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D1.3 - Recommendations for a FAIR EOSC - White Paper of the FAIR-IMPACT Synchronisation Force

Marjan Grootveld, Anne Sofie Fink, Clement Jonquet, Esteban González Guardia, Ingrid Dillo, Josefine Nordling, Joy Davidson, Liisa Marjamaa-Mankinen, Maaïke Verburg, Mike Priddy, et al.

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D1.3 Recommendations for a FAIR EOSC -

White Paper of the FAIR-IMPACT Synchronisation Force

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TERMINOLOGY

Terminology/Acronym	Description
API	Application Programming Interface
CAT	Compliance Assessment Tool
COAR	Confederation of Open Access Repositories
EOSC	European Open Science Cloud
EOSC-IF	EOSC-Interoperability Framework
EOSC-OA	EOSC-Opportunity Area
EOSC-TF	EOSC-Task Force
FAIR	Findable, Accessible, Interoperable, Reusable
GDPR	General Data Protection Regulation
HE	Horizon Europe
IPR	Intellectual Property Rights
KER	Key Exploitable Result
MAR	Multi-Annual Roadmap
MOD	Metadata for Ontology Description and Publication
OAEG	Opportunity Area Expert Group
PID	Persistent Identifier
PID Stack	The collection of services and actors, supported by standardisation, resolution mechanisms, and namespace management that results in a branded or unique PID Service to PID Managers
RDA	Research Data Alliance
SA	Semantic Artefact
SAC	Semantic Artefact Catalogue
SF2022	Report of FAIR-IMPACT Synchronisation Force Workshop 2022
SF2023	Report of FAIR-IMPACT Synchronisation Force Workshop 2023
SF2024	Report of FAIR-IMPACT Synchronisation Force Workshop 2024
SRIA	Strategic Research and Innovation Agenda
SSSOM	Simple Standard for Sharing Ontological Mappings
TF	Task Force

Executive Summary

Inspired by strategic reports on FAIR and EOSC from the period 2018-2024, the annual FAIR-IMPACT Synchronisation Force workshops discussed key topics on the road to more FAIR digital objects.



Figure 1. Detailed information on the annual workshops is available from <https://fair-impact.eu/events/synchronisation-force-events>

In this White Paper the main recommendations from these workshops are taken a step further, and mapped to two Strategic Pillars of the EOSC Multi-Annual Roadmap 2026-2027 (MAR 2026-2027) and the relevant Task Forces and Opportunity Area Expert Groups under the EOSC Association, to facilitate their uptake and impact.

1. Introduction

More than a decade ago, the FAIR data guiding principles¹ were introduced, and “since then their uptake has been impressive”. This was an observation in the White Paper² of the FAIRsFAIR project³ that we can assuredly repeat here. The FAIR-IMPACT project continued FAIRsFAIR’s Synchronisation Force annual workshops in 2022,⁴ 2023⁵ and 2024.⁶ The goal of these workshops was to assess the implementation of selected recommendations and ambitions from the Turning FAIR into Reality Report⁷ (2018), the EOSC Interoperability Framework⁸ (2021), the FAIRsFAIR White Paper (2021), the SRIA⁹ (2022) and the EOSC Multi-Annual Roadmap 2025-2027.¹⁰ We would like to thank all of the representatives of more than 120 important initiatives in the EOSC and FAIR ecosystems who provided information and recommendations; please see Appendix 2 for the list of initiatives.

This White Paper is taking the key recommendations a step further, in that they are mapped against two Strategic Pillars in the Strategic Research and Innovation Agenda of the EOSC (SRIA¹¹) as well as the relevant Task Forces¹² and Opportunity Area Expert Groups¹³ under the EOSC Association. By mapping our findings and recommendations against the core agenda of the EOSC Partnership and the charters of the main bodies of the EOSC

¹ Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data* 3, 160018 (2016). <https://doi.org/10.1038/sdata.2016.18>

² Dillo, I., Hodson, S., Pittonet Gaiarin, S., & Grootveld, M. (2021). D5.7 Recommendations for a FAIR EOSC - White Paper FAIRsFAIR Synchronisation Force 2021 (Version 1.0 Glossy). Zenodo. <https://doi.org/10.5281/zenodo.6674042>

³ <https://www.fairsfair.eu/>

⁴ Grootveld, M., Pittonet Gaiarin, S., Davidson, J., Dillo, I., O'Connor, R., Marjamaa-Mankinen, L., Verburg, M., & Jonquet, C. (2023). M1.7 - First synchronisation workshop. Zenodo. <https://doi.org/10.5281/zenodo.7692063> [SF2022]

⁵ Grootveld, M., Pittonet Gaiarin, S., Davidson, J., Dillo, I., Verburg, M., Rouchon, O., Priddy, M., Nordling, J., Marjamaa-Mankinen, L., Gonzalez, E., Fink Kjeldgaard, A.-S., David, R., & Dennis, R. (2024). M1.8 - Second synchronisation workshop. Synchronisation Force 2nd Workshop - November 2023. Zenodo. <https://doi.org/10.5281/zenodo.11082238> [SF2023]

⁶ Everhardt, M., Fink, A. S., Jonquet, C., Gonzalez, E., Dillo, I., Nordling, J., Davidson, J., Horton, L., Marjamaa-Mankinen, L., Verburg, M., Priddy, M., GRAU, N., Rouchon, O., & Pittonet Gaiarin, S. (2025). M1.9 Third Synchronisation Workshop Report - 20250211_Graphical version. Zenodo. <https://doi.org/10.5281/zenodo.14848907> [SF2024]

⁷ European Commission Expert Group on FAIR data (2018). Turning FAIR into Reality: Final Report and Action Plan from the European Commission Expert Group on FAIR data. <https://doi.org/10.2777/1524>

⁸ European Commission: Directorate-General for Research and Innovation, Corcho, O., Eriksson, M., Kurowski, K., Ojsteršek, M. et al. (2021). EOSC interoperability framework – Report from the EOSC Executive Board Working Groups FAIR and Architecture, Publications Office. <https://data.europa.eu/doi/10.2777/620649>

⁹ EOSC Association. (2023) Strategic Research and Innovation Agenda (SRIA) of the European Open Science Cloud (EOSC). Version 1.2 - 1 November 2023. https://eosc.eu/wp-content/uploads/2023/12/20231114_SRIA_1.2_final2.pdf

¹⁰ https://eosc.eu/sites/default/files/2023-01/MAR_2025-27_draft.pdf

¹¹ EOSC Association. (2024) Strategic Research and Innovation Agenda (SRIA) of the European Open Science Cloud (EOSC). Version 1.3 - 1 November 2024. https://eosc.eu/wp-content/uploads/2024/12/20241031_SRIA_1.3_final_Annex.pdf

¹² <https://eosc.eu/eosc-task-forces>

¹³ <https://eosc.eu/eosc-opportunity-area-expert-groups/>



Association, we hope to facilitate their impact and uptake. Section 2 presents the recommendations, which are intentionally short. Background narratives can be found in Appendix 1. Section 3 concludes this White Paper.

2. Recommendations for a FAIR EOSC

Building on the FAIRsFAIR annual workshops¹⁴ and the ambition to take stock of the impact of the FAIR principles a decade after their emergence, the FAIR-IMPACT Synchronisation Force workshops¹⁵ identified a number of areas for which we recommend more activity. In this White Paper, we have distilled for these areas the recommendations we believe to be the most important for the realisation of a FAIR EOSC. Within this selection, the recommendations are equally urgent. They can be taken up in parallel by the stakeholders mentioned in the respective sections, as there are no dependencies between them. Below, we show how they align with aspects of the EOSC Multi-Annual Roadmap (MAR) 2026-2027¹⁶ and can be mapped against relevant Task Forces and Opportunity Area Expert Groups under the EOSC Association, as well as a selection of Horizon Europe INFRAEOSC projects.

The link with the SRIA and the MAR

“The overall purpose of the EOSC Strategic Research and Innovation Agenda, or SRIA, is to define the general framework for future research, development and innovation activities in relation to the European Open Science Cloud.”¹⁷ The SRIA is primarily concerned with the steps needed, over a six-year period from 2021, to build the EOSC. “The Multi-Annual Roadmap, or MAR, constitutes a section of the SRIA with the purpose of informing the periodically developed Horizon Europe Work Programmes. To that end, the EOSC Association regularly updates the MAR to devise a set of priority actions and outcomes for each upcoming Work Programme. The current MAR 2026-2027, as presented in SRIA 1.3, serves to inform the Horizon Europe Work Programme 2026-2027.” (ibid.)

