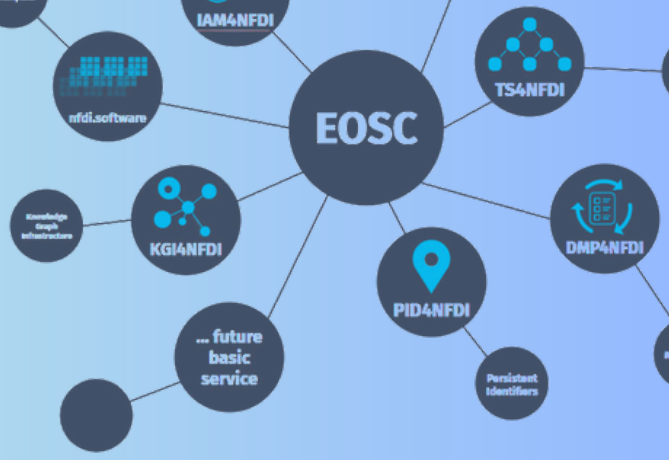
base4nfdi Basic Services for NFDI



POLICY PAPER

Base4NFDI Services and EOSC: Guidance for Interoperability

Authors:

Bernard (0000-0002-3085-7457), Jander (0000-0003-1646-6836), Manske (0009-0001-0248-4462), Miller (0000-0002-4385-7245), Rettberg (0000-0003-1888-2294), Ritter (0009-0009-7937-6580), Rißler-Pipka (0000-0002-0719-9003), Schäfer-Neth (0000-0002-6995-8706), Stein (0000-0003-3406-5104), Zänkert (0000-0001-5386-0555)

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Authors: Bernard (0000-0002-3085-7457), Jander (0000-0003-1646-6836), Manske (0009-0001-0248-4462), Miller (0000-0002-4385-7245), Rettberg (0000-0003-1888-2294), Ritter (0009-0009-7937-6580), Rißler-Pipka (0000-0002-0719-9003), Schäfer-Neth (0000-0002-6995-8706), Stein (0000-0003-3406-5104), Zänkert (0000-0001-5386-0555)

Abstract

Base4NFDI contributes to the evolution and innovation of the German RDM service landscape and is committed to ensuring interoperability across existing infrastructures beyond Germany to underpin the transition to open science. This paper introduces activities of the NFDI, the emerging Base4NFDI[1] services, current EOSC developments, and explores ways the German national initiative can find connectivity and complement the ongoing European Open Science Cloud (EOSC) activities. It examines the EOSC Interoperability Framework as a tool to find pathways for potential alignment between Base4NFDI Basic Services with EOSC, lists action areas, and gives practical guidance for Base4NFDI services to enable organisational, technical, semantic and legal interoperability. Readership is targeted towards the Base4NFDI service development teams, the NFDI and EOSC communities. EOSC activities are fast moving therefore this paper will be regularly updated.

[1] https://base4nfdi.de/

base4nfdi Basic Services for NFDI

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1. Introduction

> *"Scientific e-infrastructure is essential if we are to address the Grand Challenges of today [...] International collaboration is essential; there is no such thing as a purely local or national network anymore."*
>
> Riding the Wave. How Europe can gain from the rising tide of scientific data, 2010, p. 29[2].

The need to connect existing and also emerging international e-infrastructures to support scientific research remains hugely relevant. Since 2010 advances have been made at the European level in developing e-infrastructures[3], collaborative support networks developed by research communities and technology providers, in particular the development of disciplinary pan-European research infrastructures[4] and the establishment of the European Open Science Cloud (EOSC). At national levels, funder mandates have underpinned the development of infrastructures for scientific research and open science[5]. In Germany the **German National Research Data Infrastructure** (NFDI)[6] is part of this movement, and the activities of Base4NFDI[7], an initiative within this infrastructure, reflects the German funders' commitment to support FAIR and open science practices by establishing cross-cutting services to support research.

The **respective missions** of NFDI[8], Base4NFDI[9] and EOSC[10] are mutually compatible: the three initiatives focus on supporting the research process by enabling FAIR data sharing and in turn driving the interoperability, sustainability, multidisciplinarity of research outputs as well as taking a community-driven approach with key stakeholders from their respective communities. International connectivity is built into EOSC by default, and both NFDI and Base4NFDI explicitly mention their commitment to international and European interoperability. This paper is also inspired by the recommendations of the recent RfII paper[11] which highlights the need for interoperability between EOSC and NFDI and to avoid the emergence of parallel infrastructures.

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[2] European Commission [Ed.]: Riding the Wave. How Europe can gain from the rising tide of scientific data. Final report of the High Level Expert Group on Scientific Data A submission to the European Commission. (2010) https://www.dariah.eu/wp-content/uploads/2017/02/hlg-sdi-report.pdf
[3] https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2021
[4] https://www.esfri.eu/
[5] Garavelli, S., Märkälä, A., & Liinamaa, I. (2021). EOSC National Structures: an overview of the national EOSC coordination and engagement mechanisms in Europe. Zenodo. https://doi.org/10.5281/zenodo.5602949
[6] https://www.nfdi.de/?lang=en
[7] https://base4nfdi.de/
[8] https://www.nfdi.de/#:~:text=Unsere%20Vision%20und%20Mission
[9] https://base4nfdi.de/about/mission-statement
[10] https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science/european-open-science-cloud-eosc_en
[11] RfII – German Council for Scientific Information Infrastructures: Federated Data Infrastructures for Scientific Use. NFDI, EOSC, Gaia-X, and the European Data Spaces: Comparison and Recommendations for a Committed Engagement to Shape the European Research Data Ecosystem, Göttingen 2024, 103 p.

This describes current activities in Base4NFDI and EOSC, to examine areas of interoperability and recommend pathways forward to support these recommendations in order to achieve connectivity and alignment with EOSC and beyond.

2. Current NFDI Activities

Background to NFDI

The aim of the NFDI is to make valuable data from science and research systematically accessible, networkable, and usable in a sustainable and qualitative manner for the entire German science system (and beyond). The vision of NFDI is data as a common good for excellent research, organised by the scientific community in Germany. It is a joint initiative of the Federal Government and the Federal States, initiated in 2020 and is now comprised of 26 NFDI consortia[12]. The consortia are associations of various institutions within a research field, represent all research fields, and work together in an interdisciplinary manner to implement professional RDM. Furthermore, the non-profit association Nationale Forschungsdateninfrastruktur (NFDI) e.V. was founded to coordinate the activities for establishing a national research data infrastructure. International networking enables NFDI to synchronise its activities with international developments, e.g. as a member of the Research Data Alliance (RDA). NFDI is a member of the EOSC Association and has put forward its candidacy as a national node in the European Open Science Cloud (EOSC). Since 2020 there have been three funding rounds for consortia. In the first round, nine consortia applied successfully, in the second round ten, and in the third round eight, including Base4NFDI, a joint initiative of all 26 NFDI consortia.[13]. The NFDI is currently undergoing a "Structural Evaluation" undertaken by both the Joint Science Council[14] and the German Research Foundation (DFG)[15].

Rat für Informationsinfrastrukturen (RfII)

Instrumental in establishing the NFDI is the Rat für Informationsinfrastrukturen (RfII) – a high-profile scientific council that primarily focuses on supporting and optimising the German scientific information infrastructure. In its first policy paper, 'Performance through Diversity',[16] the RfII recommended the establishment of the NFDI. The council is composed of representatives from four different areas: *Scientific Users*, *Public*, *Information Facilities*, and *Federal and State Governments*[17]. The aim is to work towards sustainable and accessible infrastructure solutions and to release pivotal position papers which influence the development of research infrastructures. One of its main tasks, received by Germany's Joint Science Conference (GWK), is to formulate broad-based recommendations for the science

[12] https://www.nfdi.de/konsortien/
[13] https://www.dfg.de/de/foerderung/foerderinitiativen/nfdi/gefoerderte-konsortien
[14] https://www.gwk-bonn.de/en/
[15] https://www.dfg.de/en/about-us/about-the-dfg/what-is-the-dfg
[16] German Council for Scientific Information Infrastructures: Enhancing Research Data Management: Performance through Diversity. Recommendations regarding structures, processes, and financing for research data management in Germany, Göttingen 2016, 90 p.
[17] https://rfii.de/en/the-council/

system in Germany as a whole. Two critical reports (from 2022[18] and 2023[19]) from the RfII focus on the intersection of NFDI and EOSC and the need to align efforts and bring a common mutual understanding and lessons learned. A recently published report: "*Federated Data Infrastructures for Scientific Use. NFDI, EOSC, Gaia-X, and the European Data Spaces: Comparison and Recommendations for a Committed Engagement to Shape the European Research Data Ecosystem*"[20] gives clear recommendations for the further development of these scientific infrastructures, in particular stressing the need for providers of data infrastructures to:

> "*Foster compatibility among data infrastructures to enhance collaboration and efficiency. Interconnection of all relevant data infrastructures – specifically NFDI and EOSC – on both, the operating and technology levels, should be implemented to enable shared access and integrated use by researchers across disciplines and domains in a multitude of research contexts.*"[21].

These RFII reports have given an impulse for this paper.

NFDI Sections

The NFDI Sections[22] are a crucial part of NFDI and this is where the Base4NFDI services are initiated. Even before NFDI started in 2020, cross-cutting topics were identified and strategically prioritised throughout three iterations[23]. Taking up on this a process was initiated by the NFDI Directorate and the NFDI Consortium Assembly, five Sections were founded since 2021:

- Common Infrastructures (*section-infra*)
- (Meta)data, Terminologies, Provenance (*section-metadata*)
- Ethical, Legal and Social Aspects (*section-ELSA*)
- Training & Education (*section-edutrain*)
- Industry Engagement (*section-industry*)

Anyone who is from a membership institution of the NFDI can join a Section. Within the Sections are sub-groups which discuss and develop practical solutions for cross-disciplinary challenges. The Sections naturally play a crucial role in their function as a communicator between the NFDI community and Base4NFDI as it is here where ideas and needs for Basic Services are identified, discussed and ultimately decided prior to its proposal submission to Base4NFDI.

