Deliverable D3.9 Final report on the integration of services into EOSC

Author(s)	Thomas Röblitz (UiB/Sigma2), Emma-Lisa Hansson (SNIC), Ilja Livenson (UT/ETAIS)
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Deliverable lead	Thomas Röblitz
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Author(s)	Thomas Röblitz (UiB/Sigma2), Emma-Lisa Hansson (SNIC), Ilja Livenson (UT/ETAIS)
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Abstract:

Within EOSC-Nordic we started with the hypothesis that the European Open Science Cloud (EOSC) is being constructed from many services which already exist and are made available by various stakeholders: national providers, universities, research organisations, commercial companies, etc. In work package 3 (WP3), we developed tools and prototypes to answer the question "What is needed to create EOSC from existing services?". Our approach to answer that question was twofold: (1) providing tools to ensure that the building blocks (the services) are mature, and (2) establishing guidelines for the interoperability of the services. In this deliverable, we provide an overview of the work we have done, present results of using the developed tools and discuss which lessons we have learnt. We conclude by highlighting possible directions for future work.

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Introduction

More than three years ago, work package 3 (WP3) in EOSC-Nordic started with the hypothesis that the European Open Science Cloud (EOSC) will be - at least initially - built from existing services offered by various stakeholders (called *service providers* in this document): universities, research organisations, national e-infrastructure providers, regional and pan-European organisations. Key questions we wanted to answer during the project were:

- How can we support the service providers to offer their services also through EOSC?
- Are the existing services mature enough to be accepted into the EOSC service catalog?
- How can we help the service providers to improve the maturity of their services?
- What needs to be done to foster interoperability of these services?

In the remainder of the document, we first provide some context about what EOSC is and what it aims to achieve, how the whole EOSC-Nordic project was structured and what aims of EOSC were addressed by work package 3. We then describe the approach taken in work package 3 of EOSC-Nordic and provide an overview of the work done in work package 3. We briefly present work package 5 (titled "Open research data & services") of EOSC-Nordic and discuss their key findings - how they are supported by EOSC goals and what solutions work package 3 provides for their requirements. In the section "Service Provider Interviews" we report on interviews with service providers we conducted at the end of the project. We conclude the report with key recommendations for future work.

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EOSC

The European Open Science Cloud (EOSC) promises to "[...] *improve the situation for researchers in many ways, namely:*

- *Seamless access to content and services via common AAI,* [EOSC-Goal 1]
- *Access to data from various sources which is FAIR and ideally open,* [EOSC-Goal 2]
- *Access to services for storage, computation, analysis, preservation and more,* [EOSC-Goal 3]
- *Adoption of standards so data and services can be combined,* [EOSC-Goal 4]
- *Helpdesk, training and support to improve use of EOSC.* [EOSC-Goal 5]*"*

Quote from EOSC's web page[1], Labels [EOSC-Gx] were added to reference them in this document where applicable.

About EOSC

The EOSC Portal is part of the EOSC implementation roadmap as one of the expected "federating core" services contributing to the implementation of the "Access and interface" action line. It has been conceived to provide a European delivery channel connecting the demand-side and the supply-side of the EOSC and all its stakeholders. The EOSC Portal[2] is a gateway to information and resources in EOSC, providing updates on its governance and players, the projects contributing to its realization, funding opportunities for EOSC stakeholders, relevant European and national policies, important documents, and recent developments. The EOSC Portal Catalog & Marketplace acts as an entry point to the multitude of services and resources for researchers. For prospective users of the services, the Portal provides training materials and tutorials on how to use its features. The Portal also offers information for potential service providers on how to onboard their services to the EOSC Portal Catalog & Marketplace. The EOSC Portal also engages the EOSC community and stakeholders. The events and news sections cover relevant updates coming from the expanding EOSC ecosystem.

Fig. 1 shows the overview of the EOSC Portal content. Activities of work package 3 (WP3) in EOSC-Nordic were addressing issues with the categories SERVICES, RESOURCES and PROVIDERS ONBOARDING.

[1] https://www.eosc.eu/about-eosc, [online], Last accessed Oct 26, 2022
[2] https://eosc-portal.eu/about-eosc-portal, [online], Last accessed Oct 18, 2022

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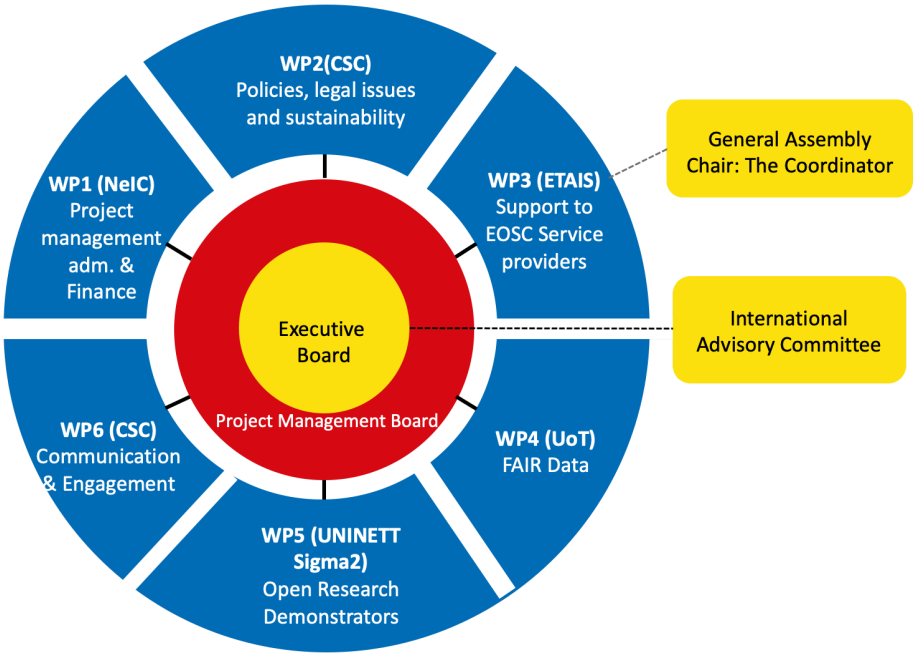
Figure 1: EOSC Portal content. Work package 3 in EOSC-Nordic was mainly concerned with the categories SERVICES, RESOURCES and PROVIDERS ONBOARDING.

Fig. 2 illustrates the different work packages within EOSC-Nordic[3]. In this report, we also briefly discuss other work packages, particularly, work package 5 for lessons learnt about the uptake of EOSC services by demonstrators and work package 2 for reviewing added value propositions for service providers considering to integrate with EOSC.



[3] https://www.eosc-nordic.eu/organisation/, [online], Last accessed Oct 18, 2022

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Figure 2: Overview of work packages in EOSC-Nordic[4]. In this report, we also briefly discuss other work packages, particularly, work package 5 for lessons about the uptake of EOSC services by demonstrators and work package 2 for reviewing added value propositions for service providers considering to integrate with EOSC.

EOSC-Nordic approach to service providers and services

Approach of EOSC Nordic Work Package 3

The two main goals of work package 3 (WP3) in EOSC-Nordic were:

[WP3-Goal 1] Identify existing Nordic generic and thematic service providers and support their integration and the discovery of their services via the EOSC portal and other relevant catalogs.

[WP3-Goal 2] Foster the organizational, semantic and technical interoperability of service providers and propose solutions for improving the interoperability approach within EOSC.

For goal 1, we have developed a model to assess the maturity of services (D3.1). In three iterations, we applied the model on dozens of services from all Nordic and Baltic countries in three iterations and used the lessons learned to incrementally enhance the model (D3.2 & D3.5). Enhancements added new aspects and also helped to improve the clarity for applying the model. The model is designed such that it associates three levels of maturity - minimum, intermediate and high - depending on which criteria are met by a service. These maturity levels may be used to help improve the maturity of services. With our work for goal 1, we intend to support EOSC's goals [EOSC-Goal 1, 2, 3 & 5] (see Section "EOSC" above).

