D2.9

Co-designed Architecture Description

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Lead by Technopolis Group Belgium (TGB)

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Abstract

This report provides recommendations from the EOSC Future project for the public procurement call for EOSC in Q3 of 2022 by the European Commission. The report offers an EOSC Future perspective on the realisation of EOSC and the procurement. A detailed list of functions that are needed to realise the Minimal Viable EOSC together with added-value functions for the EOSC-Exchange is given as possible options for the procurement. The functions are described in tables across the proposed core architecture components of the MVE: EOSC-Core (Coordination and Platform); EOSC-Exchange (including functions for the MVE, cross-disciplinary functions, and Earth Observation functions); EOSC Interoperability Framework; EOSC Support Activities. Each table specifies the expected capabilities, procurable elements, and key requirements needed to deliver the functions. The report does not provide recommendations on the prioritisation of functions, grouping of components and functions into lots for procurement, interdependencies between functions, or the scale of the procurement in terms of capacities to be procured and financial amounts to be spent on the functions.

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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
AEGIS	AARC Engagement Group for Infrastructures
AI	Artificial Intelligence
API	Application Programming Interface
A/R	Availability/Reliability
BPA	Blueprint Architecture
CESSDA	Consortium of European Social Science Data Archives
CMDB	Configuration Management Database
CMS	Configuration Management System
CMT	Configuration Management Tool
DaaS	Data as a Service
DIH	Digital Innovation Hub
DMP	Data Management Plan
DOI	Digital Object Identifier
EF	Execution Framework
EGI.eu	EGI Foundation
eIDAS	Electronic Identification, Authentication and Trust Services
EMSO	European Multidisciplinary Seafloor and Water Column Observatory
EO	Earth Observation
EODC	Earth Observation Data Centre
EOSC	European Open Science Cloud
ERA	European Research Area
ESRF	European Synchrotron Radiation Facility
HPC	High-Performance Computing
HTC	High-Throughput Computing
IdP	Identity Provider
IF	Interoperability Framework
I/O	Input/Output
ISM	Information Security Management
ISO	International Organisation for Standardisation
IT	Information Technology
JNP	JNP Strategy Management Consulting
MEEO	Meteorological Environmental Earth Observation
ML	Machine Learning

MVE	Minimal Viable EOSC
N/A	Not Applicable
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
TBD	To Be Determined
TF	Task Force
TGB	Technopolis Group Belgium
UI	User Interface
UNIMAN	University of Manchester
VA	Virtual Access
VM	Virtual Machine
VRE	Virtual Research Environment
WeNMR	Worldwide e-Infrastructure for Nuclear Magnetic Resonance
WG	Working Group

Executive Summary

This report offers recommendations from the EOSC Future project for the public procurement call for EOSC in Q3 of 2022 by the European Commission. The report offers an EOSC Future perspective, in collaboration with the INFRAEOSC-07 projects (i.e. C-SCALE, DICE, EGI-ACE, OpenAIRE Nexus, and RELIANCE) on the future architecture and implementation of EOSC with a focus on possible functions that could be procured to deliver an impactful EOSC Platform with added-value services for researchers from all disciplines. These six projects are crucial for the procurement as the procurement actions will build upon the outputs of the projects.

To guarantee the continuous delivery of an operational and impactful EOSC, the procurement should support the providers of EOSC-Core services to continue their operations and enhance the backbone of EOSC. It is also critical to continue to guarantee free-at-the-point-of-use access to relevant EOSC-Exchange resources that are currently being delivered by the INFRAEOSC-07 projects. Automated resource allocation mechanisms, based on requests without human intervention, and technical support are hereby crucial. The procurement should ensure that key outcomes delivered by these projects are adequately funded and that the procurement does not reinvent and redevelop functions that have already been realised by the projects. Otherwise, it is unlikely that EOSC will be able to full self-sustain itself after the current implementation projects. Restricting the procurement to support functions of the EOSC-Core may also hinder access to EOSC to a sizeable group of researchers who are not part of Research Infrastructure communities (including long-tail-of-science communities and individual researchers). This would prevent EOSC achieving one of its main objectives: offering an open research environment that is accessible and provides value to all researchers in Europe.

The recommendations in this report consist mainly of a detailed list of functions that are needed to realise the Minimal Viable EOSC (proposed by EOSC Future) together with added-value functions of the EOSC-Exchange (proposed by the INFRAEOSC-07-2020 projects). These functions are described in a series of tables describing key architecture component areas of the Minimal Viable EOSC as proposed by the EOSC Executive Board Working Group on Architecture and further expanded by EOSC Future. The component areas consist of the EOSC-Core and EOSC-Exchange together with the EOSC Interoperability Framework and EOSC Support Activities that are needed to deliver the EOSC-Core and EOSC-Exchange. The EOSC-Core is further subdivided into the EOSC-Core Coordination and EOSC-Core Platform and the functions of the EOSC-Exchange are further grouped into functions for the Minimal Viable EOSC as well as added-value functions for cross-disciplinary and Earth Observation research. The tables furthermore specify the expected capabilities, procurable elements (specified as technical resources, coordination activities, and support activities), and key requirements to deliver the functions. The recommendations are broken down into the following categories:

- EOSC-Core
  - Minimal Viable EOSC functions of the EOSC-Core Coordination
  - Minimal Viable EOSC functions of the EOSC-Core Platform
- EOSC-Exchange
  - Minimal Viable EOSC functions of the EOSC-Exchange
  - Added-value cross-disciplinary functions of the EOSC-Exchange
  - Added-value Earth Observation functions of the EOSC-Exchange
- EOSC Interoperability Framework
  - Minimal Viable EOSC functions of the EOSC Interoperability Framework
- EOSC Support Activities
  - Minimal Viable EOSC functions of the EOSC Support Activities

The report does not provide recommendations on the prioritisation of functions, grouping of components and functions into lots for procurement, interdependencies between functions, or the scale of the procurement in terms of capacities to be procured and financial amounts to be spent on the functions. The report is ultimately entailed to give guidance to the European Commission in the selection of functions that are critical for delivering the expected features of the EOSC-Core and EOSC-Exchange in the public procurement call.

1 Introduction

The Work Programme 2021-2022 for EOSC in Research Infrastructures under Horizon Europe consists of a public procurement of €35 million to deliver a fully operational secure cloud-based EOSC infrastructure, including a federated core and marketplace in Q3 of 2022 [1]. The procurement should build and deploy a fully operational enabling infrastructure for EOSC that provides access to a rich portfolio of FAIR data and professional quality FAIR composable services in all relevant domains from data handling to computing, processing, analysis, and storage. The resulting infrastructure should be robust, secure, scalable, flexible, and user-centric and be constantly improved and upgraded following user feedback and the state-of-the-art of the underlying core technologies. The infrastructure should also offer high-quality service management that is compliant with industry standards and provides superior user experience, usability, and ease-of-use for a high number of users with functionalities readily available. The infrastructure should further offer seamless access to data, software, and services through customised user interfaces and allow users to navigate with built-in guidance tools and analytics for (re)use and service composability.

The procurement should build on the outcomes of the EOSC Future [2] and INFRAEOSC-07-2020 (i.e. C-SCALE, DICE, EGI-ACE, OpenAIRE-Nexus, and RELIANCE) projects [3] [4] [5] [6] [7] and on key concepts of federation, standards, and processes for Open Science including the EOSC Interoperability Framework (IF) and FAIR-by-design data and services. The procurement should (1) deploy and operationalise the EOSC infrastructure for access to and exploitation of FAIR data and services (2) provide innovative, modular, customisable, and composable services to all types of users. Below are specifications of the procurement call.

The procurement should broadly deliver the following results:

- Fully operational, secure, and cloud-based EOSC infrastructure including a federated EOSC-Core platform and EOSC-Exchange offering high-quality professional services and superior user experience, usability, and ease-of-use for a high number of users with functionalities available 24/7;
- Population of EOSC with a rich set of innovative, modular, customisable, and composable services for a wide variety of users from research communities and beyond;
- Large number of data and service communities aligned in terms of standards and consolidated at (sub)domain and interdisciplinary levels;
- Established links with common European Data Spaces in crucial sectors (such as the Green Deal or Health) and synergies with the work on the European cloud federation as described in the joint declaration on building the next generation of cloud in Europe;
- Increased discovery and reuse of European research output as a result of FAIR data and services provided via EOSC as well as cross-fertilisation and a wider sharing of knowledge and technologies

The procurement of the EOSC Platform[1] should support the deployment and operationalisation of the EOSC infrastructure for access to and exploitation of FAIR data and services, specifically including the following features and functions:

- Authorisation, Authentication, and Identification (AAI) standards and services that ensure security and privacy;
- Persistent Identifier (PID) services (which are compatible with the EOSC PID policy) and mechanisms for resolution of different PID types;
- Advanced discoverability, service catalogue management, and orchestration services for all types of resources, metadata services, and ontologies for discovery of and access to data and services across the federated EOSC ecosystem;
- Efficient workflow management and mechanisms that allow data interlinking and application of data sharing policies;

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[1] We use the term 'EOSC Platform' to refer to the overall set of functionalities delivered by the EOSC-Core: user interface (including the EOSC Portal), tools/workflows/APIs to access EOSC resources, EOSC resource catalogues, interfaces for integration with EOSC-Core services (e.g. AAI, helpdesk, and ordering), and EOSC Execution Framework.

- Standardised Application Programming Interfaces (APIs) for machine-actionable and interoperable data and for interfacing with a large number of data and service communities at (sub)domain and interdisciplinary levels;
- User-friendly, responsive, and easy-to-use visualisation services, data analytics, and downloading tools designed for improved user experience;
- Thorough testing and reporting procedures;
- Auditing and reporting processes and services;
- Service quality management, monitoring, and accounting and performance management;
- Helpdesk for data and service providers and users including advice on data ownership, licensing, and privacy issues;
- Services to ensure scalability and availability that allow simultaneous use by hundreds of individual concurrent user sessions per day with a standard response time;
- Services, processes, and policies for availability and capacity management to ensure business continuity and disaster recovery;
- Application of firm cybersecurity policies and measures for the hardening and regular assessment of systems regarding potential threats, infrastructure vulnerabilities, and overall attack surface as well as well-defined procedures for incident reporting and notification;
- Support for an open metrics framework to assess EOSC uptake including usage, performance, value for money, and user satisfaction through the platform;
- Feedback mechanism to allow users to comment on EOSC-Core and EOSC-Exchange functionalities.

The procurement should also support the provision of innovative, modular, customisable and composable services to serve a wide variety of users, specifically including the following functions:

- The EOSC platform should provide secure and cloud-based access to the required resources (such as computing power, data, storage, programming tools and libraries, and operating systems) for the various user groups;
- Assistance to data and service providers to comply with the EOSC Rules of Participation, align with interoperability and FAIR standards, and prepare high-quality datasets and services for reuse through EOSC;
- Validation and certification schemes for FAIR data;
- Onboarding and management services for EOSC-Exchange;
- Mechanism to link EOSC with the EuroHPC Joint Undertaking for high-performance computing (HPC) services;
- Mechanism to link EOSC with the European cloud federation;
- Procurement mechanism for e-Infrastructure services (such as computing, storage, and processing);
- Tools and services to allow researchers to find, access, reuse, and combine data with non-research data and resources (such as from the European Common Data Spaces).

The EOSC Future project is a response to the INFRAEOSC-03-2020 call to provide integration and consolidation of the existing pan-European access mechanism to public Research Infrastructures and commercial services through the EOSC Portal [8]. The call aims to consolidate and scale up the EOSC Portal [9] and its underlying service platform in order to (1) strengthen the EOSC Portal so that it continues to provide an increasing portfolio of high-quality standard compliant and interoperable services of proven user interest and scientific relevance from a wide range of national, regional, and institutional public Research Infrastructures in Europe as well as from commercial service providers in its catalogue (2) reinforce the role of the marketplace as the access channel to integrated, composable, and reliable services (3) attract more users, in the research community and beyond, by enhancing the user experience and seamlessly accommodating their needs (4) ensure long-term sustainability taking into account relevant governance and business models.

This report provides recommendations from the EOSC Future consortium towards possible functions to be included in the procurement call for EOSC which will build on the outcomes of the EOSC Future and other key EOSC projects. The report presents functions that need to be supported to maintain and continue to evolve a rich EOSC set-up to deliver an EOSC that can have a greater impact to the European research. The report builds on a previous report from EOSC Future on proposed core capabilities and inclusion criteria for a Minimal Viable

EOSC (MVE) [10]. Section 2 proposes considerations for the procurement and the view of EOSC Future on the MVE as well as the approach taken in the following sections of the report. Sections 3 to 6 consist of tables with the expected capabilities, procurable elements, and key requirements needed to deliver the key component area functions of the MVE (from the perspective of EOSC Future) and added-value functions to be included in the EOSC-Exchange (from the perspective of key EOSC projects). Section 3 focuses on the EOSC-Core (which includes the EOSC-Core Coordination and EOSC-Core Platform). Section 4 focuses on the EOSC-Exchange (which includes functions of the MVE and functions for added-value services). Section 5 focuses on the EOSC Interoperability Framework (which is crucial for the delivery of the EOSC-Core and EOSC-Exchange). Section 6 focuses on the EOSC Supporting Activities (which are similarly crucial for delivering the EOSC-Core and EOSC-Exchange). The report closes with conclusions on the procurement and appendices detailing the current status of the functions as well as the high-level technical roadmap for EOSC Future.

2 EOSC Future Perspective

2.1. EOSC Architecture

In the past years, several projects and initiatives have been funded by the EC to establish EOSC including initial development in EOSCpilot [11], implementation in EOSC-hub [12] and EOSC Enhance [13], and work on regional and thematic EOSC cluster projects. The main EOSC stakeholders are now converging towards a common vision of EOSC that has been developed by the EOSC Executive Board Working Groups (WGs) on Architecture [14] and Sustainability [15] and is leveraging the outcomes of key past EOSC projects.

