



# Persistent Identifier Services for the German National Research Data Infrastructure

**Proposal for the Integration Phase of Base4NFDI**

Abridged Version of the Proposal submitted in July 2024

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18 December 2024

# Imprint

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<b>Date of publication</b>	18 December 2024
<b>DOI</b>	<a href="https://doi.org/10.5281/zenodo.14281255">https://doi.org/10.5281/zenodo.14281255</a>
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## About

[PID4NFDI](#) is the basic service for persistent identifiers in development for the German National Research Data Infrastructure ([Nationale Forschungsdateninfrastruktur – NFDI](#)). PID4NFDI is part of and funded through [Base4NFDI](#).

Funded by DFG as part of NFDI. Grant Number: [521466146](#)



Funded by



Deutsche  
Forschungsgemeinschaft  
German Research Foundation

## 1. General Information

### Name and Acronym of proposed Basic Service

PID4NFDI

### Service "subtitle" explaining key functionality

Persistent Identifier Services for the German National Research Data Infrastructure

### Corresponding NFDI Section

Common Infrastructures

### Lead institutions

Technische Informationsbibliothek (TIB) – German National Library of Science and Technology Welfengarten 1B, 30167 Hannover	Gesellschaft für wissenschaftliche Datenverarbeitung (GWDG) Burckhardtweg 4, 37077 Göttingen
Home: <a href="https://www.tib.eu/de/">https://www.tib.eu/de/</a> ROR ID: <a href="https://ror.org/04aj4c181">https://ror.org/04aj4c181</a>	Home: <a href="https://www.gwdg.de/">https://www.gwdg.de/</a> ROR ID: <a href="https://ror.org/00cd95c65">https://ror.org/00cd95c65</a>
Member in consortium: NFDI4Ing	Member in consortium: NFDI4Biodiversity, Text+

### Name of lead institutions principal investigators

Dr Irina Sens

Dr Sven Bingert

## Participating institutions

Principal Investigator	Institution, location	Member in [consortium]	Funding requested [yes   no]
Matthew Buys	DataCite – International Data Citation Initiative e.V. <a href="https://ror.org/04wxnsj81">https://ror.org/04wxnsj81</a>	NFDI4Ing	yes
Marcel Meistring	Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences Helmholtz Open Science Office <a href="https://ror.org/04z8jg394">https://ror.org/04z8jg394</a>	NFDI4Earth	yes

Table 1: List of participating institutions

## Initialisation Phase

From January 1st, 2024, to December 31st, 2024

## Planned runtime of the project

From January 1st, 2025, to December 31st, 2026

**Significance:** Effective and FAIR (Findable, Accessible, Interoperable, Reusable) research data management (RDM) relies on Persistent Identifiers (PIDs) for uniquely and consistently referencing and describing objects<sup>1</sup>. PIDs feature standardised metadata that enhance their findability, reusability, and overall research integrity. Moreover, they can be applied to various objects and help link them together, enhancing provenance information.

The value of PIDs increases when they have both high interoperability and high-quality accompanying metadata<sup>2</sup>.

Stakeholders throughout the research lifecycle – including researchers, institutions, and policymakers – must recognise and embrace the potential from and the responsibilities involved in maintaining PIDs. PID4NFDI aims to enhance the usability of existing PID systems for the National Research Data Infrastructure (NFDI) by supporting improvements in technical and organisational interoperability, boosting metadata quality, and creating awareness through training and outreach programs.

<sup>1</sup> Wilkinson et al. (2016).

<sup>2</sup> Cousijn et al. (2021).

**Summary of the proposal in English:** The project aims to enhance PID integration within NFDI consortia, considering varying provider maturity levels and community adoption. We focus on integrating PIDs throughout the research data lifecycle, using Data Management Plans (DMPs) and Electronic Lab Notebooks (ELNs) as pilot implementations. Special emphasis is placed on the integration of PIDs for objects for which PID registration is still emerging, such as research instruments, material samples, highly granular data, as well as projects and awards.

Our goal is to boost the impact of PIDs by improving metadata quality and interoperability through technical, organisational, and strategic measures. Furthermore, governance guidelines, outreach efforts, and a modular training concept will promote PID awareness and adoption across disciplines. This approach will be prototyped collaboratively with NFDI consortia partners, ensuring broad applicability within the NFDI framework. Interoperability, metadata, governance, training/support, and community engagement components, will together form the 'PID Coordination Hub', which will be a central entry point for users of the PID4NFDI service portfolio.