For goal 2, we have developed interoperability guidelines and implemented prototypes demonstrating how services can interoperate with each other. If EOSC shall also foster the composition of (scientific) workflows spanning several services, the services need to be able to interoperate with each other. Constructing EOSC from existing services then raises the questions, can these services interact with each other and what guidelines can be provided to ensure that they (and future services) can interact with each other. We analyzed existing frameworks for interoperability, developed a framework specifically for the needs of EOSC-Nordic (and EOSC) and applied it to three interoperability scenarios (D3.3). With our work for goal 2, we intend to support all EOSC's goals but focusing mainly on [EOSC-Goal 1 & 4] (see Section "EOSC" above).

Related work relevant to WP3

Achieving the goals of WP3 was supported by other work packages in EOSC-Nordic. Here we specifically highlight work package 5 (WP5). WP5 worked with use cases to demonstrate how EOSC services could be used in cross-border scenarios. In Section *Results of EOSC-Nordic work package 5 (WP5)*, we briefly discuss the work that has been done by WP5, their findings and how it affects results of WP3.

[4] Image taken from the EOSC-Nordic project web page at https://www.eosc-nordic.eu/organisation/, [online], Last accessed Oct 18, 2022

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Details of work done in EOSC-Nordic WP3

In work package 3, we organized work in two main tasks: **T3.1 - Integrating service providers & services in EOSC** and **T3.2 - Improving service interoperability across EOSC**. Task T3.1 was aiming at [WP3-Goal 1] (see section "Approach of EOSC Nordic Work Package 3") and resulted in the deliverables *D3.1 - EOSC Service compliance checklist and maturity model* [D31], *D3.2 - First report on mapping of EOSC prospective service providers and candidate services* [D32], *D3.3 - Service Interoperability* [D33], *D3.5 - Second report on mapping of EOSC prospective service providers and candidate services* [D35] and *D3.8 - Programmatic access and resource provisioning of Nordic services via EOSC Marketplace* [to be submitted by Nov 2022]. Task T3.2 looked into realizing [WP3-Goal 2] (see section "Approach of EOSC Nordic Work Package 3") and resulted in the deliverables *D3.4 - Programmatic access and resource provisioning of services* [D34], *D3.6 - Feasibility Assessment of the Implementation of X-Road for Research Data* [D36], *D3.7 - Report on the implementation of X-Road in the Nordics and recommendations to EOSC* [D37]. In the subsequent paragraphs we will describe the goals and main results of these deliverables. For more details we refer the interested reader to the publicly and openly available deliverable documents. Note, some of the deliverables are not yet approved by the European Commission as they were submitted during the same reporting period as this deliverable.

Deliverables aiming at WP3-Goal 1 (Integrating service providers & services in EOSC)

D3.1 - EOSC Service compliance checklist and maturity model. The two goals for creating the compliance checklist and the associated maturity model were to create a shared understanding of what an EOSC Service is in the Nordic and Baltic region, as well as create an easy to use method for evaluating existing and future services for EOSC compliance.

D3.2 - First report on mapping of EOSC prospective service providers and candidate services. For this deliverable we were creating an initial inventory of services offered by national research infrastructure providers. Basic information about 49 services from 18 providers across 8 countries were collected. Then, we used the compliance checklist and maturity model developed in D3.1 to analyze a sample of that inventory. We presented assessment results covering aspects of service management, data management and service quality, accessibility and legal requirements, sustainability and financial aspects as well as EOSC architecture compatibility. Using the maturity model in practice also led to improvements of the model.

D3.3 - Service Interoperability Framework. Ultimately, this deliverable aims at improving the interoperability of services in EOSC. It leverages existing interoperability guidelines such as the European Interoperability Framework (EIF) and efforts for an EOSC interoperability framework. The two main objectives of D3.3 are: (1) to support Nordic and Baltic service providers in enhancing the interoperability of services in cross-border environments, and (2) to contribute to discussions towards the development of the EOSC interoperability framework.

D3.5 - Second report on mapping of EOSC prospective service providers and candidate services. This deliverable builds upon work done for D3.2 by augmenting the service inventory template with criteria to analyze services in terms of cross-border consumption, cross-border collaboration, commercial usage,

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academic usage and access policies. Results of assessment and reflections on the assessment procedure allowed us to improve the overall service mapping process. In total, 60+2 services from 8 countries as well as 2 areas (Nordic & European) were analyzed.

D3.8 - Programmatic access and resource provisioning of Nordic services via EOSC Marketplace. This deliverable summarizes the efforts taken to establish an EOSC Nordic service access gateway serving as both pre-onboarding platform for connecting EOSC users with the Nordic-Baltic region as well as technical interoperability platform for users within the region. The platform is integrated with 3 of the EOSC Core services - Provider portal, Marketplace and Helpdesk - and relies on NeIC Puhuri for sustainability and further development.

Deliverables aiming at WP3-Goal 2 (Improving service interoperability across EOSC)

D3.4 - Programmatic access and resource provisioning of services. Scalability and sustainability of the EOSC model require that mostly human-driven EOSC processes be automated as much as possible. This deliverable presents ongoing work towards a system for programmatic access and resource provisioning of services. The two main objectives of the deliverable are: (1) to present the high level approach taken by EOSC-Nordic, creating a regional gateway platform for EOSC with initial focus on Service providers, and (2) to present the initial results including experienced obstacles and to sketch out the plans for the further evolution.

D3.6 - Feasibility Assessment of the Implementation of X-Road for Research Data. X-Road provides secure data exchange between organizations. For this deliverable, we performed a case study involving partners in three countries. The case studied was about using X-Road to securely transfer data from one partner to another. We report on setting up the proof of concept and discuss experiences with respect to organizational as well as technical matters. We found that X-Road is well-suited for securely transferring data in real-time applications.

D3.7 - (Second) Feasibility Assessment of the Implementation of X-Road for Research Data (was: Report on the implementation of X-Road in the Nordics and recommendations to EOSC). This deliverable reports on the second iteration of feasibility assessment of using X-Road for cross-border research data exchange. It presents experience with integrating a new service with X-Road and provides a set of recommendations for EOSC for cross-border service delivery.

Selected Results of WP3 and WP5

Maturity model

Starting from our hypothesis that the EOSC ecosystem is built - at least initially - from a set of services that already exist and are provided locally (for users of an organization) or nationally (for users within a country), service providers need guidance in making sure that their services comply with EOSC requirements. We developed the maturity model to assess how well candidate services fulfill EOSC requirements. For the design of the maturity model, we choose to focus on three aspects: (1) supporting the collection of uniform service descriptions, (2) providing guidance on improving the maturity of services, (3) addressing cross-border issues.

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With aspect (1) we want to ensure that services are easy to understand and to compare by EOSC users. A service's description should provide information about what functionality it provides, who can access the service, how to access the service, what does it cost to use the service, for how long the service will be provided, what support is provided to users of the service, etc.

The maturity model described in deliverable D3.1 [D31] supports aspect (1) by providing a minimum set of information that needs to be provided for each service (Table 1 Compliance checklist and maturity model, page 12, deliverable D3.1 [D31]). Considering the overall maturity of mapped services (see deliverables D3.2 [D32] and D3.5 [D35]) it should be noted that with proper help and guidance minimum requirements should be achievable with reasonable amounts of work.

Aspect (2) aims at guiding service providers to prioritize potential improvements to a service, for example, to provide documentation in English or to enable it being accessed via federated AAI. Ultimately such improvements shall increase the service's value for existing and future users. Providing tools for guiding such improvements may help in evaluating trade-offs between implementation efforts and increased value for users.

The maturity model (see deliverable D3.1 [D31]) defines three levels of maturity: minimum, intermediate and high. In our first assessment of existing services in the Nordic and Baltic region (see deliverable D3.2 [D32]), we found that there are a number of already mature services that could relatively be easily added to the EOSC catalog from the technical point of view. Besides technical maturity and compliance with EOSC, there may be other reasons prohibiting mature services from being added to the EOSC catalog, such as governance and funding.

The assessments also revealed more challenging areas of services, particularly, awareness, competence and managing of intellectual property rights (IPR) and GDPR compliance. Information about these areas were either not available, missing or not known also for services that were generally/technically considered mature. Thus these areas should receive more attention in future work through establishing more clearly defined requirements, and through increasing competence with the service providers to design and operate services that meet these requirements.