Based on the architecture developed by WG Architecture [16], EOSC Future has developed an expanded architecture as shown in Figure 3.1. The EOSC Future high-level architecture diagram has been developed to also show the relationship with the thematic and regional platforms developed by the ESFRI clusters [17] and regional coordinating initiatives [18], horizontal services provisioned through Virtual Access (VA) via the INFRAEOSC-07-2020 call projects (henceforth '07 projects')[19], and the EOSC support activities.
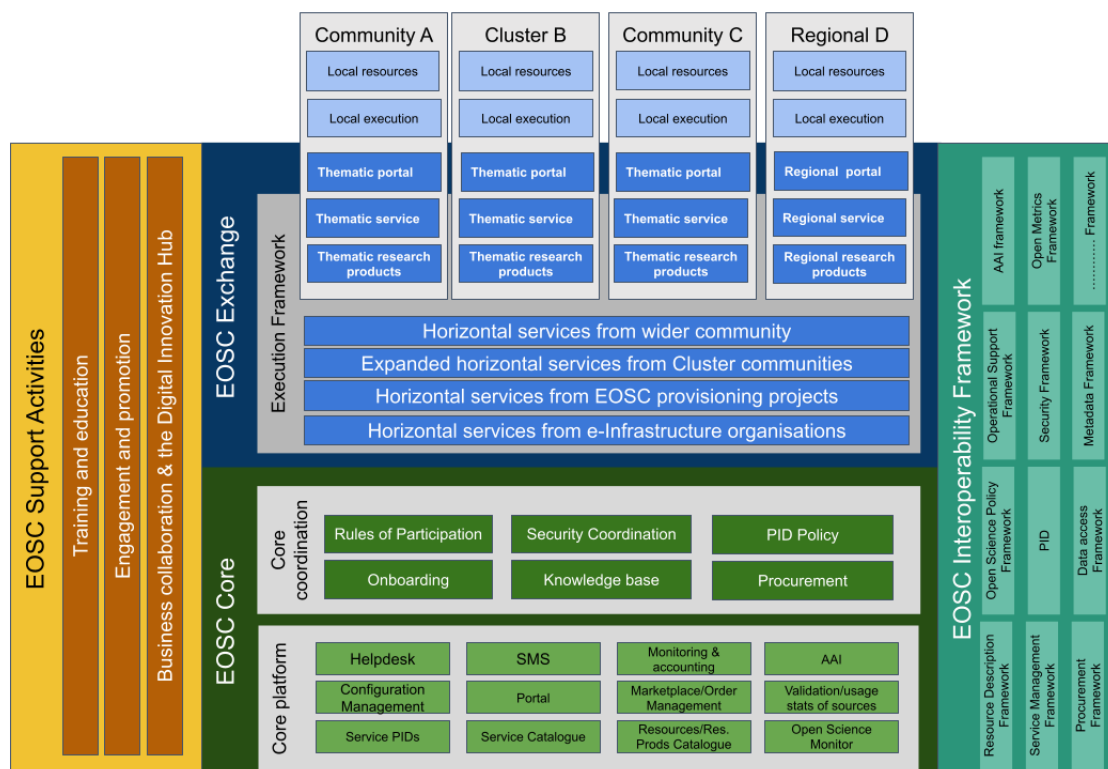

Figure 3.1: EOSC Future Architecture of EOSC (Courtesy of EOSC Future)

This expanded high-level architecture of EOSC, by EOSC Future, comprises the following elements:

- **EOSC-Core** is the set of internal services which allow EOSC to operate. It includes a core technical platform (i.e. EOSC-Core Platform) which facilitates EOSC operations in which the researcher-facing resources in the EOSC-Exchange can be integrated as appropriate. It also includes non-technical coordination functions (i.e. EOSC-Core Coordination) which operate and facilitate the technical platform, such as the onboarding and security coordination;
- **EOSC-Exchange** is the set of federation services and other resources registered into EOSC by e-Infrastructures, Research Infrastructures, and Science Clusters to serve the needs of research communities and will widen its offering to the public and private sector. Generic services and resources which target heterogeneous scientific domains and research communities are identified as 'horizontal services'. Resources which target users from a specific science, community, and/or regional domain are identified as 'thematic and/or regional resources'. The capability to compose, meaning the ability to combine research products and services, across horizontal and thematic and/or regional resources in

compliance with the EOSC IF is defined as the EOSC Execution Framework (EF). While it is expected that the majority of the horizontal services (e.g. compute, storage, data, network, and scholarly communication services) are provided by the e-Infrastructures (e.g. EGI, EUDAT, OpenAIRE, and GEANT), generic services and resources from the Science Cluster communities will also be offered as horizontal services;

- **EOSC Interoperability Framework** provides a flexible framework of standards and guidelines to support the interoperability and composability of resources in the EOSC-Core and EOSC-Exchange. The EOSC IF will allow EOSC providers to specify with which interoperability frameworks (e.g. standards, APIs, data models, exchange formats, protocols) the resources they are sharing comply. It will therefore act as the glue to connect services and research products (e.g. publications, datasets, and software) across providers in terms of their interoperability capability. The EOSC IF is defined as a Reference Architecture Framework which offers the freedom to providers to develop and operate provider-specific implementations while conforming to the EOSC IF guidelines and standards;

- **EOSC Support Activities** sit alongside the EOSC-Core and EOSC-Exchange, and comprise the training, engagement, and other human-centric activities which make EOSC more attractive and easier to use, and help users benefit from it more easily once engaged.

The Science Clusters and Science Cluster communities will be embedded in EOSC through the work of EOSC Future but will continue to implement FAIR data services for Open Science to serve the needs of their specific communities and researchers. This includes the Science Clusters (from the INFRAEOSC-04-2018 call) and Regional Initiatives (from the INFRAEOSC-05-2018-2019 call) as well as national communities, other research communities, and less organised groups from the long tail of science. These communities will bring a rich set of resources to EOSC but will also have resources and other elements outside of EOSC which are targeted at their own specific communities, including richer ontologies and domain-specific information and support.

2.2. Minimal Viable EOSC

The WG Architecture defined the MVE as a dynamic set of EOSC resources that includes:

- The subset of EOSC resources necessary for forming the added value and deliver services considered essential to be provided by EOSC at a given moment in time, allowing essential services and research products (e.g. publications, data, and software) to be discovered, composed, accessed, and analysed via EOSC, which could not be otherwise;
- The subset of EOSC-Core components that are required to operate and deliver such resources.

The relationship of the EOSC-Core, EOSC-Exchange, and EOSC Federation with the MVE, as a subset of EOSC resources, is shown in the high-level architecture diagram of EOSC in Figure 3.2. The research and innovation (R&I) community of researchers are key users and providers of the research products and services that are made available through EOSC. Publications, data, software, and services are used in the figure as exemplar resources (as there are other types of resources) that bridge across the different layers.
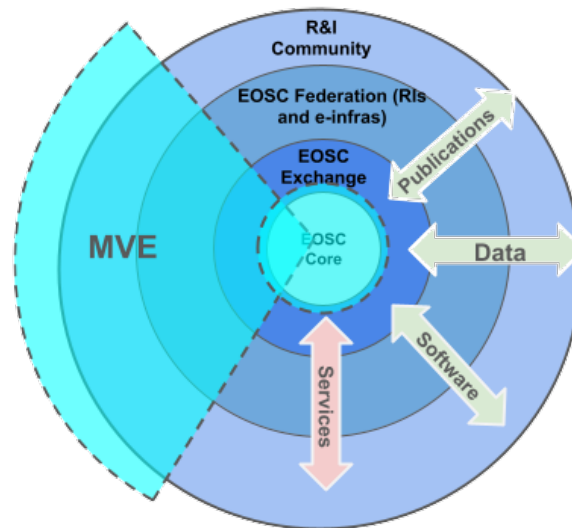
The first iteration of the MVE focuses, as defined by the WG Sustainability [20], on an initial implementation of EOSC that brings value to users beyond their current use of the infrastructures. The capabilities that are currently included in the MVE from the perspective of EOSC Future are described in the EOSC Future deliverable *D2.5a - Inventory of Core Functions and Inclusion Criteria* and are an initial extension of the MVE as defined by the WG Architecture. However, the MVE is expected to continue to evolve and grow together with EOSC. It is further foreseen that the EOSC-Core will change in the future depending on the needs of users and some components will move in and out of the EOSC-Core accordingly. Furthermore, once EOSC becomes more mature and progressively extends its scope to support the requirements of more challenging scientific cases, a more extensive definition of the MVE (e.g. with a richer EOSC-Exchange) will be very likely needed.

2.3. Implementation of EOSC

EOSC Future, in collaboration with the 07 projects, will implement the architecture for EOSC described above and deliver an operational and rich EOSC that is able to satisfy the requirements of a wide set of researcher communities regardless of their scale. While EOSC Future will implement the backbone of EOSC, delivering a fully operational and coherent EOSC-Core and coordinating the onboarding of services and resources into the EOSC-Exchange, the 07 projects will enrich the EOSC-Exchange with key services, Information Technology (IT) resources [2], and data to deliver an EOSC offering added value to European researchers for their research.

EOSC Future is expected to deliver and operate a fully operational EOSC-Core supported by a service management system that guarantees a secure and high-quality professional service delivery. EOSC Future will also realise and expand the EOSC-Exchange with services and resources across disciplines that are integrated with the EOSC-Core. For this aim, the project is working to provide well-documented specifications of EOSC-Core interfaces and the necessary technical support to providers joining EOSC. The EOSC-Exchange being shaped by EOSC Future includes resources and services from the 07 projects, e-Infrastructures, Research Infrastructures, and Science Clusters. A rich set of horizontal resources to support scientific workflows is already available and will be extended over the time (including data discovery, management, processing, analysis, transfer, preservation, and container/Virtual Machine (VM) deployment and orchestration).

Furthermore, the project is working on scaling up EOSC capabilities, integrating computing and storage resources (e.g. from the 07 projects), enabling resource composability, setting up the EOSC IF, and supporting its adoption. The project is also designing a user-friendly execution environment where researchers can select and combine resources and execute analyses with adequate capacity. This execution environment should in the long term provide seamless access for researchers to relevant free-at-the-point-of-use resources for their

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[2] We use the term 'IT resources' to refer to the (cloud, HTC, HPC) compute and storage resources and the underlying physical hardware that is needed to run scientific analyses and store datasets.

research (including data transfer, compute, and storage as well as professional training and IT support). Access to these resources should be seamless in that researchers should be able to select a resource and then exploit the resource in real time, with predefined agreements between services providers and the procedural steps to grant access to the resource hidden in the background for the researchers. EOSC Future will also increase European scientific impact by integrating and providing resources for cross-domain science through EOSC to address societal challenges and achieve a leading position in multidisciplinary scientific excellence in Europe.

Although the project is still in its first year, initial key results are expected to be delivered by September 2022 (Month 18), as described in the technical roadmap in Appendix E, when a first version of a production level and harmonised EOSC-Core will be available and professionally operated. This will include a wide set of services and resources from e-Infrastructures, Research Infrastructures, and Science Clusters being available in the EOSC-Exchange and integrated with the EOSC-Core as well as the user experience being enriched with new tools for resource sharing and discovery (e.g. integration of catalogues with the EOSC Resource Catalogue), resource allocation (e.g. easy identification of EC-funded/free-at-the-point-of-use resources), and resource composability (e.g. orchestration of data analysis on resources delivered by multiple providers). These results will be further extended and consolidated by the end of the project in September 2023 (Month 30).

The 07 projects build on the competences of pan-European e-Infrastructures of diverse domains to ensure multidisciplinary research and synergies with national and regional programmes to progressively federate resources into EOSC. In particular, they fulfil an important role in the delivery of free-at-the-point-of-use IT capacity (including compute and storage resources) to empower EOSC in order to tangibly offer an environment accessible to all European researchers and support scientific challenges of any scale. They also offer a rich set of production-level and free-at-the-point-of-use horizontal services and technical platforms that deal with common technical problems. These services offer ready-to-use capabilities that can be used by researchers and that facilitate and boost the development of scientific tools in Europe.

All 07 project services will be onboarded into EOSC and made available to European researchers through the EOSC Platform before the end of the respective projects. The 07 projects use Virtual Access (VA) instruments to allocate IT resources with custom semi-automated resource allocation processes that are integrated with the EOSC order management. The current resource allocation requires some human intervention, and the aim is to automate this process for limited amounts of resources [3]. EOSC Future and the 07 projects will work together to facilitate access to a selection of resources through a fully automated request validation process. The 07 projects are also working with EOSC Future to support relevant use cases from research communities to deliver compute and storage resources and horizontal services via EOSC according to their requirements.

The 07 projects and key activities are summarised below:

- C-SCALE is making the discovery, access, and processing of EO/Copernicus data possible through EOSC;
- DICE provides cutting-edge data management services and a significant amount of storage resources for EOSC. The data services offered via DICE through EOSC are designed to be multidisciplinary and fulfil the needs of different research communities;
- EGI-ACE is delivering the EOSC Compute Platform and contributing to the EOSC Data Commons through a federation of cloud compute and storage facilities, Platform as a Service (PaaS), and data spaces with analytics tools and federated access services;
- OpenAIRE-Nexus is delivering a framework of services for EOSC that can greatly assist in publishing research, monitoring its impact, and helping to promote its discovery;
- RELIANCE will extend EOSC capabilities with enhanced support for various research activities, boost the discovery of and access to research data (including Copernicus data), improve the extraction of relevant information, and manage the research lifecycle via research objects while promoting Open Science and FAIR principles.

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[3] Automation will not be possible for large requests since resources are limited and there need to be safeguards in place to prevent abuse of access to services.

2.4. Need for Continued Technical Support to Users

When EOSC Future and the 07 projects accomplish their mission, EOSC will become a reality in the European Research Area (ERA) and its impact on boosting research in Europe will start to emerge. However, this positive trend may be interrupted if key elements of the EOSC environment created by these projects are not adequately funded. Indeed, it is unlikely that EOSC will be able to fully self-sustain itself at the end of these projects. To neither lose past investments nor start from scratch, the current set-up needs to be sustained with public funding covering the gap until a clear sustainability model has been developed by the EOSC Association [21]. The Task Force (TF) on EOSC Financial Sustainability [22] that has recently been launched by the EOSC Association has started to produce a proposal for long-term financial sustainability of the main building blocks of EOSC (i.e. EOSC-Core, EOSC-Exchange, and EOSC Federation) and is expected to deliver scenarios and recommendations to maintain these building blocks of EOSC by the end of 2023.

To preserve the main achievements of past EOSC initiatives and continue to deliver an operational and impactful EOSC, providers of EOSC-Core services will need to be funded to continue their operations and enhance the EOSC-Core. It is also critical to continue to guarantee free-at-the-point-of-use access to relevant EOSC-Exchange services and IT resources that are currently being delivered by the 07 projects. Restricting the procurement to only support functions of the EOSC-Core may hinder access to EOSC to a sizeable group of researchers who are not part of large Research Infrastructure communities (including long-tail-of-science communities and individual researchers). This would prevent EOSC achieving one of its main objectives: offering an open environment accessible to all European researchers. While large Research Infrastructures and user communities often rely on their own services and IT resources, smaller research groups need access to free-at-the-point-of-use services and IT resources and require technical support to do research with EOSC.

The functions of the MVE and added-value functions of the EOSC-Exchange that could be supported through the procurement are presented in the coming sections. While the focus is on the technical platforms and IT tools needed to deliver the functions, coordination and support activities are also included. These are human activities that should be funded together with the technical platforms and IT tools to guarantee the delivery of the functions. For example, if the technical platform to deliver the EOSC Helpdesk is funded but there is no support team that deals with the tickets and provides users with fast and meaningful answers, the helpdesk function could not actually be delivered. These human activities should thus be considered key elements to be procured and funded at the same level of the technical platforms. For each of the functions listed in the coming sections, these key human activities have been properly identified and presented.

2.5. Funding Instruments

The functions that make up the current EOSC environment have different characteristics and levels of maturity. The funding instruments to support these functions need to be tailored to the different functions. Public procurement is an instrument that fits very well with relatively stable technical platforms that have reached a mature stage of delivery. However, to guarantee continuous innovation in EOSC, the procurement actions should be supported by project calls that identify initiatives working on service innovation and, for example, develop pilots to reach a pre-production maturity level. Project calls are also an ideal instrument to fund human coordination and support activities on the basis of existing collaborations across e-Infrastructures and Research Infrastructures and to provide secretarial support for a wide variety of activities by community organisations (e.g. RDA support). Activities related to governance and community consensus building on rules, standards, and policies (e.g. managing inclusion criteria, definition of EOSC Profiles, and EOSC IF) should be supported by organisations representing the main EOSC stakeholders (e.g. EOSC Association).

