Preface

The publication of *The FAIR Guiding Principles for Scientific Data Management and Stewardship* [1] addressed a persistent challenge within the research data management community. Although the importance of responsible research data management was widely recognized among data professionals, its objectives and benefits often remained difficult to communicate to researchers, decision-makers, and other stakeholders outside dedicated RDM teams. In particular, data managers frequently encountered uncertainty regarding the value of data documentation, the manner in which such documentation should be structured, and the benefits that systematic data stewardship could provide.

The FAIR Guiding Principles offered a concise and broadly applicable framework through which these objectives could be articulated. By defining four high-level properties—Findability, Accessibility, Interoperability, and Reusability—the principles provided a common vocabulary for describing the intended outcomes of research data management. These overarching objectives were complemented by a set of more specific sub-principles—F1–F4, A1–A2, I1–I3, and R1–R1.3—which describe characteristics and practices intended to support their realization.

The FAIR framework was readily adopted by the RDM community and increasingly informed the development of data infrastructures, services, and research data ecosystems. In many cases, these systems were designed or adapted to satisfy the more detailed FAIR sub-principles. However, the principles were deliberately formulated at a high level and therefore present several limitations for their practical implementation:

1. **FAIR is not a technical standard.** It defines desired properties of digital research objects but does not prescribe a specific technical architecture or implementation.

2. **FAIR provides limited implementation guidance.** The principles do not determine which formats, metadata schemas, software systems, protocols, or technologies should be used.

3. **FAIR depends on community standards.** Effective implementation requires research communities to agree upon relevant standards and to apply them consistently.

4. **FAIRness is incremental.** Digital objects may satisfy individual principles to different degrees and may therefore exhibit varying levels of FAIRness.

5. **Machine actionability remains limited.** The complete and autonomous interpretation and processing of digital objects by machines may rarely be achievable.

6. **Rich metadata alone do not ensure interoperability.** Interoperability additionally requires shared representation languages, controlled vocabularies, semantic alignment, and explicitly defined relationships between digital objects.

7. **FAIR does not imply unrestricted openness.** Data subject to access restrictions may nevertheless be FAIR, provided that their metadata, access conditions, and access procedures are clearly described.

8. **FAIR is not a comprehensive governance framework.** It focuses primarily on the properties of digital research objects and does not encompass all responsibilities of data producers, repositories, research infrastructures, and institutions.

The central implementation challenge may therefore be summarized as follows: the FAIR Guiding Principles define the properties that well-managed digital research objects should exhibit, but they do not themselves provide the shared standards, technical specifications, or coordinated governance required to realize those properties. Their practical effectiveness consequently depends on research communities agreeing upon and consistently applying persistent identifiers, metadata schemas, semantic vocabularies, access protocols, provenance models, licences, and other domain-relevant standards.

The present wiki seeks to address this implementation gap by supporting the coordinated application of FAIR practices across the Helmholtz Association. It provides guidance on the selection and consistent use of relevant standards, technologies, and community practices, with the aim of enabling research data products to attain the highest practicable level of FAIRness.

Introduction

The Character of This Wiki

This wiki serves as the collaborative working platform of the Helmholtz Metadata Collaboration (HMC) Hub Earth and Environment. It is conceived as a living resource that reflects the current perspectives, discussions, and activities of the Hub and its wider community. Its content is continuously refined as new requirements emerge, implementation experience is gained, and community agreements evolve.

The wiki primarily supports the development, discussion, and documentation of concepts and recommendations. More formalized outcomes derived from this work are published through the central HMC website, the website of the HMC Hub Earth and Environment, or other appropriate publications and resources.

The Helmholtz Metadata Collaboration

The Helmholtz Metadata Collaboration promotes the qualitative enrichment of research data through high-quality metadata and supports the implementation of this approach throughout the Helmholtz Association.

HMC develops and implements concepts, services, and technologies for the sustainable management of research data. Its principal objective is to ensure that the breadth and depth of research data produced by the Helmholtz Centres can be discovered, accessed, interpreted, and reused by the wider scientific community in accordance with the FAIR Guiding Principles.[1] The objective of enabling FAIR research data across the Helmholtz Association is also reflected in the *Recommendations for Policies of the Helmholtz Centres on Research Data Management*.[2]

Research data, metadata, information, and knowledge systems are created and maintained by a wide range of individuals, institutions, and stakeholder groups. The establishment of a harmonized, interoperable, and ultimately FAIR research data space therefore requires the alignment of practices, responsibilities, and technical processes across heterogeneous data infrastructures. Such alignment must be implemented not only within technical systems but also through the coordinated activities of the people and organizations responsible for producing, managing, curating, and providing access to

research data.

The Content of This Wiki

Within this wiki, the HMC Hub Earth and Environment and its partners formulate recommendations for the alignment of research data management practices across the Earth and Environment community. The wiki translates general objectives into concrete implementation guidance and provides practical support for the adoption of coordinated procedures.

To advance FAIR research data across the diverse data infrastructures of the Helmholtz Research Field Earth and Environment, the Hub has developed the **Road-to-FAIR Strategy**. This strategy comprises a series of coordinated activities through which shared requirements are identified, discussed, and translated into implementable recommendations.

As an initial step, existing data infrastructures and their interfaces are examined in order to identify established practices, recurring challenges, and approaches that may serve as transferable models. On this basis, relevant committees and stakeholder groups collaborate to define implementation measures for specific objectives. For each agreed Road-to-FAIR building block, concrete recommendations are developed and documented. These recommendations are presented in this wiki as part of a living handbook and are revised as technical environments, community practices, and institutional requirements evolve.

To support consistency and transparency, all recommendations are documented according to a common structure and a shared set of guiding questions. Their development must take account of two complementary perspectives: first, the substantive discussion and community agreement concerning the intended outcome; and second, the administrative, organizational, and technical measures required for implementation.

Each step necessary for implementation must therefore be examined individually. The perspectives, responsibilities, and requirements of the relevant stakeholder groups are considered in order to identify dependencies and influencing factors. The processes through which procedures are discussed, agreed upon, and established are also documented, including both bottom-up processes originating within communities and infrastructures and top-down processes arising from institutional strategies and policies.

This approach provides a basis for clarifying and improving procedures, responsibilities, and required actions. The successful implementation of FAIR practices ultimately depends on the active participation of the identified stakeholders and on their willingness and ability to assume clearly defined responsibilities.

Contributions

The contributors to this wiki are

- HMC Hub Earth and Environment
- Working group Arbeitskreis Metadaten
- Working group Arbeitskreis Semantik

Both working groups are formed by the HMC Hub Earth and Environment and the DataHub Earth and Environment.

For questions, comments and suggestions, please write to hmc-hub_ee@geomar.de.