Research is increasingly conducted in collaboration not only across disciplines but also across borders. Improving existing and developing new e-infrastructure tools and services more than ever requires significant investments which - traditionally - were overwhelmingly funded by local or national stakeholders. Enabling the use of services across borders will help with both challenges. Researchers will be able to more easily collaborate across borders and service providers will be able to create more income via additional users. However, cross-border use requires addressing a number of additional issues typically not found in a local / national scenario. Work for aspect (3) aimed at capturing such issues and increasing awareness among different stakeholders (mostly service providers and e-infrastructure funders).

In our second assessment (see deliverable D3.5 [D35]), we augmented the maturity model developed in deliverables D3.1 [D31] and D3.2 [D32] by adding mapping criteria which help to analyze services in terms of cross-border consumption, cross-border collaboration, commercial usage, academic use and access policies.

The majority of the services mapped are within five categories - compute, data storage, data analysis, data management and data sharing. Services are provided mainly towards (academic) researchers, and they can be accessed remotely or virtually. A **key obstacle for offering services across borders** is that consumable resources (servers, cloud-like platforms, high-performance clusters, data storage, etc.) are predominantly funded through local or national programmes which limit the audience for their

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consumption. Some services are open for cross-border collaboration requiring only that the project's principal investigator is affiliated with the organization/country that offers the services and project members can be affiliated with any other organization also abroad. While offering services for payment may seem as an alternative particularly for providers, they pose additional requirements. Providers may be limited by state aid rules and through the need for charging value added tax paid services may become less attractive for users. In deliverable D3.5 [D35], we discuss several drivers and inhibitors for cross-border consumption in more detail.

Interoperability (framework)

While offering a portfolio of individual services within EOSC already provides a great value to researchers, EOSC's full potential may only be reached when these services can interoperate seamlessly to let users easily construct complex interdisciplinary workflows. Through assessing existing services when developing the maturity model we learned about many services that are attractive for users. However, their appeal would be much larger if they could be assembled in workflows thus supporting interdisciplinary and collaborative research. Hence, we looked into what is required for services to enable interoperability and what obstacles may exist. In D3.3 [D33], we argue that EOSC's work on interoperability so far has focused mainly on data and research output, and that an efficient research data lifecycle is supported by services, software and infrastructure. Thus, our work aimed at augmenting the existing work within EOSC by highlighting service interoperability aspects and mechanisms relevant for all services geared towards open science. Specifically, we aimed to highlight how services can interrelate so as to deliver expected value to users in cross-border contexts. We provided a first description of the elements that should be addressed in order to achieve better alignment and interoperability of services.

Our starting point was to analyze existing interoperability frameworks, namely the European Interoperability Framework (EIF) and the EOSC Interoperability Framework (EOSC-IF). The EOSC-IF was still a draft when D3.3 [D33] was worked on and focused mainly on data and related research artifacts. The EIF in contrast was well established but not targeted for research communities. However, it (the EIF) defines an interoperability model distinguishing four major aspects of interoperability: legal interoperability, organizational interoperability, semantic interoperability and technical interoperability.

In addition to the four layers of interoperability described by EIF, and consequently adopted by EOSC-IF (technical, semantic, organizational and legal), we also considered recommendations covered under other underlying principles (subsidiarity and proportionality, openness, transparency, reusability, technological neutrality and data portability, user-centricity, inclusion and accessibility, security and privacy, multilingualism, administrative simplification, preservation of information and assessment of effectiveness and efficiency) and the conceptual model of the EIF. The goal was to focus on recommendations that would improve service interoperability across services providers, considering diversity of providers and services themselves. Overall, we selected recommendations based on a common understanding of the recommendations' relation to service-related concepts (e.g. service management, service architecture and design, service operations, accessibility, processing of research data). This exercise resulted in 21 recommendations.

We then used the selected recommendations as a basis for formulating questions intended for assessing the services. The purpose of the questions was to convert the ideas in the recommendations into expressions that would be comprehensible and potentially easy to answer. The questions were intended for service providers, because they are normally responsible for the services during different phases - design, development, production etc. We used an iterative process to refine the questions intended for a subset of the recommendations. In order to capture the essence of the recommendations while minimizing loaded and run-on questions, we found it was helpful to use more than one question for some of the

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recommendations. As a result, we grouped 35 questions out of the 21 recommendations into the 6 topics: core interoperability principles, generic user needs and expectations, legal interoperability, technical and organizational interoperability, semantic interoperability and conceptual model (for a detailed list of the suggested question see deliverable D3.3 [D33]).

The questions' validity were assessed in a case study with six services: three HPC services, two data management services and a resource allocation service. We found that services' compliance with the recommendations vary by a large degree. With few exceptions, the intentions of our questions seem to have been clearly understood by the service providers. However, a few questions were unclear when applied in practice, leading to unexpected responses or misinterpretations. We discussed if end-user behavior should be in scope for interoperability, how to design effective questions and whether future user requirements will increase the importance of interoperability frameworks. We suggested several topics for future work such as gearing questions specifically towards two audiences with largely separate views/needs: service providers and service consumers (see details in deliverable D3.3 [D33]).

We concluded that interoperability issues are usually complex, often requiring consideration from different viewpoints. Despite the complexities, the service providers demonstrated a high degree of awareness, insight, and responsiveness of the interoperability issues. The reflections made by the service providers are useful for achieving interoperability in practice. The **development of interoperability frameworks should leverage on engagement with the right stakeholders** e.g. service providers, end-users, policy makers, funders etc. Comparing different types of services using a homogenous set of questions is difficult because of the unique characteristics among the services. In the future, this may be solved by conducting analyses in the context of each service type and/or user base. Such comprehensive evaluations for further development would require high degrees of coordination.

Results of EOSC-Nordic work package 5 (WP5)

EOSC-Nordic's work package 5 (WP5) titled "Open research data & services" was exploring and implementing a number of use cases in different scientific domains to evaluate and demonstrate if and how EOSC services can be used. The focus of WP5 was to look into cross-border scenarios and document what works well and what needs to be improved to fully realize EOSC's potential. In this section, we briefly list the use cases WP5 has worked on, highlight their key findings and discuss how their case studies might have benefited from fully implemented goals of EOSC (see goals [EOSC-Goal 1] to [EOSC-Goal 5]). Finally, we reflect on how the needs of the use cases are served through work of WP3, that is if and how the maturity model and interoperability framework captures key findings of these use cases. For details of the work done by WP5, we refer the interested reader to the extensive deliverables for which references are provided where applicable.

In deliverable D5.1 [D51], the EOSC service B2FIND is used to harvest hundreds of thousands of metadata records from two repositories for archaeological objects in Denmark and Norway. The case study required some processing of the metadata during the ingestion procedure, and, most importantly, significant rewriting of the server-side code at B2FIND to make that more flexible. For another use case, cross-border computing through portals was studied in deliverable D5.2 [D52]. They used the EOSC service usegalaxy.eu and PlutoF to send jobs encapsulated in Singularity containers to remote resources. They considered Cloud platforms and HPC systems as execution platforms. In deliverable D5.3 [D53], the challenge of making research software setups portable was looked into. The research software environment contained natural language processing software that grew organically over many years on a single HPC system. They looked into using container technology and software packaging tools such as EasyBuild to make their installations reproducible and thereby portable. The work reported in deliverable D5.4 [D54] studies easy to use

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collaborative work environments with specific emphasis on data sharing, data reuse and resource integration. They used different platforms such as EGI, BinderHub, NIRD Service Platform to run Jupyter notebooks, share datasets within these environments and execute workflows on different backends. Finally, deliverable D5.5 [D55] reports about the effort to make (research) data management plans (DMPs) machine actionable, that is enabling machines to process the information contained in a DMP. Four existing tools to create and maintain DMPs were used as basis to enable them providing DMPs that conform to the RDA DMP Common Standard (RDCS) maDMP-schema. For example, enabling DMPs created with the Norwegian easyDMP would allow integrations with the NIRD storage allocation service and the NIRD archive such that researchers more easily get access to resources for storing and archiving data. Adopting the RDCS maDMP-schema by easyDMP would also open new possibilities for integrating with community-specific tools such as the Data Steward Wizard which is used by researchers in the Norwegian Elixir-NO community to develop data management plans.

