

FAIR Implementation Profiles (FIPs) and FAIR Enabling Resources (FERs) as accelerators of Interoperability and Reusability of Datasets across Multiple Communities

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We acknowledge and celebrate the First Australians on whose traditional lands we meet and pay our respect to our Elders past, present and future



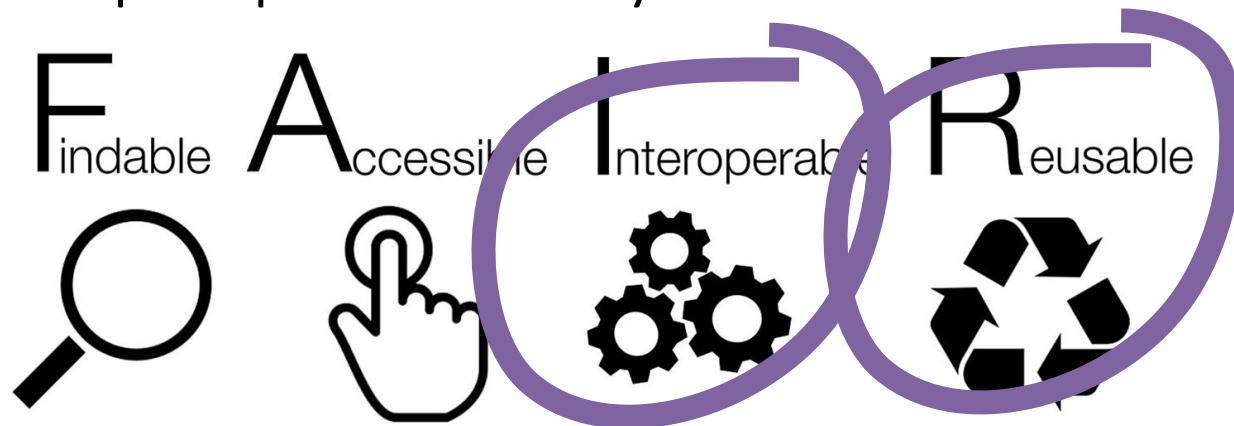
Artist: Lynnice Letty Church – Tribes: Ngunnawal, Wiradjuri & Kamilaroi (ACT and NSW)
Gadi - "to search for" in Ngunnawal language - January 2020 for NCI Gadi Supercomputer

Abstract

The Findable, Accessible, Interoperable, Reusable (FAIR) Guiding Principles of Wilkinson et al. (2016) put specific emphasis on using 'rich' metadata to enhance the ability of both humans and machines to find, access, aggregate and reuse data. Yet many datasets labelled as FAIR-compliant only meet Findable and Accessible and then only for humans. Few datasets are Interoperable and Reusable by machines mainly because there is insufficient specificity and granularity on the exact standards, formats and vocabularies implemented.

FAIR Implementation Profiles (FIPs) enable a 'community' to declare the implementation choices it makes for each FAIR principle. Each choice is then published as a FAIR-Enabling Resource (FER), which is a machine-actionable nano-publication of any object (vocabularies, services, metadata profiles, etc) used to comply with a FAIR principle. FIPs, combined with FERs, can accelerate machine-actionable interoperability and reusability of datasets acquired by different communities, and at scale. FIPs can be visualised as knowledge graphs to help identify commonalities across communities, and provide more specificity than existing FAIR assessment methodologies.

The CODATA and RDA-led WorldFAIR Project on Global Cooperation on FAIR Data Policy and Practice (<https://worldfair-project.eu/>), funded by the European Commission WIDERA Programme, reviewed different approaches to FIPs from eleven disciplinary case studies: Chemistry, Nanomaterials, Geochemistry, Social Surveys, Population Health, Urban Health, Biodiversity, Agricultural Biodiversity, Oceans, Disaster Risk Reduction and Cultural Heritage. This paper will highlight how the Geochemistry case study created FIPs at multiple 'community' levels (repository, data collection, dataset and reference) and will then compare and contrast with approaches of the other disciplines.



- The FAIR principles of Wilkinson et al. (2016) were designed to improve reuse of scholarly data by emphasising the ability of machines to find, access, aggregate and reuse data.
- Although many data producers strive to make their datasets FAIR, at best, datasets meet the findable and accessible principles and for humans only.
- Few datasets are fully machine-actionable as there is insufficient specificity and granularity regarding implementation of machine-to-machine standards, particularly for vocabularies.
- Most datasets fail on the Interoperable and Reusable Principles, particularly as these need domain criteria

WorldFAIR: Global cooperation on FAIR data policy and practice



- Funded by the European Union, HORIZON-WIDERA-2021-ERA-0 — Project: 101058393.
- Two year project from 1 June 2022.
- Nineteen partners from France, Belgium, Cyprus, Denmark, Germany, UK, Ireland, Norway (Europe); Kenya (Africa); **Australia**, New Zealand (Oceania); Brazil (Sth America); USA (Nth America).
- Project contributes to:
 - UNESCO Recommendation on Open Science
 - CODATA-ISC Decadal Programme
 - ISC Action Plan Project 2.1: 'Making Data Work for Cross-Domain Grand Challenges:
- Was based around 14 Work Packages, including 11 case study WPs
- Did pioneering work in FAIR Implementation Profiles to assist in machine-to-machine interoperability