**Summary of the proposal in German:** Das Projekt verfolgt das Ziel, die Integration von PIDs (Persistent Identifiers) innerhalb der NFDI-Konsortien zu optimieren. Dabei werden die unterschiedlichen Reifegrade der PID Provider sowie die Anforderungen der Communities berücksichtigt. Wir legen den Schwerpunkt auf die Integration von PIDs über den gesamten Lebenszyklus von Forschungsdaten hinweg und nutzen Datenmanagementpläne (DMPs) sowie elektronische Laborbücher (ELNs) als erste Umsetzungen. Besonderes Augenmerk liegt auf der Integration von PIDs für Entitäten, bei denen die PID-Registrierung noch in den Anfängen steckt, wie Forschungsinstrumente, Materialproben, hochgranulare Daten sowie Projekte und Auszeichnungen.

Unser Ziel ist es, die Wirkung von PIDs zu steigern, indem wir die Qualität und Interoperabilität der Metadaten durch technische, organisatorische und strategische Maßnahmen verbessern. Darüber hinaus werden Governance-Richtlinien, Outreach-Maßnahmen und ein modulares Schulungskonzept das Bewusstsein und die Akzeptanz von PIDs in verschiedenen Disziplinen fördern. Dieser Ansatz wird in Zusammenarbeit mit NFDI-Konsortialpartnern prototypisch umgesetzt, um eine breite Anwendbarkeit innerhalb des NFDI-Rahmens zu gewährleisten. Elemente wie Interoperabilität, Metadaten, Governance, Schulung/Support und Community Engagement bilden zusammen den PID Coordination Hub, das einen zentralen Zugangspunkt für Nutzende des PID4NFDI-Dienstleistungsportfolios darstellt.

## 2. Summary of Initialisation Phase Results

### 2.1. Change in Background and Motivation since the Start of the Initialisation Phase

Owing to hiring processes, the project partners agreed to start the project in January 2024 instead of October 2023. The full project team was in place by March 2024.

#### Response to reviewer feedback from initialisation phase

Reviews highlighted the need for metadata beyond that required for basic PID registration. Our landscape and metadata analysis evaluated current practices and needs for describing research data and other resources. The results highlight the importance of domain-specific standards and cross-disciplinary harmonisation, which are addressed by WP2 during the initialisation phase. PIDs facilitate referencing content-related and bibliographic metadata, using related identifiers (e.g. by DataCite<sup>3</sup>, see figure below) or the structure of FAIR Digital Objects (FDOs)<sup>4</sup>.

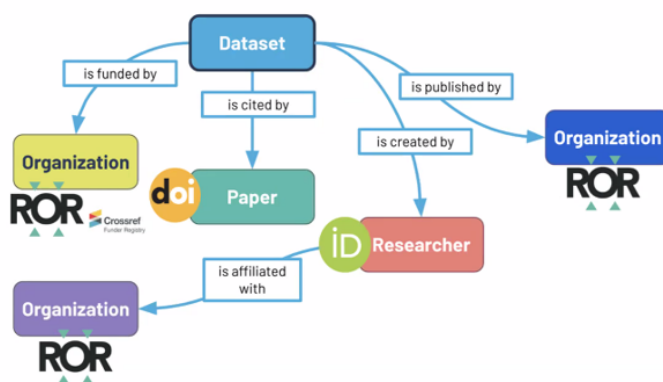


Figure 1: DataCite connection metadata to related identifiers.

Addressing user expectations of the PID service in NFDI is crucial. The existing PID services landscape is diverse, reflecting various needs within NFDI consortia. The PID4NFDI initiative aims to provide transparent information for PID registration, enabling users to better utilise existing services based on their specific needs, rather than relying on a single access point.

Two reviewers noted the distinction was unclear between this project and the DFG-funded PID Network Germany. PID Network Germany aims to establish a national stakeholder network for PIDs, creating cross-institutional standardised PID guidelines compatible with Germany's federal academic system. It will also monitor PID usage in the German science system using selected research resources. While NFDI is a key participant in PID Network Germany, that project extends beyond NFDI. In contrast, PID4NFDI puts much greater focus on the details of NFDI consortia and research data fields—developing concrete solutions for NFDI consortia use cases, such as metadata templates, PID selection tools, and training on PIDs for specific entities.

<sup>3</sup> DataCite Metadata Working Group (2024).

<sup>4</sup> Anders et.al. (2023).