Key findings of work package 5

Reports of work package 5 discuss in detail lessons learnt and directions for future work. Here we focus on key findings that could be relevant for tools developed in work package 3. WP5 found that:

- there is a lack of cross-border coordination and harmonization of access control and resource allocation (finding F1),
- services lack standardized means of interoperability (finding F2),
- researchers need substantial onboarding and training to use services at their full potential (finding F3),
- services for data management and data sharing largely exist isolated and/or provide only basic configurability to adjust them to needs in use cases or information about details of their capabilities is missing (finding F4),
- often the future availability and development of services are unclear (finding F5).

To increase the utility of EOSC as a whole these findings should be addressed in future work. Some findings may be addressed by improvements to individual services, some require coordinated actions involving improvements/standardizations at the interfaces between services and some need attention by EOSC to improve its platform.

Gap analysis considering EOSC goals and results provided by EOSC-Nordic WP3

We analyze if and how the key findings of work package 5 are addressed by both the goals of EOSC and the results of work package 3 of EOSC-Nordic.

How do EOSC goals address key findings of work package 5

Revisiting the goals of EOSC, which were provided at the start of this document and copied here for convenience, we discuss how these goals address the findings of WP5.

- *"Seamless access to content and services via common AAI,* [EOSC-Goal 1]
- *Access to data from various sources which is FAIR and ideally open,* [EOSC-Goal 2]
- *Access to services for storage, computation, analysis, preservation and more,* [EOSC-Goal 3]
- *Adoption of standards so data and services can be combined,* [EOSC-Goal 4]
- *Helpdesk, training and support to improve use of EOSC.* [EOSC-Goal 5]*"*

Finding F1 ("lack of cross-border coordination and harmonization of access control and resource allocation") is addressed by [EOSC-Goal 1]. **Finding F2** ("services lack standardized means of

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interoperability") is partially addressed by [EOSC-Goal 2]. There could be more emphasis on ensuring that services provided through EOSC can interoperate with each other in standardized ways. **Finding F3** ("substantial need for onboarding and training to use services at their full potential") is addressed by [EOSC-Goal 5]. **Finding F4** ("services for data management and data sharing provide only basic configurability") is not addressed by any of the EOSC goals individually nor by the combination of all goals. This is a shortcoming that could be addressed by conducting more (demanding) case studies and providing requirements on improving service capabilities. **Finding F5** ("future availability and development of services are unclear") is not addressed by any of the EOSC goals. This should be addressed in future work because researchers need to have trust in the availability of a service in the long-term or they may find it too risky to invest in their use (investments such as training, adjustments of their workflows, development of integrations, etc.)

How does work package 3 of EOSC-Nordic address key findings of WP5

We focus our analysis on how the maturity model and interoperability framework address these findings and derive recommendations for future work beyond the scope of EOSC-Nordic.

Finding F1 ("lack of cross-border coordination and harmonization of access control and resource allocation")**.** While the access to services is assessed through several criteria in the maturity model, specifically in section 3 ("Accessibility and legal requirements") criteria L-1 and L-2 as well as additional cross-border questions WP3 looked into with D3.5 [D35], none of these seem to address finding F1 well enough. Similarly, the interoperability framework described in deliverable D3.3 [D33] does not address this finding specifically. However, recent developments such as NeIC Puhuri[5] project, which provides a service for seamless access to (remote) services and allocation of remote resources demonstrate that solutions for the finding are being developed or already in use (for the EuroHPC JU pre-exascale system LUMI).

[Future Work 1] The maturity model and/or interoperability framework could integrate additional criteria/questions into their templates specifically improving the cross-border maturity with respect to access control and resource allocation.

Finding F2 ("services lack standardized means of interoperability"). Interoperability is addressed to a limited extent by the maturity model in section 2 ("Data management and FAIR data requirements" and envisions relevant criteria in its section 5 ("EOSC architecture compatibility"). The latter section can only be seen as a placeholder because the relevant specifications were not available at the time when the maturity model was developed and used for assessing existing services. WP3's work on the interoperability framework is poisoned to fill that gap or at least provide substantial guidance on helping providers develop and offer interoperable services.

[Future Work 2] The maturity model could be updated to cover new developments in EOSC's architecture.

[Future Work 3] A future revision of the maturity model could incorporate specific criteria or even the full interoperability framework.

Finding F3 ("substantial need for onboarding and training to use services at their full potential"). This is marginally addressed by section 1 ("Service management") criteria S-4 ("Service documentation for end users is publicly available"). Specifically, the availability of onboarding and training offerings (materials, tutorials, courses, etc.) is not covered in the maturity model.

[Future Work 4] Onboarding and training offerings should be addressed in a future version of the maturity model.

[5] https://neic.no/puhuri/, [online], Last accessed Nov 10, 2022

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Finding F4 ("services for data management and data sharing provide only basic configurability"). While such configuration capabilities seem very valuable - at least for specific use cases - it is not immediately clear how services should be assessed, because it may require detailed a-priori knowledge about what researchers need or expect from a service and this may also vary significantly from case to case. At the moment such detail is not enquired during the assessment of services. Maybe it is not even practical/feasible to provide such detail for all kinds of scenarios, but rather provide links to technical documentation and/or contact points for technical enquiries. To some extend the maturity model captures this idea with section 1 ("service management") criteria S-2 ("Contact address for end-users is publicly available"), S-4 ("Service documentation for end users is publicly available"), S-6 ("Detailed service installation documentation exist"), S-15 ("Service release notes [...]") and S-16 ("Channel to recommend service enhancements exists"). However, all the information made available and the channel to suggest enhancements may not be sufficient for a user in an ongoing case.

[Future Work 5] The maturity model could try to capture how information about the configurability of a service or means for its customizability can be assessed.

Finding F5 ("future availability and development of services are unclear"). This is directly addressed by the maturity model section 1 ("service management") criteria S-13 ("Service roadmap [...]") and section 4 ("sustainability and financial"), however, are only required for services that meet intermediate or high maturity. Due to its importance, particularly, for how long in the future a service will be available, this information may be required even for services with minimum maturity.

[Future Work 6] An update to the maturity model could consider to adjust what criteria a service must meet to fulfill one of the maturity levels minimum, intermediate or high.

Service Provider Interviews

Service providers' support in the research process

Three service providers that had previously been contributing to the WP3 results were interviewed as we aimed to get knowledge on where in the research process Nordic and Baltic HPC centers provide services to users. We also aimed to investigate the future development of these service providers and how they have used the results from EOSC-Nordic WP3. To drive the interviews and formalize the positioning of service providers in the research landscape, we have adopted the enterprise architecture approach described below.

About business architecture as a method

Business architecture refers to the structure of the business, its constituent parts, and how these interact, as well as the interfaces with the environment; users, suppliers, partners and more. The business architecture describes which conditions exist in the business, what *capabilities* the business has, how the business's processes look like, as well as which information resources and IT support are handled in the business. In this deliverable we are using the Milky Way[6] as a basis to visualize today's solutions and the imagined future ones. The Milky Way is a way to map, navigate and develop a business. The Milky Way creates an overview and insight and increased customer value. With a well-documented architecture, there is a possibility to get a common picture of the business and a good basis for decision-making and streamlining the business.

[6] Nordén, Cecilia. - Vintergatan : din verksamhetskarta : Navigera och utveckla med full kontroll. Kartlägg, navigera och öka förändringstakten. Cecilia Nordén, Linda Lilliesköld (ill.). - 2020 - Second edition. - ISBN: 9789197711944.

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The method makes it possible to make patterns visible. The Milky Way map is an anchor model (see Fig. 3) and for this deliverable insert the HPC centers into the research journey and highlight important parts where they give service to users.

The visual maps of the service providers are made through interviews lasting for about one hour with one person representing the organization and only captures the current state. The selection of the three services is too small to derive any broader conclusions on the current state of HPC services in the Nordics and the Baltics, rather it was intended to provide a sort of validation on the outcomes of WP3 in the region.