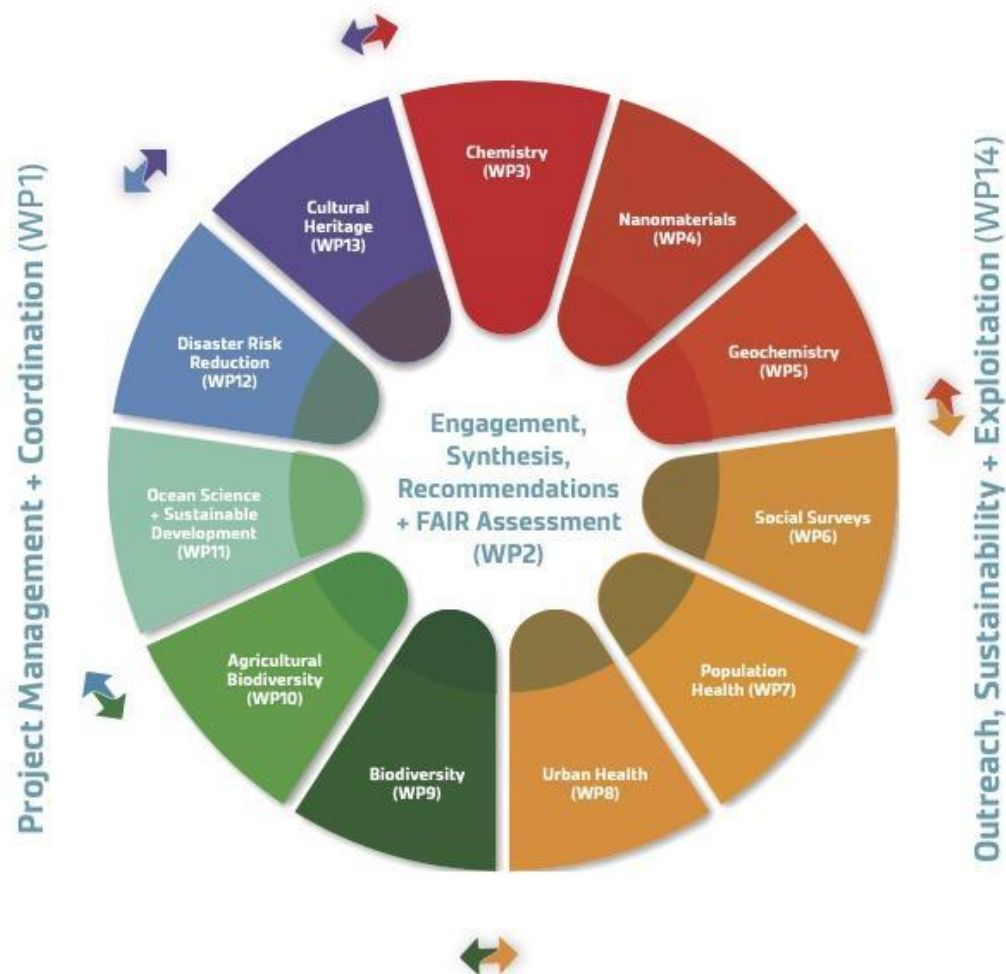


WorldFAIR Partners



WorldFAIR Case Studies

- **Chemistry** – making IUPAC assets FAIR
- **Nanomaterials** – applying NanoInchi and FAIR recommendations in Nanosafety.
- **Geochemistry** – recommendations for FAIR in geochemistry, particularly vocabularies.
- **Social Surveys Data** – data harmonisation between ESS and AussiESS.
- **Population Health** – INSPIRE - Integration of population surveys with clinical and genomics data for COVID-19 research in eastern and southern Africa.
- **Urban Health** – terminologies and making urban health data FAIR
- **Biodiversity** – improving GBIF data model in collaboration with TDWG - GBIF (Global Biodiversity Information Facility)
- **Agricultural Biodiversity** – pollinator data (KALRO, Embrapa, Meise, HiveTracks)
- **Ocean Science** – Implementing FAIR in the ODIS (Ocean Data and Information System) for the UNESCO Oceans' decade.
- **Disaster Risk Reduction** – recommendations on making DRR data and terminologies FAIR, case studies in Africa and Pacific Islands
- **Cultural Heritage** – recommendations on making cultural heritage data FAIR (particularly digital representation of heritage artefacts)



- A methodology for understanding the practices of a community in relation to FAIR.
- Developed by the GO FAIR initiative:
- A FIP is ‘a collection of FAIR implementation choices made by a community of practice for each of the FAIR Principles’.
- Set of questions, relating to each of the FAIR principles, for data and metadata, that allow a ‘community’ to state the FAIR Enabling Resources it uses to make data and metadata FAIR for each of the principles.
- Supported by an online tool: <https://fip-wizard.ds-wizard.org>
- Allows the publication of the FIPs as nanopublications, which can be very powerful, allowing machine referencing and visualisation of practice across a range of research areas.