PID Network Germany therefore provides a valuable foundation for NFDI, but adjustments are necessary to align with NFDI's unique governance structures and makes direct transfers of results impractical without modifications. PID4NFDI will adapt PID Network Germany's experiences, guidelines, and national roadmap to fit NFDI purposes. PID4NFDI will furthermore collaborate with PID Network Germany to ensure NFDI and German scholarly infrastructure are connected to international initiatives such as the European Open Science Cloud (EOSC). PID4NFDI will represent PID activities within NFDI for PID Network Germany.

## 2.2. Results of Initialisation Phase

### Interim report on requirements for finalisation of the initialisation phase

[*Edited information for publication of this proposal*] The following paragraph provides a short overview of the status of deliverables defined by Base4NFDI. A comprehensive summary of the initialisation phase results and future plans for completing the phase was provided to Base4NFDI and reviewers of this proposal as a separate report from project management tool OpenProjects..

#### a) Requirements analysis (D1.4.1)

**Due:** 12 months from start | **Percent finished:** 50% (estimate) | **Status:** survey (done) | analysis (ongoing) | report (running) | **Overview of relevant outcomes:** Survey analysis, transcribed interviews, use case profiles | **Outlook:** We will adhere to initialisation phase plans, aiming for completion by 30 August, despite hiring delays (see 2.1).

#### b) Software evaluation (D1.4.2)

**Due:** 12 months from start | **Percent finished:** 85% (estimate) | **Status:** analysis (ongoing) | report (planned) | **Overview of relevant outcomes:** PID4NFDI builds on mature PID service solutions. For details, see 'Update on Technical Readiness Level' and internal Open Project report [*removed for publication*]. **Outlook:** Further PID provider solutions will be evaluated based on survey results and requirement analysis.

#### c) Service design (D1.4.3)

**Due:** 12 months from start | **Percent finished:** 20% (estimate) | **Status:** analysis (ongoing) | report (planned) | **Overview of relevant outcomes:** Use case mapping to PID services, technical integration of concepts, metadata harmonisation, training, PID provider selection transparency, communication strategy | **Outlook:** Following the initialisation phase plan, M3 completion is set for 30 September.

#### d) Service prototype (D1.4.4)

**Due:** 12 months from start | **Percent finished:** 20% (estimate) | **Status:** analysis (ongoing) | report (planned) | **Overview of relevant outcomes:** Metadata standards

catalogue, tools for PID metadata improvement, PID registration workflow cookbooks, PID providers overview, project website | **Outlook:** Following the initialisation phase plan.

### e) Service piloting and user testing (D1.4.5)

**Due:** 12 months from start | **Percent finished:** 10% (estimate) | **Status:** analysis (ongoing) | report (planned) | **Overview of relevant outcomes:** Testing and feedback documentation | **Outlook:** Following the initialisation phase plan. Completion will follow our stakeholder workshop and the Base User Conference (November 2024).

## 2.3. Update on Technical Readiness Level (TRL) of the Proposed Basic Service

This initialisation phase involves validating service and technical concepts through analytical landscape examination. Feasibility of integrating PIDs into the NFDI framework is demonstrated, early prototypes of PID services are developed, and potential challenges are identified. Initial prototypes, including PID selection tools and use-case metadata analysis, are underway. Stakeholders are engaged to gather feedback, and prototypes and standards refinement is planned. Consequently, the TRL is estimated to be between **3 and 4** by the end of this phase.

PID4NFDI builds on mature PID provider infrastructure and services that have been operational for decades and that are globally accessible, integrated with international RDM initiatives such as EOSC, and supported by robust governance structures. These technical services, each with a TRL of **8 or higher**, include:

1. DataCite Commons/PID Graph, Fabrica, and Application Programming Interfaces (APIs), including registration of International Generic Sample Numbers.
2. ePIC Persistent Identifiers for eResearch and APIs.
3. EOSC PID Meta Resolver (PIDMR), Data Type Registry (DTR), and Compliance Assessment Toolkit (CAT),
4. ORCID API, registry, and member portal.
5. ROR API, web search, and data dump.

Emerging PID infrastructure services, such as Persistent Identification of Instruments (PIDINST) and Research Activity Identifier Service (RAiD), will also be onboarded.