This work builds upon a project at Lund University regarding operational mapping of the research data area (Hansson & Lassi, Rapport för projekt Verksamhetskartläggning forskningsdata: Ett underprojekt till uppdrag Samordning av universitetets hantering av forskningsdata, 2021[7]) and also a project on a national level in Sweden (Hansson, Lassi, Olsson, Persson, Rapportering av projektet Forskares behov av lagringslösningar för forskningsdata – ett samarbete mellan SNIC, SND, SUNET, Chalmers tekniska högskola och Örebro universitet, 2022[8]) that describes the results where an enterprise architecture approach has been used to understand, explore and describe researchers' practices and needs for support in their work with research data management, and especially data storage.

With the work done in Sweden, the researchers recognized themselves in the anchor map, and accepted this image of their research process. Thus, the map is agreed and verified not only by supporting organizations within the national collaboration in the business architecture for research data in Sweden, but also in aforementioned studies with researchers, where they reviewed and discussed the map. The map was initially made in Swedish but was translated to English and used in the interviews with researchers.

The same anchor map is used in this deliverable to map the e-infrastructure services. Even though the service providers are not in research but provide service through parts of a research journey, the service provides could recognize themselves in the research process and map out where the services take place. 8 service providers were asked to participate in the interviews and 3 service providers participated.

[7] https://doi.org/10.5281/zenodo.6247046
[8] https://doi.org/10.5281/zenodo.6353925

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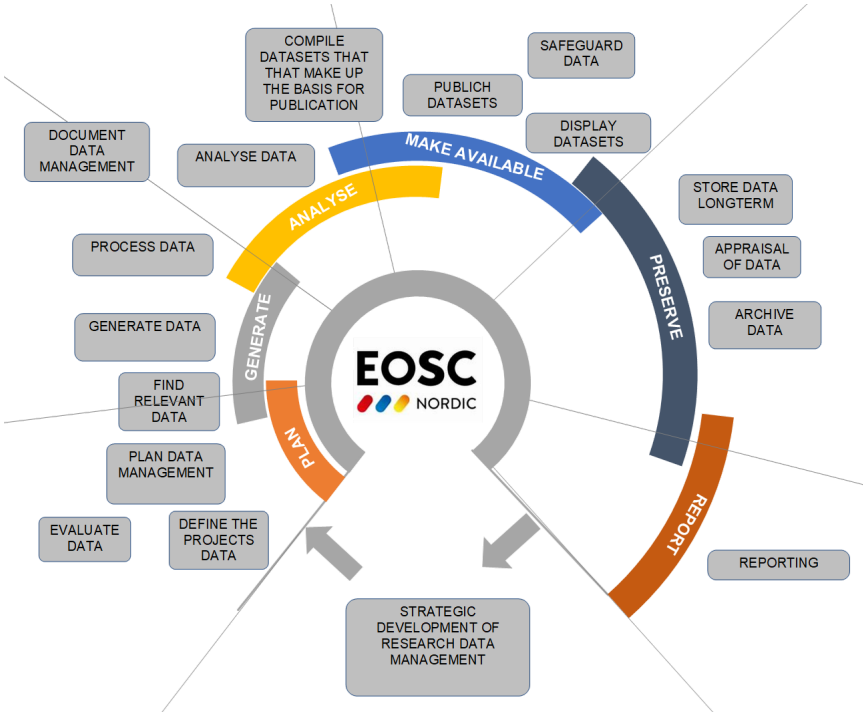

Figure 3. Anchor map of the researcher journey.

How to read the map

The inner sections are stages that represent the researcher's journey throughout a project. These stages are PLAN, GENERATE, ANALYZE, MAKE AVAILABLE, PRESERVE and REPORT.

- PLAN - The researcher seeks grants from research funders and begins to plan the handling of data throughout the research project.
- GENERATE - This stage concerns generating data, for example via surveys, interviews, observations, calculations, simulations and more. This also includes when the researcher starts processing, storing active data and documenting the data management.
- ANALYSIS - The researcher analyzes the data collected or created and compiles data sets that form the basis of publication.
- MAKE AVAILABLE - The researcher makes available the completed analyzed data, which are presented in forms that allow others to take part in them (for example, repository).
- PRESERVE - The researcher needs to preserve data stored after a research project is completed.
- REPORT - The researcher reports after completing the project to e.g. the research funder.

The gray areas are capabilities and a capability is a cohesive, limited and independent component of the business and in the business architecture. It is a component that consists of processes, information, competencies, regulations, IT support and more.

Green squares indicate where a service is active on giving service to users.

Purple square is in EOSC-nordic related areas.

The yellow squares indicate areas that need improvement.

The following maps are maps on where the respective service provider gives services to users.

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Service providers - interviews

Description of the services

In Finland, CSC services are already connected to the researcher journey and have a classification system where it is easy for a researcher to see where a service would fit into a research process. See Fig. 4 for a visual illustration of the mapping results.

The main services that SNIC[9] provides today are within compute and storage resources, with various types of compute resources and storage resources, but also user support. SNIC is a consortium with a split funding, its 10 universities and university funds 50 percent of the funding and the Research Council funds 50 percent. Starting in 2023, it is not going to be a consortium anymore. It is going to be hosted by Linköping University and Linköping University will be the sole recipient of funding and have national responsibility. See Fig. 5 for a visual illustration of the mapping results.

Services for researchers are included in Finland. Finland has domain specific IT-support and other support for researchers which includes software, documentation, tutorials & training. Finland is active in all the stages to different degrees and tries to be present throughout the research process for the researcher. The service provider representative that was interviewed is not involved in all the services that are provided, but has worked at CSC for a longer period of time and has awareness of the services provided.

RTU in Latvia provides advanced IT support, which means that RTU has team members who are domain experts helping users with the use of the services and also to make decisions in selecting the right tools for their research. It is somewhere between IT and research support. See Fig. 6 for a visual illustration of the mapping results.

How the WP3 results have been used by the service providers & how EOSC can facilitate the e-infrastructure landscape

All of the service providers are aware of the WP3 results.

CSC is partly aware of the WP3 results and thinks that the maturity model was relevant for the integration, but that other WP3 results have not been used yet.

SNIC is aware of the WP3 results and the maturity model, but has not used the WP3 results.

RTU is aware of the WP3 results and found them helpful to evaluate the maturity of RTU services. The WP3 tools helped to identify weak spots of RTU:s services and to improve their maturity.

In Finland some of CSC's services are available through the EOSC portal. At the moment, there are no plans to add more services. There are some basic issues with the integration of SNIC services into EOSC. Researchers are used to search for services in national catalogs and follow national guidelines to obtain resources for their projects. At the moment RTU is not aiming to include its services into the EOSC catalog.

Recommendations from the service providers on future work to support e-infrastructures is financial support and IT-expertise. EOSC could provide added value for a service provider by advertising their services such that researchers from other countries would know about these services. If it was data service then there might be additional benefits through EOSC interoperability of data. For HPC services, there seem to be fewer benefits. Regional service catalogs may be sufficient to advertise services and regional service catalogs may be more appropriate, at least for HPC services. The main issue is that without a good central authorization and resource allocation platform it is very hard that EOSC becomes a significant entry

[9] https://www.snic.se/

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point for users. There has been a lot of discussion for a minimal viable EOSC, but a set of common services that would make sure that EOSC works has not manifested itself yet.

Recommendations for EOSC would include clear and minimal requirements for the services to be integrated to reduce the amount of extra work for the services. There has not been much uptake of CSC's services offered through EOSC been seen. A good financial model is needed such that service consumption can be compensated.

Building up resources for EOSC could be based on EuroHPC JU jointly funded HPC machines such as LUMI. Thus, providers would benefit from pooling together different infrastructures which provide similar services.

The stages in the map

CSC assists the *planning* stage when researchers start their research data management plan. When the researchers start to generate data, CSC provides data storage. If a researcher has simulation data tools for simulation and software are provided. Software includes high performance computing software for different disciplines. Some of the tools are cross-disciplinary. CSC also has classified their service depending on if it's active data and where in the lifecycle service process the service is used by the researcher. One of the supercomputers (Mahti) is classified as *collect* and *compile*. Cloud services are used earlier in the process. The supercomputer Mahti can be used in the *generate* stage if a researcher wants to generate simulated data. On the other hand, cloud services can be used if a researcher has generated data. In the *analyze* stage CSC offers many services for meeting computing needs. In the make available & preserve stage, the Allas object storage is used where you can annotate, share and publish data also. They specifically also have long term digital preservation services for data. In the report stage, CSC supports principles for FAIR data, for example, researchers can generate DOI:s to refer to publications.