When planning the next set of initiatives that are needed to support EOSC, the four main component areas proposed in this report should be taken into consideration. This includes functions belonging to the EOSC-Core and EOSC-Exchange but also functions belonging to the EOSC Interoperability Framework and EOSC Support Activities that are crucial for delivering and operating the EOSC-Core and EOSC-Exchange. All of the required functions should further be mapped against the three main funding support channels listed above (i.e. procurement actions, project calls, and community coordination activities) and appropriate initiatives should be planned together taking into account their interdependencies. This report identifies the parallel initiatives that need to be supported to guarantee the proper delivery of each of the listed functions.

2.6. Structure of this Report

The coming sections of this report present the functions that need to be supported with adequate funding to maintain and continue to evolve the existing EOSC environment that is being extended through EOSC Future and the 07 projects. It is important to note that this EOSC environment is more than the basic MVE defined by the WG Architecture and that has been extended in deliverable D2.5a of EOSC Future. This proposed EOSC environment follows the structure of the current EOSC implementation projects and is more suitable to deliver an EOSC that will have a greater impact on European research. The procurement actions that will be launched to deliver the identified EOSC functions are expected to rely on the outputs of the current EOSC projects. This means that the procurement actions should support the operation, maintenance, and evolution of such components and not require the development from scratch of already existing components.

On the basis of the high-level architecture diagram in Figure 3.1, this document is organised around four main sections mapping the EOSC Future proposed functions to the main EOSC architecture component areas: EOSC-Core; EOSC-Exchange; EOSC Interoperability Framework; EOSC Support Activities. The EOSC-Core is subdivided into two subcomponents differentiating the EOSC-Core Coordination and EOSC-Core Platform. This report further recognises two types of functions: those functions proposed by EOSC Future as belonging to the MVE and those functions proposed by the 07 projects in the EOSC-Exchange which do not belong to the current MVE but bring added value to EOSC. The functions in the EOSC-Exchange are subdivided into three groups of functions differentiating functions belonging to the MVE, generic functions related to IT resources for all disciplines being delivered by the A1-A3 07 projects (i.e. DICE, EGI-ACE, and OpenAIRE Nexus), and functions related to IT resources for the Earth Observation (EO) sector being delivered by the A6 07 projects (i.e. C-SCALE and RELIANCE). The four coming sections present the functions of the related architecture component areas and their relevant subcomponents and groupings in a series of detailed tables:

- Table 3-1 focuses on MVE functions of the EOSC-Core Coordination;
- Table 3-2 focuses on MVE functions of the EOSC-Core Platform;
- Table 4-1 focuses on MVE functions of the EOSC-Exchange;
- Table 4-2 focuses on added-value cross-disciplinary functions of the EOSC-Exchange;
- Table 4-3 focuses on added-value Earth Observation functions of the EOSC-Exchange;
- Table 5-1 focuses on MVE functions of the EOSC Interoperability Framework;
- Table 6-1 focuses on MVE functions of the EOSC Support Activities.

Each table provides the following information on the functions whereby some details may not be applicable for a given function (and are thus marked N/A in the relevant table cells):

- **Function Name**: name revised by EOSC Future and the 07 projects according to the latest updates from the discussions around the EOSC architecture components. The revised function names will be used consistently within EOSC and across EOSC Future and 07 project deliverables;
- **Expected Capabilities**: a short description of the capability;
- **Procurable Elements Needed to Deliver the Function**: technical components and human activities that need to be procured to deliver the function. They are further split into:
  - **Technical Platform**: technical services or IT tools required;
  - **Coordination Activities**: human activities that guarantee an adequate management of the main processes supporting the function (e.g. the onboarding process to manage the registration and validation of service onboarding requests);
  - **Support Activities**: human activities to support researchers and other relevant stakeholders to use the functions (e.g. support for enrolment in the AAI federation of research communities, commercial companies and from the public sector, production of documentation, and delivery of training activities).
- **Key Requirements**: requirements that the function should satisfy to properly work within the foreseen EOSC system of systems beyond the basic functionality requirements.

The current implementation and activities related to the proposed functions are further detailed in Appendices A-G with the following additional information per function in similar tables:

- **Current Status in EOSC Future/07 Projects**: indicates the development stage:

- *Not yet developed:* development has not yet started on the capability;
- *In development:* development on the capability has started but no production service is available;
- *Initial version delivered:* development has started and an initial version of the production service is available.

- **Current Reference Implementation in EOSC Future/07 Projects**: reference to the existing services that are currently supporting the delivering of the function;
- **Expected Responsibilities from Other Stakeholders**: activities that are needed to implement the function and are expected to be delivered by other actors and thus are not to be procured. These may include EOSC Association coordination activities and work planned under future EOSC project calls;
- **Planned Activities under EOSC Future/07 Projects**: the projects where the activities are currently being developed and implemented.

It is important to stress that each entry in the function tables in the coming sections refers to a function that could be supported through the procurement call for EOSC. The report does not provide recommendations on the prioritisation of functions, grouping of components and functions into lots for procurement, interdependencies between functions, or the scale of the procurement in terms of capacities to be procured and financial amounts to be spent on the functions. It is lastly important to note that the tables detail functions and not specific technologies (i.e. platforms, tools, and software) that could be procured whereby interested organisations are expected to bid to deliver the selected functions in the public procurement call.

3 Functions of EOSC-Core

The EOSC-Core is the set of internal services which allow EOSC to operate. It includes an EOSC-Core technical platform which facilitates EOSC operations upon which researcher-facing resources in the EOSC-Exchange can rely and integrate with as appropriate. It also includes non-technical coordination functions which operate and facilitate the technical platform, such as the service management system and the security coordination.

3.1. EOSC-Core Coordination Functions

The coordination functions of the EOSC-Core ensure a harmonised delivery of the EOSC-Core (e.g. procedures and policies to support the management of core services) and support the interaction with EOSC-Exchange providers (e.g. coordination of security incident response activities) as shown in Table 3-1. Coordination functions that are strictly linked to a specific technical function of the EOSC-Core are not included in Table 3-1 but are included in Table 3-2 the *Procurable Elements Needed to Deliver the Function* column of the related technical function in for the EOSC-Core Platform in the next section (e.g. resource onboarding coordination activities are listed in Table 3-2 as an element of the EOSC Resource Catalogue).

Table 3-1: Proposed Functions of EOSC-Core Coordination [4]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	**Coordination Activities**	**Support Activities**	
EOSC Security Coordination	• Provides security coordination across EOSC while focusing on EOSC-Core • Ensures proper coordination and investigation of security incidents in EOSC-Core platforms and coordinate security incident response activities between EOSC-Core and EOSC-Exchange providers • Provides guidelines for security risk assessment for providers in EOSC-Exchange and manage the security baseline for the EOSC AAI proxy and the EOSC AAI Federation • Provides policy guidelines for security, usage, and data supporting secure usage of EOSC resources and exchange of data	Predominantly a human service based on security response/policy expertise as well as security software developed by the community (e.g. Pakiti, Secmon)	• Regular incident response coordination based on rotas to ensure rapid response by experts • Liaison with global security response teams • Collaboration with research and education efforts on threat intelligence and security operation centres	• EOSC security training for service providers • Improved awareness of ISM standards such as ISO27K via documentation and training	Capability to identify and adequately respond to security threats in order to minimise disruption to service delivery and protect identified assets
EOSC Service Management System	Service Management System that allows services and operational roles in delivering the minimum level of EOSC-Core services and supporting interaction with external services. Includes a set of roles, responsibilities, procedures, policies, and other documentation and tooling to support management of services	• Implementation which meets the needs of a collaborative content management system and ticket/workflow-based system required by the EOSC SMS • EOSC SMS processes defined according to FitSM	EOSC-Core service development, deployment, and delivery is coordinated by the SMS to maintain uniform quality and a harmonised approach	• Documented processes, procedures, and policies • Training of SMS usage and aspects supporting service development, deployment, and delivery • Training of FitSM to aid maintenance and usage of SMS	• Adherence to EOSC SMS processes, procedures, and policies • Integration with relevant aspects of local SMSes of service providers
PID Policy Compliance Assessment Framework	A flexible compliance assessment framework to verify and measure PID service providers and PID minting organisations and services with the EOSC PID Policy	• Flexible service to measure and assess compliance according to defined rules • Compliance rules to validate PID services, service providers, and owners within the EOSC landscape • Tools for reporting compliance	Coordinate and monitor regular compliance validation and reporting	• EOSC training (material) for PID service providers and PID owners • Support PID service providers and PID owners in adopting the PID Policy • Helpdesk for users and providers	• EOSC PID Policy https://dx.doi.org/10.2777/926037 • EOSC PID Policy compliance rules and validation criteria • Compliance assessment framework specification to implement validation rules

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[4] Additional information on the EOSC-Core Coordination functions including their current status in the EOSC Future and 07 projects, current reference implementation in the EOSC Future and 07 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and 07 Projects are in Appendix A.

3.2. EOSC-Core Platform Functions

The EOSC-Core Platform includes a wide set of capabilities that will deliver:

- Core functions of EOSC, including the comprehensive resource catalogues, marketplace, and AAI registry supporting the AAI federation;
- A set of common elements such as AAI, support, monitoring, and accounting that can be adopted by EOSC-Exchange providers to guarantee a uniform user experience to researchers using resources through EOSC.

Functions of the EOSC-Core Platform are described in Table 3-2 together with the IT tools, coordination activities, and support activities as well as the key requirements that are needed for their proper delivery.

Table 3-2: Proposed Functions of EOSC-Core Platform[5]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	Coordination Activities	Support Activities	
Connecting EOSC-Core Components to the EOSC AAI Federation	Provides shared log-in capabilities to EOSC-Core services. Provides a connector for the EOSC-Core Platform services to the EOSC AAI Federation	• Infrastructure proxy • AARC BPA-compatible implementation	Connect all the individual EOSC-Core services with the service owners	Support service owners in onboarding their services	AARC BPA-compatible implementation
EOSC AAI Federation	Provides a distributed federated AAI infrastructure which allows for sharing of log-in and access to services and data across EOSC	For the EOSC AAI federation a metadata registry is needed that functions as the trust anchor for the connected community and infrastructure AAIs and other participants in the AAI Federation	• Governance committee • Interoperability standards	Support for enrolment of research communities, commercial companies, and the public sector in the EOSC AAI federation	• Research communities will need to adhere to the AARC Blueprint Architecture and additional requirements as agreed in AEGIS • Allow IdP and AAI proxies from commercial companies and the public sector to join the EOSC AAI Federation adhering to the AARC Blueprint Architecture and to the EOSC AAI Federation technical requirements and policies • Provide support for new EU regulations (e.g. for eIDAS)
EOSC Accounting	The ability to track and record usage of EOSC resources (i.e. research products and services) both in EOSC-Core and EOSC-Exchange. EOSC-Core service usage will show the uptake of EOSC-Core services. EOSC-Exchange service accounting will be based on integration with thematic services and the accounting service to record service usage and show impact (e.g. to funders). EOSC research product usage will be based on aggregation of usage events collected according to the COUNTER data usage metrics from EOSC data sources. Requires configuration management and messaging service capabilities	• EOSC Accounting for services (including specialisation to Virtual Access) • EOSC Accounting for research products with infrastructure capable of acquiring PID-level usage statistics about views and downloads from EOSC data sources (including repositories, archives, databases, and publishers) according to known standards and providing tools for aggregating and	• Coordinate the EOSC Accounting EOSC Interoperability Framework definition • Coordinate the EOSC Accounting API evolution • Coordinate the EOSC Accounting format definition • Process to manage EOSC Accounting integration for EOSC-Exchange services	• Provider support via helpdesk for EOSC Accounting for services • Provider support via helpdesk for EOSC Accounting for research products • Training material for providers	• EOSC Accounting for services: – Collect, store, aggregate, and display usage information of HTC compute, storage space, cloud Virtual Machine and data set resources. This usage data is collected from the resource centres of the EOSC infrastructure – Aggregate views of user usage wherever that usage occurred – Views that allow user usage to be checked against allocation

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[5] Additional information on the EOSC-Core Platform functions including their current status in the EOSC Future and o7 projects, current reference implementation in the EOSC Future and o7 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and o7 Projects are in Appendix B.

		accessing views at the PID-level	• Integration with the onboarding process		– Provider-centric views of resource usage by users – Views that allow comparisons to be made between resource providers within and between regions and communities – Aggregate, exchange, and visualise Virtual Access metrics between different e-infrastructures, service providers, e-Infrastructures, and communities • EOSC Accounting for research products: – Follow standards for usage statistics about data, publications, and other research products (COUNTER)
EOSC Collaboration Systems	Internal tools needed to coordinate EOSC-Core and EOSC-Exchange operations. These likely include collaborative information management (e.g. a wiki and document database), task and issue tracking (i.e. a ticketing system supporting workflows), and communication management (e.g. email, chat, mailing list, and video conferencing). While individual organisations may have these capabilities, they will be needed at a larger scale to support EOSC-Core and EOSC-Exchange operations	• Implementation which meets the needs of a collaborative content management system and ticket/workflow-based system • Video conferencing software • Mailing list software	• Apply the tools in the appropriate manner to the different communities using them (understanding their needs and where necessary agreeing on suitable approaches using the tools) • Integration of workflows into user groups, their work, and the EOSC SMS	Technical support of internal tools (including vetting of access requests and migration support)	Integration with the EOSC AAI
EOSC Configuration Management System	A shared store of information on which other EOSC-Core services depends and use (including monitoring, accounting, and helpdesk). Lists resources, resource components, and configuration items which must be controlled (including data about them and changes to them) in order to effectively deliver EOSC at a federation level	Configuration Management Tool for EOSC-Core providers which includes all EOSC-Core Services, service components, metadata, software versions, and topological relationships between them and which is tightly integrated with EOSC Helpdesk	• Coordination of CMT according to the procedures defined by the configuration management process of EOSC SMS • Contacts with service owners and service providers	• Support of EOSC-Core service providers and service owners • Training material and documentation	• Integration with EOSC Helpdesk system to enable assignment of tickets to particular EOSC-Core services or their components • Topological representation of EOSC-Core services, their components, and the different types of dependencies between them • Support of EOSC service profiles