In this White Paper, we link the recommendations from the FAIR-IMPACT Synchronisation Force workshops to the MAR 2026-2027. We focus on Strategic Pillars 2 and 3 and for simplicity’s sake link each recommendation - or rather, each topic - to only one Strategic Pillar. However, progress concerning some of the recommendations will also contribute to other Strategic Pillars, since some of our topics are addressed in more than one Strategic Pillar. In addition, some recommendations address the sustainability of project outputs.

1. **MAR Strategic Pillar 2: Contributing to the web of FAIR data:** Under this heading the SRIA mentions incentivising the production and sharing of more FAIR artefacts and elaborating more coherent FAIR assessments, as well as accelerating the adoption of

¹⁴ <https://www.fairsfair.eu/advisory-board/synchronisation-force>

¹⁵ <https://fair-impact.eu/synchronisation-force>

¹⁶ The MAR 2026-2027 is part of the SRIA version 1.3, see footnote 9.

¹⁷ Source: <https://eosc.eu/sria-mar>

interoperability and semantic artefact catalogues. Furthermore, it addresses the use of PIDs and the adoption of PID technologies being developed for EOSC.

2. **MAR Strategic Pillar 3: Ensuring research security and sovereignty:** To advance this strategic goal the SRIA addresses the need to define a harmonised operational and legal framework, in order to facilitate the secure sharing and governance of data, as well as access to data. Also, it mentions the need to support and embed appraisal, retention and preservation procedures for long-term data.
3. Projects funded by the European Commission have to consider how they will sustain their outputs and what is needed for uptake by the community at large.

2.1 Contributing to the web of FAIR data

The FAIR guiding principles are considered an important instrument to make science transparent and reproducible. “EOSC is conceived as a Web of FAIR Data and Related Services for science. This is intended to highlight the interconnectedness of people, services and content.” (SRIA p. 65). Among the FAIR-enabling and FAIR-enhancing activities undertaken in recent years and discussed in FAIR-IMPACT Synchronisation Force workshops, are tools to implement metrics and assess FAIRness, development of crosswalks and adoption of semantic technologies, and investment in identifiers, which are all among the the earlier key strands mentioned in the SRIA (p. 66).

Rec. 1: Improve the awareness and uptake of FAIR in the research community by providing a platform of stories and lessons related to the implementation of FAIR and associated benefits.

A long-standing recommendation for assessing the FAIRness of a digital object emphasises that assessments should encourage enhancement rather than merely achieving a score for FAIRness. In addition, different approaches exist for computing FAIRness scores, which typically lead to different scores¹⁸. This diversity stems from the tools' divergent development trajectories. For these reasons, numbers need a narrative. A platform for stories, experiences and lessons learned on the implementation of FAIR digital objects and the FAIRification processes is a useful means to increase the importance and prioritisation of research data management (RDM) in science.

Addressing this recommendation will require the participation of research infrastructures, research communities, and in general those who champion FAIRness. For managing and sustaining the platform as well as for collecting and curating stories, capacity is needed at a central EOSC position, such as the EOSC Gravity¹⁹ project.

¹⁸ Wilkinson, M. D., Sansone, S.-A., Grootveld M., Nordling, J., Dennis, R., & Hecker, D. (2022). FAIR Assessment Tools: Towards an "Apples to Apples" Comparison. Zenodo. <https://doi.org/10.5281/zenodo.7463421>

¹⁹ EOSC GRAVITY - Supporting the EOSC Partnership in further consolidating the coordination and sustainability of the EOSC ecosystem. <https://eosc.eu/eu-project/eosc-gravity/>

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF FAIR metrics and Digital objects, OAEG on FAIR Assessment and Alignment

Background narrative: Appendix A1

Rec. 2: Develop community-lead recommendations and governance for tests, metrics and tools for the assessment of FAIRness, supported by utilising a comprehensive catalogue of methods, metrics and tests.

Community-specificity is an essential part of FAIR. However, given the large number of (sub)communities and the existing diversity in FAIR assessment tools, the risk of unwieldy fragmentation of FAIR is huge. Moreover, FAIRness assessment scores can be lower with discipline-specific metrics than with generic metrics. In other words, community-specific assessment also has its drawbacks. It is crucial, therefore, that communities explicitly and transparently take the lead in making recommendations or selections for their field, commit to comply with them where possible, and agree on how the community (or communities) will govern them. Ideally, the governance will utilise a catalogue of methods, metrics and tests, for selecting relevant items and/or for adding new ones with the appropriate metadata with the aim to address the notable diversity in FAIR assessment tools currently in use, each with biases which are not always explicitly obvious. Whilst efforts are being made to harmonise such tools^{20,21}, it is also important to have clear metadata about the tools and the assessment methods, including any known focus or bias, plus guidance, both in improving FAIRness and in gauging the results of a FAIR assessment. A catalogue of FAIR-assessing methods, metrics and tests that makes use of this metadata and guidance can help to foster a sense of trust in such tools, evaluate differences in scores between discipline-specific and generic assessments and their applicability and value to a community.

Addressing this recommendation will require the participation of current and future developers of FAIR assessment tools as well as the participation of disciplinary communities and RIs. Work on this recommendation should also take into account the relevant report from the earlier EOSC TF on Fair Metrics and Data Quality²². This TF also started a

²⁰ Candela L., Mangione D., Pavone G. (2024) The FAIR Assessment Conundrum: Reflections on Tools and Metrics. Data Science Journal, 23: 33, pp. 1–21. <https://doi.org/10.5334/dsj-2024-033>

²¹ Wilkinson, M., & Garijo, D. (2025). D1.2 FAIRness Reference Model for Digital Objects V1. Zenodo. <https://doi.org/10.5281/zenodo.14794901>

²² <https://eosc.eu/advisory-groups/fair-metrics-and-data-quality>; Wilkinson, M., Sansone, S.-A., Grootveld, M., Dennis, R., Hecker, D., Huber, R., Soiland-Reyes, S., Van de Sompel, H., Czerniak, A., Thurston, M., Lister, A., & Gaignard, A. (2024). Report on FAIR Signposting and its Uptake by the Community. Zenodo. <https://doi.org/10.5281/zenodo.10490289>

governance discussion²³, which drew a response from FAIR-IMPACT²⁴ and which deserves to be continued.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF FAIR metrics and Digital objects, OAEG on FAIR Assessment and Alignment

Background narrative: Appendix A1

Rec. 3: Enhance metadata and semantics expertise to enable the creation and sharing of FAIR Semantic Artefacts.

To foster the creation and sharing of FAIR Semantic Artefacts (SAs) – a broader term to include ontologies, terminologies, taxonomies, thesauri, vocabularies, metadata schemas –, it is crucial to strengthen expertise in metadata and semantics across scientific communities and data stewards. Ensuring that SAs are FAIR-by-design and then shared via relevant Semantic Artefact Catalogues (SACs) requires a solid understanding of metadata standards, ontology engineering, and semantic web technologies. Capacity-building initiatives, such as training programs, workshops, and hands-on support, should be implemented to equip stakeholders with the necessary skills to design, document, and publish high-quality SAs. Additionally, given that the main reason to develop SAs is to describe, annotate or index data, fostering collaboration between domain experts and semantic specialists will enhance the quality and usability of SAs, ensuring they meet both technical and domain-specific requirements.

FAIR-IMPACT has significantly contributed to this goal by gathering, synthesising, and disseminating materials that facilitate the use of SAs at various organisational and technical levels within EOSC. It has developed a semantic framework to support governance, creation, sharing, reuse, FAIRness assessment, and interoperability of SAs, in part based on interoperable SACs such as the ones developed by the OntoPortal Alliance.²⁵ These efforts, along with technical developments such as connectors between data repositories and SACs, further demonstrates the potential impact of well-integrated semantic artefacts. This work addresses an important part of the recommendation of the EOSC Interoperability Framework.²⁶ Strengthening metadata and semantics expertise will ensure that these advances are widely adopted and effectively implemented across diverse scientific domains.

²³ Mark D. Wilkinson, Susanna-Assunta Sansone, Eva Méndez, Romain David, Richard Dennis, David Hecker, Mari Kleemola, Carlo Lacagnina, Anastasija Nikiforova, & Leyla Jael Castro. (2022). Community-driven Governance of FAIRness Assessment: An Open Issue, an Open Discussion (Final). Zenodo. <https://doi.org/10.5281/zenodo.7390482>

²⁴ Verburg M., Priddy M., Huber R., Jonquet C., Chue Hong N., Garijo D., Kechagioglou X., Davidson J., Dillo I., & Kalaitzi V.. (2023). FAIR-IMPACT project response to "Community-driven governance of FAIRness assessment: an open issue, an open discussion" (1.0). Zenodo. <https://doi.org/10.5281/zenodo.7848127>

²⁵ <https://ontportal.org/>

²⁶ 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>

Addressing this recommendation will require investing in capacity-building initiatives (e.g., RDA²⁷ or W3C²⁸ working groups), fostering collaboration between domain experts and semantic specialists (maybe inside Research Infrastructures), and encouraging researchers and data stakeholders to adopt best practices to ensure the creation and sharing of high-quality FAIR Semantic Artefacts.