Historically, CSC is highly focused on capabilities for analyzing data. Supercomputers operated by CSC are tailored towards analyzing data. Nowadays CSC is aiming at offering additional capabilities.

SNIC services are on when a researcher has computational needs or when a researcher believes to have computational needs. This includes storage needed during the computations, but excludes long term storage (archiving/preservation of results). SNIC offers services both for *generating* and for *analyzing* data (with a focus on analytics). Researchers generate data by using compute resources. SNIC has no mandate to *make available* and to *preserve* datasets. The universities in Sweden are responsible for those stages. SNIC operates storage resources, but those are used for data that is processed on compute resources. The user support can perhaps be put into the stages *generate* and *analyze* too. User support includes everything from first line support to application experts that know specific software.

The main capabilities developed in SNIC are *process data* and *analyze data*. Researchers obtain compute allocations to process and analyze data. SNIC services are widely used by researchers in about 1800 projects per year. SNIC also has a broad spectrum of disciplines using national HPC resources, from humanities, to social sciences to chemistry and physics. SNIC supports all sciences when it comes to providing allocations for processing and analyzing data.

The main field of RTU work is in the stages *generate* data and *analyze* data. RTU is less involved in stage *make available* because usually it is made available in repositories which are outside of RTU:s mandate. In some cases, RTU provides access to data which is stored on HPC.

When new users start using RTU services, they are trained in how to use them. Such onboarding training lasts for a minimum of one hour. Domain experts at RTU can help novice users to select the right tools for

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their research. On the HPC machine, this concerns usually software they use to *generate* or *analyze* data. In addition, RTU provides regular support for any problem a user experiences on the services. The data which is generated on HPC usually comes from simulations and it could be analyzed with additional tools.

RTU is well developed in *processing data*, *analyzing data* capabilities and employs experienced staff who can support users. Personal assistance is augmented by documentation.

How the services are provided

Researchers pay for usage and usually most users get access to RTU services. RTU reviews applications, but if they are ready to pay for what they use, most likely RTU will provide the service without a scientific evaluation of their project proposal. RTU provides assistance to assess what type of service they need (HPC or something else).

A researcher with Swedish affiliation goes through a proposal process. All proposals undergo a technical review. Larger proposals also require a scientific review. SNIC allocations are limited to a maximum of one year. Allocations are distributed as quota per month.

National research infrastructures which have received funding from the Swedish Research Council may enter into agreement with SNIC, buying services which could be compute and storage resources and also assistance by SNIC personnel.

For a small amount of CSC's services users can self register and start using the services. For heavier use there is an application process. The stages depend on when a researcher starts to use the services. Users do not need to use CSC services from the start, they can combine other service offerings, for example, during the stages *plan* and *generate,* and then use CSC services during the analyze stage.

Plans on further development of the services

In Finland there is quite a wide selection of training courses provided, anything from using analysis, to using our software to basic supercomputing, machine learning, bioinformatics, programming and how to use the services in general.

In RTU, providing assistance to users via the domain experts works very well. It seems that providing only generic IT support is not sufficient for many novice users. Very often those users that have not received this advanced support tend to disappear quite soon. The best support is provided when the supporting person comes from the same domain as the user. Sometimes they are referred to as mediators (between users and IT support).

SNIC:s future projects/development needs to involve more partners with national mandates. Even the Nordic and Baltic countries are very different, some have very broad mandates and a very broad interface with national organizations; in some countries it is the opposite and there is distance between the organizations. Those differences need to be taken into account, particularly for cross border collaboration.

The positive aspect is that there is a greater awareness among the organizations on how the Nordic and Baltic landscape actually looks like. There is a transition right now from SNIC to NAISS, so for SNIC there is not going to be any more development.

RTU is continuously improving its services such that they become more user friendly. A specific area of future development is to use eduGAIN[10] for identification. The HPC services shall be augmented by a

[10] https://edugain.org/

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Cloud platform that would allow users to run virtual machines with a graphical interface which is preferred by many who are not used to a command line interface.

CSC uses agile methodologies for continued improvement of CSC's services. It is seen as critical to run production quality services at scale. CSC aims to constantly improve the quality of its services. In Finland there is quite a wide selection of training courses provided, anything from using analysis, to using our software to basic supercomputing, machine learning, bioinformatics, programming and how to use our services in general.

In Finland what works less well is spreading the knowledge about the services to the researchers. They have the mandate to support all researchers in Finland, however, many of the researchers are not aware about the full service portfolio that is being offered. To increase the visibility they work with marketing, roadshows and attends specific university events so that more researchers become aware of the service. Training is a good way to reach researchers.

AAI and level of assurance

CSC provides the finnish federation Hakka. More recently support for the life science AAI and Puhuri AAI based on MyAccessID was added.

For the level of assurance CSC is working on the formal definitions for the internal interpretation of the level of assurance. While not widely used yet, it may be used for supporting sensitive data services. For a very large platform that has a lot of capability, CSC would require a higher level of assurance.

SNIC uses the national AAI SWAMID[11] which is provided by SUNET. For international collaboration, SNIC is also a part of the PUHURI project which has developed an integration between SNIC's proposal system and the one developed for LUMI. SNIC and SUNET have contributed to the Puhuri project by providing personnel and expertise specifically regarding the adoption of MyAccessID. While such work is not part of the actual research process, it is an important supporting service.

SNIC requires a minimal level of assurance for identities since SWAMID is used. Almost every Swedish university or higher education institution nowadays has a SWAMID assurance level 2. There is a level 3 and a few universities which have gotten assurance level 3 during the last year.

RTU does not currently provide access through a federated AAI, but Puhuri is a candidate service that could be integrated into RTU services. Instead a separate identification for users is used. This uses a local database where users are manually registered. Obviously, this includes a lot of manual work because an administrator is registering new users in the system.

Users sometimes realize later in their research that they do not have enough local resources and that they need HPC resources. RTU users, very often, when they plan or apply for a new project, they underestimate their computing needs for that project. Users do not reach out in the research planning phase because they may not be aware that they are in need of HPC resources. Instead they reach out when the local machines are not capable of satisfying the need for computational resources..

Collaboration with other service providers

CSC hosts the LUMI project which is a collaboration of 10 countries and the EU commission. In addition, CSC is heavily involved in NeIC projects and several EU projects, and collaborates with other service providers through these projects. CSC also participates in Nordunet.

Collaborations are well established and ongoing over many years. GDPR does not hinder collaboration, but we need to take it into account. In addition, cross border collaboration may be affected by national

[11] https://www.sunet.se/services/identifiering/swamid

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interpretation of legislation, for example, handling of restrictions on processing sensitive data. Issues concerning sensitive data are, for example, addressed through Elixir [12].

RTU collaborates with other service providers. Regarding cross border collaborations, RTU does not have active cross-border collaboration right now. In the past, RTU collaborated with University of Tartu HPC on IT services to integrate RTU services in their marketplace and their research organization.

So far, no legal problems preventing collaboration were encountered for RTU. For cross-border scenarios, applications from the industry or private companies coming from another country were not considered, because there is not sufficient legal experience at RTU to handle such requests appropriately. For applications from academic institutions there seems to be fewer restrictions. Researchers from a Danish University used RTU's HPC service. In that particular case there was a PI from RTU, but it was not a requirement. The users from Denmark paid for the project budget, but that money was coming from part of the budget which was already allocated to RTU.