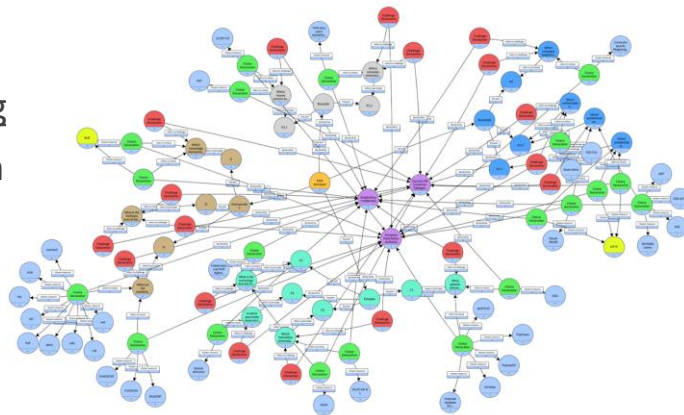
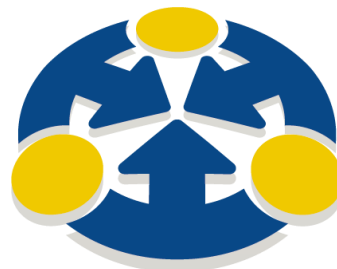


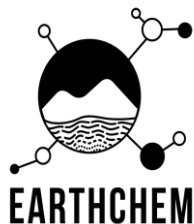
Figure from <https://www.go-fair.org/how-to-go-fair/fair-implementation-profile/>, Figure courtesy of Barbra Magagna, Umweltbundesamt GmbH and Kristina Hettne, CDS University Library Leiden



FAIR principle	Question	FAIR enabling resource types
F1	What globally unique, persistent, resolvable identifiers do you use for metadata records?	Identifier type
F1	What globally unique, persistent, resolvable identifiers do you use for datasets?	Identifier type
F2	Which metadata schemas do you use for findability?	Metadata schema
F3	What is the technology that links the persistent identifiers of your data to the metadata description?	Metadata-Data linking mechanism
F4	In which search engines are your metadata records indexed?	Search engines
F4	In which search engines are your datasets indexed?	Search engines
A1.1	Which standardized communication protocol do you use for metadata records?	Communication protocol
A1.1	Which standardized communication protocol do you use for datasets?	Communication protocol
A1.2	Which authentication & authorisation technique do you use for metadata records?	Authentication & authorisation technique
A1.2	Which authentication & authorisation technique do you use for datasets?	Authentication & authorisation technique
A2	Which metadata longevity plan do you use?	Metadata longevity
I1	Which knowledge representation languages (allowing machine interoperation) do you use for metadata records?	Knowledge representation language
I1	Which knowledge representation languages (allowing machine interoperation) do you use for datasets?	Knowledge representation language
I2	Which structured vocabularies do you use to annotate your metadata records?	Structured vocabularies
I2	Which structured vocabularies do you use to encode your datasets?	Structured vocabularies
I3	Which models, schema(s) do you use for your metadata records?	Metadata schema
I3	Which models, schema(s) do you use for your datasets?	Data schema
R1.1	Which usage license do you use for your metadata records?	Data usage license
R1.1	Which usage license do you use for your datasets?	Data usage license
R1.2	Which metadata schemas do you use for describing the provenance of your metadata records?	Provenance model
R1.2	Which metadata schemas do you use for describing the provenance of your datasets?	Provenance model

- FAIR Implementation Profiles (FIPs) are about the community of practice that wishes to interoperate their datasets agreeing on choices about the resources they are going to use to comply with each of the FAIR principles.