				• Interoperability with other configuration registries
EOSC-Core Helpdesk	Helpdesk platform and technical support teams and to manage service incidents and service requests for EOSC-Core Platform services	• Helpdesk platform for EOSC-Core services • Frequently Asked Questions Portal	Procedures of Incident and Service Request Management Process to manage support units and assign the responsible teams to support units and ticket workflows	• Support and registration of EOSC-Core Service Providers and support unit assignment • Organisation of training webinars and workshops for support agents • Support of EOSC users by ticket triage and ticket distribution to the responsible unit	• Integration with already existing helpdesks of EOSC infrastructures • Delivery of helpdesk as a service to EOSC communities • Integration of the helpdesk webforms with service portals • Implementation of multiple communication channels (including chat)
EOSC Monitoring	The ability to check the status, availability, and reliability of EOSC resources both in the EOSC-Core and EOSC-Exchange. Supports the ability to monitor and observe EOSC resource availability as a measure of resource quality. Basic monitoring based on service endpoint or webpage accessibility. Advanced monitoring based on special probes developed as part of integration with the resource. Requires configuration management capabilities and messaging service capabilities	• Monitoring for EOSC-Core services • Monitoring for EOSC-Exchange services	• Coordinate the monitoring EOSC Interoperability Framework definition • Coordinate the API evolution • Coordinate the metrics definition • Process to manage monitoring integration for EOSC-Exchange services • Integration with the onboarding process	• Helpdesk for EOSC Monitoring for EOSC-Core services • Helpdesk for EOSC Monitoring for EOSC-Exchange services • Training material for providers	• Real-time monitoring of services • Reporting availability and reliability • Visualisation of service status • Provide dashboard interfaces • Send real-time alerts • Support for multiple tenants, configurations, metrics, and profiles to add flexibility and ease of customisation • Loosely coupled to support APIs in the full stack so that components are independent in their development cycles • High availability of the different components of the system
EOSC Order Management System	System to manage orders for services made through the central EOSC catalogue (directly from researcher-facing portal or potentially passed from other catalogues which display services pulled from the central catalogue). Collects customer/user requests with relevant data and passes these to providers via API, email, or other	• Platform to configure and visualise resource offerings • Platform to manage user spaces (and user orders) • EOSC Marketplace	Order management process with a focus on orders related to multiple resources to be composed (i.e. resource bundles)	• Support the integration of third-party order management systems • Support for the definition of agreements and business models	• Support of EOSC Interoperability Framework guidelines for order management to enable the integration of order management systems from third parties • A set of agreements/business models in place

	means. Supports collection of order metrics	• EOSC Order Management Platform		• Maintenance and evolution of the EOSC Interoperability Framework guidelines for order management	
EOSC Resource Catalogue: Services and Data Sources [6]	The EOSC service catalogues are a part of the overall EOSC resource registry and catalogue ecosystem. A database of records for providers, services, and external catalogues which is compatible with the EOSC Profiles specifications. Accessible via the web from the EOSC Provider Portal or EOSC Provider Portal APIs to deposit or update provider and service records. A content provider to the EOSC Marketplace, EOSC Resource Registry, and other connected catalogues (e.g. thematic and regional catalogues) that is exposed to researchers, research communities, and third catalogues. Data sources are specific EOSC services providing deposition, preservation, and discovery functionality for research products. The EOSC Service Catalogue data model (i.e. the EOSC profiles) will be extended with additional metadata needed for data sources (including the EOSC Registry, EOSC Provider Portal, EOSC Marketplace, and EOSC API support)	• EOSC Service Catalogue front office website offering users AI-supported search, filtering, and ordering capabilities • EOSC Provider Dashboard for providers to register and maintain resource registrations • Database of service resources registered into the EOSC Resource Catalogue • EOSC Marketplace as the main entry point for users to discover, search, access, and order the list of resources coming from the resource catalogue • AI-based platform to support recommendations derived from service and research product metadata (i.e. the EOSC Research Graph)	• Onboarding process to manage the registration and validation of service onboarding requests https://eosc-portal.eu/providers-documentation/eosc-portal-onboarding-process • Proactive actions to engage with RI/cluster catalogue providers to maximise participation and ensure alignment/up-to-dateness with EOSC Interoperability Frameworks	• EOSC provider training (material) and activities (including webinars, community calls, and courses) • Support providers in onboarding resources into the resource registry • Helpdesk for users and providers	• Support EOSC Service/Data Source Profiles https://eosc-portal.eu/providers-documentation • Support for EOSC Provider Dashboard APIs https://providers.eosc-portal.eu/openapi • Support ingestion and export from/to other EOSC catalogues - Support log-in via the EOSC-Core AAI for users to order resources and providers to manage the registrations of resources • Collect usage statistics on resource requests and ordering • Integration with the EOSC Order Management System • Integration with an AI platform to support AI-based recommendations
EOSC Resource Registry: Research Products, Services, and Data Sources	The EOSC Research Product Catalogues are a part of the overall EOSC Resource registry and catalogue ecosystem. The EOSC Research Product Catalogue collects and interlinks metadata records of EOSC research products (including publications, data, and software) and	• EOSC Research Product Catalogue: a knowledge graph built by aggregating, harmonising, and deduplicating metadata about the research products (including	• Onboarding process to manage the registration and validation of data source and related research product onboarding requests in accordance with the EOSC Interoperability	• EOSC provider technical support and training (material) • Support providers in onboarding research products into the EOSC Resource Registry	• Support EOSC Research Product Profiles (currently OpenAIRE guidelines for content providers, under extension to bioschemas.org) • Support for EOSC Research Product Provider Dashboard API

[6] The function 'EOSC Data Sources as a Subtype of Services within the EOSC Profiles' from D2.5a has been merged with this function in D2.9.

EOSC services (from the EOSC Service Catalogue) with authors, communities, organisations, services, funders, and projects. The EOSC Research Product Catalogue supports the onboarding (and validation for metadata including FAIRness) of EOSC research product profiles (collected from EOSC data sources) and of EOSC service profiles (collected from the EOSC Service Registry) as well as the discovery and navigation of EOSC resources and faceted views for statistics. The EOSC Research Product Catalogue will incorporate an AI-based recommendation system (which is an adapted version of the AI recommendation system used in the EOSC Service and Data Resource Catalogue). The AI-based recommendation system allows advanced discovery capabilities for the EOSC Resource Catalogues and connected catalogues, drawing on both the EOSC Resource Catalogues and research products through the OpenAIRE Research Graph	publications, datasets, and software) collected from EOSC data sources (including institutional and thematic repositories, archives, databases, RI/cluster catalogues, and aggregators) and interlinked with scholarly communication registries (such as ORCID, ROR.org, DataCite, and Crossref), funders, and projects • EOSC Data Source Provider Dashboard: tools to ensure EOSC data sources can register to EOSC and share metadata about the research products that they contain with the EOSC Resource Catalogue (according to the EOSC-Core Interoperability Framework guidelines) • EOSC Research Graph: a knowledge graph obtained by aggregating metadata records about services (from the EOSC Service Catalogue) and research products (from the EOSC Research Product Catalogue) together with the semantic links between them • AI infrastructure capable of using the EOSC Research Graph metadata and the Open Access	Framework for research products • Proactive actions to engage with RI/cluster catalogues and EOSC data source providers to maximise participation and ensure alignment/up-to-dateness with EOSC Interoperability Frameworks • Definition, documenting, software publishing, and maintenance of the AI algorithms	• Helpdesk for users and providers	• Support ingestion and export from/to other EOSC Research Product Catalogues • Support log-in via EOSC-Core AAI for providers to manage the registration of resources • Collect usage statistics on research products from EOSC Accounting for research products

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		research product files downloaded via the metadata to provide user-profiled discovery mechanisms • EOSC Resource Catalogue discovery portal: a discovery portal enabling user profiling and search and browse capabilities over the EOSC Resource Catalogue exploiting AI infrastructure and the EOSC Research Graph			
PIDs for EOSC Services	Provides a method to uniquely identify services in EOSC-Exchange and avoid duplication of services despite multiple entry points through which services can be onboarded (directly to EOSC-Exchange via regional or thematic catalogues). This is a service for providers to mint PIDs for their services or for catalogue owners to generate and mint PID for services onboarded within EOSC-approved catalogues	PID service for the registration of PIDs issued for service descriptions in EOSC-recognised catalogues (e.g. EOSC-Exchange and thematic and regional catalogues)	Coordinate and manage the PID namespace for EOSC-recognised catalogues. This is related to the onboarding and connecting resource catalogues to the EOSC Resource Catalogue	• EOSC catalogue owners training (material) • Support catalogue owners in connecting thematic and regional catalogues to EOSC-Exchange • Helpdesk for catalogue owners	• Support the registration of PIDs for all services registered within all EOSC-recognised catalogues • Must be compliant with EOSC PID Policy • Integration of the EOSC Resource Catalogue with the EOSC PID service to register PIDs for the onboarded services

4   Functions of EOSC-Exchange

This section presents a set of functions of EOSC-Exchange that make EOSC a rich environment where European researchers can easily find and access IT resources to perform impactful science. This set includes a wide variety of horizontal functions that can support research in different scientific fields and are sustained by free-at-the-point-of-use IT resources. Some of these functions were identified by the WG Architecture and adopted by EOSC Future to be included in the MVE. Some of these functions answer to a specific point of the procurement call related to the access to and availability of computing power, data, storage, programming tools, and library resources in EOSC. And some of these functions are discipline-specific focusing on Earth Observation research. The tables below detail MVE functions of the EOSC-Exchange as well as functions that are currently being delivered by the 07 projects including added-value functions of the EOSC-Exchange for cross-disciplinary research and added-value functions of the EOSC-Exchange for Earth Observation research.

4.1.   EOSC-Exchange MVE Functions

Functions of the EOSC-Exchange that form part of the MVE are described in Table 4-1 together with the IT tools, coordination activities, and support activities as well as the key requirements that are needed for their proper delivery.

Table 4-1: Proposed MVE Functions of EOSC-Exchange[7]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	**Coordination Activities**	**Support Activities**	
EOSC Data Transfer	A possible horizontal service to be offered via EOSC-Exchange. Enable the movement of data files asynchronously between source and destination storage endpoints (including mechanisms to ensure automatic retry in case of failure and for optimisation of performance for large files or large numbers of files)	• EOSC Data Transfer service • Client tools • Web User Interface	• Operations of the service • Coordination of the storage service providers to be compatible with EOSC Interoperability Framework/EOSC Data Access Framework	• Support for end users • Training material and documentation	• Compatible/interoperable with the EOSC Research Data as a Service • EOSC AAI integration
EOSC Helpdesk as a Service	A helpdesk platform where providers can deploy a support unit using their own staff and a helpdesk to support their own services. Prevents them needing their own technical platform and ensures their helpdesk is compatible and integrated with the EOSC Helpdesk Integration Framework	• Helpdesk platform for EOSC-Exchange services • Frequently Asked Questions Community Portals	Onboarding process to manage the registration and delivery of the helpdesk as a service to EOSC service providers and communities	Organisation of training webinars and workshops for support agents	Multiple community-branded helpdesk portals with self-service (including FAQ and knowledge base) functions provided to communities
EOSC Research Data as a Service	A horizontal service to be offered via EOSC-Exchange. The service is grounded on an EOSC Data Access Framework (to be defined) that establishes how EOSC data sources (i.e. archives, repositories, and databases) can uniformly offer access to their research data files via common protocols. The service can search and find via the EOSC Resource Catalogue the research data records that are made available by such data sources and download and merge the related data files to deliver the resulting collection to the user (in accordance with data access standards such as the Dataspaces). The service can also take advantage of the metadata crosswalk functionality to be provided by the EOSC Metadata Registry service that will be delivered via INFRA-2021-EOSC-01-03	• Service to deliver EOSC Research DaaS • EOSC Metadata Registry (INFRAEOSC-01-03) • EOSC Interoperability Framework Registry/Database	Onboarding process to manage the registration and validation of EOSC data sources that comply with the EOSC Data Access Framework	• EOSC provider technical support and training (material) • Support EOSC data source providers in complying with the EOSC Data Access Framework	• Definition of the EOSC Data Access Framework • Support to EOSC AAI delegation to enable the service to access other sources on behalf of the consuming user/service • Adoption of known standards for data access (e.g. Data Spaces)

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[7] Additional information on EOSC-Exchange functions to be included in the MVE including their current status in the EOSC Future and 07 projects, current reference implementation in the EOSC Future and 07 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and 07 Projects are in Appendix C.

4.2. EOSC-Exchange Added-value Cross-disciplinary Functions

Functions of the EOSC-Exchange for added-value cross-disciplinary research are described in Table 4-2 together with the IT tools, coordination activities, and support activities as well as the key requirements that are needed for their proper delivery. These functions have been proposed as exemplars of cross-disciplinary services that bring added value to EOSC and are currently being delivered by the 07 projects under the A1, A2, and A3 calls. There are other added-value services for cross-disciplinary research from the Research Infrastructures and Science Clusters that could be considered relevant for the EOSC-Exchange and for the procurement call. The below list is thus not exhaustive and could be further complemented with other horizontal functions. There are three 07 projects funded under the A1, A2, and A3 calls:

- **DICE** (A2 project delivering data services): Storage and data management infrastructure for EOSC providing generic services and building blocks to store, find, access, and process data in a consistent and persistent way. This includes several services for data discovery, data repositories, and data archives and a personal/project workspace that researchers and research teams can use when data is not yet stable and is frequently changing during the data processing and analysis steps of the research data lifecycle;

- **EGI-ACE** (A1 project delivering distributed and cloud computing resources): The EOSC Compute Platform as a federated and hybrid (cloud/HPC/HTC/container) infrastructure of free-at-the-point-of-use IT resources accessible through different types of platforms (including workflow managers, VM orchestrators, Artificial Intelligence (AI)/Machine Learning (ML) frameworks for model training and delivery, and Notebook frameworks) that facilitate the execution of user workloads. EGI-ACE also delivers horizontal services that provide scientific capabilities that are attractive for multiple significantly broad scientific domains;

- **OpenAIRE Nexus** (A3 project delivering services supporting scholarly communication and Open Access): Services to implement and accelerate Open Science workflows for publishing research (including a catch-all repository, overlay journals, data management plans, and anonymisation of data), monitoring research (including citations for articles/data/software, article processing charges, usage of research data, and research impact for policy makers/institutions/Research Infrastructures/Science Clusters), and discovering research (at regional and research community levels) across disciplines.

Table 4-2: Proposed Added-value Cross-disciplinary Functions of EOSC-Exchange[8]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	**Coordination Activities**	**Coordination Activities**	
Compute Infrastructure	Infrastructure Layer of the EOSC Compute Platform: Distributed cloud compute and storage resources federated into a pan-European hybrid infrastructure to support processing, analytics, and other data and compute-intensive use cases. The resources are delivered to users and user communities via integrated resource discovery and resource allocation processes that respect and integrate existing institutional, national, and European infrastructure leveraging existing funding from MS and research performing organizations. The infrastructure is managed via integrated authentication-authorisation, security response, availability/reliability monitoring, usage accounting, capacity management, customer relationship management, and change management processes	• Cloud compute resources • Data-intensive compute services • Container execution resources • Information system (including configuration management) • A/R monitoring system • Accounting system • Messaging system • Helpdesk system • IT Service Management system • Operations portal • Software provisioning infrastructure	• Running the IT Service Management processes: – Customer Relationship Management (including resource allocation) – Supplier management – Release and deployment management – Change management – Availability and continuity management	• Call for user and use cases • Webinars • Training • Technical consultancy for users • Technical consultancy for providers	• Federate the compute resources of National EOSC Nodes • Interoperability with EOSC-Core (in particular EOSC AAI) • Interoperability with the 'data layer' of EOSC (for staging data between the data and compute layers)
Compute Platforms	Platform Layer of the EOSC Compute Platform: Federation enabling compute services for the execution of user workloads in the compute infrastructure layer of the EOSC Compute Platform. This includes workload managers (to orchestrate large number of jobs), workflows managers,	• Hybrid cloud orchestrators • Workload Managers • Software and data distributors	• Running the IT Service Management processes: – Customer Relationship Management (including resource allocation)	• Webinars • Training • Technical consultancy for users	• Interoperability with the infrastructure layer of the EOSC Compute Platform • Interoperability with software distribution tools (including Virtual Machine/container/binary catalogues)

[8] Additional information on added-value EOSC-Exchange functions for cross-disciplinary research including their current status in the EOSC Future and 07 projects, current reference implementation in the EOSC Future and 07 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and 07 Projects are in Appendix D.