[12] https://elixir-europe.org/

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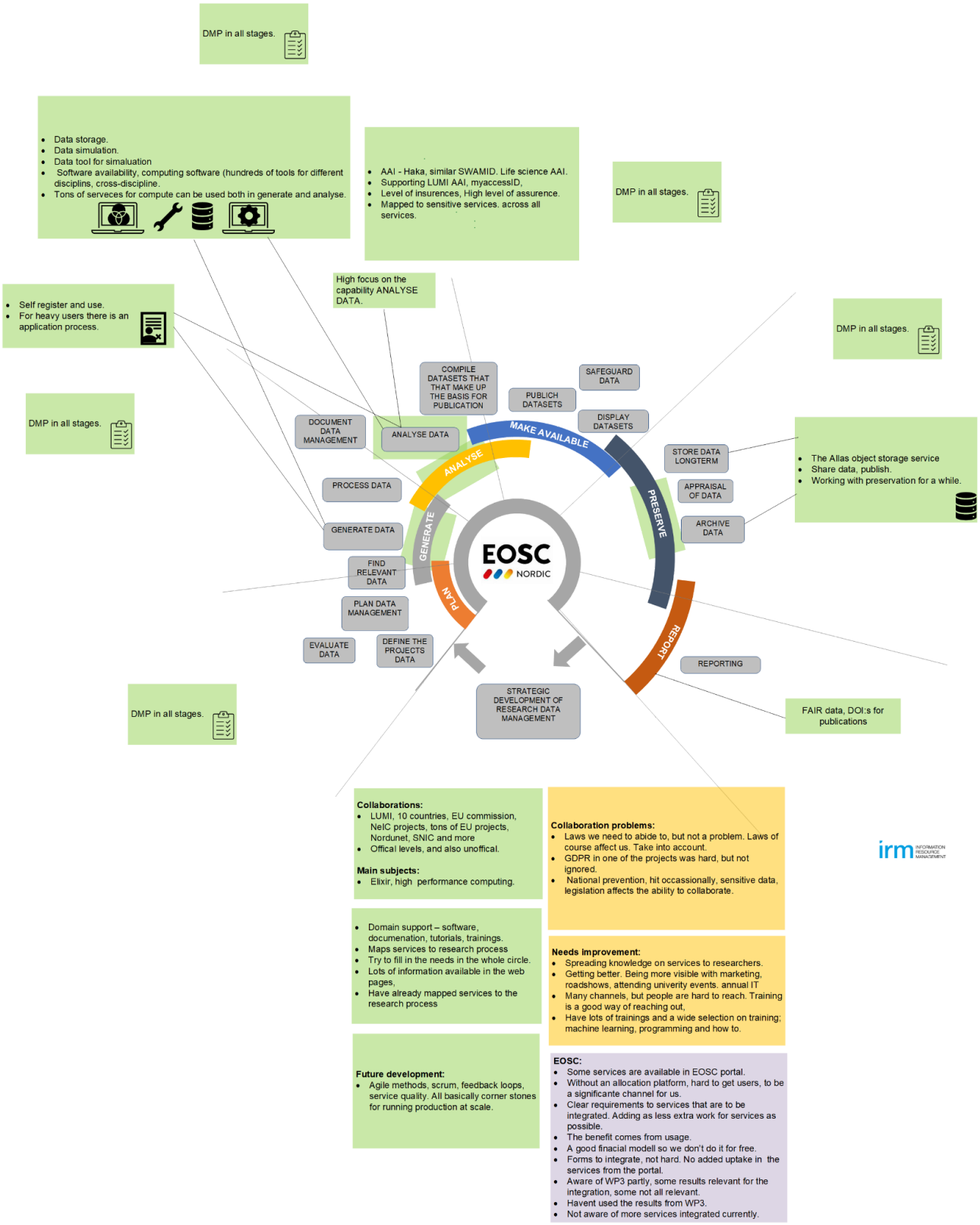

Figure 4. CSC mapping of services into the researcher journey.

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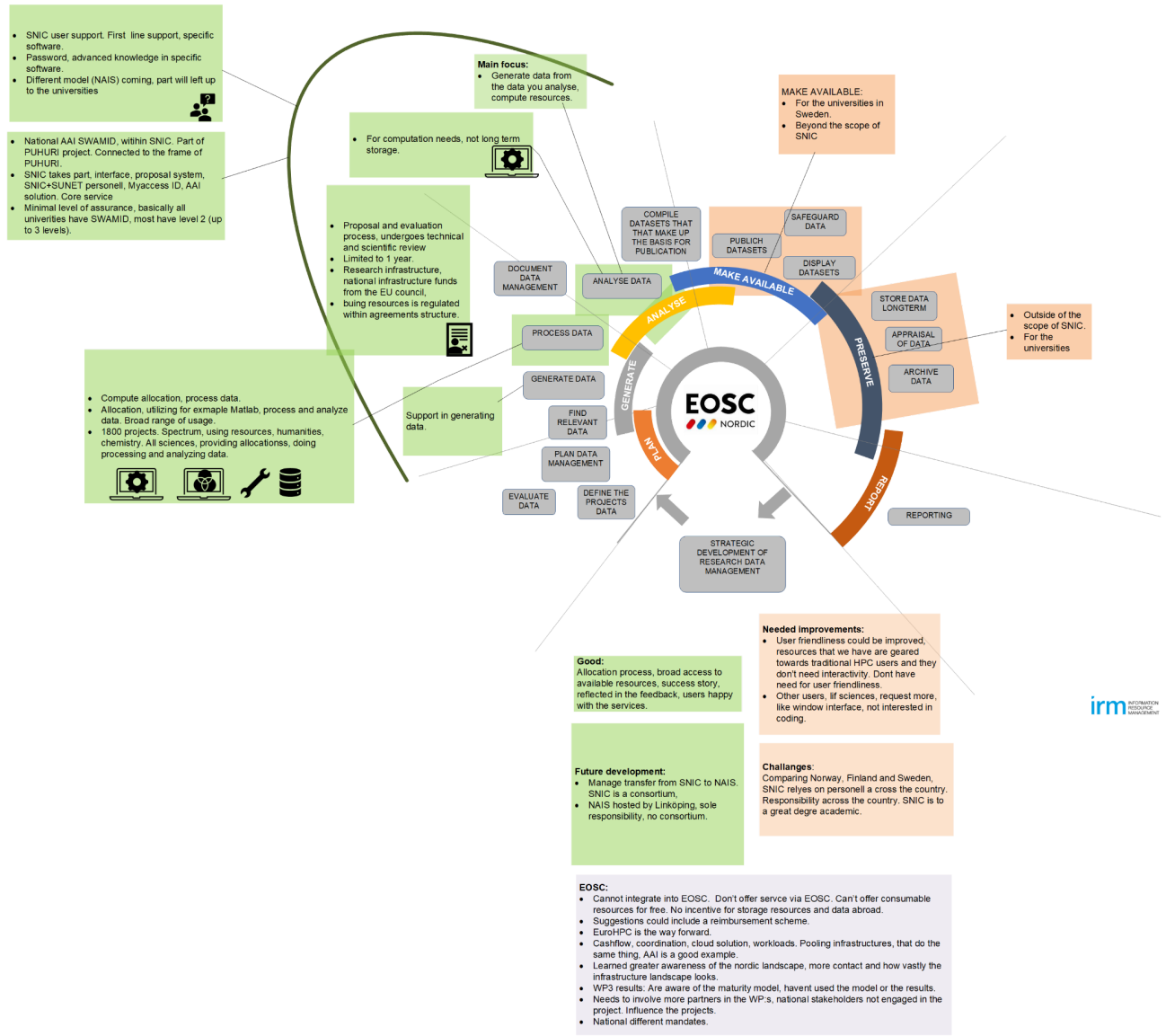

Figure 5. SNIC mapping of services in the researcher journey.