Relevant EOOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF Technical and Semantic Interoperability, OAEG on Metadata, Ontologies and Interoperability. These structures may enhance the adoption and enable the incorporation of community-specific feedback and comments.

Background narrative: Appendix A2

Rec. 4: Develop semantic interoperability through FAIR Semantic Artefacts, via adoption of policies, guidelines and mappings.

This recommendation aims at more synchronisation of SAs that stem from different disciplines especially by aligning them. The establishment of clear policies and guidelines for SA creation, usage and mapping will ensure that SAs are harmonised and meet community-driven standards. Encouraging the adoption of SAs is essential for improving data integration, exchange and FAIRness. Additionally, mappings between different SAs should be developed and maintained to bridge gaps between domain-specific SAs and facilitate cross-domain interoperability. This requires the implementation of transparent workflows and governance mechanisms that support the alignment of SAs while applying the FAIR principles to these crosswalks and mappings. Collaboration between research communities, infrastructure providers, and policymakers is key to promoting best practices and ensuring the sustainability of semantic interoperability efforts. By embedding these principles into institutional and funding policies, SA-enabled semantic interoperability can better support Open Science and reproducible research.

Addressing this recommendation will require promoting the adoption of policies and guidelines for semantic interoperability, developing mappings and crosswalks that adhere to FAIR principles, and enhancing the interoperability of SACs through standardised API (such as MOD-API²⁹) and technical connection (such as OntoPortal Federation³⁰). This might involve the same actors (working groups, RIs, standardisation bodies, data stakeholders) as Recommendation 3.

Relevant EOOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF Technical and Semantic Interoperability, OAEG on Metadata, Ontologies and Interoperability.

Background narrative: Appendix A2

²⁷ <https://www.rd-alliance.org/>

²⁸ <https://www.w3.org/>

²⁹ Wilson, A., & Jonquet, C. (2024). D4.3 - Specification of shared metadata description of semantic artefacts and their catalogues including common reference API (V1.0 - DRAFT NOT YET APPROVED BY THE EUROPEAN COMMISSION). Zenodo. <https://doi.org/10.5281/zenodo.12579779>

³⁰ <https://ontoportals.github.io/documentation/administration/federation/>

Rec. 5: Ensure the interoperability and long-term persistence of PID services and seek convergence of PID systems within a PID stack.

Building sustainability and collaboration structures around PIDs in the context of the EOSC Federation and beyond is a multi-layered issue. The persistent identifier infrastructure must be built on a foundation that ensures long-term commitment and sustainability.

Addressing this recommendation

Various PID actors, such as PID Service Providers, PID Owners, PID Authorities and PID Standards Bodies, need to align themselves and conform to and align on a number of important considerations within the PID stack to ensure interoperability and sustainability. A proposed coordination mechanism between EOSC and PID Providers³¹ would support this proposed interoperability measure and would also allow integration of existing and emerging PIDs into EOSC.

As research communities play a significant role in adopting PIDs through endorsement and by shedding light on the community needs for further developments, it is crucial to be transparent towards the user community by keeping an open dialogue. The current PID services rely on varying technologies and associated policies with contractual agreements that create significant challenges for overall interoperability. EOSC and other research funders are essential: first, to provide incentives for advancing interoperability and second, to help to ensure the sustainability of PID stacks.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF on Long-term data retention, OAEG on PIDs

Background narrative: Appendix A3

Rec. 6: Integrate widely used PIDs into researchers' workflows.

The issues and risks within the PID landscape are increasingly to be addressed from a social perspective, rather than solely a technical one.

Addressing this recommendation requires that the researchers adapt widely used and adopted PIDs of research communities, infrastructures and institutions into their workflows. To facilitate the uptake and make using PIDs 'normal', it is recommended that researchers have early and positive experiences with PIDs. Data stewards should facilitate this communication, ensuring researchers understand the value and functionality of PIDs from the outset.

Relevant EOSC-A Task Forces and Opportunity Area Expert Groups: OAEG on PIDs

Background narrative: Appendix A3

³¹ Mejias, G., Cousijn, H., Marjamaa-Mankinen, L., Nordling, J., van Lieshout, N., & Gonzalez-Beltran, A. (2023). M3.2 - Proposal for an EOSC PID Service providers coordination mechanism. Zenodo. <https://doi.org/10.5281/zenodo.8405818>

2.2 Ensuring research security and sovereignty

The EOSC Interoperability Framework distinguishes four perspectives on interoperability: legal, organisational, semantic, and technical. Often, the semantic and technical perspectives seem to draw the most attention. To catch up on the legal and organisational perspective we included these in the Synchronisation Force workshops. They are part of MAR Strategic Pillar 3: “Define a harmonised operational and legal framework”. Also mentioned under that Pillar are the appraisal, retention, and preservation procedures for long-term data and other digital assets.

Rec 7: Scale up the knowledge on legal and operational interoperability through a central support programme including training and advice. Support capacity building for Research Infrastructures to acquire and apply such knowledge.

Similar to discussions about semantic interoperability it proves hard to untie the various aspects such as licensing, IPR, data-sharing agreements, and ownership of digital objects. Research Infrastructures, specifically those that distribute data, face particular challenges due to their fragmented nature that crosscuts institutional setups, legal frameworks and/or national borders, while having limited capacity to harmonise information. An integrated support programme on legal and organisational interoperability that includes training and a contact point for expertise and advice would provide a common foundation. This can take the form of a EU central hub for managing, protecting and licensing data for research-performing organisations and service/data providers, referring also to basic level knowledge, e.g. about IPR and GDPR, which should build on existing training and knowledge hubs.

Addressing this recommendation requires RIs and future Horizon Europe projects³² such as WorldFAIR+³³, TITAN³⁴, and SIESTA³⁵ handling sensitive data. For managing and sustaining the programme capacity is needed at a central EOSC position, such as the EOSC Gravity project.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAE): Legal and operational interoperability is not addressed in Task Forces or Opportunity Area Expert Groups

Background narrative: Appendix A4

Rec. 8: Continue collaboration on legal and organisational interoperability in new Horizon Europe projects.

Often discussions of enhancement of legal and organisational interoperability will turn into very elaborate and very complex action plans supported by lists of premises and limitations,

³² <https://eosc.eu/horizon-europe-projects/>

³³ <https://worldfair-project.eu/>

³⁴ <https://eosc.eu/eu-project/eosc-titan/>

³⁵ <https://eosc.eu/eu-project/siesta/>

which narrows the benefits to be achieved. A lot could be gained from collaboration on these subject matters and finding ways adapted to specific settings to progress and enhance between EOSC projects and the EOSC Ecosystem as a whole. As an example a focussed approach for enhancing legal interoperability for a case study was adopted very successfully in the WorldFAIR project.³⁶

Addressing this recommendation requires that projects seek collaboration on this topic. At the time of writing relevant Horizon Europe projects include WorldFAIR+, TITAN, and SIESTA (as above). In addition, RIs can play a role.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): Legal and operational interoperability is not addressed in Task Forces or Opportunity Area Expert Groups.

Background narrative: Appendix A4

Rec. 9: Advocate Creative Commons licenses as the default option.

For the sake of legal and organisational interoperability, Creative Commons (CC) licenses should be advocated as the default option, that is, unless another license or license family is predominant within a specific research domain or community. This recommendation aligns with the EOSC Interoperability Framework's support for permissive licenses. "A list of EOSC-recommended licences and their compatibility with Member States' recommended licences should be provided."

Addressing this recommendation requires the active support of EOSC and other major entities, such as the Common European Data Spaces³⁷ and AI factories³⁸. A default license family should be included in the EOSC Federation Handbook³⁹.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): Legal and operational interoperability is not addressed in Task Forces or Opportunity Area Expert Groups

Background narrative: Appendix A4

Rec. 10: Advance transparency in repository processes to increase their trustworthiness.