## 3. Working Concept for the Development of the Basic Service

### 3.1. Service Integration Concept

Our landscape analysis has identified significant fragmentation of the PID landscape within NFDI consortia, marked by diverse application scenarios and varying levels of PID integration maturity. **This project aims to enhance support and promote the early adoption of PIDs throughout the research data lifecycle within NFDI consortia.** Improved metadata quality, interoperability, and research collaboration will be achieved through



documented best practices for future service rollouts. Specific needs for new applications have been identified beyond traditional PID use cases such as datasets, publications, and organisations. Priority will be given to holistic PID integration throughout the entire research data lifecycle, including emerging PID types. This will encompass instruments, material samples, highly granular entities, projects, and awards as they are developed and utilised.<sup>5</sup>

PID strategies and selection will be documented in **DMPs**, and PIDs for DMPs will be promoted. Collaboration with projects and communities, particularly **DMP4NFDI**, will help standardise PID selection in DMPs and harmonise metadata across disciplines, enhancing consistency and interoperability. Machine-processable DMPs will feature technical integration of PIDs and related services, linking research resources effectively. Support for PID integration will be provided via the Research Data Management Organizer. Additionally, project PIDs (e.g. RAiDs) will be used to effectively track project impacts and outcomes.

PIDs will also be integrated into **ELNs** to comprehensively document instruments, data, methods, and material samples; streamline workflows; and improve research management by linking research outputs with contextual details. Prototyping in collaboration with the **ELN working group** and platforms such as **Chemotion-NFDI4Chem**, **RSpace**, and **eLabFTW** are essential for developing and testing these PID integrations. Moreover, our integration efforts will target high-level software solutions used by multiple consortia, ensuring broad applicability and impact while addressing individual consortia needs.

Governance, training, and outreach will drive PID awareness, visibility, and adoption, and improve metadata quality and FAIR practices.

**Governance:** Guidelines for PID selection in DMPs and ELNs will be created, forming the basis of a PID Selection Tool.

**Training:** Modular training materials will be developed, covering DMPs, ELNs, and PID types.

**Outreach:** Outreach efforts will increase project impact, foster collaborations, and involve stakeholders.

Our activities will be consolidated in the **PID Coordination Hub for NFDI**, providing best practices, examples, and support for managing PIDs and associated metadata, and thus optimising standardised approaches across NFDI. The service primarily targets repository managers, infrastructure services providers, and researchers and research organisations implementing or using PID services.

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<sup>5</sup> [edited information for publication of this proposal] El-Gebali et al. (2024): D1.1 Landscape of PID practices.

## Bringing use-cases into production

To **promote PID integration** in NFDI, **use cases** and potential collaboration partners from various disciplines were identified based on our **landscape analysis** and prior work by the NFDI PID Working Group<sup>6</sup>. These use cases act as **blueprints** for **documenting best practices** in PID integration during the ramp-up phase. Support will focus on improving metadata, selecting PID systems, and technical integration. Expertise from **focus groups on ELNs and DMPs** will help refine service development and provide feedback for iterative improvement. PID4NFDI will be supported by DMP4NFDI, the ELN working group, and several use case partners which provided a Letter of Commitment (See also Overview in paragraph 4. Support Actions).

### 3.2. Future Development and Ramp-up Outlook

#### Transition to ramp-up phase and vision of operative service

The **overall vision** of PID4NFDI is to support PID integration across consortia, disciplines, infrastructure services, and use cases. This will be achieved by harmonising PID systems within NFDI and leveraging the global PID provider landscape. Aligning PIDs to international standards will enable realisation of a PID Graph, ensuring seamless linking of research resources. A potential NFDI PID Graph will illustrate resource (re)use, providing a comprehensive analysis of the German research landscape and NFDI's impact. During the integration phase, PIDs will be incorporated into selected use cases and services. In the ramp-up phase, this approach will be broadened to maximise PID potential across NFDI infrastructure services. Integrating PIDs into DMPs and ELNs will facilitate advancement of Scientific Knowledge Graphs (SKGs). Many NFDI consortia, including NFDI4Earth and NFDI4Culture, utilise SKGs or Knowledge Graphs (KGs) to manage FAIR metadata. KGI4NFDI<sup>7</sup> also offers a basic KG technology service. This integration will strengthen PID use throughout the research data lifecycle, including scholarly communication.

PID4NFDI will document successful PID integration and management based on previous phases and will offer hands-on support through a **help desk** and regular **training** workshops. Training will be developed with research institutions and consortia, and include modular self-paced online courses on PID usage and management. During the integration phase, feasibility checks will be conducted on the use of **metadata quality dashboards** for visualising and managing linked research resources via PIDs, see this example from the TIB DataCite consortium.<sup>8</sup>

To ensure long-term sustainability and service support, a **business model will be developed** that aligns with existing governance requirements. An ambassador network

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<sup>6</sup> Bingert et al. (2022); Hagemann-Wilholt (2023); Schrader et al. (2023).