[18] RfII – Rat für Informationsinfrastrukturen: Datenpolitik, Open Science und Dateninfrastrukturen: Aktuelle Entwicklungen im europäischen Raum, Göttingen 2022, 92 S.
[19] RfII – Rat für Informationsinfrastrukturen: Föderierte Dateninfrastrukturen für die wissenschaftliche Nutzung. NFDI, EOSC und Gaia-X: Vergleich und Anregungen für eine engagierte Mitgestaltung des Ausbaus und der Weiterentwicklung, RfII Berichte No. 4, Göttingen 2023, 48 S.
[20] RfII – German Council for Scientific Information Infrastructures: Federated Data Infrastructures for Scientific Use. NFDI, EOSC, Gaia-X, and the European Data Spaces: Comparison and Recommendations for a Committed Engagement to Shape the European Research Data Ecosystem, Göttingen 2024, 103 p.
[21] RFII, 2024, pp 57
[22] https://www.nfdi.de/sections/?lang=en
[23] Bierwirth et al. (2020). Leipzig-Berlin-Erklärung zu NFDI-Querschnittsthemen der Infrastrukturentwicklung. Zenodo. https://doi.org/10.5281/zenodo.3895209

The Service Landscape in NFDI

Among their many activities the NFDI consortia are consolidating and scaling up existing discipline-specific solutions and services to support their specific communities. Combing what already exists has been the premise of the consortia development, and Base4NFDI services, to make the services ultimately more embedded and used from the start[24]. In NFDI, a service is "understood as a technical-organisational solution, which typically includes storage and computing services, software, processes, and workflows, as well as the necessary personnel support for different service desks"[25]. These are examined in a 2023 white paper, and are categorised according to based on the de.NBI[26] service categories[27]: As Amelung et al. describe in their *White Paper: Interim Report Reference (2023)*[28], the de.NBI service categories are "generic enough to cover services across domains and can be extended, if necessary"[29]. This potential for extension led to adding three additional categories to the 6 service categories proposed by de.NBI: i) Databases, ii) Libraries/API, iii) Workflows/Pipelines, iv) Tools/Applications, v) Web applications, vi) Support/Consulting, vii) Data Curation, viii) Training, and ix) Storage (with vii) to ix) being added by Amelung et al.)[30].

NFDI and the European Dimension

The member institutions of the NFDI Consortia have strong links to European EOSC related projects. 18 members are involved in current EOSC projects (see Appendix). Nine NFDI members contribute to three of the new EOSC task forces[31]. The NFDI Directorate is a partner in EOSC Beyond[32], a flagship project to develop EOSC Core infrastructure. Also via its member institutions the NFDI Association takes part in the European research infrastructures like ERICs[33] and European science clusters. As the NFDI was built around disciplinary consortia these correspond to disciplinary oriented ERIC-structures and science clusters on the European level. Engagement in ERICs was for most institutions who are part of a NFDI consortium today preliminary and necessary work in order to be well prepared for the NFDI. Therefore, many ERICs are represented in the NFDI consortia, for example: EMBL (GHGA); ELIXIR/DE.nbi – (Biodiversity, DataPlant); CESSDA, ESS, SHARE

[24] Rat für Informationsinfrastrukturen: Schritt für Schritt – oder: Was bringt wer mit? Ein Diskussionsimpuls zu Zielstellung und Voraussetzungen für den Einstieg in die Nationale Forschungsdateninfrastruktur (NFDI), Göttingen 2017, 4 S.
[25] Konsortialversammlung des Vereins Nationale Forschungsdateninfrastruktur (NFDI) e.V. (2022). Stellungnahme der NFDI-Konsortien zu Basisdiensten. Zenodo. https://doi.org/10.5281/zenodo.6091657
[26] https://www.denbi.de/
[27] Amelung, L., Anthofer, V., Danabalan, R., Demandt, É., Ebert, B., Elschner, E., Espinoza, S., Eufinger, J., Fuchsloch, S., Götz, B., Henzen, C., Hunold, J., Idda, T., Jansen, L., Krieger, U., Rodrigues, C. M., Meister, M., Miller, B., Pitroff, S., … Zinke, W. (2023). White Paper: Interim Report Reference. Zenodo. https://doi.org/10.5281/zenodo.7688729
[28] See above.
[29] See above, p. 17.
[30] See above, pp. 17-18.
[31] https://eosc.eu/eosc-task-forces/
[32] https://www.eosc-beyond.eu/
[33] https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-infrastructures/eric_en

(KonsortSWD-nfdi4society); CLARIN (Text+); DARIAH, EHRI, RESILIENCE (NFDI4Culture[34], NFDI4Memory[35], NFDI4Objects[36], Text+[37]).

Background to Base4NFDI

Base4NFDI is a DFG-funded initiative, launched in 2023, and establishes a framework to provide cross-disciplinary services to drive FAIR practices to underpin the transition to open science in Germany and beyond. The idea for establishing cross-cutting services to meet the needs of the scientific community germinated in the *Leipzig-Berlin-Erklärung zu NFDI-Querschnittsthemen der Infrastrukturentwicklung* (statement regarding NFDI cross-cutting topics within the research infrastructure landscape) published in 2020[38] which identified cross-cutting topics. Base4NFDI substantiates the work on topics by supporting the NFDI Sections[39] in identifying Basic Service candidates. Through involving relevant stakeholders and leveraging the existing service infrastructure in Germany it ensures services' suitability and adoption. It accompanies the development and consolidation of the services in three successive development phases, at the same time leveraging synergies between the NFDI consortia. With a long-term perspective, Base4NFDI contributes to the evolution and innovation of the NFDI service landscape which by definition is part of the European service landscape.[40]

Definition of a Base4NFDI Basic Service

Base4NFDI takes a bottom-up approach to service development ensuring that the services are developed within a community process allowing buy-in and gradual adoption. A Basic Service itself can be defined as a technical-organisational solution, which typically includes storage and computing services, software, processes, workflows, and operating staff. Such Basic Services are useful to potential all existing and future consortia, build on and bundle existing solutions, are trackable via KPIs, and are characterised by scalability and sustainable operating models. A key factor, compared to other international infrastructure programs, is that these Basic Services are co-designed by the community in a bottom-up process. Services are discussed and decided upon in the NFDI Sections[41], as mentioned above. After submission of the proposal and a technical evaluation, it is eventually the community through their consortium leads that decides in the Consortia Assembly whether a Basic Service is funded or not. Characteristics of each phase are set out in Table 2 below.

[34] https://nfdi4culture.de/index.html
[35] https://4memory.de/
[36] https://www.nfdi4objects.net/
[37] https://text-plus.org/
[38] Glöckner, F. O., Diepenbroek, M., Felden, J., Overmann, J., Bonn, A., Gemeinholzer, B., Güntsch, A., König-Ries, B., Seeger, B., Pollex-Krüger, A., Fluck, J., Pigeot, I., Toralf, K., Mühlhaus, T., Wolf, C., Heinrich, U., Steinbeck, C., Koepler, O., Stegle, O., … Bernard, L. (2019). Berlin Declaration on NFDI Cross-Cutting Topics (Version 1). Zenodo. https://doi.org/10.5281/ZENODO.3457213
[39] https://www.nfdi.de/sections/?lang=en
[40] https://base4nfdi.de/about/mission-statement
[41] https://www.nfdi.de/sections/?lang=en

Elements of a Basic Service

The Base4NFDI services take a three-phase approach to development: Initialisation, Integration and Ramp-Up[42]. Table 1 sets out the features of each phase (see below). Note that while the TRL level is fixed, elements in each phase are still evolving.

Features of the three Base4NFDI phases		
Initialisation phase (1 year)	**Integration phase** (2 years)	**Ramp-Up phase** (2 years)
End of phase TRL: 5-6 Technical development: Service is developed as proof of concept and has been initially tested	**End of phase TRL:** 7-8 Technical development: Service is fully developed and deployed	**End of phase TRL:** 9 Technical development: Service is scalably deployed with a long-term perspective, monitoring and KPIs are in place
Interoperability: Interoperability across NFDI Services	**Interoperability:** Interoperability with European activities and EOSC	**Interoperability:** Where relevant, services are part of the EOSC Interoperability Framework
Openness: Open Source software and open licences for reuse	**Openness:** Open Source software and open licences for reuse	**Openness:** Open Source software and open licences for reuse
Support and Training: Identification of target groups and learning needs. Personas framework for the services are created	**Support and Training:** Training material created	**Support and Training:** Availability for all user groups and a sustainability concept. Concrete documentation for users
Security: Security issues are not applicable for all projects at this stage	**Security:** Security Incident response: DFN-CERT responsible for AAI* , other services tbc	**Security:** Security Incident response: DFN-CERT responsible for AAI, other services tbc
User requirements: This is the main focus of this phase, to assess whether there is buy-in to the service across the NFDI consortia.	**User requirements:** Based on the user requirements of the previous phase, the service meets the requirements. If the service is not voted in by the consortia at the end of this	**User requirements:** Once roll out has taken place periodic assessment of the service will take place to ensure user buy-in.

[42] https://base4nfdi.de/process/criteria-for-basic-services

	phase, there is an opportunity to be added to a toolpool.	
Governance: Not the focus of this phase	**Governance:** One or more institutions have committed themselves to run the service operationally.	**Governance:** Service capabilities and limitations are clearly defined. In the eventuality the service is part of the EOSC Node, the Base4NFDI services will need to have these agreements in place for users and providers as well as an understanding of scalability.

