redirect the initial request to the provider's or community mailing list without further integration.
- **3.** Direct usage: in this integration the EOSC Helpdesk can be used by the community as the ticketing system for its onboarded services (as a service).

These three options can be chosen during the onboarding process or upon later request created via EOSC Helpdesk.

5.4. EOSC Accounting

EOSC Accounting is composed of two independent services, Service Accounting and Research Product Accounting. They are able to aggregate (push and pull) usage indicators for different types of EOSC Resources.

²¹ https://github.com/zammad/zammad-documentation/blob/main/api/intro.rst



Both offer a number of integration options and will be integrated with the EOSC Resource Catalogue to expose their data in the next months.

5.4.1. EOSC Accounting for services

The EOSC Accounting Service is a platform designed to efficiently collect, aggregate, and exchange metrics across various infrastructures, providers, and projects. The system provides a REST API, which accepts input from diverse resources, stores it in a database, and aggregates the incoming data. It also offers an intuitive user interface that allows clients to interact with the platform and access accounting data for specific time periods. All API resources are only accessible to authenticated clients, ensuring secure access to sensitive data.

The key functionalities offered by the EOSC Accounting Service are:

- Efficient collection, aggregation, and exchange of metrics.
- REST API that accepts input from diverse resources.
- Database storage and aggregation of incoming data.
- Intuitive user interface for accessing accounting data.
- Secure access to sensitive data through authenticated clients.

5.4.1.1. High-level Architecture

The Accounting Service is responsible for collecting data from a variety of sources, including different resources, projects, providers, and installations. This data is collected and processed in a centralised database, allowing clients to access and analyse accounting data across multiple systems and projects.



Figure 5.6: EOSC Accounting for Services High-Level Architecture.



The Accounting Service architecture has the following structure:

Functional aspects:

- 1. User Interface: The user interface is the primary point of interaction for clients to access the Accounting Service. It provides a graphical interface that allows users to view and interact with accounting data.
- 2. REST API: The REST API is the main entry point for incoming accounting data from diverse resources. It receives input data from external systems and stores it in the database. The API is responsible for aggregating and processing the data, making it available for querying through the user interface.
- 3. Authentication and Authorization: The Accounting Service uses the EOSC AAI Proxy for authentication, which provides a single sign-on mechanism for clients to access the service. Once authenticated, clients are granted access to the system based on their role-based access control (RBAC) permissions. The authorization system is responsible for managing user access and permissions and enforcing security policies.
- 4. Database: The database is the primary storage for accounting data. It receives incoming data from the REST API and stores it in a structured format that enables efficient querying and reporting. The database also supports data aggregation, which allows for the calculation of metrics.

Non-functional aspects:

- Integration and Interoperability: The Accounting Service is designed to integrate with other systems and services within the EOSC ecosystem. It provides APIs for external systems to access accounting data, and it can also consume data from other systems to enrich its own data. The Accounting Service also supports interoperability with different infrastructure providers and projects, enabling seamless data exchange and aggregation.
- 2. High Availability: high availability for the Accounting API involves ensuring that the API is always available to handle requests, even in the face of hardware failures, network outages, and other types of disruptions. Our high-availability architecture contains:
 - a. Load Balancing: Deploying multiple instances of the API and using a load balancer to distribute requests across them, ensuring that no single instance is overloaded.
 - b. Replication: Maintaining copies of the API's data and code across multiple servers, so that if one server fails, another can take over seamlessly.
 - c. Monitoring and Alerting: Continuously monitoring the API and sending alerts if any issues arise.