	Virtual Machine orchestrators, AI/ML frameworks for model training and delivery, and Notebook frameworks. The platforms are compatible with the diverse types of compute resources from the infrastructure layer	• AI/ML environments • Notebook hubs	− Supplier management − Release and deployment management − Change management − Availability and continuity management		• Interoperability with the data layer of EOSC (for staging data I/O)
Compute Services for Multidisciplinary Science	Multidisciplinary services that provide scientific capabilities attractive for multiple significantly broad scientific domains such as: simulation and forecasting tools, AI-based imaging data processing tools, AI as a service, and data access and analysis tools.	• JupyterHub and Binder • AI platforms for data processing • Set of horizontal services able to support multiple scientific domains as for example: − WeNMR portal (HADDOCK2.4, DisVis, PowerFit, SpotOn, AMPS-NMR) − UseGalaxy.eu − SeaDataNet Web Ocean Analysis − EMSO Data Portal − CCP4	• Running the IT Service Management processes: − Customer Relationship Management (including resource allocation) − Supplier management − Release and deployment management − Change management − Availability and continuity management	• Promotion of talks at scientific conferences • Training • Technical consultancy for users	• Interoperability with the infrastructure layer and platform layer of the EOSC Compute Platform • Interoperability with the 'data layer' of EOSC (for staging data I/O)
Data Archive	High volume cost-efficient data services in which bit preservation level durability is ensured. Mid-term storage resources after/between projects. Accessible from computing facilities to store non-active research data	Storage capacity supporting bitwise preservation of data objects	• Configuration of user groups and storage quotas • IT Service Management activities:	• Webinars • Training • Documentation and helpdesk for users	Interoperability with the 'data layer' of EOSC (for staging data between the data and compute layers)

			– Customer Relationship Management (including resource allocation) – Capacity management – Supplier management – Release and deployment management – Change management – Availability and continuity management	• Technical consultancy for community data managers	
Data Discovery	Research data are made discoverable from many different communities and scientific disciplines to support cross-disciplinary research. Via these services data source owners can make their repositories harvestable and make their research data both findable and widely discoverable in EOSC	• Web interface to allow users to search and find data • Database of aggregated harvested metadata • Software pipeline for metadata harvesting and ingestion from the communities' repositories	• Harvesting and ingestion procedures activities • IT Service Management activities: – Customer Relationship Management (including resource allocation) – Change management – Availability and continuity management	• Webinars • Training • Technical consultancy for providers to join the harvested communities	Data harvestable via standard protocols (following EOSC IF)
Data Repository	Category of services for maintaining research data in a FAIR way. Research data is well described via community-defined metadata templates, persistent identifiers are registered for data sets and data objects, if data is open accessible, is closed and/or under embargo, and is made available according to appropriate licences. Provides long-term data	• Web interface for users to search/browse/download data and to create new datasets (including the annotation according to the metadata schema) • APIs to upload/download datasets	• Maintenance of the default metadata schema • Creation of community-specific metadata schemas • Setting up of dedicated community instances	• Webinars • Training • Documentation and helpdesk for users • Technical consultancy for community data managers	• Interoperability with EOSC-Core (in particular EOSC AAI) • Interoperability with the 'data layer' of EOSC (for staging data between the data and compute layers)

		PID generation procedure and association to dataset	Creation of Prefixes and related PID hosting		
	resources preservation and sharing. Stores non-active FAIR data	• Database of metadata associated to the uploaded data • Storage capacity with bitwise preservation to store uploaded datasets	• IT Service Management activities: – Customer Relationship Management (including resource allocation) – Capacity management – Release and deployment management – Change management – Availability and continuity management		
EOSC Anonymisation Tools	Apply anonymisation from desktops and transparently publish sensitive research data (following GDPR compliance). Support publishing anonymised data into repositories complying with the interoperability framework defined by EOSC research product publishing working group	Software required to implement advanced data anonymisation processes (e.g. pseudo K-anonymisation) over datasets provided in multiple data formats	N/A	Documentation and helpdesk required to ensure proper adoption and usage of the service	Compliance with EOSC research product publishing working group
EOSC APC Monitoring	Keep track and provide access to the Open Access record of European expenditure for article processing charges across the countries	Infrastructure to collect and provide access to APC information collected from libraries and institutions in Europe	Data aggregation and curation needed to map APC information into a common representation model	Documentation and helpdesk required to ensure proper adoption and usage of the service	Integration with EOSC Monitoring and EOSC Accounting
EOSC Catch-All Repository	FAIR publishing, long-term-preservation, access to interlinked research products (including publications, datasets, and software), linked to funding and communities, linked to EOSC services, and community management and curation capabilities	Service to enable deposition, preservation, discovery, and access to research products by supporting linking to other EOSC resources	N/A	Documentation and helpdesk required to ensure proper adoption and usage of the service	• Compliance with EOSC research product publishing working group • Compliance with EOSC AAI and integration with EOSC Monitoring and EOSC Accounting

EOSC Citation Index Service	Keep track and provide Open APIs to access the largest collection of Open Access citations between DOIs as exposed by publishers world-wide and the largest collection of Open Access (CC0) citations between articles and datasets/software, datasets and datasets, as exposed by Crossref, DataCite, and EMBL-EBI	Infrastructure to collect and provide access to article-article citations Infrastructure to collect and provide access to article-datasets/software citations	Data aggregation activities to interface with data sources and ensure correct cleaning and mapping of links metadata	Technical support needed to ensure collection of links according to the standards identified by the EOSC Interoperability Framework	Compliance with EOSC AAI and integration with EOSC Monitoring and EOSC Accounting
EOSC Community Dashboard	Enables the deployment on demand of web portals, called community Gateways, for the discovery and browse of research products (including publications, datasets, and software), projects, and organisations related to a specific community. The community can be scientific (on a specific research topic) or geographically/jurisdictionally identified (e.g. community of ELIXIR researchers in Greece or community of a network of universities) and content is identified and collected from the EOSC Research Graph	• EOSC Research Graph • Mining infrastructure to identify relationships between publications, datasets, and software and a given geo-oriented or discipline-oriented community	Curation activities to support the definition and fine-tuning of mining/ML/AI tools that identify the portion of the EOSC Research Graph associated with a given community	Technical support needed to onboard a community, identify their requirements, and customise the actions needed to deploy a dedicated web portal	N/A
EOSC Data Management Plan Service	Allow researchers to manage machine-actionable Data Management Plans to ensure publishing FAIR data in trusted EOSC data sources and support funders to monitor trends and actions in data management	Service to enable the creation and management of DMPs by groups of collaborators, based on the European Commission template, in such a way that the DMPs can be consumed programmatically to ensure linking to EOSC resources and scholarly communication entities (e.g. organisations, projects, funders, and communities) via PIDs	N/A	Documentation and helpdesk required to ensure proper adoption and usage of the service	• Compliance with EOSC research product publishing working group • Compliance with EC DMP templates • Compliance with EOSC AAI and integration with EOSC Monitoring and EOSC Accounting
EOSC Monitor Dashboard	Enables the deployment on demand of customisable web portals providing research impact statistics about 'research initiatives' (including funders, infrastructures, clusters, and organisations) and their EOSC research resources (including services,	• EOSC Research Graph • Mining infrastructure to identify relationships between publications, datasets, software and a given 'research initiative' that captures the	Curation activities to support the definition and fine-tuning of mining/ML/AI tools that identify the portion of the EOSC Research Graph associated	Technical support needed to onboard 'research initiatives', identify their requirements, and customise the actions needed to deploy a	Compliance with EOSC AAI and integration with EOSC Monitoring and EOSC Accounting

	publications, datasets, and software). Statistics are derived from the EOSC Research Graph	semantics of research impact (e.g. "datasets have been created thanks to the activities of this RI/cluster")	with a given 'research initiative'	dedicated web portal for research impact	
EOSC Overlay Journal Platform	Management of Open Access journals exploiting the network of Open Access repositories (e.g. HAL, arXiv, Zenodo, B2SHARE) as identified by the interoperability framework defined by EOSC research product publishing working group	Platform to support the creation and management of journals (including submission, open peer review, and integration with ORCID) that exploit Open Access repositories as the deposition and submission overlay	Curation activities required to ensure journal boards are operating according to the policies of the service	N/A	Compliance with EOSC AAI and integration with EOSC Monitoring and EOSC Accounting
Personal/Project Workspace	Researchers and research teams use personal/project workspaces when doing active research when data is not yet stable and is frequently changing during the data processing and analysis steps of the research data lifecycle. Mid-term storage during project active resource data. Good connection to computing facilities. Possibility to share data with co-workers	• Web interface for users to upload/download their data and manage access from other users • APIs to upload/download dataset • Group management layer to assign permissions • Storage capacity	• Setting up of dedicated instances and/or specific quotas of storage • Creation of communities dedicated folders/groups • IT Service Management activities: – Customer Relationship Management (including resource allocation) – Capacity management – Release and deployment management – Change management – Availability and continuity management	• Webinars • Training • Documentation and helpdesk for users • Technical consultancy for community data managers	• Interoperability with EOSC-Core (in particular EOSC AAI) • Interoperability with the 'data layer' of EOSC (for staging data between the data and compute layers) • Integration with EOSC Monitoring and EOSC Accounting
Policies-Based Data Archive	Services with the capability for advanced data management practices on the basis of policies (e.g. automated quality and integrity checks, registration of persistent	Software layer with the capability to implement data management policies (e.g. data replication,	• Configuration of policies requested by the customer	• Webinars • Training	• Interoperability with the 'data layer' of EOSC (for staging data between the data and compute layers)

| identifiers, and replication across geographical locations). Mid-term and long-term data resources accessible from computing facilities to store non-active research data. Value-added services (including integrity checks and replications) for long-term stable data archives | registration of PIDs, data integrity checks, and automated data publications)

Storage capacity supporting bitwise preservation of data objects | • Configuration of user groups and storage quotas

• IT Service Management activities:
  – Customer Relationship Management (including resource allocation)

  – Capacity management

  – Supplier management

  – Release and deployment management

  – Change management

  – Availability and continuity management | • Documentation and helpdesk for users

• Technical consultancy for community data managers | • Integration with EOSC Monitoring and EOSC Accounting

• Integration with an EOSC Federated AAI compliant AAI proxy to provide access to EOSC users |

4.3. EOSC-Exchange Added-value Earth Observation Functions

Functions of the EOSC-Exchange for added-value Earth Observation research are described in Table 4-3 together with the IT tools, coordination activities, and support activities as well as the key requirements that are needed for their proper delivery. These functions have been proposed as exemplars of domain-specific services that bring added value to EOSC and are currently being delivered by the 07 projects under the A6 call. There are other added-value services for domain-specific research from the Research Infrastructures and Science Clusters that could be considered relevant for the EOSC-Exchange and for the procurement call. The below list is thus not exhaustive and could be further complemented with other domain-specific functions. It should be noted that some domain-specific functions could be relevant for other domains and thus be offered as horizontal services (e.g. Earth Observation Analytics and Compute Federation). There are two 07 projects funded under the A6 call:

- **C-SCALE** (A6 project delivering additional research-enabling services): Earth Observation Compute and Data Federation and a rich set of Earth Observation analytics to facilitate the exploitation of EO/Copernicus data in EOSC;
- **RELIANCE** (A6 project delivering additional research-enabling services): Services to manage FAIR research objects in EOSC and perform semantic searches and recommendations. Also delivers Copernicus Data Pipelines and a service for Earth Observation Data Cubes Management in EOSC.

Table 4-3: Proposed Added-value Earth Observation Functions of EOSC-Exchange[9]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	**Coordination Activities**	**Coordination Activities**	
Copernicus Data Pipelines	Integrated intermediate service layer for the systematic execution of EO applications continuously delivering data and information to different research users. A data pipeline is the solution provided to a specific data challenge defined by a researcher as a tailored data processing workflow responsible for information extraction from a wide range of large volume data sources that are executed within defined spatial and temporal intervals	Uses shared data processing infrastructures where the applications are deployed. The service manages the IaaS and cloud resources, orchestrates the execution of the triggered Data Pipelines, and publishes the results	Activities related to the encoding of the Application Package and data flow management (i.e. data manifest for inputs and outputs)	Support to algorithm integration which defines the parallelisation strategy, data management requirements, and production plan in a cloud environment	Dedicated cloud application integration environment with software tools, libraries, and access to distributed EO data repositories
Earth Observation Analytics	Scientific tools, applications and virtual machine images that can be used and customised on the infrastructure resources for EO data analysis	• Platform services to: – manage complex workloads – train AI models – deploy automated clusters – run containerised applications – perform interactive analysis with Notebooks • Data management services to transfer, catalogue, cache, and federate data across multiple compute and data sites	The research communities, through use cases, will co-design, test, pilot, refine, and ultimately help create a federated infrastructure that delivers data and platform services that are useful for the community	• Call for user and use cases • Webinars • Training • Technical consultancy for users • Technical consultancy for providers • Network of experts to help port the application to the infrastructure	• Interoperability with the infrastructure layer and platform layer of the EOSC Compute Platform • Interoperability with the data layer of EOSC (for staging data I/O) • Standardised options for setting up the interface to connect the processing graph to a compute back-end and translate it to an actual job on that back-end

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[9] Additional information on added-value EOSC-Exchange functions for earth observation research including their current status in the EOSC Future and 07 projects, current reference implementation in the EOSC Future and 07 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and 07 Projects are in Appendix E.