*Table 1: Features of Base4NFDI service development at each phase. *AAI = Authentication and Authorisation Infrastructure.*

As of October 2024 there are currently eight Base4NFDI service candidates underway, all - apart from one - are in the Initialisation phase[43]. The service projects are listed below, in alphabetical order and further information about each service can be found on the Base4NFDi website[44].

1. **DMP4NFDI** is a centralised Basic Service for managing data management plans (DMPs) and software management plans (SMPs) across the NFDI.
2. **IAM4NFDI** is concerned with connecting and expanding existing and emerging Identity and Access Management (IAM) systems in a way that researchers from different domains and institutions are able to access digital resources within NFDI as easily as possible
3. **Jupyter4NFDI** aims to address the fragmented deployment of Jupyter Notebooks across NFDI consortia by offering a centralised service.
4. **KGI4NFDI** advocates for a central and reusable Knowledge Graph Infrastructure (KGI) to enhance interoperability within the research domain and support the NFDI's objectives
5. **nfdi.software** aims to create a central marketplace to improve access to NFDI research software, addressing the needs of various scientific disciplines for sustainable research software use and development.

[43] https://base4nfdi.de/process/criteria-for-basic-services
[44] https://base4nfdi.de/projects

6. **PID4NFDI** will design a work programme to build an NFDI foundation service on established PID infrastructures.

7. **TS4NFDI** is a cross domain service for the provision, curation, development, harmonization and mapping of terminologies.

Fig. 1: Base4NFDI current Basic Service projects.

3. Current EOSC Activities

EOSC was initiated 2015 with the aim to establish a "federation" of connected infrastructures and services for open science to support FAIR data implementation for European researchers[45]. The EOSC Federation is now governed by both the EOSC Association - a membership-led governing entity of EOSC - and the EOSC Tripartite Governance[46] - a coordination body composed of the EU Commission, the EOSC Association and the EU Member States and Associated Countries (comprised of the Steering Board). Together these two bodies ensure the strategic coordination of EOSC activities. In the complex landscape of EOSC frameworks, national players, research infrastructures and fast changing activities within EOSC projects, the following activities are identified as relevant to Base4NFDI to consider on the pathway to EOSC alignment with the Basic Services:

- **EOSC Frameworks: Strategic Research and Innovation Agenda (SRIA), Multi-Annual Roadmap (MAR) and EOSC Interoperability Framework:** Key documents that define the theoretical and technical building blocks for the roll-out of EOSC.
- **EOSC Node developments**:[47]
    - **National EOSC Nodes in the Federation:** National Nodes will be developed in order to contribute to EOSC developments. In 2025 the concept of European EOSC Nodes will be developed via a pilot phase overseen by the EOSC Association. The NFDI (the Association's mandated organisation) has applied to become a potential EOSC Node, with the outcome still unknown at the time of writing.
    - **EOSC EU Node:** At the European level there is a 3-year phase to establish a multi-disciplinary and multi-national service portfolio via procured services[48]. The EOSC Beyond project[49] will also contribute to the development of these core services.

For the purposes of this paper however the most relevant frameworks for the Base4NFDI services will be highlighted. While it is acknowledged that the EOSC Node developments are highly relevant these are not the focus of activity at present during the early stages of the Basic Service developments. The most critical frameworks, and standards and reference documents are visualised in the image below:

[45] https://eosc.eu/eosc-about
[46] https://www.eosc.eu/sites/default/files/EOSC_Memorandum_30_July_2021.pdf
[47] https://indico.cern.ch/event/1332413/contributions/5753095/attachments/2818575/4921337/EOSC_Javier_Albacete.pdf
[48] The initial website is here: https://open-science-cloud.ec.europa.eu/
[49] https://www.eosc-beyond.eu/

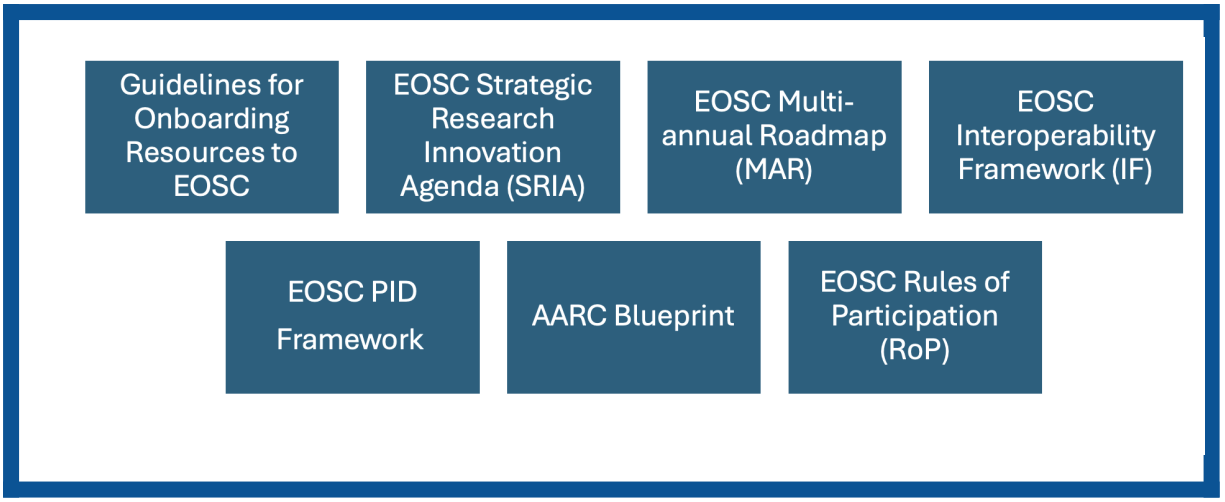

Fig. 2: Key Frameworks and papers from EOSC relevant for Base4NFDI.

EOSC Strategic Research and Innovation Agenda

The 2023 edition of the Strategic Research and Innovation Agenda (SRIA)[50] is a community-led stakeholder process to establish the basis of a roadmap to establishing EOSC. According to the SRIA; there are three strategic objectives of EOSC:

1. Establish open science practices as the"'new normal"
2. Define standards and tools to allow researchers to use, access, find and combine results
3. Establish a sustainable and federated infrastructure to enable this sharing

The SRIA sets out 14 action areas to employ EOSC as well as the seven following "Implementation challenges": *Identifiers, Metadata and ontologies, FAIR metrics and certification, AAI, User environments, Resource provider environments, EOSC Interoperability Framework*. It also sets out 'Boundary areas' which focus less on the technical implementation and more on the social, financial and legal and training challenges that should be tackled when implementing EOSC[51].

Integral to the SRIA is the **Multi-annual Roadmap (MAR)**[52] which clarifies the steps different players can take to align with the implementation of EOSC: these are given at European, national and institutional level. A number of objectives across the timeframe 2021-2027 are set out in three phases which span many topics for national implementation - aligned with the above general objectives of the SRIA. For example: the need for national PID strategies; investing in sustainable digital infrastructures; the inclusion of national data competence centres in open science practices and EOSC alignment.

[50] https://eosc.eu/wp-content/uploads/2023/12/20231114_SRIA_1.2_final2.pdf
[51] See EOSC Association AISBL (2023). *Strategic Research and Innovation Agenda (SRIA) of the European Open Science Cloud (EOSC)*, p. 142
[52] See EOSC Association AISBL (2023). *Strategic Research and Innovation Agenda (SRIA) of the European Open Science Cloud (EOSC)*, p. 71.

Strongly highlighted in the SRIA is the concept of the **Minimal Viable EOSC (MVE)**. This is a critical model to understand the core functions of the EOSC operations. The three elements of the MVE are:

1. **The EOSC Core:** Enabling generic services to operate the EOSC to ensure minimum functionality. This includes discovery, sharing, access and reuse of data.
2. **The EOSC Exchange:** The interoperability layer that provides a standardised set of exchange mechanisms to make federated services findable and accessible. It ensures that the services are available and multiple services can be provided. Service providers become providers in the EOSC Exchange according to the Rules of participation.
3. **The EOSC Federation:** Network of scientific services and data, and nodes, to serve the needs of the research community.

The SRIA recommends that the MVE approach is used as "widely as possible" to overcome national fragmentation[53].

The SRIA, MAR and MVE provide a framework, benchmarks and relevant areas against which to measure relevant steps to build a federated open science landscape. Mapping these activity areas to those of Base4NFDI will contribute to a deeper understanding of where the areas of interoperability exist (see Chapter 3).

EOSC Interoperability Framework

The EOSC Interoperability Framework (IF) was initiated in 2021 by[54] and deals primarily with interoperability across data and research outputs. The report sets out recommendations and categorises interoperability into four areas: technical, semantic, organisational, and legal. Importantly it sets out guidelines and best practices within EOSC for service providers and resource providers who wish to contribute to EOSC by promoting commonly used standards. The current version of the interoperability registry is implemented into the new EOSC portal which will be launched at the EOSC Symposium 2024 and is already available online.[55] A previous version is published in the EOSC Future public wiki[56]. More information on the IF will be set out in Chapter 3.