Depositing digital objects such as research data with Trustworthy Digital Repositories (TDRs) and, where possible, certified repositories is crucial for 'keeping data FAIR' over time and realising a FAIR EOSC. Certification of data repositories is one way to provide evidence of trustworthiness. However, even uncertified repositories can take steps to increase their

³⁶

https://worldfair-project.eu/social-surveys/?kubio-preview=saved&kubio-random=aFaW_HNHO-DK4y7vHB68

³⁷ <https://digital-strategy.ec.europa.eu/en/policies/data-spaces>

³⁸ <https://digital-strategy.ec.europa.eu/en/policies/ai-factories>

³⁹ <https://eosc.eu/eosc-federation-handbook/>

trustworthiness by making their policies and processes more transparent to end users. This is encapsulated in the principle of ‘trust through transparency’.

Addressing this recommendation requires coordinated efforts from service providers, host organisations, and international initiatives such as COAR⁴⁰ and RDA Working Groups^{41,42}. Supporting the implementation of this recommendation is also in the remit of the EOSC FIDELIS⁴³ and EOSC EDEN⁴⁴ Horizon Europe projects, which started in January 2025. FIDELIS will foster the development of a European network of trustworthy repositories and EOSC EDEN will develop and establish a framework to identify what data are candidates to long-term preservation based on use, benefit, and quality.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF Long-term data retention, TF FAIR metrics and Digital objects, OAEG on FAIR Assessment and Alignment

Background narrative: Appendix A5

Rec. 11: Build an inclusive and collaborative network of TDRs to share experiences and expertise.

TDRs currently operating in the EOSC context have valuable experience to share with those seeking to increase their trustworthiness. Peer to peer knowledge exchange can be a powerful resource but can often be difficult to coordinate and sustain. While there has already been some activity related to developing and supporting networks of TDRs to share experiences, more work is needed to ensure that these networks are inclusive, sustainable and enable strong collaboration between all involved stakeholders - at both the European and global level.

Addressing this recommendation requires some form of governance for TDR networks. In Europe the EOSC FIDELIS project will help to address this recommendation by establishing and operating a sustainable European network of trustworthy repositories within the EOSC ecosystem. There must also be cooperation across the current TDR initiatives to build and sustain a network of TDRs - not just in Europe but globally.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OEAG): OAEG on FAIR Assessment and Alignment. Other initiatives such as COAR and TDR-related RDA working groups should also be involved.

Background narrative: Appendix A5

⁴⁰ <https://coar-repositories.org/>

⁴¹

<https://www.rd-alliance.org/groups/community-based-catalogue-requirements-trustworthy-technical-repository-service-providers/activity>

⁴² <https://www.rd-alliance.org/groups/data-repository-attributes-wg/activity>

⁴³ <https://csc.fi/project/fidelis/>

⁴⁴ <https://csc.fi/en/project/eosceden/>

Rec. 12: Provide different kinds of support to help repositories increase their trustworthiness

To ensure availability of TDRs in the EOSC, support at different levels is needed to improve the overall transparency of repositories and, where appropriate, to help them progress toward certified status. Financial support is also necessary to enable both service provision and enhancement but also to enable repository staff to take advantage of peer exchange and training opportunities.

Addressing this recommendation depends upon the establishment of sustainable access to financial support and skills development resources and will require continued cooperation between TDRs and network initiatives, funding sources and user communities. In Europe, EOSC FIDELIS will help to address this recommendation in the short term through the provision of financial support to help repositories to adopt FAIR-enabling practices and through the provision of training and mentoring.

Relevant EOSC-A Task Forces (TF) and Opportunity Area Expert Groups (OAEG): TF Long-term data retention.

Background narrative: Appendix A5

2.3 Sustainability of project outputs

Although sustainability of project outputs is not explicitly mentioned in the MAR 2026-2027 Strategic Pillars, one could argue that it is a key instrument for achieving the MAR goals and the SRIA objectives: it is hard to imagine how a sustainable EOSC Federation would come about if no project outputs, Key Exploitable Results et cetera would live on beyond the projects' ends. However, their long-term sustainability is a common challenge for many projects. It was therefore decided to host a dedicated session during the Synchronisation Force Workshop 2024.

Rec. 13: Incorporate relevant outputs from EOSC-related projects in the EOSC Federation Handbook.

The EOSC Federation Handbook⁴⁵ documents decisions taken by the EOSC Tripartite Governance on the EOSC Federation and will serve as the reference document for the operation of the Federation. This Handbook seems an obvious place to incorporate or reference project outputs that are relevant for the federation of nodes. These can be policies, guidelines and recommendations or tools, technical components, etc. The first full draft of the Handbook already contains a limited number of such references.

Addressing this recommendation would require effort from the EOSC Association and/ or the Handbook editorial team.

⁴⁵ <https://eosc.eu/eosc-federation-handbook/>

Rec. 14: Identify potential sustainability pathways for project outputs.

EOSC still remains to a certain extent a moving target and is currently not available for the integration, endorsement or uptake of solutions provided by the various projects. Shifts in the environment are very challenging for projects to respond to within the limits of their agreed work.

Addressing this recommendation requires collaboration between the EOSC Association and the EOSC-related projects to identify potential sustainability pathways. This dialogue was started at the EOSC Winter School 2024 with a dedicated area on sustainable pathways to impact for INFRAEOSC projects,⁴⁶ was integrated in the opportunity areas in the EOSC Winter School 2025,⁴⁷ and should continue into the future. Relevant projects contribute to sustainability pathways also through their participation in EOSC Horizon Europe coordination meetings and the EOSC Forum.⁴⁸

Rec. 15: Create a Sustainability Handbook to capture the common challenges, possible solutions and experiences from projects.

Each project produces a unique collection of outputs in a unique context. However, there are common challenges and opportunities that all projects share. A sustainability Handbook could provide useful references for new projects considering sustainability.

Addressing this recommendation could be an activity carried out in networking events like the EOSC Winter School. EOSC-related projects could discuss and collaboratively create such an output.

⁴⁶

<https://eosc.eu/eosc-focus-project/winter-school-2024/infraeosc-projects-sustainable-pathways-to-exploitation-of-key-results/>

⁴⁷ <https://eosc.eu/events/eosc-winter-school-2025/>

⁴⁸ <https://forum.eosc.eu/>

3. To conclude

Three years ago the FAIRsFAIR project wrote in its White Paper: “The EOSC vision is wonderful, but challenging. EOSC is a multi-stakeholder initiative, drawing together European member states, public and private providers, and research communities. Implementing a FAIR EOSC requires conscious efforts towards synchronising and aligning both information and developments throughout EOSC, and towards avoiding unnecessary duplication of work”.⁴⁹ The FAIR-IMPACT Synchronisation Force fully agrees with this. In the three annual workshops 2022-2024 we saw various examples of progress on the joint journey towards more FAIR digital objects; the FAIR guiding principles obviously have an impact.

Nevertheless, the need for synchronisation and alignment remains. This is reflected in feedback from workshop participants, who value the Synchronisation Force for “sharing information, as the landscape is very crowded” and for “allowing convergence and harmonisation”. The 15 recommendations for targeted activity that we identified and linked to MAR 2026-2027 Strategic Pillars, EOSC Task Forces and Opportunity Area Expert Groups strongly underline this. In particular, across the topics addressed in the current White Paper, we see a need for pulling together and sharing knowledge in various forms for different stakeholders: lessons learned from implementing FAIR, expertise on metadata and ontology, knowledge on legal and organisational interoperability, expertise on what makes repositories trustworthy, and a handbook for projects about sustaining their project outputs. Not all of this may sound innovative. It is foundational, however, and essential for collaboration towards a FAIR EOSC.

In the process we concluded that no Task Force or Opportunity Area Expert Group currently addresses legal and organisational interoperability. Yet there is work to be done, considering recommendations 7-9. To remedy this we appeal to the EOSC Association to found a group within the OAEG on Metadata, ontologies and interoperability, focussing on these two perspectives on interoperability. Alternatively a new OAEG dedicated to legal and organisational interoperability could be introduced, related to for instance the SIESTA⁵⁰ project and the Common European Data Spaces.⁵¹

In January 2025, FAIR-IMPACT and many other EOSC-related projects, Task Forces and Opportunity Area Expert Groups participated in the EOSC Winter School 2025. Under the heading ‘Encouraging collaborative efforts among stakeholders’ they addressed the MAR Strategic Pillars. In the spirit of synchronising the efforts for a FAIR EOSC, we recommend that stakeholders who help implement our recommendations take into account the relevant actions identified in the Winter School.⁵²

⁴⁹ Dillo, I., Hodson, S., Pittonet Gaiarin, S., & Grootveld, M. (2021). D5.7 Recommendations for a FAIR EOSC - White Paper FAIRsFAIR Synchronisation Force 2021 (Version 1.0 Glossy). Zenodo. <https://doi.org/10.5281/zenodo.6674042>. P. 18

⁵⁰ <https://eosc.eu/eu-project/siesta/>

⁵¹ <https://digital-strategy.ec.europa.eu/en/policies/data-spaces>

⁵² <https://eosc.eu/eosc-focus-project/winter-school-2025/>

Appendix 1 - Narratives

The narratives in this appendix provide background information for the recommendations in Section 2. Readers looking for even more context are referred to the three reports about the Synchronisation Force Workshops in 2022,⁵³ 2023,⁵⁴ and 2024.⁵⁵ In the narratives below the reports are referred to as [SF2022], [SF2023], and [SF2024], respectively.