<sup>7</sup> <https://base4nfdi.de/projects/kgi4nfdi>

<sup>8</sup> See Appendices Metadata Dashboards Examples (<https://drive.google.com/file/d/1ffDR3Z8EN6pSAgWuaF1Ch7XfyTACdrwG/view>) and Kibana Reports (<https://drive.google.com/file/d/1nxhGW8ydXbvwpq5nIT33jP0aXZpgv7U/view>).

will foster peer support and best practices. While support structures from funding organisations and NFDI administration will further enhance compliance with the PID strategy.

## Relationship with EOSC

The NFDI service is integrated within a PID **framework** aligned with EOSC and EOSC PID Policy. Key partners GWDG and DataCite—funded by the FAIRCORE4EOSC project—are developing crucial EOSC-Core components, including CAT,<sup>9</sup> DTR<sup>10</sup> and PIDMR.<sup>11</sup> Relevant outputs also include EOSC RAiD<sup>12</sup> and EOSC Research Software APIs and Connectors (RSAC)<sup>13</sup> in collaboration with organisations such as CERN and FIZ Karlsruhe<sup>14</sup>. These components address gaps in the current EOSC Association Strategic Research & Innovation Agenda<sup>15</sup> and were a key focus of the PID Policy and Implementation Task Force,<sup>16</sup> supported by TIB, GWDG, and DataCite<sup>17</sup>. The FAIR-IMPACT project,<sup>18</sup> involving 29 partners including DataCite, offers a framework for expanding FAIR PID solutions across EOSC, which is relevant to PID4NFDI<sup>19</sup>. TIB, an EOSC Association Member, will continue to actively participate in EOSC-related events.

## Quality criteria and key performance indicators (KPIs) of service

PID4NFDI will build on established PID provider services to ensure functionality and interoperability, addressing the requirements of NFDI stakeholders identified in the initialisation phase. By leveraging existing technical resources and project partners expertise, the project aims to provide a reliable and scalable service. The modular service components will facilitate easy modification, maintenance, and adaptation to evolving user needs.

PID4NFDI will offer **comprehensive documentation and a helpdesk** for user support. Success will be evaluated by tracking indicators such as increase in integration and registration of PIDs in NFDI infrastructure services by our use case partners. This enables both quantitative monitoring and trend identification; for example, adoption of specific resource types. Monitoring of metadata quality improvements can also be visualised in a PID Graph providing statistical information on linking and reuse of resources. Service usage, after its full provision, will be assessed through both quantitative and qualitative indicators, including user numbers, platform visits, service requests, support sessions, consultations, training attendance, and user feedback.

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<sup>9</sup> <https://eosc.eu/roadmap/eosc-compliance-assessment-toolkit>

<sup>10</sup> <https://eosc.eu/roadmap/eosc-data-type-registry>

<sup>11</sup> <https://eosc.eu/roadmap/eosc-pid-meta-resolver>

<sup>12</sup> <https://faircore4eosc.eu/eosc-core-components/research-activity-identifier-service-raid>

<sup>13</sup> <https://faircore4eosc.eu/eosc-core-components/eosc-research-software-apis-and-connectors-rsac>

<sup>14</sup> <https://faircore4eosc.eu/>

<sup>15</sup> <https://eosc.eu/sria-mar/>

<sup>16</sup> <https://eosc.eu/advisory-groups/pid-policy-implementation/>

<sup>17</sup> <https://eosc.eu/eosc-task-forces/>

<sup>18</sup> <https://eosc.eu/eu-project/fair-impact/>

<sup>19</sup> <https://fair-impact.eu/>

PID4NFDI impact on the NFDI community and beyond will be evaluated by tracking publication citations, downloads, workshop and event counts, and collaborative efforts.

### 3.3. Risks and Challenges

**Ensuring long-term availability and maintenance** of PID services within NFDI requires clear role definitions and sustainable funding, including maintaining PID4NFDI's resources beyond the project's funding period. Additionally, **insufficient awareness** of the value of PIDs and their metadata undermines adherence to the FAIR Principles and results in superficial use of PIDs that fails to leverage their full potential for providing context, provenance, citation details, and more.

**Effective use of metadata** requires alignment with international standards, user requirements, accessible system interfaces, and inclusion of clear licences governing reuse<sup>20</sup>. **Establishing a scalable PID service** also requires advanced technical infrastructure and compatible metadata schemata, high technological readiness, and a strategy for interoperability. This includes ensuring secure data provenance, and integrating discipline-specific metadata with generic schemata for effective reuse by both humans and machines.