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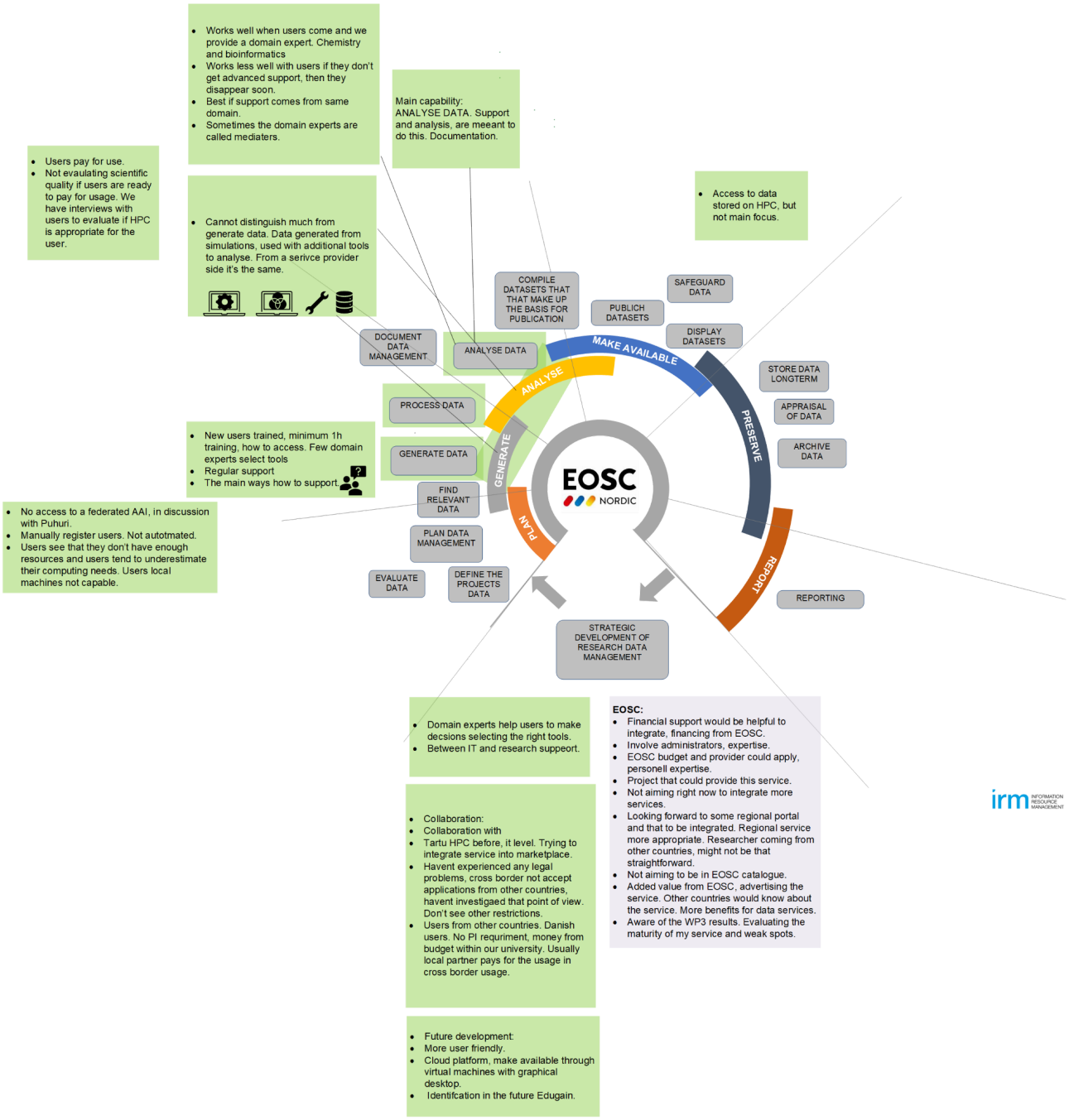

Figure 6. RTU mapping of services in the researcher journey.

Discussion of the interviews

The interviews show similarities and differences among the three service providers. One of the countries offers domain specialists. In Sweden, the map clearly showcases how compartmentalized the services are throughout the researcher journey, where SNIC can assist in the stages of generate/analyze while making available/preserve are stages that the universities are responsible for. CSC stands out from the other service providers since they have made progress in explaining to users where their services fit into a user's research process. All the services are heavily focused on stage *analyse*, but also support the stage *generate*

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well. All of the services are positive on the services provided however reaching out to new users is something that is being struggled with.

They suggest that EOSC could improve the infrastructure in the Nordics and the Baltics through coordination, projects that include data issues and data specialists. Some of the issues discussed with the providers are limitations on opening up their services to users abroad because the services are built and operated through national funding (for a more in-depth discussion of obstacles see deliverable D3.5 of work package 3).

The mapping cannot answer questions such as which capabilities are needed for high-quality research data management, what is the ideal state and how do we reach the ideal state. Answering such questions would require a much more in depth study similar to the ones previously made in Sweden and would involve researchers, research facilities, support organizations, funders, e-infrastructure and more. The selection of services is too small to get an analysis. What is visible in the maps is how the services are different, even though they provide similar services

Conclusion

Work package 3 of EOSC-Nordic did significant pioneering work to verify the hypothesis that the European Open Science Cloud will be built from existing services. Using the tools developed by WP3 service providers - not only in the Nordic and Baltic region - can assess the maturity of their services for onboarding them onto EOSC and use the maturity levels to further improve the accessibility and cross-border usage of their services. With the interoperability framework service providers also have gotten clear guidelines on how to ensure that their services can interoperate with other EOSC services. Eventually these tools will lead to even better services, more interoperable services and thus added value for users of the European Open Science Cloud.

Addressing needs of users is a process that requires continuous updates and improvements to keep results relevant. Therefore, in the future we see necessary work to (1) update the maturity model to new requirements from users and changes in the EOSC architecture and procedures, and (2) work closely with users to validate the tools developed in different scenarios. In section *How does work package 3 of EOSC-Nordic address key findings of WP5*, we layed out specific recommendations for future work to further increase the value of work package 3 results. These recommendations are based on analyzing gaps between WP3 results and key findings made by WP5. A future revision of the maturity model and/or interoperability framework should

- **[Future Work 1]** integrate additional criteria/questions into their templates specifically improving the cross-border maturity with respect to access control and resource allocation,
- **[Future Work 2]** cover new developments in EOSC's architecture,
- **[Future Work 3]** incorporate specific criteria of or even the full interoperability framework,
- **[Future Work 4]** include criteria for onboarding and training offerings,
- **[Future Work 5]** try to capture how information about the configurability of a service or means for its customizability can be assessed, *and*
- **[Future Work 6]** consider to adjust what criteria a service must meet to fulfill one of the maturity levels minimum, intermediate or high.

Despite these findings and future work being needed, we think that work package 3 of EOSC-Nordic has demonstrated that the European Open Science Cloud can be built from existing services, and that the

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interoperability of services will provide a more capable ecosystem for users than just a collection of siloed individual services.

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Appendix 1 - Interview questions

The following questions were asked to the service providers.

The process and where the service fits into the process

- Does your service catalog include services for researchers?
  - Yes, only IT-support (what IT-support do you provide?)
  - Yes, other support (what does the service include?)
  - Yes, both IT-support and other support
  - No
- Where in the researcher's research process do you give support?
  - THE PLANNING STAGE - When the researcher seeks grants from research funders and begins to plan the handling of data throughout the research project.
  - FIND/COLLECT DATA - for example via surveys, interviews, observations, calculations, simulations and more. This also includes when the researcher starts processing, storing active data and documenting the data management.
  - ANALYSIS STAGE - When the researcher analyzes the data collected or created and compiles data sets that form the basis of publication.
  - AVAILABILITY STAGE - When the researcher makes available the completed analyzed data, which are presented in forms that allow others to take part in them (for example, repository).
  - REPORTING STAGE - When the researcher reports after completing the project to e.g. the research funder.
  - PRESERVATION STAGE - When the researcher needs to preserve data stored after a research project is completed.
  - Other
- How do you support researchers in their research process?
- What do you think works well with the support and what do you think works less well?
- Are you providing access to services via federated AAI? If so, which one? Are you requiring a minimal level of assurance for identities? where in the process would this fit in?
- How are your services provided? Is there an application process for researchers? Can they purchase the services? When is the researcher performing this task?

Collaboration

- Do you collaborate with other service providers?
  - Cross-border collaborations?
  - How do you collaborate?
  - Are there any problems with the collaborations that can impact providing the services towards researchers?
  - What are the main areas you collaborate in?

EOSC Services

- Is the EOSC infrastructure helpful for your services? How, why? If not, what could EOSC do to provide added value?Do you have any recommendations for future work to support providers in integrating their services into EOSC?
- Anything you would like to add that we haven't addressed regarding your services?

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- Do you offer services in/via EOSC?
    - How was the procedure to integrate these services?
    - Did you see broader/additional uptake of these services?
- Are you aware of WP3 results (e.g., maturity model)?
    - Did you use WP3 results?

The future

Are you planning to integrate additional services?

How will you continue to improve the services (What other development efforts are planned in the future)?

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