EOSC Rules of Participation

The EOSC Rules of Participation[57] set out the framework conditions in which service providers, resources and users should operate in EOSC. It sets out 8 areas to comply with. These are: *1) Principles of Openness; 2) FAIR principles; 3) EOSC architecture alignment; 4) Principles of ethical behaviour; 5) Users to contribute to EOSC* and *6) Adhering to terms and*

[53] See EOSC Association AISBL (2023). *Strategic Research and Innovation Agenda (SRIA) of the European Open Science Cloud (EOSC)*, p. 71.
[54] European Commission: Directorate-General for Research and Innovation, Corcho, O., Eriksson, M., Kurowski, K., Ojsteršek, M. et al., *EOSC interoperability framework – Report from the EOSC Executive Board Working Groups FAIR and Architecture*, Publications Office, 2021, https://data.europa.eu/doi/10.2777/620649.
[55] https://open-science-cloud.ec.europa.eu/resources/interoperability
[56] https://wiki.eoscfuture.eu/display/PUBLIC/EOSC+IF+Guidelines+overview
[57] European Commission: Directorate-General for Research and Innovation (2021). *EOSC rules of participation*, Publications Office. [online] Available at: https://op.europa.eu/en/publication-detail/-/publication/a96d6233-554e-11eb-b59f-01aa75ed71a1/language-en

conditions and *7) Reference to the resources they use* and *8) Participation in EOSC* is subject to applicable policies. The chapter on: "EOSC Service align with EOSC architecture and interoperability Guidelines" highlights the following:

- Services needing authentication should use credentials for federated AAI as defined by the EOSC AAI taskforce.
- Services shall be described by commonly agreed metadata schemes and publish: terms of use, licensing, AAI and cost requirements.
- Services should define their own quality targets via SLAs that the EOSC core may monitor.

Up to date information about the current status of the Rules of Participation can be found in the EOSC Federation Handbook, currently in draft[58].

Other Standards and Guidelines

Other outputs are relevant to the technical implementation of EOSC:

- **PID Policy and Implementation,** whose main aims are to "highlight mature and recognised PID infrastructures for emerging resource types, to standardise the PID graph, to integrate PIDs into FAIR data management, and to address PIDs and sensitive data [...]"[59]. Furthermore, "it will provide different kinds of recommendations on PIDs management and will set up criteria and certification of PIDs"[60].
- **AARC blueprint for Architecture,** "which provides a set of building blocks for software architects and technical decision makers who are designing and implementing access management solutions for international research collaborations"[61].
- **Guidelines for onboarding resources to EOSC,** a document which puts forward guidelines for Onboarding Resources to EOSC Exchange[62]: Developed in the EOSC Future project this document describes the layers of interoperability needed, including metadata in order for services, research outputs to share in the EOSC Federation.

[58] https://eosc.eu/eosc-federation-handbook/
[59] https://eosc.eu/advisory-groups/pid-policy-implementation/
[60] https://eosc.eu/advisory-groups/pid-policy-implementation/
[61] https://eosc.eu/task-force-deliverab/eosc-aai-architecture-2022/
[62] Dietrich, M., & Scardaci, D. (2024). Guidelines for Onboarding Resources to EOSC Exchange (v5.0) (5.0). EOSC-Future. https://doi.org/10.5281/zenodo.10621226

EOSC Node Developments

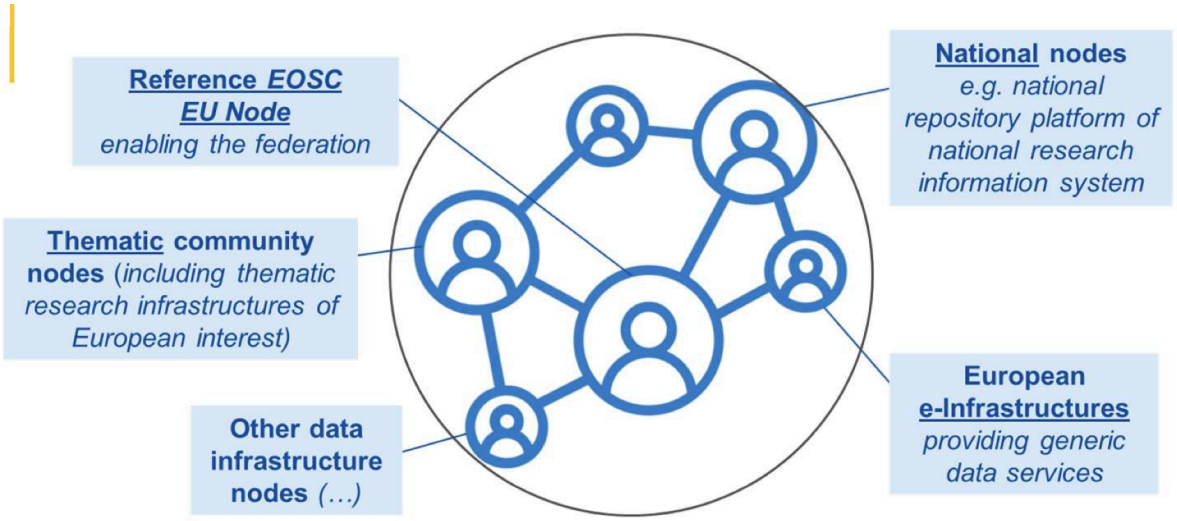

Fig. 3: EOSC Nodes within the Federation[63].

Over the next few years the EOSC Association will run a pilot phase to establish the first set of EOSC Nodes in Member States. These national Nodes will enable national entry points to the federation. This will enable services and data to be offered in compliance with the EOSC Federation rules[64]. National players will - via the Node - commit to providing not only research outputs (data catalogues, services) which are called 'resources' but also 'capabilities' that facilitate the EOSC Core. [65] The developments around the German EOSC Node are very early and will warrant further discussion during the course of 2025.

EOSC EU Node

The EOSC EU Node and the EOSC Federation are due to be launched in October 2024 at the EOSC Symposium[66]. The EOSC EU Node services have been procured by the European Commission[67], developed by a third party and will be governed by the EOSC Tripartite.
A number of services are listed on the EOSC EU Node website however these will be more fully defined in October 2024 when they go live[68]. These include:

[63] Taken from: https://indico.cern.ch/event/1332413/contributions/5753095/attachments/2818575/4921337/EOSC_Javier_Albacete.pdf
[64] https://eosc.eu/wp-content/uploads/2024/05/EOSC-A_GA8_20240527-28_Paper-G_Update_EOSC_Nodes_requirements-DRAFT-v240524.pdf
[65] For more details on this see: https://zenodo.org/records/10621226
[66] https://eosc.eu/symposium2024/
[67] https://open-science-cloud.ec.europa.eu/about/eosc-eu-node
[68] https://open-science-cloud.ec.europa.eu/services

- File Sync and Share
- Interactive Notebooks
- Large File Transfer
- Virtual Machines
- Cloud Container Platform
- Bulk Data Transfer

As a parallel activity, the NFDI Directorate is an associated partner in the EOSC Beyond project[69] and the role is to establish a prototype for a National German node based on services being developed in the NFDI consortia. This is part of activities in the EOSC Beyond project to actively pilot national Nodes and to test solutions for establishing a Node. Base4NFDI will take an active part in these activities as part of the German Node[70].

The EOSC Beyond project develops a number of components that will comprise the EOSC Core[71]. Of interest to Base4NFDI are the following components in Table 3 (Chapter 3) and efforts will be made to watch developments and map to the Base4NFDI activities in the coming years.

EOSC Beyond /EOSC EU Node Service	**Projected Release Date**
Resource Catalogue (Service Catalogue, Service Providers Dashboard, Knowledge Graph, Research Product Provider Dashboard)	4/2025
EOSC Knowledge Graph Adapted to suit the EOSC Node concept, linking onboarded resources to specific Research Infrastructures, clusters etc. Largely based on the OpenAIRE Research Graph[72]	4/2025
EOSC Marketplace/Tool Market & Order Management including metadata aggregation of the services and extensions to support embedding EOSC Execution Framework capabilities	6/2025
AAI Authentication and authorization based on highest security standards that include Multi-Factor Authentication and passwordless authentication for enhanced security, focusing on interoperability of and support for these methods across members of the EOSC AAI Federation	6/2025
PID Including metrics for accessing the data, machine readable , PIDs for instruments based on standards agreed by the research community;	8/2025

[69] https://www.eosc-beyond.eu/
[70] https://www.eosc-beyond.eu/pilot/nfdi
[71] Scardaci, D. (2024). EOSC Beyond D5.1 Collaboration with the implementing entities of the EOSC EU Node and Technical Roadmap (1 Under EC Review). Zenodo. https://doi.org/10.5281/zenodo.13165339
[72] https://graph.openaire.eu/

development of a EOSC Core adapter for the PID service	

Table 2: EOSC Beyond: Roadmap for EOSC services and Base4NFDI actions.

4. Base4NFDI and EOSC: Pathways to Interoperability

Summarising the discussion on the EOSC Interoperability Framework (IF)

Interoperability across research outputs as well as services is critical to implement a federated approach to establish EOSC across borders and regions. To achieve a culture of creating and sharing research in accordance with the FAIR principles[73], research outputs need to be validated and made suitable for reuse across many domains, whereas technical services need to be seamlessly integrated into the EOSC landscape. This is achievable via interoperability mechanisms and guidelines. The European Interoperability Framework (EIF), which is a precursor to the EOSC IF, defines interoperability as the "*ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their Information and Communication Technology systems*"[74]. In February 2021 the EOSC Working Groups FAIR and Architecture published the EOSC IF report[75] which divides interoperability into four different types:

1. **Technical interoperability:** Ability of an IT system or software application to communicate and exchange data with other systems without any restrictions.
2. **Organisational interoperability:** Aligning business processes, expectations and responsibilities to achieve mutual goals.
3. **Semantic interoperability:** Ability to the meaning of data exchanged is understood by both parties or machines.
4. **Legal interoperability:** As long as the FAIR principles are respected, regulatory and policy measures should be in place. Organisations that work in different legal jurisdictions and policy environments can work together if legal interoperability is enabled.