## 4. Support Actions from Base4NFDI / NFDI Sections, and Integrating NFDI Consortia / Efforts

Support from	Work package	Contact person Basic Service
Base4NFDI: DMP4NFDI service	<b>All WPs</b> – Support on identifying best practices on PIDs in DMP integration throughout research data lifecycle; providing contact to DMP providers within NFDI	Jürgen Windeck (ULB Darmstadt) juergen.windeck@tu-darmstadt.de
Base4NFDI IAM4NFDI service	<b>WP3</b> – Registration of new types and PID service providers will require authentication through the NFDI AAI solution developed by IAM4NFDI, enabling group-specific entries in DTR and domain-specific profiles.	Marcus Hardt (KIT Karlsruhe) hardt@kit.edu
Section (Meta)data, Terminologies, Provenance	<b>WP2 &amp; WP4</b> – Support on organising exchange with working groups on: Cookbooks, Guidance & Best Practice, TS, Search & Harvesting	Oliver Koepler (TIB Hannover) oliver.koepler@tib.eu
Section Common Infrastructure (incl. ELN WG)	<b>All WPs</b> – Support in setting up focus groups on ELNs and DMPs (recruitment from respective working groups, base service, and beyond)	Sonja Schimmler (Fraunhofer Fokus) sonja.schimmler@fokus.fraunhofer.de Nicole Jung (KIT Karlsruhe) nicole.jung@kit.edu

<sup>20</sup> Burger et al. (2021); Strecker (2021).

Section Training & Education	<b>WP4</b> – Support in collecting and evaluating training material and exchange with other training groups	Sonja Herres-Pawlis (RWTH Aachen) sonja.herres-pawlis@ac.rwth-aachen.de
Section Industry Engagement	<b>WP2 &amp; WP3</b> – Support for exchange with companies providing commercial solutions for use cases (instrument manufacturers, inventory systems, ELN providers)	Florian Stahl (Universität Mannheim) florian.stahl@uni-mannheim.de

Table 2: Support needs from Base4NFDI / service stewards.

PID services, in general, are integrated in all consortia. These are specific use cases that will require special attention during the next project phase.

Involved efforts from consortia	Description of contribution from consortia: Providing insights on	Consortium and contact
Participation in focus groups and workshops giving feedback on developed tools, solutions, materials	Use case ‘highly granular entities’ according to elements within datasets and audio-visual materials	KonsortSWD Janete Saldanha Bach (GESIS) Janete.SaldanhaBach@gesis.org
	Use cases ‘instruments’, ‘material samples’, ‘highly granular entities’, ‘facility usage awards’	Daphne4NFDI Rolf Krahl (HZB) rolf.krahl@helmholtz-berlin.de
	Use case ‘material samples’ within different NFDI consortia and on cross-consortia / institutional integration of PIDs	Thorge Peterson (CAU Kiel) petersen@rz.uni-kiel.de
	Use case ‘material samples’	NFDI4Objects Marcel Riedel (DAI Berlin) marcel.riedel@dainst.de
	PID integration in DMPs, use case ‘highly granular data’ and interoperability of PID systems	NFDI4Ing Ilona Lang (RWTH Aachen) lang@itc.rwth-aachen.de
	Use of Instrument Identifier for the Sensor Management System delivering requirements for the service	NFDI4Earth Jan Bumberger (UFZ Leipzig) jan.bumberger@ufz.de
	Use case ‘highly granular data’ and metadata schema requirements	NFDI4Cat Thomas Bönisch (HLRS Stuttgart) boenisch@hlrs.de
	ELNs in Life Sciences	RSpace (Section Industry Engagement)

Table 3: Contributions required from integrating consortia.

