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 an implementation standard. The principles describe desired characteristics of digital research objects, but they do not prescribe a technical architecture, metadata schema, file format, protocol, vocabulary, or software solution. Wilkinson et al. explicitly state that the principles are neither a standard nor a specification.

2. The principles do not explain exactly how FAIRness should be achieved. Because they deliberately “precede implementation choices,” considerable interpretation is required. Communities and repositories must decide which identifiers, metadata schemas, ontologies, protocols, licenses, and provenance models to use. Consequently, two implementations may both claim to follow FAIR while remaining technically incompatible.

3. FAIR depends on community agreement outside the principles themselves. Principle R1.3 requires compliance with domain-relevant community standards, but FAIR does not define which standards are authoritative or how communities should agree on them. The practical interoperability of data therefore depends on consistent implementation of shared standards, not merely on declaring adherence to FAIR.

4. FAIRness is gradual rather than binary. The principles are independent, separable, and can be implemented incrementally or in different combinations. A resource may therefore be highly findable but poorly interoperable or reusable. The label “FAIR” alone does not communicate which principles have actually been satisfied or to what degree.

5. Complete machine actionability may be unattainable. Wilkinson et al. describe machine actionability as a continuum. A machine might identify an object but be unable to parse its format, interpret its semantics, determine its license, or decide how it may be reused. They acknowledge that

the ideal situation in which machines fully understand and autonomously operate on a digital object is rarely achieved.

6. Rich metadata do not automatically guarantee meaningful interoperability. Metadata may exist and use formal representations while still employing incompatible terminologies or ambiguous relationships. Principles I1–I3 indicate what interoperable metadata should possess, but they do not ensure semantic alignment across disciplines or infrastructures.

7. FAIR does not mean open or unrestricted. Data may be FAIR while requiring authentication or authorization. Sensitive data can remain restricted as long as its metadata, access conditions, and procedures are adequately described. FAIR, therefore, improves the ability to discover and assess data access but does not itself guarantee access.

8. The framework primarily concerns discoverability and reuse, not every dimension of responsible data stewardship. The original principles do not constitute a comprehensive framework for evaluating scientific quality, correctness, ethical acceptability, long-term preservation, social justice, governance, or trustworthiness. These matters may affect reuse, but they are not specified as independent FAIR requirements. This is a boundary of the framework rather than an explicit criticism made by the authors.

The central limitation can therefore be summarized as follows: FAIR defines the properties that a well-managed digital research object should exhibit, but it does not provide the common standards or coordinated implementation required to produce those properties. Its practical success depends on research communities agreeing upon and consistently applying persistent identifiers, metadata schemas, semantic vocabularies, protocols, provenance practices, and licenses.

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.

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