Earth Observation Compute Federation	A federated computing infrastructure that brings together European computing providers to deliver a federated infrastructure to support Copernicus and EO use cases that deal with data- and compute-intensive workloads (including Copernicus DIAS and other research-oriented providers). Resources accessible through homogeneous interfaces using a common AAI framework to facilitate analysis of Copernicus and other EO dataset (e.g. Sentinel-series satellite data distributed across multiple providers)	• Compute resource providers (including cloud IaaS, Kubernetes, HTC, and HPC) • Container (including Docker, uDocker, Singularity) • PaaS orchestration • Platforms to access EO data • Federated AAI • Notebooks	IT Service Management activities: • Customer Relationship Management (including resource allocation) • Capacity management • Supplier management • Release and deployment management • Change management • Availability and continuity management	• Call for user and use cases • Technical consultancy for users • Technical consultancy for providers	• Interoperability with EOSC-Core (including AAI, accounting, monitoring, and helpdesk) • Interoperability with the 'data layer' of EOSC (for staging data and offering data to other providers)

Earth Observation Data Federation	A distributed infrastructure providing Earth Observation data and implementing a distributed long-term EO data archive. Existing resources are federated in terms of authentication and a product discovery layer is added to look up datasets or individual products across the federation	• EO Data providers
		
		• Federation Catalogue
		
		• Metadata Query Service
			• IT Service Management activities:
			   – Customer Relationship Management (including resource allocation)
			
			   – Capacity management
			
			   – Supplier management
			
			   – Release and deployment management
			
			   – Change management
			
			   – Availability and continuity management
				• Call for user and use cases
				
				• Technical consultancy for users
				
				• Technical consultancy for providers
					• Interoperability with EOSC-Core (including AAI, accounting, monitoring, and helpdesk)
					
					• Interoperability with the 'compute layer' under EOSC when accessing data

EOSC Earth Observation Data Cubes Management	Seamless discovery, access, and view services for Copernicus and non-Copernicus data distributed across relevant infrastructure. Advanced access capabilities to optimise data transfer and	A Data Cube layer deployed in the data processing infrastructure where the data are stored and able to support the indexing and	N/A	• Continuous indexing of Copernicus and non-Copernicus data	• Integration with AAI • Integration with Notebooks

	boost the development of data processing pipelines and temporal analysis	access to data stored in public buckets in external infrastructures		• Helpdesk for front-end and API	
EOSC Research Object Management Platform	Storage, lifecycle management, publishing and preservation of scientific investigations and campaigns via research objects (ROs), exportable as RO-crates, in line with FAIR principles and EOSC Semantic Interoperability Framework. Support scientists to: create and maintain high-quality ROs that can be interpreted and reproduced; collaborate along this process; share, publish, and search these objects and their metadata; manage their evolution; monitor and preserve them to support their accessibility and reusability. Connect other EOSC services (e.g. for data storage, computing, and publication)	Service to enable the RO management which makes these resources available to others, allows to publish and release them through a PID, and allows to discover and reuse pre-existing scientific knowledge. Allows leveraging other EOSC services (e.g. data storage, computing, and publication)	• Activities related to RO-crate definition • Activities related to definition of Semantic Interoperability Framework and semantic publishing	Helpdesk required to support users and share documentation, tutorials, and training materials	• Support RO-crate specification and ingestion/generation of RO-crates • Integration with EOSC AAI • Connection with EOSC catch-all repositories • Integration with EOSC data storage services • Python library to be used within EOSC Notebooks • Compliance with EOSC Semantic Interoperability Framework
EOSC Semantic Recommendation	The recommender system suggests research objects that might be of interest according to the user's research interests. The recommender system follows a content-based approach in that it compares the research object content with user interests to draw the list of recommended items. This comparison is based on the annotations added by the semantic enrichment process. The user's interests are identified from the top concepts in the user's research objects. These concepts are then compared with the concepts that annotate the research objects in the whole collection. The user's interests can be increased by adding specific research objects from other users or adding a different scientist. In the former case, the main concepts of the research object are added to the user's interests. In the latter case, the scientist interests are added to the user's interests	Recommender system for research object platform	N/A	N/A	N/A
EOSC Semantic Search	API to improve the exploration of the research object (RO) collection hosted by	Platform to index the RO metadata generated by an	N/A	N/A	N/A

	a RO Hub and to allow the users to make facet and semantic searching over them based on their text content.	enrichment service with fields associated to each possible type of content metadata			
EOSC Text Enrichment	The semantic enrichment process is in charge of generating new metadata out of the text content of files or collections of resources as research objects. This metadata comprise the main concepts found in resources containing text, the main knowledge areas in which these concepts are most frequently used, the main expressions (known in computational linguistics as noun phrases) found in the text, and named entities that are further classified into people, organisations, and places	Semantic enrichment process platform	N/A	Helpdesk support team	N/A

5   Functions of EOSC Interoperability Framework

The EIF provides a flexible framework of standards and guidelines to support the interoperability and composability of resources in the EOSC-Core and EOSC-Exchange. The EIF will act as the glue to connect services and research products (e.g. publications, datasets, and software) across resources and providers. The function that could be supported by the procurement to guarantee the delivery of the EIF is the EOSC Interoperability Framework Management which is a structure to manage, update, circulate, and promote the EIFs that are created through EOSC projects and EOSC Association TFs. This function is detailed in Table 5-1.

Table 5-1: Proposed Functions of EOSC Interoperability Framework[10]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	Coordination Activities	Support Activities	
EOSC Interoperability Framework Management	• A structure to manage, update, circulate and promote the EOSC Interoperability Frameworks which are created through the projects and task forces to support and enable interoperability within EOSC. Interoperability includes technical, policy, process, and administrative interoperability • EOSC Interoperability Frameworks include: – Resource Description Framework – Open Science Policy Framework – Operational Support Framework AAI Framework – Service Management Framework – PID Framework (but this is already covered in its own entry) Security Framework – Open Metric Framework (but this is already covered in its own entry) – Procurement Framework – Data Access Framework – Metadata Framework – Helpdesk Integration Framework – Other frameworks (TBD)	Repository of all IFs	Coordinate the establishment of IFs and the making of existing IFs available through the repository	• Support the dialogue on establishing IFs • Support communities in making their IFs available through EOSC	The IF is at the heart of EOSC-Core and makes sure that a system-of-systems materialises

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[10] Additional information on EOSC Interoperability Framework functions including their current status in the EOSC Future and 07 projects, current reference implementation in the EOSC Future and 07 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and 07 Projects are in Appendix F.

6 Functions of EOSC Support Activities

The EOSC Support Activities comprise training, engagement, monitoring and other human-centric activities which support the operation of EOSC-Core and EOSC-Exchange and make EOSC more attractive and easier to use as well as help users benefit from EOSC. The functions that could be procured are described in Table 6-1.

Table 6-1: Proposed Functions of EOSC Support Activities[11]

Function Name	Expected Capabilities	Procurable Elements Needed to Deliver the Function			Key Requirements
		Technical Platform	**Coordination Activities**	**Support Activities**	
EOSC-Core Support	Support for use of or integration with EOSC-Core resources (including training and specialist consultancy). Need to support researchers to use EOSC-Core elements (e.g. using EOSC AAI to access a thematic service) or by providers (e.g. a thematic provider using EOSC Accounting to show usage for Virtual Access repayment)	• Predominantly a human service • Make use of the EOSC collaboration system to maintain and track supporting activities • Rely on the EOSC Helpdesk for the engagement with EOSC users and providers	• Coordinate and oversee the supporting activities • Engage with the first, second, and third line support of EOSC-Core services	• Provide first line support • Second and third line support is provided through the supporting activities of EOSC-Core services	• Rely on the availability of the EOSC Helpdesk and EOSC collaboration system • Rely on second and third line support provided through the supporting activities of EOSC-Core services
EOSC Digital Innovation Hub	A structure to co-design and deploy experiments with the commercial sector to benefit from, exploit, and contribute to EOSC. Support the uptake of EOSC by the commercial sector in multiple ways	• EOSC DIH website • EOSC DIH slack workspace	• Coordinate the operation and expansion of the EOSC DIH community • Manage the full lifecycle of business pilots (including technical requirement analysis for identifying appropriate EOSC services) • Identify services/solutions required by EOSC to be developed by industry • Establish corridors with other DIHs to support the pan-European network and connect at the regional level • Serve as an industrial engagement channel for other European Commission projects and	• Piloting and co-design • Facilitate access to EOSC technical services • Consultancy and training • Community and visibility	• EOSC Marketplace specifying if services can be offered for industry co-creation for easier identification • EOSC governance structures recognising the EOSC DIH as a principal mechanism for industry engagement • Tighter connection between EOSC Marketplace and EOSC DIH (both human and technical)

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[11] Additional information on EOSC Support Activities functions including their current status in the EOSC Future and 07 projects, current reference implementation in the EOSC Future and 07 projects, expected responsibilities from other stakeholders, and planned activities under the EOSC Future and 07 Projects are in Appendix G.

			initiatives for engaging with EOSC	
EOSC Knowledge Hub	The EOSC Knowledge Hub, seamlessly integrated with the EOSC Portal, has two essential components: a training resource catalogue and a learning platform, both intended to support FAIR sharing and reuse of training resources in EOSC	• Training Resource Catalogue (including aggregation of material based on RoP and quality standards, validation of metadata according to specifications, tools for annotation, tools for tracking usage, linked to AAI, and linked to EOSC Portal AI) • Learning Platform (Learning Management System which includes tool for authoring, extension for learning paths and badges, certification mechanism, curation and annotation, usage tracking, and links to AAI) • Knowledge Hub which provides access to both of the above (front-end)	• Outreach to user communities of trainers, research groups, universities, and SMEs/industry • Coordination with providers of similar training platforms • Coordination with EOSC Association for long-term sustainability • Outreach to user communities for co-development, evaluation, and curation of learning content	• User training (of five identified actor groups: consumers, providers, facilitators/intermediaries, trainers, and EOSC Future project specific) • Engagement through coordination with EOSC-F WP10 and 07 projects	• Use of EOSC AAI for access and use of materials and content • Minimum metadata requirements and FAIR compliance (based on work from RDA ETHRD IG outputs) • Fulfil RoP for onboarding of materials
EOSC Observatory	An interactive dashboard for gathering and presenting the results of the monitoring of EOSC readiness, implementation, and uptake for MS/AC and the EOSC Partnership. The observatory will support the European Commission, EOSC Steering Board, and EOSC Association as a policy intelligence tool for the authoritative collection and presentation of activities related to EOSC (including policies, investments, infrastructures, and resources). The observatory is expected to play a key role in the monitoring and shaping of EOSC and will support decisions on FAIR/open data and infrastructures in national and	• Domain and website • Server and Virtual Machine • Contact and functional emails • Content Management System • Survey tool • APIs for data ingestion	• Technical operation and maintenance of the dashboard • Content management of content on the dashboard • Strategic coordination across key stakeholders providing data (including EOSC Steering Board, EOSC Association, and national representatives for Open Science) • Engagement with key stakeholders for	Helpdesk for the back-end data gathering, analysis, and presentation for key stakeholders providing data	• Use of EOSC AAI as a log-in and identification for the back-end data gathering, analysis, and presentation for key stakeholders providing data • Alignment of standards and APIs for interoperability of data, usage statistics, and indicators from key data sources (including the EOSC Platform, thematic and regional portals, OpenAIRE Open Science Observatory, and national monitoring systems) to support the back-end data gathering, analysis, and presentation for key stakeholders providing data

	European programmes (including AI and the Data Spaces)	• Data curation and annotation tool • Data analysis tool • Data visualisation tool • Usage analytics tool	consensus and validation of presented data (including umbrella associations such as European University Association and Science Europe)		• Maintenance of provenance to ensure the quality of collected data • Mechanism to ensure digital preservation for 3-5 year cycles (including timeseries options)
EOSC Open Science Help Desk and Collaborative Tools	A decentralised and coordinated helpdesk to support service and content providers to share their resources in EOSC and to help researchers in finding support from the most relevant source (ideally closer to them geographically and/or thematically)	EOSC Open Science Helpdesk	Setting up a European network of Open Science desks at country and community levels	EOSC support and training (material) to enable exchange of information, dissemination, and alignment across national and community desks	N/A
EOSC Open Science Metrics	Platform for Next Generation Metrics. Access to statistics regarding Open Science (such as production of open/FAIR artifacts and FAIRness and openness indicators of research data and research software by organisation, provider, data source, country, community, funder, funding stream, project, and costs). Ability to define new indicators by analysing content of the EOSC resource catalogue graph. Development of Open Science impact indicators based on citations, usage data, and links	• An interactive dashboard for facilitating and presenting the results of the monitoring of EOSC Open Science output, uptake, and costs (for publications) • A business intelligence tool with: – Big data analytics platform to provide responses on demand, supporting complex queries (including comparisons) – A visualisation platform for presentation of results by country, research domain, and funder – A sandbox interface to the big data analytics platform that allows policy makers, research managers, and Open	• Identification of the indicators with the support of the community and implementation of the related algorithms on top of the EOSC Research Graph, EOSC Accounting, and EOSC Monitoring • Coordination with national monitoring systems	Documentation necessary to interpret the metrics and indicators for transparency of methods and data	• Standardised indicators • APIs for data exchange

				Science researchers to produce own indicators		
EOSC Open Science Support	Support for researchers and providers to better embed Open Science practices and services in their work. Provide support and alignment at national, regional, and thematic levels to ensure a unified approach in data stewardship and legal and ethical knowledge of using the EOSC Interoperability Framework to better understand how to publish and use data and services. Build the EOSC Knowledge Hub that will allow trainers and all relevant actors to share and discover related information (including courses, support material, and tutorials)	• EOSC Knowledge Hub • EOSC Web Portal	• Curation of the material in the EOSC Knowledge Hub (including metadata and files) • Integration of local catalogues	EOSC technical support and training (material) for the integration of EOSC Knowledge Hub sources and assets	Definition of the protocols for the integration of material catalogues with EOSC Knowledge Hub
EOSC Web Presence	The EOSC Web Presence should provide basic information on EOSC including key components (such as EOSC-Core, EOSC-Exchange, EOSC Interoperability Framework, and Supporting Activities), governance, and the opportunities to participate in EOSC. This information could be split across multiple sites (e.g. https://eosc-portal.eu and https://eosc.eu) but should be linked	• Domain and website • Server and Virtual Machine • Contact and functional emails • Content Management System • Newsletter tool • Social media accounts • Usage analytics tool	• Technical management and maintenance of the platform • Content management of content on the platform	N/A	Use of EOSC AAI for log-in and identification

7   Conclusions

This report has provided recommendations from the EOSC Future project for the public procurement call for EOSC in Q3 of 2022 by the European Commission. The report has offered an EOSC Future perspective, in collaboration with the INFRAEOSC-07-2020 projects, on the future architecture and implementation of EOSC with a focus on possible functions that could be procured to deliver an impactful EOSC Platform with added-value services for researchers from all disciplines. The recommendations consist mainly of a detailed list of functions that are needed to realise the Minimal Viable EOSC (proposed by EOSC Future) together with added-value functions for the EOSC-Exchange (proposed by the INFRAEOSC-07-2020 projects). These functions have been described in a series of tables describing key architecture component areas of the Minimal Viable EOSC as proposed by the EOSC Executive Board Working Group on Architecture and further expanded by EOSC Future. The component areas consist of the EOSC-Core and EOSC-Exchange together with the EOSC Interoperability Framework and EOSC Support Activities that are needed to deliver the EOSC-Core and EOSC-Exchange. The EOSC-Core has been further subdivided into EOSC-Core Coordination and EOSC-Core Platform. The functions of the EOSC-Exchange have been further grouped into functions for the Minimal Viable EOSC as well as added-value functions for cross-disciplinary and Earth Observation research. The tables further specify the expected capabilities, procurable elements, and key requirements to deliver the functions. The report does not provide recommendations on the prioritisation of functions, grouping of components and functions into lots for procurement, interdependencies between functions, or the scale of the procurement in terms of capacities to be procured and financial amounts to be spent on the functions. This report is entailed to give guidance to the European Commission in the selection of functions that are critical for delivering the expected features of the EOSC-Core and EOSC-Exchange in the public procurement call.