A1. Metrics and assessing FAIRness

Metrics and assessing FAIRness is an actively developing landscape and the sessions on this topic were designed to critically discuss and reflect on the next steps that should be taken in the community. Since the initiation of the Synchronisation Force workshops,⁵⁶ which took place in the FAIRsFAIR project, FAIR metrics and assessment has been a recurring topic. The scope of the topic and the landscape has broadened to cover additional digital objects beyond data (e.g. software, semantic artefacts, data management plans) and the varying levels of development of metrics, tests, and tools. Through the series of FAIR-IMPACT workshop sessions covering metrics and assessing FAIRness, we have been considering this extended use of the FAIR principles and their value to the research community. Although newer, interest is strong in the FAIRification and assessment of these other research outputs. These discussions contributed to the Metrics and Assessing FAIRness recommendations presented in this White Paper [SF2022, SF2023].

The overarching theme has been that FAIR should not be seen as the end goal but instead a means to reach other goals, as the original principles were also labeled as ‘guiding’ for the same reason [SF2024]. A recommendation from the first FAIR-IMPACT Synchronisation Force session emphasised that assessments should encourage enhancement rather than merely achieving a score for FAIRness. Participants of that session concurred that the primary objective should shift towards facilitating the practical application of FAIR principles rather than solely focussing on their measurement.

This led to focussing upon the application of principles, a platform for stories on the implementation of FAIR digital objects and the FAIRification processes, which was developed as a recommendation in subsequent workshops, taking advantage of the successes as a useful means to increase the importance and prioritisation of research data management

⁵³ Grootveld, M., Pittonet Gaiarin, S., Davidson, J., Dillo, I., O'Connor, R., Marjamaa-Mankinen, L., Verburg, M., & Jonquet, C. (2023). M1.7 - First synchronisation workshop. Zenodo. <https://doi.org/10.5281/zenodo.7692063>

⁵⁴ Grootveld, M., Pittonet Gaiarin, S., Davidson, J., Dillo, I., Verburg, M., Rouchon, O., Priddy, M., Nordling, J., Marjamaa-Mankinen, L., Gonzalez, E., Fink Kjeldgaard, A.-S., David, R., & Dennis, R. (2024). M1.8 - Second synchronisation workshop. Synchronisation Force 2nd Workshop - November 2023. Zenodo. <https://doi.org/10.5281/zenodo.11082238>

⁵⁵ Everhardt, M., Fink, A. S., Jonquet, C., Gonzalez, E., Dillo, I., Nordling, J., Davidson, J., Horton, L., Marjamaa-Mankinen, L., Verburg, M., Priddy, M., GRAU, N., Rouchon, O., & Pittonet Gaiarin, S. (2025). M1.9 Third Synchronisation Workshop Report - 20250211_Graphical version. Zenodo. <https://doi.org/10.5281/zenodo.14848907>

⁵⁶ Dillo, I., Hodson, S., Pittonet Gaiarin, S., & Grootveld, M. (2021). D5.7 Recommendations for a FAIR EOSC - White Paper FAIRsFAIR Synchronisation Force 2021 (Version 1.0 Glossy). Zenodo. <https://doi.org/10.5281/zenodo.6674042>

and other research outputs in science. Such stories could include experiences shared by researchers on the advantages of good data management, the perspective of institutions or communities that choose to invest in this, but also examples of digital objects that follow good practices without being improved or overhauled to be FAIR, or stories from outside of the EOSC or academic research context, to highlight the common advantages. There are obvious challenges with such a platform, such as its management, curation of stories, sustainability, and the potential need for governance.

There is a notable diversity in FAIR assessment tools currently in use, each with biases which are not always explicitly presented. Discussions around this led to a participant consensus on the potential benefits of a more systematic cataloguing of FAIR assessment methods and tests, applicable across various research outputs. Current efforts to harmonise FAIR assessment tools, especially for data objects, were acknowledged in the workshop sessions, such as the work currently being carried out in OSTRails.⁵⁷ These efforts respond to the tools' divergent development trajectories. It is important to have metadata that is clear, transparent, and the same across different metrics and tools. This contributes to the metrics and tools themselves becoming more FAIR. Moreover, guidance about how to interpret the results from a FAIR assessment tool, metrics and tests is important for both those who are involved in improving the FAIRness of a digital object and for those wishing to reuse it. Having such information about metrics and tools can showcase the biases that are part of them, and can allow users to then make their own informed decision about trusting and using each metric and tool.

Moreover, navigating a landscape of many different sets of metrics and tools designed for specific use cases is currently already challenging for users.⁵⁸ With further fragmentation, this will only increase, and multidisciplinary research will not easily find the right metrics for their assessment. Creating metrics is relatively easy, but endorsement, uptake, and convergence is hard. Even with the creation of metrics, it is important to be aware about the biases that are part of them. By clearly presenting biases in metrics, developers can reduce overconfidence and help shift the focus from the automated tool as purely performing an assessment function to one of guidance. Similarly to trustworthiness and certification, FAIRness and assessment should be seen as a journey, not an all-or-nothing principle.

A further challenge identified in the Metrics and Assessing FAIRness sessions is that the implementation of FAIR and the interpretation of FAIR assessments is mostly done by humans, which brings along anthropological challenges. Discipline-specific standards may be agreed upon, but might not be actually adhered to in practice. Discipline-specific assessment tools may be more accurate, but also may lead to lower FAIRness scores due to their strictness, causing frustration and possibly a user preference for the generic tools that present higher scores. Community-specific metrics are challenging due to the diversity in

⁵⁷ Delivering the Commons to Plan-Track-Assess research in EOSC. <https://ostrails.eu>; Wilkinson, M., & Garijo, D. (2025). D1.2 FAIRness Reference Model for Digital Objects V1. Zenodo. <https://doi.org/10.5281/zenodo.14794901>

⁵⁸ Examples of these challenges can be found in Antonioletti, M., Wood, C., Chue Hong, N., Breitmoser, E., Moraw, K., & Verburg, M. (2024). Comparison of tools for automated FAIR software assessment (1.0). Zenodo. <https://doi.org/10.5281/zenodo.13268685>

FAIR practices and existing communities. Developing metric sets may lead to further fragmentation of FAIR. There are risks associated with diversifying FAIR metrics, not least in the frustration users have when different metrics and tools lead to widely varying results. However, at the same time, the FAIR principles are ambiguous enough to result in more than one, or a small set of minimally different interpretations and implementations, which is why the landscape currently consists of many different metrics and tools. Harmonisation has been an ongoing effort in which it is hard to progress, and it risks ignoring important unique qualities of disciplines and their research objects. Reaching a balance between harmonisation and diversity will remain a challenge into the future. Guidance and an understanding of what is being assessed may aid in minimising the challenge.

It is important to note that data quality, in the sense of ‘fitness for purpose’, is important for daily research practice and its value, but it is not a perspective addressed by FAIR. A dataset can have objectively poor quality, but it may be essential to answering a particular research question, where the issues with the data object are known and managed.

A2. Metadata, semantics and interoperability

In a federated environment such as EOSC, and in the spirit of collaboration among scientific communities to foster knowledge, the use of Semantic Artefacts (SAs) is fundamental for semantic interoperability. Semantics can only be adopted if the communities agree on the terminology, vocabulary and concepts to use and on how to describe the relationships between them. The need to enhance metadata and semantic expertise, as well as to develop semantic interoperability through FAIR Semantic Artefacts, emerges from critical challenges faced within the EOSC and broader scientific communities. As data-driven research expands across disciplines, ensuring that metadata and semantic artefacts are created, shared, and reused in a FAIR manner becomes essential. However, many scientific communities lack the necessary expertise, infrastructure, and governance mechanisms to effectively manage and utilise SAs. This situation has led to fragmented approaches, inconsistent metadata practices, and difficulties in achieving true interoperability between datasets and research outputs.