Declaring FAIR Enabling Resources (FERs) for each principle



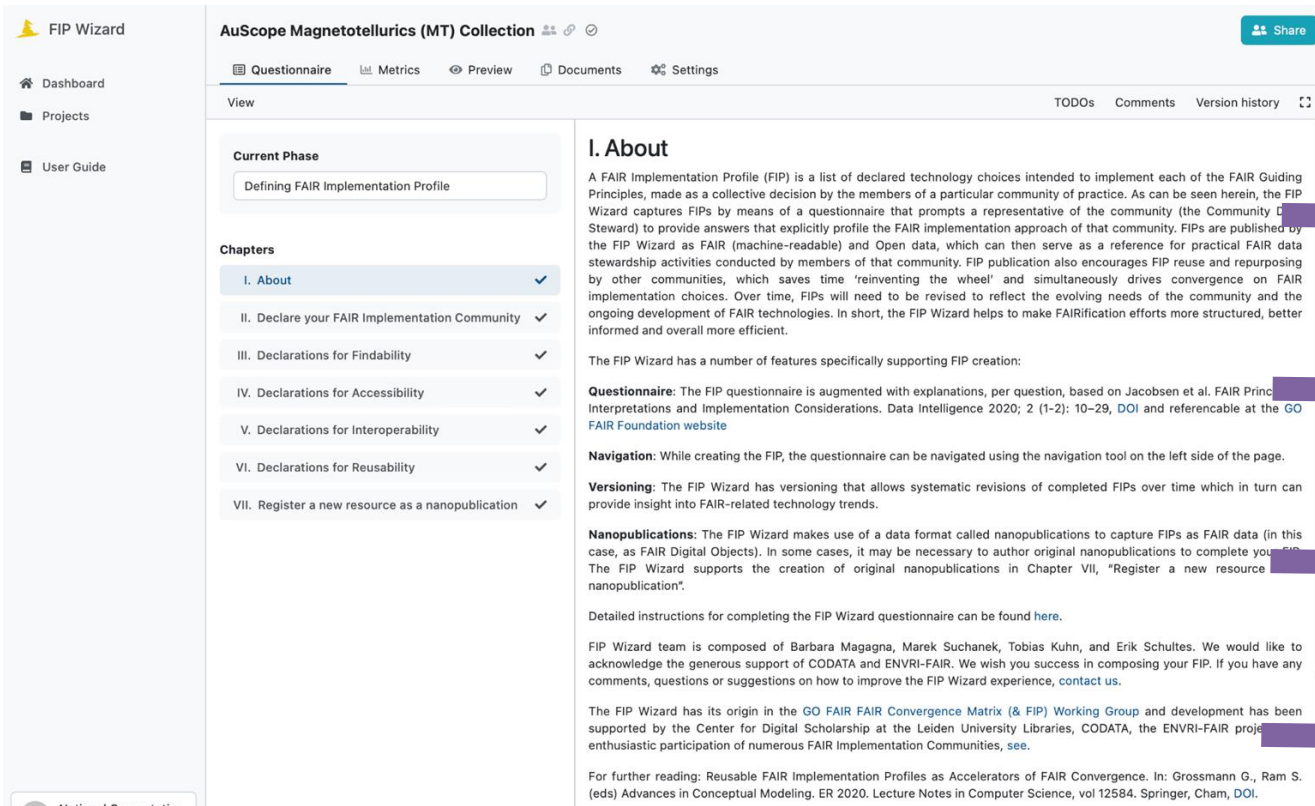
AusGeochem

- Each FAIR principle can be linked to a FER: there can be multiple FERS per principle
- A FER is a micro-publication with a PID that provides a link to any online resource that declares a FAIR Principle
- A FER could be a machine-actionable service to access data, a vocabulary, methodologies used or description schema of the data produced by that method.

F1	Which metadata schemes do you use for metadata?	Metadata schemes
F2	What is the technology that links the persistent identifiers of your data to the metadata description?	Metadata-Data linking mechanism
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I1	Which knowledge representation languages (allowing machine interpretation) do you use for datasets?	Knowledge representation language
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I3	Which models, schema(s) do you use for your datasets?	Data schema

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Which structured vocabularies do you use to encode your datasets?
Which models, schema(s) do you use for your metadata records?
Which models, schema(s) do you use for your datasets?

For more on FERS see: Schultes, E., Magagna, B., Hettne, K.M., Pergl, R., Suchánek, M., Kuhn, T. (2020). Reusable FAIR Implementation Profiles as Accelerators of FAIR Convergence. In: Grossmann, G., Ram, S. (eds) Advances in Conceptual Modeling. ER 2020. Lecture Notes in Computer Science, vol 12584. Springer, Cham. https://doi.org/10.1007/978-3-030-65847-2_13



The screenshot shows the 'FIP Wizard' interface for the 'AuScope Magnetotellurics (MT) Collection'. The left sidebar contains navigation options: Dashboard, Projects, and User Guide. The main content area is titled 'Questionnaire' and shows a 'Current Phase' of 'Defining FAIR Implementation Profile'. A list of 'Chapters' is visible, with 'I. About' selected. The 'I. About' section contains several paragraphs of text, including a definition of a FAIR Implementation Profile (FIP), a list of features supporting FIP creation, and instructions for completing the questionnaire. The text is partially obscured by arrows pointing to the right.