## 5. Work Programme

### 5.1. Overview of Work Packages

Work package	Deliverables (D) and milestones (M)	Responsible partner
WP1 – Integration Strategy and Governance	<p>M1.1 Workshops with focus groups on ELNs and DMPs (T1.1)</p> <p>D1.1 PID Selection Tool (T1.2)</p> <p>D1.2 NFDI-wide PID Guidelines (T1.3)</p> <p>D1.3 Instructions for adaption of EOSC CAT in NFDI PID Services (T1.4)</p>	<p>Lead: TIB</p> <p>Participation: OS Office, GWDG</p>
WP2 – Enhancing Metadata Quality and Interoperability	<p>M2.1 Analysis of metadata and standards according to selected use cases (T2.1)</p> <p>D2.1 Guidelines on improving metadata quality (T2.2)</p> <p>D2.2 Metadata consultation framework (T2.3)</p> <p>M2.2 Completion of technical feasibility assessment for metadata monitoring tools (T2.3)</p> <p>D2.3 Integration strategy framework (T2.4)</p> <p>M2.3 Feedback and verification of interoperability among selected use cases (T2.4)</p> <p>D2.4 Guidelines and best practices for linking research outputs, enriching PID metadata for instruments and samples, and providing practical resources for researchers (T2.5)</p> <p>D2.5 Integrated PID registration processes for samples and instruments into DMPs and ELNs (T2.5)</p> <p>M2.4 Increased collaboration among consortia and disciplines, and increased rate of PID registrations for samples and instruments (T2.5)</p> <p>D2.6 Comprehensive report on metadata requirements for project and facility usage award PIDs (T2.6)</p> <p>M2.5 Facilitation of accelerated adoption of PIDs for projects and facility usage awards (T2.6)</p>	<p>Lead: DataCite</p> <p>Participation: GWDG, TIB</p>
WP3 – Technical Implementation of Services in the Coordination Hub	<p>D3.1 Blueprint architecture for PID provider service integrations in a PID Graph and DataCite Commons, designed on persistent identification of instruments (T3.1)</p> <p>M3.1 Coordination Hub is linked to the NFDI PID for instrument service B2INST and DTR for implementing community extensions of the instrument identifier as supported by the service (T3.1)</p> <p>M3.2 Prefix registration available in Coordination Hub (T3.2)</p> <p>M3.3 Coordination Hub links DTR for implementing community extensions of the instrument identifier as supported by the service (T3.3)</p> <p>M3.4 Access to DTR using the NFDI AAI solution to register and use various types, including profiles (T3.3)</p>	<p>Lead: GWDG</p> <p>Participation: TIB</p>
WP4 – Training and Support	<p>D4.1 Curated collection of training material published on PID4NFDI website (T4.1)</p> <p>D4.2 Develop training materials (T4.2)</p>	<p>Lead: TIB</p> <p>Participation: DataCite, GWDG</p>

	M4.1 Feedback survey and workshop on training materials (T4.3) M4.2 Integration into Coordination Hub and NFDI training infrastructure (T4.4)	
WP5 – Outreach and Community Engagement	M5.1 Provision of entry point for Coordination Hub (T5.1) D5.1 Frequently asked questions (T5.1) D5.2 Online structured contact form (T5.2)	Lead: OS Office Participation: GWDG, DataCite, TIB
WP6 – Project Management		Lead: TIB Participation: GWDG

Table 4: Overall work programme with work packages, deliverables, milestones, and responsible partner.

## 5.2. Detailed Work Programme

### WP1 – Integration Strategy and Governance

<b>Responsible</b>	DataCite	GWDG	OS Office	TIB (Lead)
<b>Person months</b>	0	7	7	7,2

#### Objectives

A comprehensive strategy for selecting and integrating PIDs throughout the research data lifecycle will be developed, promoting early adoption and proper usage based on findings from the initialisation phase. Requirements and challenges for NFDI and PID consumers will be addressed through engagement with representative user groups. Governance requirements for optimised PID use will be the focus of this WP.

#### **T1.1 Set up research data lifecycle-orientated focus groups (Lead: OS Office)**

Two focus groups will be established to integrate PIDs into ELNs and DMPs, based on previous surveys and stakeholder input<sup>21</sup>. These groups will evaluate current ELN and DMP features and identify requirements for holistic PID integration. Collaboration with ELN and DMP providers through the ELN Working Group and DMP4NFDI will guide discussions on PID practices and challenges, leading to prototype PID integration at various maturity levels. Focus will be on PIDs for instruments, material samples, highly granular data, projects, and awards, with more mature PID objects also being included. Consultations will include a workshop for each focus group and ongoing asynchronous discussions for iterative service development.

#### **T1.2 Develop a PID Selection Framework (Lead: TIB)**

Sustaining PID infrastructure involves costs, and as the landscape of PID providers grows, discrepancies in governance and fee models persist despite expanding research networks. To address this, the fee and membership models of PID providers identified during the initialization phase, will be analysed to clarify registration costs and benefits.

Transparent disclosure of models will be encouraged, and clear communication on interoperability and stakeholder responsibilities will be promoted<sup>22</sup>. These efforts will inform NFDI-wide guidelines (see T1.3) and a PID Selection Tool for PID4NFDI users, facilitating informed choices of PID types and providers. Development will be iterative, leveraging initial findings, existing resources<sup>23</sup>, and focus group feedback.

<sup>21</sup> See, for example, El-Gebali et al. (2024): D1.1 Landscape of PID practices.