The FAIR-IMPACT project has addressed these challenges by developing a semantic framework that supports governance, creation, sharing, reuse, FAIRness assessment, and interoperability of semantic artefacts for EOSC. The project has provided practical tools, methodologies, and recommendations, targeting various disciplines such as agri-food, ecology, earth sciences, humanities, and astronomy. These efforts have highlighted the pressing need for structured governance models, standardised metadata descriptions, and enhanced interoperability mechanisms between Semantic Artefact Catalogue (SACs) and data repositories. Despite these advancements, widespread adoption remains a challenge due to the lack of expertise and coordinated policies, which motivated two key recommendations presented.

Recommendation 3 emphasises the need to enhance metadata and semantic expertise to enable the creation and sharing of FAIR Semantic Artefacts. The findings from FAIR-IMPACT illustrate that while there are established methodologies, their uptake is limited due to gaps

in knowledge and best practices across different research domains. The development and consolidation of resources, such as the FAIR-by-design ontology development methodology and governance models, demonstrate the importance of structured guidance. Investing in training, fostering cross-disciplinary collaboration, and promoting the use of existing tools such as OntoPortal-based catalogues will be crucial to overcoming these barriers.

Recommendation 4 focuses on the necessity of developing semantic interoperability through FAIR Semantic Artefacts via the adoption of policies, guidelines, and mappings. FAIR-IMPACT's work on MOD, an SA metadata standard, FAIR mappings, and crosswalks with SSSOM,⁵⁹ has shown that while technical solutions exist, their effectiveness relies on harmonised policies and frameworks. The creation of technical connectors between data repositories and SACs further demonstrates the potential impact of well-integrated semantic artefacts. However, without consistent guidelines and interoperability measures, scientific communities may continue to face challenges in linking and reusing semantic resources efficiently. Establishing robust governance, standardising mappings, and reinforcing interoperability mechanisms will be essential steps toward achieving seamless data integration within and beyond EOSC. In the workshop we observed an interest in interoperability policies and identified the need for specific indicators to measure service compliance and to guide users in their adoption, similar to guidelines (see example⁶⁰).

FAIR-IMPACT Synchronisation Force workshops outcomes

In 2022, the session on metadata, semantics, and interoperability focussed on semantic artefacts, encompassing ontologies, vocabularies, taxonomies, and metadata schemas, which are crucial for achieving semantic interoperability within the European Open Science Cloud (EOSC). While these artefacts are widely used, their adoption and development vary significantly across disciplines. Some fields, such as social sciences, have a proliferation of artefacts, while others lack mature solutions. This variability, combined with the absence of global governance and standardised practices, complicates cross-domain interoperability.

Challenges identified include the difficulty in finding high-quality semantic artefacts, ensuring their FAIRness, managing multilingualism, and securing their long-term maintenance and governance. Many scientific communities lack guidance on which artefacts to use, while others struggle with overlaps or inconsistencies between artefacts. Despite these limitations, semantic artefact catalogues like BioPortal, AgroPortal, or in a sense FAIRSharing provide valuable resources for addressing these issues. However, the session emphasised that work on crosswalks and mappings between artefacts remains in its infancy, with few shared strategies or standardised practices.

Recommendations based on the Synchronisation Force workshop 2022 session [SF2022]:

⁵⁹ <https://mapping-commons.github.io/sssom/>

⁶⁰ Tanderup, N., Nygaard Bai, B., Fink, A. S., Gonzalez-Beltran, A., Gonzalez, E., & van Kemenade, J. (2024). M6.1 Outcome of testing components to achieve core technical & semantic interoperability in cross-domain use cases (1.0). Zenodo. <https://doi.org/10.5281/zenodo.10940164>

- Maintenance, sustainability, and governance of semantic artefacts deserve attention and agreement across disciplinary communities.
- The FAIR-at-large community should intensify the work on crosswalks and mappings to produce more best practices.
- Semantic artefact catalogues are to be developed community by community to address (some of) these needs.

In 2023, the session on metadata, semantics, and interoperability emphasised the challenges of achieving semantic and technical interoperability across scientific domains, often regarded as the most complex of the FAIR principles. Participants explored the compliance of research institutes with the EOSC Interoperability Framework's recommendations and the broader need for aligning semantic artefacts across disciplines. A preliminary survey revealed that while 70% of attendees utilise semantic artefacts primarily for metadata description, 40% engage with data from disparate domains, highlighting the critical need for cross-domain synchronisation mechanisms.

Multiple initiatives were highlighted for their role in advancing cross-disciplinary interoperability. Despite these advances, foundational elements like stable semantic artefact catalogues and crosswalks/mappings remain underdeveloped. Moreover, the absence of universally accepted definitions for terms like "metadata" and "semantic artefact" continues to hinder interoperability.

Recommendations based on the Synchronisation Force workshop 2023 session [SF2023]:

- Establishing a common understanding of semantic artefact definitions to minimise ambiguity is paramount.
- It is imperative to align semantic artefacts within and across different disciplines.
- The community requires expanding services that support the adoption and practical implementation of semantic artefacts. Enhancing access to and across semantic artefact catalogues registries could support these objectives.

In 2024, the session reinforced the importance of SAs within the EOSC Interoperability Framework and emphasised the role of indicators and metrics, such as those enabled by the Compliance Assessment Toolkit⁶¹ (CAT), in evaluating the implementation of EOSC-IF recommendations. Experts from various institutions debated interoperability challenges, particularly the need for clear policies and governance models to promote the adoption of SAs across disciplines.

Ongoing efforts to improve semantic interoperability include: (i) the EOSC-IF and its evolving policy framework, highlighting the need for a holistic approach encompassing both technical and semantic interoperability; (ii) Semantic Artefact Catalogues as a cornerstone for

⁶¹ Hugo, W., Steinhoff, W., Lieshout, N., Buys, M., Zamani, T., van Rijsselberg, F., & Märkälä, A. (2024). D2.2 – Compliance Assessment Toolkit. Zenodo. <https://doi.org/10.5281/zenodo.12683218>

enabling the FAIR principles; (iii) mappings and crosswalks and tools to facilitate SA and metadata alignment. Throughout the session, participants stressed the importance of providing incentives, user-friendly tools, and institutional support to ensure widespread adoption.

Recommendations based on the Synchronisation Force workshop 2024 session [SF2024]:

- The EOSC-IF provides a set of recommendations that need to be implemented. The use of indicators and metrics can assess the framework's implementation. The use of a tool such as Compliance Assessment Toolkit (CAT) can facilitate this assessment and the recommendations.
- Extend the set of semantic objects described in the EOSC-IF to include artefacts such as mappings and crosswalk.
- Recognise the semantic artefact catalogue as a critical part of the long-term viability of any research data infrastructure.

A3. Persistent Identifiers

PIDs can be perceived as a glue linking research information together and they form an essential component of the FAIR principles as well as for the development of EOSC.

The EOSC Persistent Identifier (PID) policy⁶² defines a set of expectations on usage requirements of persistent identifiers to support a well-functioning FAIR research environment in EOSC. Since its publication in 2020, there has been ongoing discussion about the requirements of its implementation. To address this, the EOSC Association established the PID Policy and Implementation Task Force (2021-2023),⁶³ which liaised with EOSC projects (e.g. FAIR-IMPACT and FAIRCORE4EOSC) to provide feedback on ongoing developments. The Task Force also identified strategic gaps and areas for improvement, contributing to the EOSC Partnership's Strategic Research and Innovation Agenda (SRIA).

Three FAIR-IMPACT Synchronisation Force workshops were organised to facilitate dialogue on PIDs within a broader community, including various projects, initiatives, and stakeholders from both the EOSC and FAIR ecosystems. Throughout the series, we have explored PID provision and usage, along with the development of PID policies from the perspective of various stakeholders. We also examined the need for a coordination mechanism for PID service providers to support future developments. The first Synchronisation Force workshop [SF2022] explored the key concepts of EOSC PID policy, possible PID policies of communities and related practices at the time. The second workshop [SF2023] focussed in particular on the identification of different roles included in the EOSC PID Policy, and also covered the recent developments of the Compliant Assessment Toolkit (CAT)⁶⁴ for evaluating PID service

⁶² European Commission: Directorate-General for Research and Innovation, Hellström, M., Heughebaert, A., Kotarski, R., Manghi, P. et al., *A Persistent Identifier (PID) policy for the European Open Science Cloud (EOSC)*, Publications Office. (2020) <https://data.europa.eu/doi/10.2777/926037>

⁶³ <https://eosc.eu/eosc-association/eosc-task-forces/eosc-a-task-forces-2021-2023/>

⁶⁴ <https://faircore4eosc.eu/eosc-core-components/compliance-assessment-toolkit-cat>

compliance with the EOSC PID Policy and other pertinent standards. Additionally, the workshop provided insights into community processes for selecting PID service providers, as well as PID-related workflows and the management of sensitive data. The third workshop [SF2024] focussed on identifying requirements for realising an inter-connected coordination among PID actors, as well as assurance of sustainability of PIDs.