The following section identifies areas of interaction between Base4NFDI and EOSC according to the four interoperability areas mentioned above. The current status of the EOSC IF and Architecture is illustrated in the landscape report[76] as an output of the EOSC Future project. The discussion is ongoing in the renewed EOSC Task Force "Technical and Semantic

[73] Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data* 3, 160018. [online] Available at: https://doi.org/10.1038/sdata.2016.18.
[74] Available on https://ec.europa.eu/isa2/sites/default/files/eif_brochure_final.pdf.
[75] European Commission: Directorate-General for Research and Innovation, Corcho, O., Eriksson, M., Kurowski, K., Ojsteršek, M. et al., *EOSC interoperability framework – Report from the EOSC Executive Board Working Groups FAIR and Architecture*, Publications Office, 2021, https://data.europa.eu/doi/10.2777/620649.
[76] Orazio, Scardaci Diego, Sciacca Eva, Hériché Jean-Karim, Van De Sanden Mark, Klaas Wierenga, Manghi Paolo, Tamburri Damian, et al. 'A Landscape Overview of the EOSC Interoperability Framework - Capabilities and Gaps'. Zenodo, 2 October 2023. https://doi.org/10.5281/zenodo.8399710.

Interoperability"[77] which started in July 2024. Due to necessary technical implementation, onboarding of resources and providers as well as onboarding and connecting the upcoming Nodes of the EOSC Federation, the focus is very much on the technical interoperability. A definition of the IF is given in the most recent paper on "EOSC Federation: Architecture and Federating Capabilities":

> *"EOSC Interoperability Framework (EOSC IF): An extensible framework of interoperability guidelines that acts as the glue to support the interoperability and composability of EOSC Node resources. The EOSC IF is a reference framework to promote standards and best practices but offers the freedom to providers/nodes to develop and operate provider-specific implementations while conforming to the EOSC IF guidelines and standards."*[78]

Technical Interoperability

The IF recommends the following areas of technical interoperability for service providers in the EOSC Federation: [79]

- Technical interoperability should focus on IT systems working with other systems or services without any restrictions.
- The need for authentication to services and obtaining the rights to use it. This often needs to be performed at a community level. Use a Common Security and privacy framework, including an Authorisation and Authentication Infrastructure
- Use Service Level Agreements for all EOSC providers that are easily understandable
- Need for a clear PID policy which establishes appropriate PID usage, given the changing nature of the PID landscape (e.g. new PID types).

Base4NFDI will need to follow the interoperability guidelines for "Node Services" or being part of the "Federated Capabilities". For example, the IAM4NFDI service will take part in the federated capabilities while DMP4NFDI can be considered as a "Node Service". Depending on the degree of connection (entry in the EOSC service registry, harvesting of data or exchange of information via community proxies in the EOSC AAI) one or more interoperability guidelines will apply. The outline for the federated capabilities, core services and node services is already described in the EOSC Future D3.2b "EOSC Architecture and Interoperability Framework" up to a level of details regarding the specification of the interface/ protocol for each service.[80] The IF registry provides documentation and guidelines for each of the already existing EOSC core services or federated capabilities.[81] More details are set out in the recent report "EOSC Federation: Architecture and Federating Capabilities".[82]

[77] See: https://eosc.eu/advisory-groups/technical-and-semantic-interoperability-task-force/.
[78] Scardaci, D., Dietrich, M., & Manghi, P. (2024). EOSC Federation: Architecture and Federating Capabilities. Zenodo. https://doi.org/10.5281/zenodo.13939396.
[79] See above, p. 15.
[80] The EOSC Future Deliverable is published here (see pp. 12): https://eoscfuture.eu/wp-content/uploads/2024/03/EOSC-Future-WP3-GEANT-D3.2b-EOSC-Architecture-and-Interoperability-Framework-2023-06-20.pdf.
[81] https://open-science-cloud.ec.europa.eu/resources/interoperability
[82] Scardaci, D., Dietrich, M., & Manghi, P. (2024). EOSC Federation: Architecture and Federating Capabilities. Zenodo. https://doi.org/10.5281/zenodo.13939396.

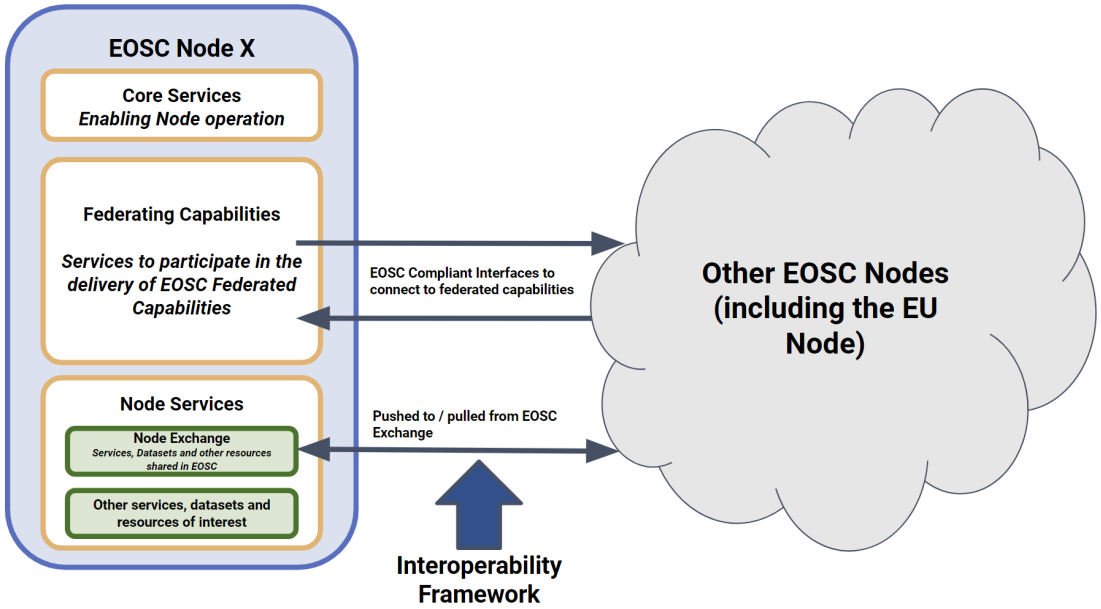

Fig. 4: Cited from: Scardaci, D., Dietrichs, M., Manghi, P. (2024): "EOSC Federation: Architecture and Federating Capabilities"[83]

Technical interoperability: Actions and main take-away's

- Further understand more how the Base4NFDI services can enter the EOSC Federation as resources providers or to offer 'capabilities' to the EOSC Core a more critical examination of the **Guidelines for Onboarding Resources to EOSC** will be needed per service [84].
- Follow the EOSC Interoperability Framework and the guidelines in the IF registry[85] to align guidelines for service providers in EOSC.
- Watch the development of the **services of EOSC Beyond** to identify any areas of technical interoperability and overlap between the services.
- Contribute to NFDI activity in the **EOSC Beyond Node Pilot** in 2025 to clarify how the national node can be established at a technical level.
- Follow updates from the EOSC TF "Technical and Semantic Interoperability"[86], **EOSC EU Node** and discussions with the EOSC procurement service providers focusing on technical interoperability with the Base4NFDI services. Also discuss the development of parallel services and how they will complement Base4NFDI services.
- After setting up the service, publish your own interoperability guidelines and onboard them to the IF registry.

[83] Scardaci, D., Dietrich, M., & Manghi, P. (2024)
[84] Dietrich, M., & Scardaci, D. (2024). Guidelines for Onboarding Resources to EOSC Exchange. Zenodo. https://zenodo.org/records/10621226.
[85] https://zenodo.org/records/7929870
[86] See: https://eosc.eu/advisory-groups/technical-and-semantic-interoperability-task-force/

Organisational Interoperability

The EOSC IF recommends[87]:

- The need to document, integrate and align processes of different organisations providing resources to EOSC so that they are easily available, accessible and user focused.
- Clear governance processes on how user communities use frameworks (AAI, ontologies etc.).
- Services should set out clear terms of use and about how to ingest or output data to standardised metadata formats.

Organisational interoperability will become clearer with the building of the EOSC Federation starting in January 2025 with 5-10 initial EOSC Nodes. The necessary "Rules of Participation" including responsibilities and policies will be announced and outlined in the *EOSC Federation Handbook*.[88] Nevertheless, each EOSC Node (also the potential German NFDI Node needs to have internal policies and rules in place). The responsibility for service provision, maintenance and interoperability towards the EOSC Federation lies in the hands of the Node. The requirements for EOSC Nodes[89] are already a good reference for organisational interoperability.

Organisational interoperability: Actions and main take-aways

• During Base4NFDI Ramp-Up phase: Set up a service and data policy in Base4NFDI with clear statements on the participation in the EOSC Federation
• Align the future Base4NFDI Service Catalogue metadata scheme with the EOSC Marketplace metadata scheme[90]
• Base4NFDI services should work closely to adopt elements from the EOSC community frameworks. Most relevant are:
  ○ EOSC Rules of Participation
  ○ EOSC EU PID Policy

[87] European Commission: Directorate-General for Research and Innovation, Corcho, O., Eriksson, M., Kurowski, K., Ojsteršek, M. et al., *EOSC interoperability framework – Report from the EOSC Executive Board Working Groups FAIR and Architecture*, Publications Office, 2021, https://data.europa.eu/doi/10.2777/620649
[88] See: https://eosc.eu/eosc-federation-handbook/
[89] See: https://eosc.eu/wp-content/uploads/2024/05/EOSC-A_GA8_20240527-28_Paper-G_Update_EOSC_Nodes_requirements-DRAFT-v240524.pdf
[90] Dietrich, M., & Scardaci, D. (2024). Guidelines for Onboarding Resources to EOSC Exchange. Zenodo. https://zenodo.org/records/10621226

Legal Interoperability

Legal interoperability according to the EOSC IF[91] is about ensuring interoperability across datasets and making them usable, in particular around metadata and licensing. Further work is needed to understand how this could apply to services. It is worth keeping legal interoperability across services on the development of Base4NFDI services during the Ramp-Up phase.