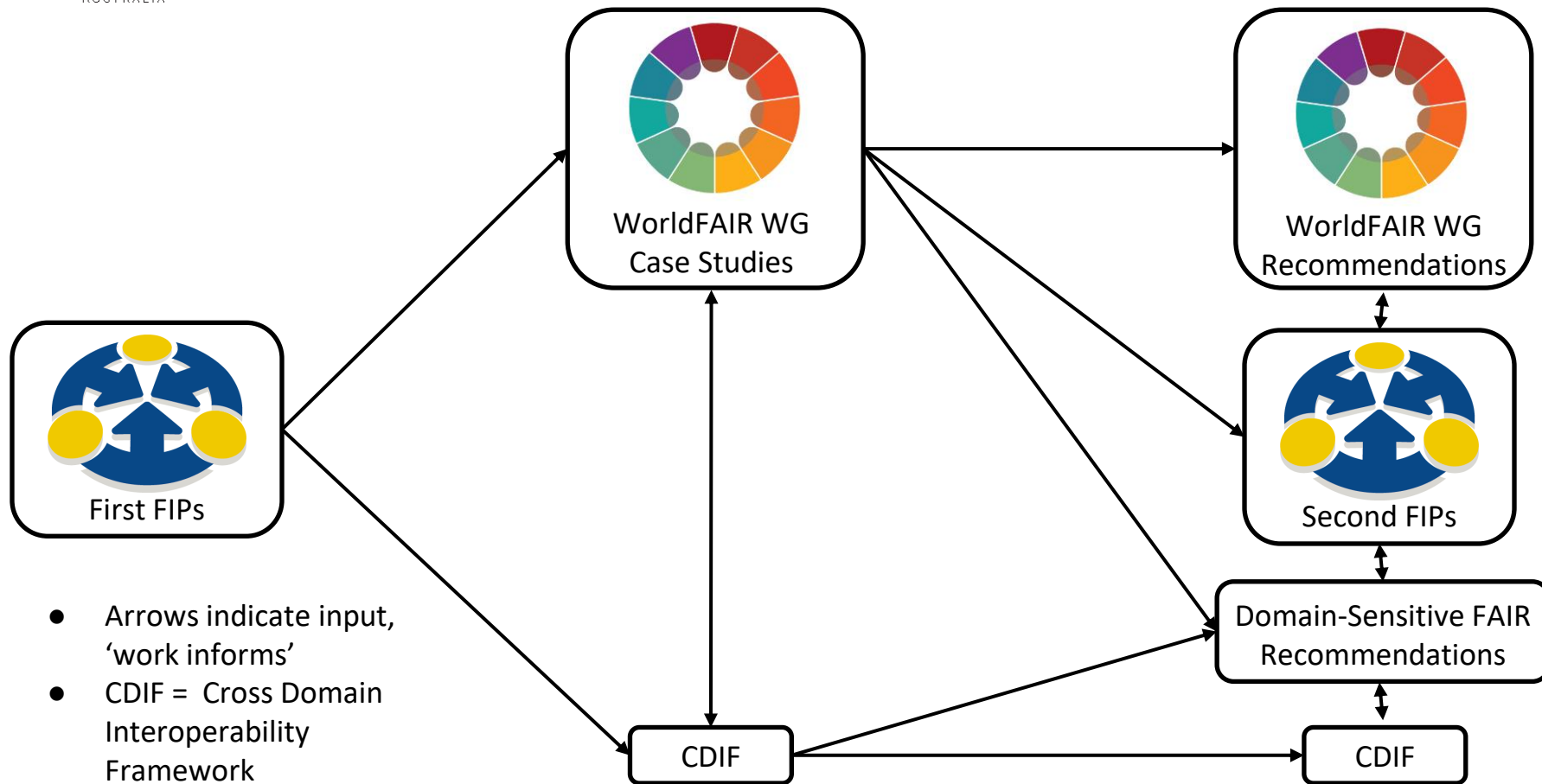
PDF

Excel

JSON

Other

WorldFAIR Objectives and Methodology



- Arrows indicate input, 'work informs'
- CDIF = Cross Domain Interoperability Framework

How has WorldFAIR used FIPs?

9.2 Appendix Two: FAIR Implementation Profile for AUSSI-ESS (managed by ADA)

This table summarises the FAIR Implementation Profile for the ADA services supporting the AUSSI-ESS through the ADA Dataverse and related services.

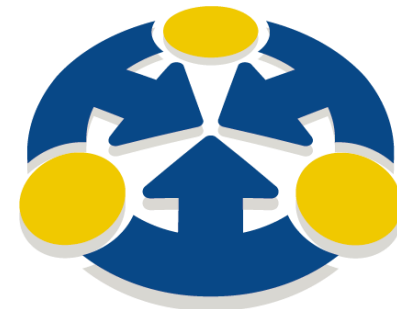
Table 6 FAIR Implementation Profile (FER) for AUSSI-ESS – Australian Data Archive

FAIR Principle name	Referring to Metadata/Data	FIP question	FER Enabling Resource used in WPO6 Social Surveys
F1	MD	What globally unique, persistent, resolvable identifier service do you use for metadata records?	DataCite DOI resolution service
F1	D	What globally unique, persistent, resolvable identifier service do you use for datasets?	DataCite DOI resolution service
F2	MD	What metadata schemas do you use for findability?	DDI Codebook Version 2.1
F2	MD	What metadata schemas do you use for findability?	DataCite metadata schema version 3.1
F3	D	What is the schema that links the persistent identifiers of your data to the metadata description?	No implementation choice has been made by this community
F4	MD	Which service do you use to publish your metadata records?	ADA Dataverse
F4	D	Which service do you use to publish your datasets?	ADA Dataverse
A1.1	MD	Which standardized communication protocol do you use for metadata records?	HTTPS Hypertext Transfer Protocol Secure
A1.1	MD	Which standardized communication protocol do you use for metadata records?	REST Representational state transfer
A1.1	D	Which standardized communication protocol do you use for datasets?	HTTPS Hypertext Transfer Protocol Secure
A1.1	D	Which standardized communication protocol do you use for datasets?	REST Representational state transfer
A1.2	MD	Which authentication & authorisation service do you use for metadata records?	None for open records; SAML2 Security Assertion Markup Language 2.0
A1.2	D	Which authentication & authorisation service do you use for datasets?	SAML2 Security Assertion Markup Language 2.0
A2	MD	What metadata preservation policy do you use?	RDA Core Trust Seal Certification
I1	MD	What knowledge representation language (allowing machine interoperation) do you use for metadata records?	JSON JavaScript Object Notation
I1	MD	What knowledge representation language (allowing machine interoperation) do you use for metadata records?	XML eXtensible Markup Language Schema

- A methodology for understanding the practices of a community in relation to FAIR.
 - Initial FIPs completed
 - Report 'FAIR Implementation Profiles (FIPs) in WorldFAIR: What Have We Learnt?': <https://doi.org/10.5281/zenodo.7378109>
- Very useful tool for understanding current and potential FAIR practices in a given community.
- Assists in focusing reflection on practice, how this may be improved. Utility of an 'as is' and an 'aspirational' FIP.
- Essential for the WorldFAIR approach:
 - Helps identify shared practices across domains.
 - See analysis of this in WorldFAIR D11.1 'An assessment of the Ocean Data priority areas for development and implementation' <https://doi.org/10.5281/zenodo.7682399>
 - Helps towards the functional breakdown and solutions in CDIF.