5.4.1.2. Interoperability Guidelines

EOSC Accounting for service offers 3 integration options:

- Integration Option 1: Integrate with an aggregator of accounting data: This use case is for a Project or E-infrastructure that wants to publish aggregated / summarised Accounting data for its services (on boarded or not).
- 2. Integration Option 2: Integrate with a Single Provider: This use case is for a single provider that wants to publish accounting data for its services (it is expected that the majority of these will be onboarded already.
- 3. Integration Option 3: Make use of Accounting data: This is the use case where one wants to make use of the Accounting data collected (e.g Marketplace or Service Registry Dashboards)

5.4.2. EOSC Accounting for research products

The EOSC Research Products Accounting is operated by OpenAIRE's UsageCounts service. The service collects usage activity from events from EOSC Data sources, i.e. EOSC services that host collections of research products, like articles, books, datasets, etc. and include data repositories, software repositories, and publication repositories. The service forms metrics of usage activity of these Data sources, categorising the data retrieved by number of downloads, number of views, number of repositories and all derivative quantitative open metrics, comprehensively. UsageCounts service provides standards for usage data exchange, it complies to the COUNTER Code of Practice for reliable and comparable reports, it respects user's privacy via IP anonymization of usage events, it offers global coverage and enables accumulation of usage for the same research products by exploiting the metadata deduplication functionality of the EOSC Research Graph.



Repository	PUSH	Ö	
CRIS	Tracked event	Processing script	
eJournal		🐟 matomo	
National	Metadata	I-Index UsageStatistics-DB	
Node	PULL	*	
Publisher	COUNTER Report	Processing script	

Figure 5.7: Research Product accounting: system architecture

5.4.2.1. High-level Service Architecture

The service's architecture is shown in Figure 5.6 comprises two approaches or workflows:

- A PUSH Workflow which allows server-side real-time tracking using platform specific tracking software or using a generic log file parser based on Python that parses web server log files. Usage events are dispatched to the Matomo Analytics platform by exploiting the platform's API. The PUSH workflow supports anonymization of IPs.
- A PULL Workflow that collects COUNTER CoP usage statistics reports. The reports are retrieved using the Sushi-Lite API2.

5.4.2.2. Standard protocols adopted by Research Product Accounting

The list of protocols referred by the guidelines is shown in Table 5-4.

Protocol/API	Short Description	References
Matomo Tracking API	UsageCounts uses Matomo's Tracking API to track research product's metadata views and downloads. It sends HTTP requests (GET or POST) to the service's tracking HTTP API endpoint with the correct query parameters set.	https://developer.matomo.org/a pi reference/tracking-api
COUNTER_SUSHI API	The COUNTER_SUSHIAPI represents a RESTful implementation of SUSHI automation intended to return COUNTER reports and snippets of COUNTER usage in JSON format	https://app.swaggerhub.com/ap is/COUNTER/counter-sushi_5_o _api/1.o.o

Table 5-4: List of protocols



	RESEARCH_DATA_SUSHI API	
	represents a RESTful	
	implementation of SUSHI	https://app.swaggerhub.com/ap
RESEARCH_DATA_SUS HI API	automation intended to returns	is/COUNTER/researchdata-sush
	COUNTER Research Data Release 1	i_1_o_api/1.o.o
	reports and snippets of usage in	
	JSON format	

5.4.2.3. Integration procedure: how EOSC Providers can integrate with the EOSC Research Product Accounting

Integration with the UsageCounts Service, comprises the following steps for EOSC Providers, for the PUSH and PULL workflows, respectively:

PUSH Workflow:

- 1. registration of the Provider via the EOSC provider's portal or via OpenAIRE Provide.
- 2. registration to the UsageCounts Service on OpenAIRE provide
- 3. installation of the tracking code
- 4. tracking of usage events from the provider
- 5. validation of tracking of usage events from the provider
- 6. retrieval of usage statistics reports presented in the EOSC provider's portal or by <u>OpenAIRE Provide</u> or via a SUSHI-Lite API endpoint.

PULL Workflow:

- 1. registration of the Provider via the EOSC provider's portal or via OpenAIRE Provide.
- 2. registration to the UsageCounts Service on OpenAIRE provide
- 3. registration of the SUSHI-Lite API provider's endpoint
- 4. retrieval of usage statistics reports
- 5. retrieval of usage statistics reports presented in the EOSC provider's portal or by OpenAIRE Provide, or via a SUSHI-Lite API endpoint.

For detailed information on the interoperability guidelines, refer to the published document in Zenodo.org: https://zenodo.org/records/8362353.