Legal Interoperability: Actions needed
• Towards the Ramp-Up phase identify what legal issues are relevant at Basic Service level. The planned Base4NFDI Business Models workshop planned for 2025 will identify initial pathways forward. • Examine how recommendations in the **FAIRImpact** report on legal interoperability[92] can apply to services. It sets the Data Catalogue Vocabulary (**DCAT)**[93] as the best standard to adopt for legal interoperability. • Add criteria to the Base4NFDI service portfolio metadata: ○ Rights, access policies, licensing • Close alignment with the NFDI Section ELSA during Ramp-Up Phase.

Semantic Interoperability

This type of interoperability is relevant to the future Service Portfolio of Base4NFDI which will have developed a metadata schema to describe its services and make them discoverable and accessible. The IF recommends for semantic interoperability that:

- Precise definitions for all metadata schemas
- A minimum metadata model to ease discovery for federated research data
- Clear protocols and building blocks for the federation of semantic catalogues

These schemas should therefore be interoperable with any guidelines for resources in the EOSC Marketplace. The most recent of this is the EOSC Future output which explains the metadata profiles to be employed[94].

[91] European Commission: Directorate-General for Research and Innovation, Corcho, O., Eriksson, M., Kurowski, K., Ojsteršek, M. et al., *EOSC interoperability framework – Report from the EOSC Executive Board Working Groups FAIR and Architecture*, Publications Office, 2021,
[92] Rouchon, O., Kraaikamp, E., Gonzalez, E., Fink Kjeldgaard, A. S., Pedersen Tenderup, N., Davidson, J., Hodson, S., Rettberg, N., & Scharnhorst, A. (2024). D6.2 - Core metadata schema for legal interoperability (Version v1). Zenodo. https://doi.org/10.5281/zenodo.11104269
[93] https://www.w3.org/TR/vocab-dcat-3/
[94] Dietrich, M., & Scardaci, D. (2024). Guidelines for Onboarding Resources to EOSC Exchange (v5.0) (5.0). EOSC-Future. https://doi.org/10.5281/zenodo.10621226

Semantic Interoperability: Action and standard to be employed
• Align the Base4NFDI service catalogue metadata service descriptions with future Onboarding Resources to EOSC Exchange as set out in the recent EOSC Future guidelines[95]. • Close collaboration with the NFDI Task Force Metadata which is based within the NFDI Metadata Section[96].

International Interoperability

Although not the focus of this paper, Base4NFDI also considers how its services become interoperable with other international infrastructures. The Global Open Research Commons[97] (GORC) is emerging as a model that other international infrastructures are using to shape their activities at policy, technical, interoperability and monitoring level. GORC define a research commons as "...a shared virtual space that presents the researcher with a marketplace for data and services"[98]. The model can work both at a disciplinary level[99] but also for defining generic services infrastructure at national level[100]. Among the instigators of the work have been the European Commission[101] and Australian Research Data Commons. The GORC can provide a framework to ensure interoperability of Base4NFDI with international infrastructures.

International Interoperability: Ongoing action items:
• Base4NFDI will work towards organisational interoperability in aligning the Basic Services to EOSC: most relevant is the training materials for all the services. The outcome of the support and training can be aligned at EOSC level, for example the EOSC Community of Practice[102] for Training and the Skills for EOSC project[103]. • Base4NFDI will follow RfII's recommendations to clearly communicate Base4NFDI service offering in the EOSC marketplace to avoid parallel activities. • Base4NFDI plans to become active on the GORC Working Group to align German national activities with European and international frameworks.

[95] See above.
[96] https://www.nfdi.de/section-meta/?lang=en
[97] https://www.rd-alliance.org/groups/gorc-international-model-wg/
[98] https://www.rd-alliance.org/group_output/the-global-open-research-commons-international-model-version-1-1/
[99] For example see the new Health data commons GORC profile: https://www.rd-alliance.org/groups/health-data-commons-gorc-profile-wg/
[100] For example see the work around GORC in Norway: https://www.rd-alliance.org/wp-content/uploads/2024/05/GORC20WG20REASON20presentation.pdf
[101] https://events.geant.org/event/1628/contributions/1804/attachments/1040/1589/1.1-GORC_Javier_LA.pdf
[102] http://www.openaire.eu/cop-training
[103] https://www.skills4eosc.eu/

Base4NFDI Services' fit with the EOSC Interoperability Framework

For each service in the Integration phase Base4NFDI will work with the Basic Service teams to assess the different levels of interoperability needed to be achieved. The following table lists the Basic Services' main description, their significance to the EOSC, how they follow the interoperability layers after the EU Interoperability Framework (technical, semantic, organisational, and legal layer), how privacy and security is accustomed for, their foreseen governance and scalability models, possible challenges, future work, and finally, how the service teams' members are engaged within the EOSC context.
This has been done for IAM4NFDI as seen in the table below:

Name	Identity and Access Management - **IAM4NFDI**
Description	IAM4NFDI is concerned with connecting and expanding existing and emerging Identity and Access Management (IAM) systems in a way that researchers from different domains and institutions are able to access digital resources within NFDI as easily as possible, including access to and exchange with external infrastructures and resources such as the European Open Science Cloud (EOSC). A decentralised, federated IAM is required. This way, users from approx. 400 German research and higher education institutions plus approx. 5000 home organisations worldwide -number increasing - will be able to access services and resources provided by the NFDI Authentication & Authorisation Infrastructure (NFDI-AAI).
Website	https://base4nfdi.de/projects/iam4nfdi
Significance	The NFDI-AAI as major output of IAM4NFDI is the building block for connecting NFDI services with EOSC services on the AAI level via established Authorisation and Authentication protocols and a set of well-established common standards and policies. This interoperability is achieved since the NFDI-AAI is connected to the national identity federation DFN-AAI which participates in the inter-federation eduGain. The eduGain interfederation service connects identity federations around the world. Building upon the same open standards, best practices and frameworks as the EOSC AAI, the NFDI-AAI has the potential to easily connect to it, once the EOSC AAI is set in place. With regard to interoperability, the guidelines and policy framework of the AARC Community (Authentication and Authorisation for Research and Collaboration)[104] play a decisive role, and the NFDI-AAI is based on these.
Technical interoperability	The concept of the so-called Community AAI (CAAI) is the central building block of the NFDI-AAI. All CAAI instances to be operated in the NFDI-AAI are building blocks to implement the AARC Blueprint

[104] https://aarc-community.org/

	Architecture (BPA). The BPA is designed to enable federated access management for international research collaborations[105,106] and plays an important role in the design of the EOSC AAI, too. The cluster of NFDI CAAIs is surrounded by a set of proxies (edu-ID, infrastructure proxy, ...), that enable the connection of the CAAIs with each other. This integrates authentication sources (Identity Providers) in eduGAIN, ORCID and Social Media platforms as well as external infrastructures such as EOSC and EGI (more are possible). Based on the same attribute profiles as detailed in the upcoming AARC Guideline G056[107] and the same Single Sign-on standards (SAML2, OpenID Connect), the NFDI-AAI and the EOSC AAI are supposed to interconnect seamlessly.
Semantic interoperability	A good example for enabling semantic operability is the support for the AARC Guidelines for expressing resource capabilities (G027)[108] and for expressing group membership and role information (G069)[109], which are also part of the IAM4NFDI Policy Framework. Otherwise, a common cross-community and -infrastructure access management would not be possible.
Organisational interoperability	While still under development, the governance model of the NFDI-AAI is based on the AARC Policy Development Kit[110] and regulates the relationship between the virtual organisations (VOs) and the top-level infrastructure (i.e. the NFDI-AAI). It also obliges the communities and VOs to comply with well-established international standards for data protection and incident response. It is supplemented by templates for acceptable use policies and privacy statements[111]. In terms of operational aspects, the terms and conditions for NFDI-entities within Germany are laid out in the IAM4NFDI service description[112]. Furthermore, being part of and connected to eduGAIN is crucial. Identity Interfederation is part of EOSC Core, which provides the essential functionality required to enable Open Science practices across domains and countries[113].
Legal interoperability	Standardised human and machine-readable policies with a centralised source of knowledge and support on copyright and licenses, in agreement with the GDPR, are listed under AARC-BPA[114] and developed for IAM4NFDI on their website[115]. DFN holds contracts with all participants of the DFN-AAI Federation that acts as the NFDI entity for eduGAIN. Home IdPs have different identity qualities but