How did the WorldFAIR Case Studies use FIP?

- FIPs used to assist comparison of practice across the European Social Survey and the Australian Social Survey. Helped identify shared infrastructural needs (registries) and fed into recommendations.
 - See D6.1 'Cross-national Social Sciences survey FAIR implementation case studies', pp.24-27: <https://doi.org/10.5281/zenodo.7599652>
- Used in analysis to identify "both generic and domain-specific (meta)data exchange conventions and FERs with high potential to bridge other WorldFAIR case studies to and with ODIS (Oceans Data Information System).
 - See D11.1 'An assessment of the Ocean Data priority areas for development and implementation', pp.16-28: <https://doi.org/10.5281/zenodo.7682399>
- Two FIPs used to help understand 1, the 'FAIR application of IUPAC standards in supporting chemistry data exchange', and 2, 'the FAIR status of IUPAC standards for those who need to use them'.
 - See D3.1 'Digital recommendations for Chemistry FAIR data policy and practice', pp.42-44 (discussion of FERs, FIPs and CDIF in chemistry and across domains) and 59-67 (FIPs): <https://doi.org/10.5281/zenodo.7887283>
- Extended discussion of the FIPs process and reflections on implications for diverse data in nanomaterials / nano-safety domains.
 - See D4.1 'Nanomaterials domain-specific FAIRification mapping', pp.59-74 (As-Is' Nanomaterials FIP): <https://doi.org/10.5281/zenodo.7887341>
- FIPs as a basis guide (work in progress) for good practice in urban health and for the SALURBAL project.
 - See D8.1 'Urban Health Data - Guidelines and Recommendations', pp.11-14 (discussion) and pp.28-57 (FAIR Primer for the SALURBAL data platform): <https://doi.org/10.5281/zenodo.7887523>



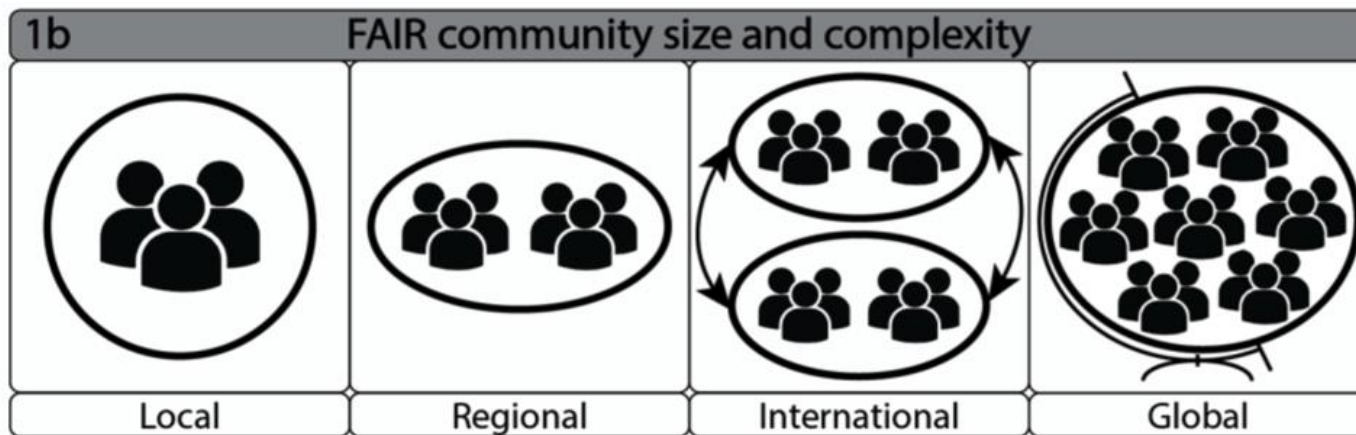
WorldFAIR

FIPs can be developed at varying levels of granularity - one size does not fit all

1. At the level of a Community
 - E.g. a Science Union or an International collaboration.
2. At the level of an individual Repository
 - a reference FIP can be produced that provides high level insights into say which metadata standard they are using, or what standards they using for services.
3. At the level of a Data Collection:
 - More specific, but just provides generic ideas of what resources are being used.
 - E.g., FERs specify vocabularies at the community level.
4. At the level of a Dataset:
 - Very specific with each FER cited, which in turn makes it possible to enable machine-to-machine interoperability using standards such as [Simple Standard Sharing for Ontology Mappings](#) (SSSOM) or to create a knowledge graph across all datasets of an aggregation (e.g., an national dataset made up of

FIPs can be developed at varying Community sizes

1. The Local community: a single institution or group;
2. The Regional community: a combination of groups from universities, government agencies, or a national standards group
3. An International community would involve collaboration between two or more countries; and
4. A global community endorsed by an International Authoritative body such as an International Science Union, Association or Society, or an International Standards Body.