Appendix A: Status of EOSC-Core Coordination Functions

Function Name	Current Status in EOSC Future/07 Projects	Current Reference Implementation in EOSC Future/07 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/07 Projects
EOSC Security Coordination	Initial version delivered	• Existing federated security response coordination involving 07 projects EGI-ACE and DICE • Alignment with the research and education community via GEANT, eduGAIN, and WISE	Mandate by EOSC-A for adherence across EOSC of policies and procedures produced by the area security coordination	EOSC-F T7.5 - EOSC Security Operations and Policy
EOSC Service Management System	Initial version delivered	EGI SMS within EGI-ACE	Support of the EOSC SMS and its continuing development, improvement, and maintenance	SMS deployed as part of work in EOSC-F WP7 with support in WP4, WP5, and WP6
PID Policy Compliance Assessment Framework	Initial version delivered	Enforcement and implementation of the EOSC PID Policy, tools, processes, and infrastructure is an objective of call INFRAEOSC-01-03 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-infra-2021-eosc-01-03	• Maintain EOSC PID Policy (EOSC-A) • Maintain compliance and validation criteria (EOSC IF) • Maintain compliance framework specification (EOSC IF)	• EOSC-F T3.3 EOSC Interoperability Framework Task Forces will support work on areas including PIDs • EOSC-F WP9 training will include materials on PIDs

Appendix B: Status of EOSC-Core Platform Functions

Function Name	Current Status in EOSC Future/07 Projects	Current Reference Implementation in EOSC Future/07 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/07 Projects
Connecting EOSC-Core Components to the EOSC AAI Federation	Initial version delivered	N/A	N/A	EOSC-F T7.3 - EOSC Federated Authorisation and Authentication linked to work in WP4 and WP5 evolving EOSC-Core services
EOSC AAI Federation	In development	N/A	Endorsement of the AEGIS guidelines https://aarc-project.eu/about/aegis	EOSC-F T7.3 - EOSC Federated Authorisation and Authentication
EOSC Accounting	In development	• EOSC Accounting for services including specialisation to Virtual Access prototype to be made available Q2 2022: – GridJob Usage Record Standard used within WLCG and EGI for exchanging grid accounting metrics for individual grid jobs https://wiki.egi.eu/wiki/APEL/MessageFormat#Job_Records – APEL Grid Summary Job Record Standard used within WLCG and EGI for exchanging grid accounting metrics for aggregations of grid jobs https://wiki.egi.eu/wiki/APEL/MessageFormat#Summary_Job_Records – Cloud Virtual Machine Usage Record Standard adopted by the EGI Federated Cloud for exchanging cloud accounting metrics https://wiki.egi.eu/wiki/Federated_Cloud_Architecture#Cloud_Usage_Record – OGF StAR Open Grid Forum standard for Storage Accounting Records used to exchange storage space usage data http://www.ogf.org/documents/GFD.201.pdf • EOSC Accounting for research products: – OpenAIRE UsageCounts http://usagecounts.openaire.eu	• Rules of Participation (EOSC-A) • Maintain compatibility with monitoring services for 07 projects • Support of a monitoring API to integrate with other services/projects	• EOSC-Core services developed in EOSC-F T4.3 • Initial EOSC Interoperability Framework guidelines available soon with integration support in EOSC-F T6.2 • Informal working group on Virtual Access metrics setup in EOSC-F. COUNTER of practice frameworks to be included in the discussion (RDA WG)
EOSC Collaboration Systems	Initial version delivered	https://wiki.eoscfuture.eu https://jira.eoscfuture.eu	Ability to deliver these tools independent of time-bound projects in order to avoid the overhead of migration between successive	N/A

			projects as well as the disruption caused by this for users	
EOSC Configuration Management System	In development	N/A	Support of CMT APIs and interoperability guidelines for service registration and management of service profiles	EOSC-F T4.4.1 to develop a CMDB that will include a description of EOSC-Core services and will be integrated with a ticketing system to enable easy tracking
EOSC-Core Helpdesk	In development	https://helpdesk.eosc-portal.eu	Support of helpdesk APIs and specifications and interoperability guidelines for easy integration and usage of the EOSC helpdesk system	• GGUS from KIT is currently delivered and there are plans for an update to the underlying technology • EOSC-F T4.4 - EOSC Back-Office Helpdesk System and WP5 - Front Office
EOSC Monitoring	Initial version delivered	• Monitoring for EOSC-Core services https://eosccore.ui.argo.grnet.gr • Monitoring for EOSC-Exchange services https://argo.eosc-portal.eu • Argo Monitoring Framework https://argoeu.github.io/argo-monitoring	• Rules of Participation (EOSC-A) • Maintain compatibility with monitoring services for 07 projects • Support of a monitoring API to integrate with other services/projects	Monitoring for EOSC-Core services developed in EOSC-F T4.3 with initial versions already in place and integration support through T6.2
EOSC Order Management System	Initial version delivered	• EOSC Marketplace https://marketplace.eosc-portal.eu • EOSC Service Order Management Back Office https://opsportal.eosc-portal.eu/home	N/A	EOSC-F T4.2.4 - EOSC Resources Order Management Software
EOSC Resource Catalogue: Services and Data Sources	Initial version delivered	https://providers.eosc-portal.eu https://api.eosc-portal.eu https://marketplace.eosc-portal.eu	• Maintain EOSC Profiles standard (EOSC IF) • Maintain API standard for connecting EOSC catalogues and supporting the exchange of resource description information (EOSC IF) • Maintain RoP and inclusion criteria to onboard providers and resources (EOSC-A)	EOSC-F T4.2.1 - Extend/Evolve the Registry with Catalogue Onboarding/Integration Support for assigning PIDs to services, new functionalities for providers, new functionalities for EOSC onboarding teams, and adaptation of APIs to the evolution of the profiles
EOSC Resource Registry: Research	In development	• OpenAIRE Research Graph https://graph.openaire.eu	N/A	Part of EOSC-F T3.2.1, T4.2.2, and A4.2.3 and WP5 - Front Office

Products, Services, and Data Sources		• OpenAIRE PROVIDE https://provide.openaire.eu • OpenAIRE EXPLORE https://explore.openaire.eu • OpenAIRE CONNECT https://connect.openaire.eu • EOSC Marketplace https://marketplace.eosc-portal.eu		
PIDs for EOSC Services	Not yet developed	No initial version of the service available Candidate services made available through DICE via EUDAT B2HANDLE and DataCite DOI Registration service https://marketplace.eosc-portal.eu/services/b2handle?q=B2HANDLE https://marketplace.eosc-portal.eu/services/datacite-doi-registration-service	• Maintain EOSC Profiles standard for PIDs for services (EOSC IF) • Maintain API standard for the registration of PIDs in the EOSC PID service (EOSC IF) • Maintain the EOSC PID for services namespace (EOSC-A)	EOSC-F T4.2 - EOSC Back-Office Management Tools for Providers includes activities on assigning PIDs to resource profiles and extending resource catalogue software to support PIDs

Appendix C: Status of EOSC-Exchange MVE Functions

Function Name	Current Status in EOSC Future/07 Projects	Current Reference Implementation in EOSC Future/07 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/07 Projects
EOSC Data Transfer	Not yet developed	EGI Data Transfer based on CERN FTS software https://www.egi.eu/services/data-transfer https://fts.web.cern.ch/fts	N/A	Plans to horizontalise data transfer services from similar services from thematic clusters (from ESCAPE)
EOSC Helpdesk as a Service	In development	N/A	Support of helpdesk API, specifications, and interoperability guidelines for easy integration and usage of the EOSC Helpdesk system	Helpdesk activities in EOSC-F T4.4 https://docs.google.com/document/d/1tDdpPOxRUr5wIQ2gmH41AfCQABcENU7qgXJoHzsxxPA
EOSC Research Data as a Service	Not yet developed	N/A	N/A	N/A

Appendix D: Status of EOSC-Exchange Added-value Cross-disciplinary Functions

Function Name	Current Status in EOSC Future/07 Projects	Current Reference Implementation in EOSC Future/07 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/07 Projects
Compute Infrastructure	Advanced version delivered	The infrastructure layer within the EOSC Compute Platform delivered by the EGI-ACE project https://marketplace.eosc-portal.eu/services/egi-cloud-compute https://marketplace.eosc-portal.eu/services/egi-cloud-container-compute-beta https://marketplace.eosc-portal.eu/services/egi-high-throughput-compute https://marketplace.eosc-portal.eu/services/egi-online-storage	Make the EOSC Compute Platform a recognised entity within the EOSC-Exchange and participate in its promotion to EOSC users	EGI-ACE
Compute Platforms	Advanced version delivered	The Platform layer within the EOSC Compute Platform delivered by the EGI-ACE project https://marketplace.eosc-portal.eu/services/egi-notebooks https://marketplace.eosc-portal.eu/services/egi-datahub https://marketplace.eosc-portal.eu/services/egi-data-transfer https://marketplace.eosc-portal.eu/services/egi-workload-manager https://marketplace.eosc-portal.eu/services/elastic-cloud-compute-cluster-ec3 https://marketplace.eosc-portal.eu/services/infrastructure-manager-im https://marketplace.eosc-portal.eu/services/deepaas-training-facility	Make the EOSC Compute Platform a recognised entity within EOSC-Exchange and participate in its promotion to EOSC users	EGI-ACE
Compute Services for Multidisciplinary Science	Advanced version delivered	EGI-ACE includes such services as part of its thematic services area ESFRI clusters include candidate services	Participate in its promotion to EOSC users	EGI-ACE
Data Archive	Advanced version delivered	https://marketplace.eosc-portal.eu/services/b2safe https://marketplace.eosc-portal.eu/services/datacare-object-based-	Promotion to EOSC users/communities	DICE

		storage https://marketplace.eosc-portal.eu/services/cscs-object-storage?q=CSCS+Object+Storage		
Data Discovery	Advanced version delivered	https://marketplace.eosc-portal.eu/services/b2find?q=B2FIND	Promotion to EOSC users/communities	DICE
Data Repository	Advanced version delivered	https://marketplace.eosc-portal.eu/services/b2share https://marketplace.eosc-portal.eu/services/b2handle?q=B2HANDLE https://marketplace.eosc-portal.eu/services/datacite-doi-registration-service?q=DataCite+DOI+registration+service	Promotion to EOSC users/communities	DICE
EOSC Anonymisation Tools	Advanced version delivered	OpenAIRE Amnesia https://amnesia.openaire.eu	N/A	OpenAIRE Nexus
EOSC APC Monitoring	Advanced version delivered	OpenAPC https://openapc.net	N/A	OpenAIRE Nexus
EOSC Catch-All Repository	Advanced version delivered	OpenAIRE Zenodo.org https://zenodo.org	N/A	OpenAIRE Nexus
EOSC Citation Index Service	Advanced version delivered	OpenAIRE Scholexplorer https://scholexplorer.openaire.eu OpenCitations https://opencitations.net	N/A	OpenAIRE Nexus
EOSC Community Dashboard	Advanced version delivered	OpenAIRE CONNECT https://connect.openaire.eu	N/A	OpenAIRE Nexus
EOSC Data Management Plan Service	Advanced version delivered	OpenAIRE Argos https://argos.openaire.eu	N/A	OpenAIRE Nexus
EOSC Monitor Dashboard	Advanced version delivered	OpenAIRE MONITOR https://monitor.openaire.eu	N/A	OpenAIRE Nexus
EOSC Overlay Journal Platform	Advanced version delivered	https://episciences.org	N/A	OpenAIRE Nexus
Personal/Project Workspace	Advanced version delivered	https://marketplace.eosc-portal.eu/services/b2drop	Promotion to EOSC users/communities	DICE
Policies-Based Data Archive	Advanced version delivered	https://marketplace.eosc-portal.eu/services/b2safe	Promotion to EOSC users/communities	DICE

Appendix E: Status of EOSC-Exchange Added-value Earth Observation Functions

Function Name	Current Status in EOSC Future/07 Projects	Current Reference Implementation in EOSC Future/07 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/07 Projects
Copernicus Data Pipelines	Advanced version delivered	Terradue Ellip Solutions https://www.terradue.com/portal/ellip	Provision of the ICT resources (including storage and CPU) necessary for the planned usage scenario, operations management for the hosted service, and web applications customised for the service execution and monitoring	RELIANCE
Earth Observation Analytics	In development	Use cases in the C-SCALE project will in collaboration with the infrastructure providers create deployment recipes and templates for easier reuse later and thus populating the PaaS layer	N/A	C-SCALE
Earth Observation Compute Federation	Initial version delivered	C-SCALE Compute Federation includes Cloud, HTC, HPC, Batch, and interactive processing in a distributed set of providers focusing on supporting EO use cases	Promotion to EOSC users/communities	C-SCALE
Earth Observation Data Federation	In development	Only individual providers currently exist and are used in an isolated fashion by various projects	• Promotion to EOSC users/communities • Volunteering to join the federation if they have services relevant to it	C-SCALE
EOSC Earth Observation Data Cubes Management	Advanced version delivered	MEEO ADAM Platform https://adamplatform.eu	• Provision of cloud resources to deploy the ADAM Data Access Service component • Access to Copernicus and non-Copernicus data stored in the infrastructures	RELIANCE
EOSC Research Object Management Platform	Advanced version delivered	ROHub https://reliance.rohub.org	• Make Research Objects recognised entities and named research outputs within EOSC-Exchange • Endorsement of the RO-crate specification • Promotion to EOSC users/communities • Maintain compliance framework specification (EOSC IF)	RELIANCE
EOSC Semantic Recommendation	Advanced version delivered	N/A	Promotion to EOSC users/communities	RELIANCE
EOSC Semantic Search	Advanced version delivered	N/A	Promotion to EOSC users/communities	RELIANCE
EOSC Text Enrichment	Advanced version delivered	N/A	Promotion to EOSC users/communities	RELIANCE

Appendix F: Status of EOSC Interoperability Framework Functions

Function Name	Current Status in EOSC Future/07 Projects	Current Reference Implementation in EOSC Future/07 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/07 Projects
EOSC Interoperability Framework Management	In development	N/A	• EOSC-A needs to drive the establishment of working groups that produce interoperable specifications • EOSC-A needs to establish a governance organisation and procedures to maintain the EOSC IF	EOSC-F WP3

Appendix G: Status of EOSC Support Activities Functions

Function Name	Current Status in EOSC Future/o7 Projects	Current Reference Implementation in EOSC Future/o7 Projects	Expected Responsibilities from Other Stakeholders	Planned Activities under EOSC Future/o7 Projects
EOSC-Core Support	In development	https://helpdesk.eosc-portal.eu Planned to be replaced by a new service based on a different technology (e.g. Zammad)	N/A	Support for integration of EOSC-Core services in EOSC-F T6.2, training coordination through WP9, and interoperability guidelines from T3.2
EOSC Digital Innovation Hub	Initial version delivered	The EOSC DIH was originally established by EOSC-hub and is now being expanded via EOSC Future T8.2. Collaborations have been set up with each of the o7 projects for defining what services can be offered to industry (i.e. business pilots). Formalisation with EGI-ACE, DICE, and OpenAIRE have been completed with discussions ongoing with C-SCALE and Reliance	• All activities listed to deliver the function should continue to be supported after EOSC Future ends • More formal collaboration with EOSC-A to increase visibility and importance of the DIH and to exchange information ensuring objectives, value, and results are aligned and shared	EOSC-F T8.2 - DIH

EOSC Knowledge Hub	In development	• The Knowledge Hub is being specified in EOSC-F WP9 with implementation and delivery through coordinated activities with WP5 and WP7
		
		• The Training Resource Catalogue will be populated with materials in an initial pilot phase from four existing catalogues which will serve as a testbed: EOSC Pillar, ELIXIR TeSS, SSHOC, and DARIAH
			• Various expected outputs from several EOSC-A Task Forces including but not limited to:
			  – Plans for long-term sustainability
			