[105] https://aarc-community.org/guidelines/aarc-g045/
[106] https://aarc-community.org/architecture/
[107] https://wiki.geant.org/display/AARC/AARC+Architecture
[108] https://aarc-community.org/guidelines/aarc-g027/
[109] https://aarc-community.org/guidelines/aarc-g069/
[110] https://aarc-community.org/policy/policy-development-kit/
[111] For the actual implementation in NFDI-AAI, see https://doc.nfdi-aai.de/policies/
[112] https://zenodo.org/uploads/13149756
[113] https://eosc.eu/wp-content/uploads/2023/12/20231114_SRIA_1.2_final2.pdf
[114] https://aarc-community.org/guidelines/
[115] https://doc.nfdi-aai.de/policies/

	follow the REFEDS Assurance Framework[116] to establish trust between IdPs, communities/VOs and Service Providers.
Privacy and security	Standard security protocols (OIDC, SAML, x.509) are in place between authorisation entities (Service Providers) and authentication entities (Identity Providers). The european privacy requirements are met in accordance with GDPR.
Governance	Service Level Agreements and governance models are provided and undergo frequent revisits[117].
Sustainability	During the project period, AAI services will be offered free of charge. After the end of the project, the services will need to be financed in a sustainable way, for example through contracts with the individual NFDI consortia or by a superordinate institution, which could act as a broker or an intermediary between the parties involved. For the later phases, the governance model can be used as part of the contract framework.
International involvement	Service team members are active members in the EOSC Task Force for "Technical and Semantic Interoperability" with subgroup "Authentication and Authorisation Infrastructure" (since 2024) and already participated in the former Task Force "Authentication and Authorization Infrastructure Architecture (AAI)" (2021-2023). Furthermore, some of the project partners of IAM4NFDI also participate in "EOSC Beyond" , which also addresses IAM- and AAI-related aspects. Several team members are part of working groups of the Research and Education FEDerations (REFEDS) group. Furthermore, some team members collaborate within the activities of the GÉANT project.
Future work	Connect Community AAIs, generic services, and infrastructure services in order to establish the NFDI-AAI. The infra proxy plays a decisive role here, as it enables structured access to services that are relevant for several communities. Another important part of this work are the so-called incubator sprints for implementing and supporting novel AAI solutions for Research Communities and their Community AAIs[118].
Challenges	When it comes to details, the interoperability between NFDI-AAI and EOSC resp. EOSC AAI is still a bit of a moving target due to the relatively new concepts of the EOSC Federation and the EOSC Nodes that are not reflected by the EIF. But with many of its members participating in the task force mentioned above, the AARC activities and EOSC Beyond, the IAM4NFDI project team is not only in the position to follow the relevant developments in EOSC, but also to help shape upcoming standards and the EOSC AAI itself.

[116] https://refeds.org/assurance
[117] https://zenodo.org/uploads/13149756
[118] https://incubators.nfdi-aai.de/

Table 3: Base4NFDI Services' fit with the EOSC Interoperability Framework.

5. Three Actions for Base4NFDI and its Basic Service Teams

To realise the above priority areas, three actions are put forward for the Base4NFDI team and its services in order to move ahead with EOSC interoperability activities:

Action 1

Align the Base4NFDI framework and services with European and international initiatives
Relevant for: members of the Base4NFDI Office team responsible for Internationalisation (Task Area 4 within Base4NFDI)

- Base4NFDI will stay aware of and actively contribute to relevant EOSC developments from: EOSC Association, the EOSC EU Node services, German EOSC Node. In particular developments in the newly established Task Force for Semantic Interoperability will be followed[119].
- As the Base4NFDI service catalogue develops, ensure alignment with evolving EOSC Marketplace metadata standards, in particular the EOSC Interoperability Guidelines to effectively describe the services, so the services can be found, used and authenticated.
- Follow relevant outcomes of ongoing EOSC Horizon projects such as EOSC Beyond, FAIRImpact and FAIRCore4EOSC.
- Share technical outcomes from EOSC projects and any recommendations from the EOSC Task Forces. Also ensure any standards are aligned with international recommendations and standards from international frameworks such as RDA.
- Set up formal connections with providers of the EU EOSC Node, via Memorandums of Understanding with e-Infrastructures and facilitate regular exchanges. Discuss complementary services and overlaps. In particular: EUDAT, OpenAIRE, EGI and GÉANT.
- Keep abreast of evolving European national initiatives which are also establishing OS infrastructures. Of note are Ireland[120] and the Netherlands[121]. Connections will also be maintained with RDA, ARDC, and relevant infrastructures through the Base4NFDI International Advisory Board[122].
- Base4NFDI will facilitate communication of the approach and guidelines established by the Global Open Research Commons[123] (GORC) to the NFDI WG Overall Architecture and potential services that build up research data commons in the German landscape.

[119] https://eosc.eu/advisory-groups/technical-and-semantic-interoperability-task-force/. Sören Lorenz, Geomar a co-spokesperson from Base4NFDI is a member of this group.
[120] https://norf.ie/
[121] Open Science Netherlands https://www.openscience.nl/en
[122] https://base4nfdi.de/about/international-advisory-board-base4nfdi
[123] https://www.rd-alliance.org/groups/gorc-international-model-wg/

Action 2

Contribute to German NFDI EOSC Node Activities

Relevant for: Base4NFDI Integration and Ramp-up Team (TA2 and TA3) and members of the Base4NFDI Office team responsible for Internationalisation (TA4)

- The Base4NFDI Internationalisation TA4 team will follow the EOSC German Node developments and will communicate relevant roadmaps on this pilot stage if the NFDI Node application is successful. The activities within the EOSC Beyond pilot will also be communicated where relevant to the Service teams. As Base4NFDI develops the Ramp-Up phase criteria and frameworks for operating and business models, this will become more relevant for offering services via EOSC.
- Base4NFDI will attend the EOSC Round table and contribute to further iterations or consultations of the EOSC SRIA and MAR (Multi-annual Roadmap)[124].

Action 3

Establish pathways to EOSC interoperability along each of the Base4NFDI service phases

Relevant for: Base4NFDI service teams, Base4NFDI service stewards

- **Proposal preparation stage:** The service providers that comprise the Base4NFDI services teams are by default well-embedded in European and international activities. The service teams so far have already demonstrated an understanding of complementary activities at the European level during section discussions and in the proposals[125]. Existing connections and complementary services at European level should be included in the Initialisation phase proposal.

- **Initialisation phase:** This phase is primarily concerned with requirements-gathering across the consortia and initial software testing around the service. Some consideration towards EOSC prepared-ness will happen during this phase.
    - **Organisational interoperability:** Projects should be aware of EOSC and complementary initiatives, but there is no onus to integrate or share services via EOSC at this stage.
    - **Technical interoperability:** Awareness should be developed around the options for EOSC interoperability such as open APIs and openly licensed software development.
    - **Software**: Design code as simple and reusable and provide it open source. Follow standard practices such as enabling comments and appropriate naming conventions. Good coding practice and extensive documentation will enable interoperability with other software elements. Use open specifications, where available, to ensure technical interoperability when establishing European public services[126].

[124] https://eosc.eu/sria-mar/
[125] https://base4nfdi.de/overview-submission-rounds
[126] https://ec.europa.eu/isa2/sites/isa/files/eif_brochure_final.pdf

- **Integration phase:** One of the aims of the Integration phase is interoperability with European initiatives. Interoperability will be in line with the "Guidelines for onboarding resources to EOSC" [127] In line with these, Base4NFDI has compiled a minimal set of service attributes serving as criteria for signing off the Base4NFDI phases. Fulfilment will automatically ensure a basic interoperability with EOSC. Missing details will be discussed on a per-service basis between service teams, service stewards, and TA2/TA3 staff, focusing on:
    - **Organisational interoperability:** Identify relevant European initiatives per service, prioritise relevant EOSC initiatives, and initiate networking. Discuss with identified initiatives. A list of relevant and complementary initiatives and services should be created during the Integration phase.
    - **Technical interoperability:** Discuss a possible entry to the EOSC Exchange and where relevant the potential for providing capabilities to the EOSC Core.
        - For each service, use the EOSC Guidelines for Onboarding Resources to develop technical interoperability with the EOSC Federation[128].
        - Define what protocols and interfaces are being deployed and check via the Interoperability Framework. Use common and internationally accepted standards.

  Base4NFDI service teams will join an internal 'EOSC Connectivity meetings', facilitated by Base4NFDI. The outcome will be a 'checklist for EOSC interoperability' and a plan for the Integration stage for each service, which will be supported by the Base4NFDI service stewards[129].

- **Ramp-up phase:** In addition to operationalising a service in a sustainable manner, this phase makes scalable and sustainable the achievements of the Integration phase.
    - **Organisational interoperability:** With the hosting institutions, examine whether the service might qualify to enter the EOSC Federation and to which extent the institutions would be able to support this.
    - **Technical interoperability:** Same as for Integration phase and an understanding of any capabilities that might be offered within the German EOSC Node offering.
    - Closely examine the 'Guidelines for Onboarding Resources to develop technical interoperability with the EOSC Federation' and identify onboarding which haven't been met so far. Discuss with the service providers the possibilities to achieve full interoperability.

[127] Dietrich, M., & Scardaci, D. (2024). Guidelines for Onboarding Resources to EOSC Exchange (v5.0) (5.0). EOSC-Future. https://doi.org/10.5281/zenodo.10621226
[128] https://zenodo.org/records/10621226
[129] https://base4nfdi.de/about/people/service-stewards