Maturity of International Community helps no end

- Some Communities are globally organised and have international bodies that coordinate standards:
 - Chemistry had IUPAC
 - Biodiversity had GBIF
- Both have dedicated, funded groups supporting standards development
- Geochemistry had too many groups with no coordination between them and no funding



FAIR Implementation and FAIR Assessment

- A lot of effort being put into FAIR Assessment.
- ‘We now have so many FAIR Assessment tools, we will need a tool to assess these tools...’, Michel Schoupe, EOSC Lustrum event, Vienna, October 2023.
- The priority for WorldFAIR is to help enable research communities to develop, articulate and implement FAIR practices.
- **The FAIR Implementation Profiles horse should come before the FAIR assessment cart.**

Whether > what > how: increased utility of information

- FAIR Data Maturity Model and FAIR assessment tools just ask *whether* the FAIR principle is addressed.
- FIPs ask *which* FER is used.
- WorldFAIR WPs suggested that we need to provide easier ways of communicating *how* the FERs are being used: in domains and across domains.



Image from <https://www.phrases.org.uk/meanings/put-the-cart-before-the-horse.html>

- Supported by



<https://onegeochemistry.github.io/>



- Endorsed by:



Starting Simple - Interoperability between 2 systems



FAIR principle	Question	FAIR enabling resource type
F1	What globally unique, persistent, resolvable identifiers do you use for metadata records?	Identifier type
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B1.1	Which usage license do you use for your metadata records?	Data usage license
B1.1	Which usage license do you use for your datasets?	Data usage license
B1.2	Which metadata schemes do you use for describing the provenance of your metadata records?	Provenance model
B1.2	Which metadata schemes do you use for describing the provenance of your datasets?	Provenance model



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<https://img.freepik.com/premium-vector/gear-wheels...g?size=626&ext=jpg&ga=GA1.2.1254696273.1668346327>

FIPs for each will indicate needed FERs



Comparing FAIR Implementation Profiles will clarify where:

- FAIR Enabling Resources are missing and need to be developed
- Crosswalks should be developed between existing FERs and stored (e.g., SSSOM)

Publishing FAIR Implementation Profiles will:

- Enable other (sub)disciplines to use and tailor to the FAIR Enabling Resource used by that discipline furthering cross domain interoperability.

Build your FAIR Implementation Profile

This is a template. Please copy the file before filling it out.



Community description	
Name of Community	e.g. ENVRI
Description of Community	
Supporting Links	
Research Domain	e.g. Environmental Sciences
Data Steward	e.g. ORCID #
Date of FIP creation	



PDF

FAIR principle	Question	FAIR enabling resource types	Your answers
F1	What globally unique, persistent, resolvable identifiers do you use for metadata records?	Identifier type	e.g. PURL, DOI
F1	What globally unique, persistent, resolvable identifiers do you use for datasets?	Identifier type	
F2	Which metadata schemas do you use for findability?	Metadata schema	
F3	What is the technology that links the persistent identifiers of your data to the metadata description?	Metadata-Data linking mechanism	
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R1.1	Which usage license do you use for your metadata records?	Data usage license	
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Excel

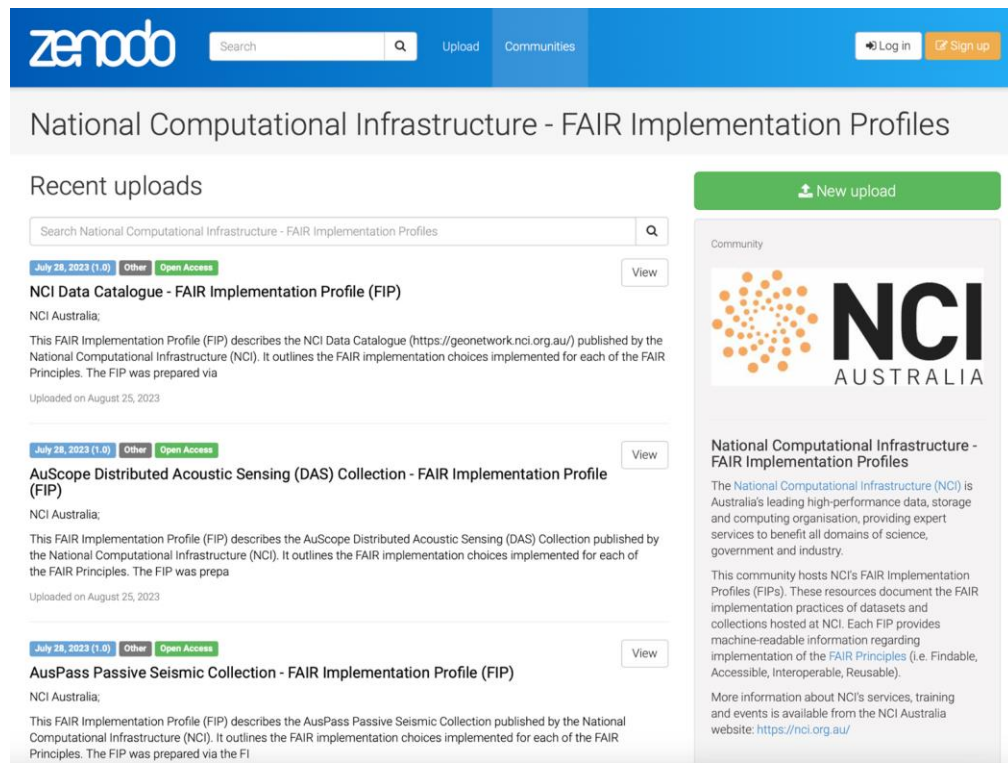
Used methodology developed in WorldFAIR project (<https://worldfair-project.eu/>)