During the dialogue, several challenges were identified and corresponding recommendations were made to address them. Some of the recommendations relate to already ongoing projects, such as Skills4EOSC,⁶⁵ which plans curricula for Data Stewards. In the context of PIDs, Data Stewards are recognised for facilitating communication and guiding researchers in understanding the value and functionality of PIDs. It is also already acknowledged that they will play an important role when consulting research communities to gain a clearer understanding of their needs.

The majority of recommendations from the three workshops have been consolidated into two key recommendations in this White Paper.

The information gained from the PID Task Force reports, milestone reports and final deliverables of the two sister projects, FAIR-IMPACT and FAIRCORE4EOSC, has been and will be utilised in the work of the Opportunity Area Expert Group 01 Persistent Identifiers, established in 2024.

A4. Legal & organisational interoperability

For the FAIR-IMPACT project addressing interoperability from all four perspectives found in the EOSC Interoperability Framework - legal, organisational, semantic, and technical perspective - has been a prerogative. Often, the semantic and technical perspectives seem to have drawn most attention. To catch up on the legal and organisational perspective the second round of the annual Synchronisation Force workshop sessions series added for the first time a session on legal and organisational interoperability.

This initial session focussed on facilitating collaboration among organisations governed by varied legal and organisational frameworks, policies, and strategies. It addressed the need to ensure that differing legislations do not hinder establishing European public services within and across Member States.

The key question for the this session was: *“What is the status and adoption of the legal and organisational recommendations presented by the EOSC Interoperability Framework⁶⁶ in different scientific domains?”*:

Selected recommendations in the EOSC Interoperability Framework as point of departure were:

⁶⁵ <https://www.skills4eosc.eu/>

⁶⁶ EOSC Interoperability Framework

<https://op.europa.eu/en/publication-detail/-/publication/d787ea54-6a87-11eb-aeb5-01aa75ed71a1/language-en>

- A clear management of permanent organisation names and functions needs to be provided.
- Standardised human and machine-readable licences, with a centralised source of knowledge and support on copyright and licences.
- A clear list of EOSC-recommended licences and their compatibility with Member States' recommended licences.
- GDPR compliance for personal data.

Recommendations based on the Synchronisation Force workshop 2023 session [SF2023]

- EOSC and other relevant entities should advocate for Creative Commons (CC) licenses unless another license or license family is predominant within a specific research domain or community. This aligns with the EOSC Interoperability Framework's support for permissive licenses. "A list of EOSC-recommended licences and their compatibility with Member States' recommended licences should be provided."
- Data creators and users should be shielded from the complexities of license impacts, necessitating both harmonisation and comprehensive guidance potentially provided by local or domain-specific data stewards. EOSC is encouraged to take an active role in this harmonisation effort.
- An integrated support programme for managing, protecting and licensing data is recommended for research-performing organisations.

The goals in 2024 was to collect feedback from concrete implementation of legal and organisational policies in data repositories, projects, and organisations.

Recommendations based on the Synchronisation Force workshop 2024 session [SF2024]

- Training for those involved in RIs and service/data providers with (EU) central hubs to bring everyone to the same level of understanding - even basic level - is required, e.g. about knowledge of IPR and GDPR.
- EOSC-related platform/contact point for advice on legal (organisational) interoperability-related documents - knowledge base, reference resources, good examples, etc. - for basic guidelines. Easy access to expertise and expert contact.
- Continued collaboration on legal and organisational interoperability for future projects such as FIDELIS, WorldFAIR+, and Climate-ADAPT4EOSC.
- Capacity building for RIs to have them leverage the expertise needed to develop the machine-actionable descriptions of what can/cannot be done - Use Case approach.

Across the sessions it was hard to untie the respective aspects such as licensing, IPR, data-sharing agreements, and ownership. Additionally, the non-legal status of FAIR principles exacerbates these difficulties. The insufficient formalisation of these aspects hampers legal

and organisational interoperability, restricts adoption, and complicates the machine-actionability of licensing constraints.

A5. Trustworthy and FAIR-enabling repositories

According to the *Turning FAIR into Reality* report, depositing research data with Trustworthy Digital Repositories (TDRs) and, where possible, certified repositories is crucial for realising a FAIR ecosystem.

The topic of TDRs was discussed at each of the three Synchronisation Force workshops between 2022 and 2024. During the course of the TDR workshops, three main themes emerged. These are transparency as a key means of demonstrating trustworthiness; the value of having access to an inclusive and collaborative network of TDRs to enable peer to peer engagement; and the need for various types of support to enable repositories to improve their trustworthiness. Below, we summarise the recommendations that were put forward in relation to each of these three themes. For more detail on these recommendations and the content of the workshops, please see the individual Synchronisation Force workshop reports [SF2022, SF2023, SF2024].

Theme: value of increased transparency

SF workshop discussions considered the role of certification in demonstrating trustworthiness. Participants agreed that certification can be a marker of trustworthiness but stressed that we should also focus on making repository policies and processes more transparent to enable end users to make informed decisions about the services they use. When it comes to certification, it is also important to recognise that there are different routes available and we should not push for a single certification scheme. Instead we should allow repositories and their user communities to determine the best route for their particular needs. It is also worth noting that the process of preparing for certification can be very valuable even if the repository is not seeking to achieve certified status.

Recommendations relating to transparency:

- Focus on making a wider range of aspects relating to trust transparent rather than just looking at certified status [SF2022]
- Increase process transparency to enable users to more effectively assess repository trustworthiness, as encapsulated in the principle of “Trust through transparency” [SF2023]
- Assess the advantages and disadvantages for generic and discipline-specific trustworthiness schemes. Wherever possible, harmonise trustworthiness schemes to better enable the provision of support [SF2024]

Theme: inclusive and collaborative networks of TDRs have a key role to play

The participants of the SF workshops discussed recent and ongoing activities to develop and support networks for TDRs to share experiences, including work being carried out by several

national and international initiatives. However, the sustainability of such initiatives is problematic and there is a need to enable more active cooperation between local, European and global initiatives.

Recommendations relating to TDR networks:

- An incremental approach to adoption of good practices is what we should be striving for and we should build on previous work to support this, such as COAR's Community Framework for Good Practices in Repositories [SF2022]
- Due to their evident advantages, support networks for repositories at all levels should be established. Cooperation across initiatives to build and sustain a network of TDRs is also needed - not just in Europe but globally. [SF2023]
- As we move towards the development of a European network of trustworthy repositories, an inclusive approach focussing on strong collaboration between all involved stakeholders is essential [SF2024]

Theme: support for repositories is needed

During the SF workshops, participants discussed the need for support at different levels to improve the overall transparency of repositories and, where appropriate, to help them progress toward certified status. Peer to peer support can be incredibly valuable but can often be difficult to coordinate and sustain. Financial support is also necessary to enable both support provision and to help repository staff to take advantage of training opportunities.

Recommendations relating to support for repositories:

- More sustainable support is needed for repositories to become trustworthy and/or certified and there is potential to replicate the national approach being implemented in France through RDA [SF2022]
- When developing and providing support, it is important to realise that a mixed approach of general and tailored support is most effective [SF2023]
- Financial support is also needed [SF2023]
- Effort should be made to build more communities of practice around the topic of trustworthiness and certification, as an essential form of peer to peer support [SF2024]

Appendix 2 - Participating organisations

The participants of the FAIR-IMPACT Synchronisation Force workshops in 2022-2024 represent the following initiatives and organisations. Affiliation and organisation type(s) were provided and selected, respectively, at registration.