			  – RoP compliance monitoring
			
			  – Coordination with Advisory Group on Research Careers and Curricula
			  – Funding to maintain and grow the Knowledge Hub should be supported through future project calls
				EOSC-F WP5 for implementation - EOSC-F WP7 for delivery - EOSC-F WP9 for specification

EOSC Observatory	In development	The EOSC Observatory is being developed and tested in EOSC Future in T2.3 in collaboration with the EOSC Steering Board and EOSC Association	All activities listed to deliver the function will need to be continued after EOSC Future ends	EOSC Future T2.3 - EOSC Observatory
EOSC Open Science Help Desk and Collaborative Tools	In development	OpenAIRE Open Science network https://www.openaire.eu/contact-noads	N/A	Development (including adoption and adaptation) of a helpdesk platform to be used as a service in EOSC-F WP4
EOSC Open Science Metrics	Initial version delivered	The Open Science Metrics will be embedded in the EOSC-F EOSC Portal in WP5 based on the	This platform provides the quantitative metrics for the EOSC Observatory. It is linked	Open Science Monitor in EOSC-F WP5 EOSC Observatory in EOSC-F WP2

		OpenAIRE Nexus OpenAIRE Observatory https://osobservatory.openaire.eu	to national monitoring systems. Expected from future calls: operation, enhancement with new indicators, quality of data via annotation and curation tools, and coordination activities for consensus on indicators	
EOSC Open Science Support	In development	OpenAIRE Open Science Support https://www.openaire.eu/support	N/A	Develop the EOSC Knowledge Hub as a Learning Management System to host courses and material and a catalogue of training material for EOSC users and providers in EOSC-F WP5 and WP9 EOSC-F WP5 - Front Office
EOSC Web Presence	Initial version delivered	• Handover of EOSC Portal from EOSC Enhance for operation and development of EOSC Portal • Operation and development of EOSC Portal and EOSC Future websites https://eosc-portal.eu https://eoscfuture.eu	• Continuation of EOSC Web Presence for operation and development of EOSC Platform by relevant stakeholders (such as EOSC-A or future projects) • Continuation of EOSC Portal website after EOSC Future ends https://eosc-portal.eu	• EOSC-F WP10 on Stakeholder Engagement, Outreach & Marketing • Connection with EOSC Association in EOSC-F WP2 • Work on Architecture and other high-level structures in EOSC-F WP3 and WP5 -Front Office

Appendix H: EOSC Future High-Level Technical Roadmap

Area	By Month 6	By Month 18	By Month 30
EOSC-Core	**EOSC Marketplace** • Shows all data collected from provider and resource profiles. Allows for scoring and rating **Provider Portal & Resource Registry** • Allows direct onboarding (web + API) but as transfer of provider and resource records from other registries and vice-versa **EOSC AAI** • EOSC AAI Federation operational **Monitoring & Accounting** • Allows checking of services based on availability of their web pages/endpoints. Can support better integration via specific metrics. Accounting supports usage tracking to support virtual access reimbursement by the EC **Helpdesk** • Helpdesk covers core services. Customisation based on new/updated technology and connected to the Service Management System **Order Processing** • Order management is set up and includes integration of providers. Already used for services inherited from EOSC-hub and others that previously enabled it **EOSC Portal Metrics Dashboard** • The dashboard provides statistics about services and requests of access and is fully integrated with the EOSC Portal	**EOSC Marketplace** • Connected to monitoring to be able to enrich feedback with availability data. Includes AI/ML-based suggestion engine interfaces to automatically pull in resources from other catalogues in the EOSC central registry **Provider Portal & Resource Registry** • Increased automatic validation tools and automatic flagging of resources which are likely to require review **EOSC AAI** • e-Infrastructure SP-proxies and cluster community AAIs fully integrated to EOSC AAI Federation. Community AAIs can integrate **Monitoring & Accounting** • Automated/self-service integration of monitoring probes and metrics offered to providers. Monitoring can track availability and reliability and accounting of usage based on parameters in provider and resource profiles (location, sector, organisation type) **Helpdesk** • Helpdesk covers core services and can redirect tickets to providers who have their own helpdesk. Helpdesk can be tested by providers who wish to use it **Order Processing** • Order management can deploy and provision resources from selected providers, including from 07 projects **EOSC Portal Metrics Dashboard** • The dashboard is enriched with additional information on EOSC resource providers and on activities of researchers in EOSC	**EOSC Marketplace** • Describe supported interfaces, standards, workflow languages, and metadata supported by EOSC resources. An advanced user dashboard is available **Provider Portal & Resource Registry** • Inbuilt or integrated management/workflow engine to support management of applications, review of records, auditing and quality control as well as automatic provider communication **EOSC AAI** • Community AAIs seamless integration with EOSC AAI federation through self-service onboarding **Monitoring & Accounting** • Automated monitoring includes automated thresholds, raising issues, or alarms in the Service Management System based on results. Accounting is related to capacity data offered by providers **Helpdesk** • Helpdesk-as-a-service available as optional add-on during onboarding. Integrated with central helpdesk functions **Order Processing** • Order processing for thematic services can bundle orders for horizontal or basic services needed to deliver the thematic service and include deployment and provisioning **EOSC Portal Metrics Dashboard** • The dashboard provides statistics related to the combined/integrated usage of EOSC resources

| EOSC-Exchange | • Resources onboarded through prior projects (e.g. EOSC-hub, EOSC Enhance, eInfraCentral) remain available
• All horizontal resources from 07 projects are onboarded
• A selection of resources from prior projects and 07 projects are integrated with functions from EOSC-Core
• Initial cluster services have been onboarded and are listed in the Resource registry in the EOSC portal and accessible through the EOSC Marketplace
• Horizontal services (publishing workflows, data transfer, data packaging, container deployment) are demonstrated through 07 service instances
• Resource requests are passed to the provider | • First release of EOSC File Transfer Service as first service arising from the clusters to become a horizontal service
• Majority of cluster resources (services, data) are available through the central resource registry and EOSC Marketplace
• All main 07 horizontal services are integrated with EOSC-Core functionalities
• Numerous other horizontal services (publishing workflows, data transfer, data packaging, VM/container deployment and orchestration) are integrated with EOSC-Core functionalities
• EOSC-Exchange offers AI/ML-enabled suggestion functions for using the portal(s)
• EOSC-Exchange highlights which services can be easily integrated or composed
• The onboarding process is extended to include validation of data sources to align to community (FAIR) metadata guidelines
• The onboarding process for resources is extended to not only list them but also to include optional integration steps in the same workflow
• Resource requests can lead to automatic provisioning of resources | • Production release of EOSC File Transfer Service
• First releases of other horizontal services arising from clusters and communities
• Ability to create thematic execution environments/VREs based on integration of compliant thematic, horizontal, and core resources
• The onboarding process allows for automated/self-service integration with some EOSC-Core functionalities
• The onboarding process for resources is extended to include more optional integration steps in the same workflow
• Resource requests integrated with procurement as well as provisioning functions
• EOSC-Exchange includes numerous services from communities other than those represented by the clusters |
| EOSC Interoperability Framework | **Resource Description Framework**
• Provider and resource description framework v3.2 including data sources

Identifiers
• Initial overview of available PID frameworks and guidelines for selecting PID types

AAI
• Initial technical guidelines for Research Infrastructures and e-Infrastructures to connect AARC-compliant AAI Proxies to the EOSC Federated AAI. EOSC AAI Federation guidelines accepted by the cluster communities and e-Infrastructures

Metadata and Ontologies
• Initial guidelines for metadata discovery and exchange on the basis of existing generic guidelines (e.g. OpenAIRE, DataCite, EUDAT, DCAT) | **Resource Description Framework**
• Provider and resource description framework v3.5 including research products and interoperability guidelines/best practices for horizontal services in EOSC-Exchange

Identifiers
• Initial guidelines for new PID types (e.g. instruments, services, software, organisations) and standards to connect PID frameworks to PID Graphs. Draft guidelines for PID service providers for minimum Kernel Type Information

AAI
• Initial technical guidelines to connect IdP and AAI proxies from public and private sector service providers to the EOSC Federated AAI should become technical guidelines for cross-infrastructure credential delegation and verification for supporting multi-step agent-driven workflows | **Resource Description Framework**
• Provider and resource description stable release v4.0 incorporating new features requested by the user and provider communities

Identifiers
• Draft interoperability framework for a PID meta-resolver and guidelines for PID service providers for minimum Kernel Type Information

AAI
• Technical interoperability guidelines for supporting cross-sector access to the EOSC Federated AAI

Metadata and Ontologies
• Guidelines for minimum metadata to support the discovery, metadata exchange, and cross-walks of research products across communities

Accounting |

Accounting • Initial guidelines for reporting accounting metrics for virtual access by INFRAEOSC-07 projects **Monitoring** • Initial guidelines for monitoring service URLs registered in the EOSC Catalogue **Order management** • Initial guidelines for managing orders specifying interfaces to forward orders to providers **Helpdesk** • Initial guidelines for handling user requests for services registered in the EOSC Catalogue **Data Platforms for Processing** • Initial guidelines for data ingesting and movement for processing in hybrid cloud environment **Data Publishing and Open Data** • Initial guidelines for data repository **Cloud Compute Containerisation and Orchestration** • Initial guidelines for VM/container management and orchestration **HTC-HPC Compute** • Initial guidelines for HPC/HTC clusters on demand and multi-tenant containerised job submission **Machine Learning** • Initial Interoperability guidelines for Machine Learning and review of existing interoperability guidelines (e.g. from EOSC-hub, OpenAIRE Advance, FAIRsFAIR)	**Metadata and Ontologies** • Initial guidelines for communities to publish community-specific metadata and ontologies in EOSC **Accounting** • Initial interoperability framework for service providers for automated reporting of accounting metrics for VA **Monitoring** • Initial interoperability framework for service providers for monitoring service availability **Order Management** • Initial interoperability framework for service providers for automatic dispatching of the orders for services registered in the EOSC Catalogue **Helpdesk** • Initial interoperability framework for service providers for automatic dispatching and handling of user requests for services registered in the EOSC Catalogue **Data Platforms for Processing** • Guidelines for data ingesting and movement for processing in hybrid cloud environment improved according to user communities' feedback **Data Publishing and Open Data** • Guidelines for data repository improved according to user communities' feedback **Cloud Compute Containerisation and Orchestration** • Guidelines for VM/container management and orchestration improved according to user communities' feedback **HTC-HPC Compute** • Guidelines for HPC/HTC clusters on demand and multi-tenant containerised job submission improved according to user communities' feedback **Machine Learning**	• Extended interoperability framework for service providers for automated reporting of accounting and usage metrics **Monitoring** • Extended interoperability framework for service providers for monitoring service availability of services registered in the EOSC Catalogue **Order Management** • Extended interoperability framework for service providers for automatic dispatching of orders for services registered in the EOSC Catalogue **Helpdesk** • Extended interoperability framework for service providers for automatic dispatching and handling of user requests for services registered in the EOSC Catalogue **Data Platforms for Processing** • EOSC-endorsed guidelines for data ingesting and movement for processing in hybrid cloud environment adopted by one or more horizontal services **Data Publishing and Open Data** • EOSC-endorsed guidelines for data repository adopted by one or more horizontal services **Cloud Compute Containerisation and Orchestration** • EOSC-endorsed guidelines for VM/container management and orchestration adopted by one or more horizontal services **HTC-HPC Compute** • EOSC-endorsed guidelines for HPC/HTC clusters on demand and multi-tenant containerised job submission adopted by one or more horizontal services **Machine Learning** • EOSC-endorsed interoperability guidelines for Machine Learning

		• Guidelines for Machine Learning/Deep Learning data analytics services improved according to user communities' feedback	
Clusters and Science Projects	**SP Deployment** • Preparation phase of SPs: cluster SPs started integration and adaptation of cluster/Research Infrastructure tools and services into the broader EOSC framework, including integration with AAI, data sources moved into EOSC (FAIR) data stores, and catalogued, software development and exchange platforms available, workflow deployment mechanisms adapted **Clusters' Input to EOSC Horizontal Services** • List of candidate services from clusters which can be generalised to be EOSC-wide offerings, with several already being developed to be EOSC-ified	**SP Deployment** • Initial deployment of SPs done: Most of the SPs have fully operational workflows using integrated EOSC services and tools, make use of EOSC Interoperability Framework, provide feedback from the science communities to the service deployment and operation, and can use resources made available through the Science Clusters/Research Infrastructures **Clusters' Input to EOSC Horizontal Services** • EOSC software catalogue/repository populated with identified cluster-provided services and tools	**SP Deployment** • Full scale operation of SPs to the point where many have full scientific analyses ready or close to publication as full demonstrations of open cross-disciplinary science. Demonstrations of the full lifecycle of data processing, storage, analysis and publishing supported by resources available and transparently integrated through EOSC. Workflows deployed across cluster/Research Infrastructure resources and where appropriate on commercial cloud and/or European HPC resources **Clusters' Input to EOSC Horizontal Services** • General availability of Research Infrastructure-originated horizontal services (as appropriate) visible through EOSC Portal and catalogues
User Experience - Resource Sharing and Discovery	• Researchers can see and reach all thematic and regional portals from the EOSC Portal • Researchers can see services from the thematic clusters through EOSC • A researcher from PaNOSC can seamlessly use compute and/or storage resources provided by the e-Infrastructures to analyse data from the PaNOSC Research Infrastructure using the PaNOSC (UmbrellaID) identity and without having to re-register across infrastructures • A researcher from a new community not involved in EOSC can get a 'virtual tour' of available resources	• A researcher searching on EOSC Portal sees a comprehensive set of resources from multiple communities and clusters • Usage statistics for datasets (views, downloads) will be collected and made available • Researchers using resources through EOSC will have common elements such as AAI, support, monitoring, and accounting • A researcher from PaNOSC can access an ESCAPE resource with the PaNOSC (UmbrellaID) identity. • Researchers using a thematic portal see resources (services,data) pulled in from the central EOSC registry	• A researcher can do the full lifecycle of data processing, storage, analysis, and publishing supported by resources available and transparently integrated through EOSC • EOSC allows research communities to build cross-disciplinary portals • Researchers can gauge the quality and suitability of resources based on usage statistics and feedback from other services

		• A richer set of horizontal services to support science is offered to researchers	
User Experience - Resource Allocation	• A researcher can request resources offered by INFRAEOSC-07 projects through the EOSC Marketplace	• A researcher requesting resources through the EOSC Marketplace portal can request access to EC-funded resources	• Requesting resources through EOSC includes the possibility to access commercial or centrally funded resources • Researchers can request HPC resources (e.g from EuroHPC) directly through the EOSC Marketplace
User Experience - Resource Composability	• Researchers can see example cases of complex workflows using multiple resource providers • Researchers can access and use EOSC computing and storage resources • Researchers can see a rich range of horizontal resources and request access to them	• Researchers can orchestrate data analysis on computing resources provided by multiple e-Infrastructure resource providers and transfer back the output to his/her storage system	• Researchers can compare and select resources based on how easy they are to compose and connect to. • Communities can offer their users fully integrated (end-to-end) workflows and a number of these are available for various research topics

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