We published our FIPS in the NCI Zenodo Community

✓ Publish FIPs (in multiple file formats)

✓ Generate DOIs for them

✓ Manage versions



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National Computational Infrastructure - FAIR Implementation Profiles

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NCI Data Catalogue - FAIR Implementation Profile (FIP)

NCI Australia;

This FAIR Implementation Profile (FIP) describes the NCI Data Catalogue (<https://geonetwork.nci.org.au/>) published by the National Computational Infrastructure (NCI). It outlines the FAIR implementation choices implemented for each of the FAIR Principles. The FIP was prepared via

Uploaded on August 25, 2023

July 28, 2023 (1.0) Other Open Access View

AuScope Distributed Acoustic Sensing (DAS) Collection - FAIR Implementation Profile (FIP)

NCI Australia;

This FAIR Implementation Profile (FIP) describes the AuScope Distributed Acoustic Sensing (DAS) Collection published by the National Computational Infrastructure (NCI). It outlines the FAIR implementation choices implemented for each of the FAIR Principles. The FIP was prepared via

Uploaded on August 25, 2023

July 28, 2023 (1.0) Other Open Access View


AusPass Passive Seismic Collection - FAIR Implementation Profile (FIP)

NCI Australia;

This FAIR Implementation Profile (FIP) describes the AusPass Passive Seismic Collection published by the National Computational Infrastructure (NCI). It outlines the FAIR implementation choices implemented for each of the FAIR Principles. The FIP was prepared via the FI

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Community



National Computational Infrastructure - FAIR Implementation Profiles

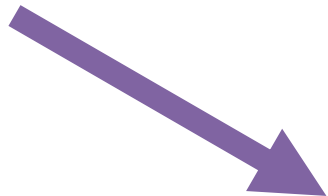
The National Computational Infrastructure (NCI) is Australia's leading high-performance data, storage and computing organisation, providing expert services to benefit all domains of science, government and industry.

This community hosts NCI's FAIR Implementation Profiles (FIPs). These resources document the FAIR implementation practices of datasets and collections hosted at NCI. Each FIP provides machine-readable information regarding implementation of the FAIR Principles (i.e. Findable, Accessible, Interoperable, Reusable).

More information about NCI's services, training and events is available from the NCI Australia website: <https://nci.org.au/>

We linked the FIPs to the Catalogue entry



✓ Published FIPs can be cited and linked to relevant resources



AuScope Magnetotellurics (MT) Collection

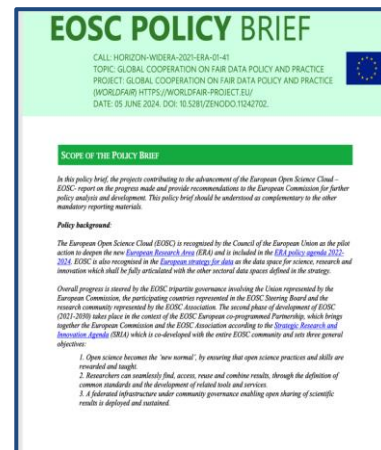
This collection includes AuScope-funded geophysical data, as well as data that has been acquired by universities, industry, federal/state government agencies since the 1950s. Magnetotelluric (MT) survey data has been collected from thousands of sites across Australia.

Data Access

Register for local access	https://my.nci.org.au/mancini/project/my80/join
NCI local file path	/g/data/my80/AuScope_MT_collection/
 NCI THREDDS Data Server https://dapds00.nci.org.au/thredds/catalogs/my80/catalog.html	<input type="button" value="Open link"/>
 FAIR Implementation Profile (FIP) https://doi.org/10.5281/zenodo.8185349	<input type="button" value="Open link"/>

Lessons Learned from WorldFAIR

- Not just about filling in an EXCEL spreadsheet
- Not just about training researchers - many researchers want to comply with FAIR but do not have access to required infrastructures.
- The maturity of your International Community counts - the more mature and coordinated, the more likely they are to have globally agreed vocabularies, standards and protocols required for FAIR.
- It is critically dependant on whether you have the correct research infrastructure to fully implement machine-actionable FAIR
- For Australia, implementation of the National PID strategy is critical.
- See WorldFAIR EOSC policy brief on recommendations



Hodson, S., & Gregory, A. (2024). WorldFAIR (D1.4) Second Policy Brief (Version 1). Zenodo. <https://doi.org/10.5281/zenodo.11242702>