Affiliation	Organisation type	Country
Accurids	Data Infrastructures	Germany
Alma Mater Studiorum - University of Bologna	Research-Performing Organisations	Italy
ASREN	National-Level Initiatives; Data Infrastructures	Germany
ATHENA Research Center	Service Providers; Research-Performing Organisations	Greece
Barcelona Supercomputing Center (BSC)	National-Level Initiatives; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures; Service Providers	Spain
BIH QUEST Center for Responsible Research at Charité - Universitätsmedizin Berlin	Research Communities & Infrastructures	Germany
Bochum University of Applied Sciences	Research-Performing Organisations	Germany
CERN	Research-Performing Organisations	Switzerland
CESSDA ERIC	Research Communities & Infrastructures	Norway
CINECA/EUDAT	Service Providers; Data Infrastructures	Italy
CINES	Data Infrastructures	France
CLARIN ERIC	Research Communities & Infrastructures	Netherlands
CNR	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Research-Performing Organisations	Italy
CNRS	Service Providers; Research-Performing Organisations	France
COAR	Data Infrastructures	Canada



CODATA	Other	France
CREAF	Research-Performing Organisations	Spain
CRG	Service Providers; Data Infrastructures	Spain
CSC - IT Center for Science	Service Providers; Data Infrastructures	Finland
CSIC	National-Level Initiatives; Research-Performing Organisations	Spain
DANS-KNAW	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Data Infrastructures	Netherlands
DataCite	Data Infrastructures	Germany
DeiC	Research Communities & Infrastructures	Denmark
Digital Curation Centre (DCC), University of Edinburgh	Service Providers; Research Communities & Infrastructures	United Kingdom
Digital Repository of Ireland	Research Communities & Infrastructures; Research-Performing Organisations; National-Level Initiatives	Ireland
DKRZ / IPCC DDC	Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Germany
DONA Foundation	Service Providers; Research Communities & Infrastructures; Data Infrastructures	Switzerland
e-Science Data Factory	Other	France
Eastern Switzerland University of Applied Sciences	Research Communities & Infrastructures	Switzerland
ELIXIR Hub	Research Communities & Infrastructures	United Kingdom
ELIXIR Norway, Department of Informatics, University of Oslo	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Data Infrastructures	Norway
EMBL-EBI	Research-Performing Organisations	United Kingdom
ENIT	Research-Performing Organisations	France
EOSC Association	Policy-Making Organisations; Scientific Societies & Academies	Belgium, Germany

ERINHA	Research Communities & Infrastructures	Belgium
ETT	Service Providers	Italy
EUDAT	Service Providers	Finland
Euro-BioImaging ERIC	Research Communities & Infrastructures	Finland
European Clinical Research Infrastructure Network (ECRIN-ERIC)	Research Communities & Infrastructures	France
European Commission - Directorate-general RYD, Directorate-general RTD	Research Funding Organisations; Policy-Making Organisations	Belgium
Finnish Meteorological Institute	Research-Performing Organisations	Finland
Finnish Social Science Data Archive	Data Infrastructures	Finland
FIZ Karlsruhe	Service Providers	France
Forschungszentrum Juelich	Research-Performing Organisations	Germany
Foundation for Research and Technology - Hellas (FORTH)	Research-Performing Organisations	Greece
GARR	Service Providers; National-Level Initiatives; Other	Italy
GÉANT	Service Providers	Netherlands
GO FAIR Foundation	Policy-Making Organisations	Netherlands
Grenoble Alpes University (UGA)	Scientific Societies & Academies	France
GRNET	Research Communities & Infrastructures; Data Infrastructures	Greece
GWDG	Service Providers; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Germany
Harvard Medical School	Research-Performing Organisations	Germany
Hasselt University	Individuals In Science; Publishers; Scientific Societies & Academies; Other	Belgium
HEAnet	National-Level Initiatives	Ireland

Heidelberg University	Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Germany
Helmholtz Association, Helmholtz Open Science Office	Research Communities & Infrastructures; Research-Performing Organisations; Policy-Making Organisations; Data Infrastructures	Germany
Helmholtz Metadata Collaboration / Alfred Wegener Institute	Research Communities & Infrastructures; Data Infrastructures	Germany
Helsinki University Library	Research-Performing Organisations	Finland
HH	Citizen Science Organisations; Scientific Societies & Academies	Algeria
Ifremer / French RI Data Terra	Service Providers; National-Level Initiatives; Data Infrastructures	France
INAF - Italian National Institute for Astrophysics	Service Providers; Research Communities & Infrastructures; Research-Performing	Italy
INRAE	Research Communities & Infrastructures; Individuals In Science; Research-Performing Organisations	France
Inserm	Research-Performing Organisations	France
Institute of Applied Biosciences, Centre for Research and Technology Hellas	Research-Performing Organisations	Greece
IT4Innovations National Supercomputing Center	Research Communities & Infrastructures	Czech Republic
Jisc	Service Providers; National-Level Initiatives; Research Communities & Infrastructures	United Kingdom
Katholieke Universiteit Leuven	Research-Performing Organisations	Belgium
Laboratoire d'Océanographie de Villefranche	Research-Performing Organisations	France
Leibniz Institute of Vegetable and Ornamental Crops (IGZ) e.V. & Information Centre for Economics	Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Germany
Leibniz Universität Hannover	Research Communities & Infrastructures; Research-Performing Organisations	Germany
Leibniz-Institut für Katalyse e.V. Rostock, Germany & NFDI4Cat	Research Communities & Infrastructures; Research Performing Organisations	Germany



LifeWatch ERIC	Service Providers; Research Communities & Infrastructures; Research-Performing Organisations	Italy
Lund University/ICOS Carbon Portal	Research-Performing Organisations	Sweden
MARIS	Data Infrastructures	Netherlands
Ministère de l'Enseignement Supérieur et de la Recherche	National-Level Initiatives; Policy-Making Organisations	France
National Oceanography Centre - British Oceanographic Data Centre	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	United Kingdom
National Research Council	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Italy
Nationale Forschungsdateninfrastruktur (NFDI) e. V.	National-Level Initiatives; Data Infrastructures; Research Communities And Infrastructures	Germany
NFDI4BIOIMAGE	National-Level Initiatives	Germany
NOC-BODC, Blue Cloud	Research Communities & Infrastructures	United Kingdom
Observatoire de Paris	Research Performing Organisations	France
OpenAIRE	Service Providers; Research Communities & Infrastructures; Policy-Making Organisations; Data Infrastructures	Greece
OPERAS	Research Communities & Infrastructures	Belgium
Premotec GmbH	Service Providers; Research Communities & Infrastructures; Research-Performing Organisations	Switzerland
Radboud University Nijmegen	Research-Performing Organisations	Netherlands
Research Data Alliance	Research Communities & Infrastructures; Scientific Societies & Academies	Belgium, Germany
Research Software Alliance	Research Communities & Infrastructures	Australia
Semanticly	Service Providers	Greece



Sikt - Norwegian Agency for Shared Services in Education and Research	Service Providers; National-Level Initiatives; Data Infrastructures	Norway
SOCIB	Service Providers; Data Infrastructures	Spain
SURF	Service Providers	Netherlands
Tampere University	Research-Performing Organisations; Data Infrastructures	Finland
The University of Manchester	Research Communities & Infrastructures; Research-Performing Organisations	United Kingdom
Trust-IT	Other	Italy
TU Graz	Research-Performing Organisations	Austria
TU Wien Library	Research-Performing Organisations	Austria
UC3M	Research-Performing Organisations	Spain
UCL Advanced Research Computing	Research-Performing Organisations; Data Infrastructures	United Kingdom
UK Data Service, University of Essex	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	United Kingdom
UKRI	Service Providers	UK
University of Freiburg	Service Providers; Research-Performing Organisations; Data Infrastructures	Germany
University of Ljubljana/FDV-ADP	Data Infrastructures	Slovenia
University Medical Center Groningen	Service Providers; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Netherlands
University Medical Center Utrecht	Research Communities & Infrastructures; Research-Performing Organisations	Netherlands
Universidad de Murcia	Research-Performing Organisations	Spain
Universidad Politécnica de Madrid	Research-Performing Organisations	Spain
Università del Salento	Research-Performing Organisations	Italy
Universitat Politècnica de València	Research-Performing Organisations	Spain



Université Côte d'Azur, CNRS, Inria, I3S	Research Communities & Infrastructures; Scientific Societies & Academies	France
University of Copenhagen	Research-Performing Organisations	Denmark
University of Edinburgh	Research-Performing Organisations	United Kingdom
University of Essex, UK Data Archive	Service Providers; Data	United Kingdom
University of Limerick	Research-Performing Organisations	United Kingdom
University of Ljubljana, Faculty of Social Sciences, Slovenian Social Science Data Archives	Service Providers; National-Level Initiatives; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	Slovenia
University of Notre Dame	Research-Performing Organisations	United States
University of Oslo	Research-Performing Organisations	Norway
University of Oxford	Research-Performing Organisations	United Kingdom
University of Oxford, UK; ELIXIR-UK; FAIRsharing	Service Providers; Research Communities & Infrastructures; Research-Performing Organisations; Data Infrastructures	United Kingdom
University of Trento	Scientific Societies & Academies	Italy
University Stefan cel Mare of Suceava	Research-Performing Organisations; Research Funding Organisations	Romania
Vrije Universiteit	Research-Performing Organisations	Netherlands
Western Norway University of Applied Sciences	Research Communities & Infrastructures; Research-Performing Organisations	Norway
X-officio	Policy-Making Organisations; Service Providers	Sweden
ZBW	Research-Performing Organisations	Germany