5.5. EOSC Order Management

Order Management is about the interaction between consumers and providers to access services and their offers, published in the EOSC Marketplace. It consists of:

- User facing part exposing the offerings and allowing the user to ask for the access (submit the order) using the parameters defined by the provider, and providing further information on the order (e.g. scientific purpose).
- User facing part supporting the management of the issued orders or access requests, keeping the user updated on their status and offering a communication channel with the provider(s) in the scope of the order.
- Provider facing UI allowing to create and manage their offers for a given service along with the list of parameters to be filled in by the user when placing an order.
- Provider facing UI gathering orders issued by the users. It allows providers to manage the orders.

All these components are part of the EOSC Marketplace.

In addition, dedicated APIs are available to the providers willing to integrate their order management system with the EOSC Order Management Service:

- Offerings API: expose functions that are necessary to manage offerings from the provider's order management system, including their technical parameters and ordering configuration.
- Ordering API: enables integration with the ordering process. External Order Management Systems (OMSes) can use it to manage orders internally but keep updated the status of the orders in the EOSC Order Management service. This allows users to deal with all their EOSC orders via a consistent and homogeneous order workflow and support.



The following figure presents an overview of the EOSC Order Management APIs in the scope of the interoperability patterns in order management. Users are presented with a consistent EOSC Marketplace user interface, while communities, providers and operations teams can leverage the APIs to achieve a high interoperability level and provide a homogeneous order management service to the users.



Figure 5.8: Order Management architecture

5.5.1. Integration Options

Integrators (providers and communities) can choose from 3 integration patterns:

- In a minimal setup, a provider can use EOSC Marketplace UI to configure their offerings and leverage SOMBO for order management, avoiding any implementation and integration cost whatsoever. SOMBO is a catch-all order management system provided by EOSC.
- A provider can choose to use an in-house order management system that fully integrates with EOSC Marketplace APIs both for offering and order management. Existing community systems can be extended this way, exposing the communities to EOSC users while maintaining the same set of tools for operations.
- In a special case, when the providers use OMS based on a JIRA solution, the technical integration is more straightforward and requires minimum integrational development on the provider side.

These three integration options are described in the following figure.





Figure 5.9: Order Management interoperability patterns

The integration options can support the exchange of the following data:

- EOSC Marketplace Project: a collection of EOSC resources ordered by a user to deal with a specific research project.
- Project items: all resources added by the user to a given Marketplace project. Including open access services, research products (relevant publications, datasets) and orderable services (and underpinned service orders).
- Messages sent in the scope of a Marketplace Project.
- Messages sent in the scope of a single service order.

The EOSC Order Management service includes an appropriate authorisation system that allows only authorised users to access and update offerings and orders. More detailed information is available in the EOSC Order Management interoperability guidelines.



6. Conclusions

The model behind the federated EOSC architecture has to define the capabilities offered by the EOSC federated system and how third-party initiatives can join EOSC participating in the delivery of these capabilities. Interfaces to connect community services to the EOSC Capabilities are described in the EOSC Interoperability Guidelines (IGs) part of the EOSC Interoperability Framework. The minimum set of capabilities that should be supported by a community to join EOSC is defined in the EOSC RoP.

Taking into account these technical considerations on the model, EOSC Future implemented an EOSC Federated system to create a common European portfolio and marketplace of resources (datasets, services, other research products) by federating them. For this aim, a number of EOSC Capabilities have been identified (resource catalogue, accounting, order management, etc). The EOSC Platform, as an integrated operational environment, is the distributed system that operates core and horizontal services enabling the capabilities to federate with. In EOSC Future implementation, the only prerequisite for communities to join EOSC is to share/register one or more of its resources (services, catalogues, research products, etc) in the EOSC Resource Catalogue.

Now that a first implementation of a model behind the federated EOSC architecture is available, it is time to assess it and refine as needed the capabilities offered by EOSC and its RoP according to the requirements of the European research communities. This assessment will be done by follow-up actions and, in particular in the context of the EOSC Procurement, that will deploy and operate the EOSC EU Node, and EOSC Beyond project, that will develop the next generation of EOSC Core services.