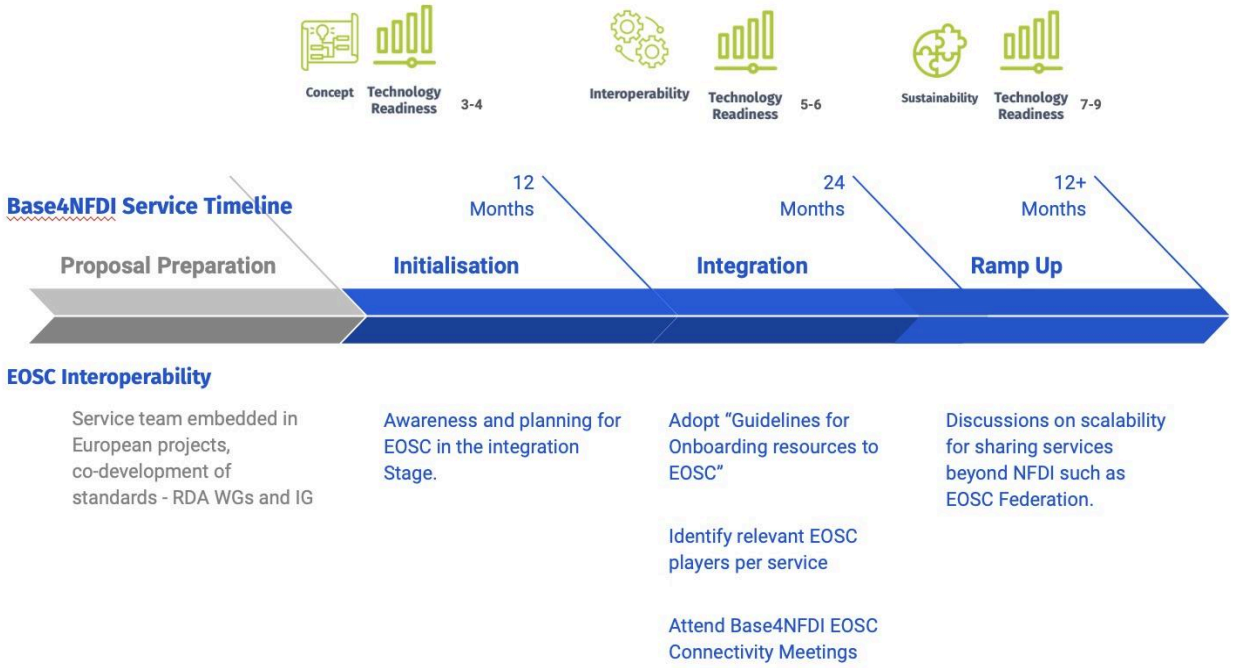

Fig. 5: The three phases of Base4NFDI services: A timeline for interoperability.

6. Next Steps and Considerations

EOSC aims to create a culture of sharing FAIR research data and outputs, and develops user-driven infrastructures. This mirrors what NFDI and Base4NFDI are establishing. Efforts to make EOSC and Base4NFDI interoperable will underpin and contribute to the sustainability of EOSC and vice versa. All initiatives are a collaborative effort, created in an iterative way. Base4NFDI is committed to contributing and being interoperable with the building blocks of EOSC along its journey to establishment.

It should also be noted that most Base4NFDI Basic Service projects are at the very start of service development. Working towards EOSC alignment assumes a central role only first in the Integration phase of the services, while other deliverables such as requirements analysis or software pilots are the priorities of the Initialisation phase.

The Base4NFDI team should be fully aware of EOSC developments and keep abreast of the frameworks mentioned above to assess progress in terms of interoperability of its own services. 2025 will see the roll out of the EOSC EU Node services and the development of the German Node via the EOSC Beyond Pilot. These activities will be closely followed.

The following challenges will also need to be tackled by Base4NFDI and could be the subject of future papers:

- Providing services within the EOSC framework will be complex. There are many open questions such as how to serve users beyond the agreed user base. Coming to an agreement with funders is necessary as well as clear messaging and agreement around what are the incentives in going beyond the existing remit to a wider community.
- While the intention of EOSC is to facilitate access to services “free at the point of use”[130] the services come with costs to maintain, build and operate. Mixed pricing models will also be an issue for the Base4NFDI services if they operate in an EOSC environment where there are different business models and a mixed landscape of public and private sector providers.
- Both Base4NFDI and EOSC need to attract users and both initiatives will have challenges and will need to intensify efforts for service usage. This could be a future area of alignment. Base4NFDI’s approach to support and training will encourage use of the services, placing the end user at the centre and will align with any EOSC development, at EOSC EU level or national node level.

Part of Base4NFDI’s mission is to work towards this alignment and realising these recommendations, in particular highlighting how nationally created services can be visible and used in the international context, and avoid overlaps. Base4NFDI intends to steer its service teams to this end.

[130] https://www.e-ciencia.es/tinman-report/

This paper is intended as a starting point and provides actions for the Base4NFDI service teams. This report will be updated in 12 months time when Base4NFDI services will be in the Integration phase and EOSC alignment activities will have started.

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II. Glossary

ARDC	Australian Research Data Commons; Australia's leading research data infrastructure facility.
Base4NFDI	A joint initiative of all 26 NFDI consortia; aims to integrate and establish basic services as common, interoperable solutions for FAIR research data management.
DFN	Deutsches Forschungsnetz (German National Research and Education Network), operating and developing the communications infrastructure for Germany's broader scientific community.
EGI	Open Ecosystem for Research and Innovation; a federation of computing and storage resource providers united by a mission of delivering advanced computing and data analytics services for research and innovation.
EIF	European Interoperability Framework; a set of recommendations which specify how administrations, businesses and citizens communicate with each other within the EU and across Member State borders.
EOSC	European Open Science Cloud; a European Commission initiative aiming at developing an infrastructure providing its users with services promoting open sciences practices. Building the envisaged infrastructure follows a System of systems approach.
EOSC Association	257 member organisations, including NFDI; aiming at advancing Open Science to accelerate the creation of new knowledge, inspire education, spur innovation, and promote accessibility and transparency.
EOSC Beyond	Aims at establishing next generation services for operational and sustainable EOSC Core infrastructures.
EOSC Core	The EOSC Core platform federates existing and new infrastructures into a system of systems, providing APIs and metadata, Interoperability Frameworks, portal capabilities.
EOSC IF	EOSC Interoperability Framework; a generic framework that can be used by all entities participating in the development and deployment of EOSC.
EOSC MAR	EOSC Multi-Annual Roadmap; defines a set of priorities for future investment in EOSC.
EOSC Marketplace	A multi-disciplinary hub and a single access point for researchers, providers, and businesses to perform and support Open Sciences

	practices.
EOSC Nodes	A European platform and information gateway to explore, engage, and enrich research collaborations.
EOSC SRIA	EOSC Strategic Research and Innovation Agenda; defines the general framework for future research, development, and innovation activities in relation to EOSC.
ERIC	European Research Infrastructure Consortium; establishes a research infrastructure of European importance on a non-economic basis.
EUDAT	Data shared and preserved across borders and disciplines.
FAIRCore4EOSC	The project focusses on the development and realisation of core components for EOSC, supporting a FAIR EOSC and addressing gaps identified in the SRIA.
FAIRImpact	The project aims to support the uptake of FAIR data principles and practices by research performing organisations, data services providers, and repositories through a dedicated support programme.
GÉANT	Collaboration of European National Research and Education Networks; delivering infrastructure and services to advance research and education.
GORC	Global Open Research Commons; a model for improved interoperability and collaboration; a working group from the Research Data Alliance
GWK	Gemeinsame Wissenschaftskonferenz (Joint Science Conference); dealing with all questions of research funding, science and research policy strategies, and the science system which jointly affect the Federal Government and the Länder.
NFDI	Nationale Forschungsdaten Infrastruktur (National Research Data Infrastructure); aiming at data as a common good for excellent research, organised by the scientific community in Germany.
NFDI Association	295 member institutions; promoting science and research through a national research data infrastructure that establishes and develops comprehensive research data management in Germany while also increasing the efficiency of the entire German science system.
NFDI Consortia	26 consortia, representing diverse scientific disciplines (cultural sciences, social sciences, humanities, engineering, life sciences, natural sciences).
NFDI Sections	5 sections, working on cross-consortium standards, metadata standards and formats.

OpenAIRE	Open Access Infrastructure for Research in Europe; globally promoting open scholarship and improving discoverability, accessibility, shareability, reusability, reproducibility, and monitoring of data-driven research results.
RDA	Research Data Alliance; community-driven initiative aiming at building the social and technical bridges that enable researchers and innovators to openly share and re-use data across technologies, disciplines, and countries to address the grand challenges of society.
RfII	Rat für Informationsinfrastrukturen (Council for Scientific Information Infrastructures); aiming at facilitating and accelerating digital transformations in the sciences on a national level within Germany.

III. Appendix

EOSC Horizon Europe Project	NFDI Member institution
AI4 | Artificial Intelligence for the EOSC	KIT (Karlsruhe Institute for Technology)
AquaINFRA | Infrastructure for Marine and Inland Water Research	DKRZ (Deutsches Klimarechenzentrum), Helmholtz-Zentrum Hereon, Hochschule Bochum, KIT, TU Dresden
BY-COVID | BeYond COVID	Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V., Albert-Ludwigs-Universität Freiburg, Informationszentrum Lebenswissenschaften
Blue-Cloud2026	Alfred-Wegener-Institut - Helmholtz Zentrum für Polar- und Meeresforschung
CRAFT-OA | Creating a Robust Accessible Federated Technology for Open Access	University of Göttingen (UGOE), Max Weber Stiftung (MWS), Technische Informationsbibliothek (TIB)
EOSC Beyond	DESY, FZ Jülich, GWDG, KIT
EOSC ENTRUST	GESIS
EOSC4Cancer	Deutsches Krebsforschungszentrum Heidelberg (DKFZ), Uni Freiburg
FAIR-EASE | FAIR EArth Sciences & Environment services	Alfred-Wegener-Institut - Helmholtz Zentrum für Polar- und Meeresforschung
FAIR-IMPACT	Universität Bremen, KIT
FAIRCore4EOSC	GWDG, Schloss Dagstuhl - Leibniz-Zentrum für Informatik, FIZ Karlsruhe, Deutsches Klimarechenzentrum GmbH (DKRZ),
OSCARS | Open Science Clusters' Action for Research and Society	FZ Jülich
OStrails | Open Science Plan-Track-Assess Pathways	RWTH Aachen
SciLake | Scientific Data-Lake-as-a-Service	Deutsches Forschungszentrum für Künstliche Intelligenz (DFKI)
Skills4EOSC	KIT
StRESFRI | European STRategy Forum on	https://www.esfri.eu/partners

Research Infrastructures (ESFRI)	
TITAN	Charité – Universitätsmedizin Berlin, Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.

Table 4: EOSC Horizon Europe Projects to support EOSC, and related NFDI Member institutions.