<sup>22</sup> See, for example, Principles on Open Scholarly Infrastructure: <https://openscholarlyinfrastructure.org/>.

<sup>23</sup> See, for example, the PID Guide: [https://www.pidwijzer.nl/en/pid\\_results/new](https://www.pidwijzer.nl/en/pid_results/new).



### T1.3 Develop NFDI-wide PID Guidelines (Lead: OS Office)

NFDI-wide PID guidelines will be developed in coordination with PID Network Germany<sup>24</sup>. A structured, collaborative process will define NFDI-wide standards, compliance mechanisms, and support structures, incorporating criteria from the PID Selection Framework (see T1.2). Community engagement will be fostered by offering consortia and section members opportunities to participate through exchange formats and open dialogue. Progress reports will ensure transparency, detailing how community input has shaped the initiatives. This approach aims to build trust and encourage ongoing engagement. Insights from case studies and best practices will ensure broad acceptance and maximise utilisation of the guidelines within the NFDI community.

### T1.4 Ensure connectivity to EOSC (Lead: GWDG)

The EU-project FAIRCORE4EOSC is developing CAT<sup>25</sup> to evaluate PID provider compliance with specific policies. Although focused on EOSC PID policy, CAT is designed to accommodate other international, national, or consortium-based policies. The latest outcomes of the project will be evaluated to provide practical instructions for incorporating CAT into the PID4NFDI Coordination Hub. Guidelines will be established and supported by CAT, enabling regular audits, feedback loops, and a transparent system for reporting and addressing non-compliance.

### WP2 – Enhancing Metadata Quality and Interoperability

Responsible	DataCite (Lead)	GWDG	OS Office	TIB
Person months	41	4	0	2

### Objectives

Metadata quality across NFDI services will be enhanced by identifying gaps, developing best practices, ensuring alignment among PID services, and supporting infrastructure managers. Key use cases, such as research instruments, material samples, and highly granular entities (e.g. projects and awards), will be prioritised to improve metadata usability, quality, and interoperability, thereby creating a robust PID and metadata ecosystem.

### T2.1 Metadata quality assessment and gap analysis (Lead: DataCite)

Building on the initialisation phase, existing metadata and standards within NFDI services will be analysed to identify gaps and areas for improvement. Focus will be placed on aforementioned key use cases, with entities integrated into ELNs and DMPs,

<sup>24</sup> Ziedorn et al. (2024).

<sup>25</sup> Compliance Assessment Toolkit, <https://eosc.eu/roadmap/eosc-compliance-assessment-toolkit>.

thus facilitating PID assignment and strategy selection within these platforms, and paving the way for integration into SKGs.

## **T2.2 Develop best practices and guidelines (Lead: DataCite)**

Building on T2.1 findings, guidelines and best practices for improving metadata quality will be developed in cooperation with T4.2 and T5.1. Guidelines will include examples tailored to various resource types and infrastructure manager needs, ensuring metadata adheres to standardised formats and schemata. A Metadata Completeness Checklist for repositories also will be created.

## **T2.3 Tools for metadata assessment and monitoring (Lead: DataCite)**

The development of tools for assessing and monitoring metadata quality, such as prototypes for metadata dashboards, will be explored. These tools will enable NFDI service providers to check their metadata, generate reports, and gain actionable insights. A technical feasibility assessment will guide the dashboards development. They will be part of a Metadata Consultation Framework for ongoing support on metadata quality. Preliminary work on FAIR Checker tools will be considered, and collaboration with the Search and Harvesting working group within the (Meta)data, Terminologies, Provenance section.

## **T2.4 Promote integration and interoperability (Lead: DataCite, GWDG)**

PID services will be aligned with FDO profiles to facilitate interoperability across NFDI repositories. This includes developing strategies to integrate metadata enhancements with existing systems and broader initiatives such as the EOSC PID policy (see T1.4). Additionally, Data Typing as a service will be incorporated, linking DTR from FAIRCORE4EOSC, to support the PID Coordination Hub in standardising data typing across services.

## **T2.5 Specific focus on material samples and research instruments: Monitoring and guidance (Lead: DataCite, TIB)**

Analysis of NFDI's PID landscape shows a demand for PIDs for physical objects such as material samples and research instruments. Hence, PID registration for these research outputs will be promoted by providing templates and examples for integration into DMPs and ELNs, enabling integrations in SKGs, and guided by the PIDINST White Paper<sup>26</sup> and FAIR Workflows<sup>27</sup>. PID adoption will enhance management, tracking, and sharing of these outputs, streamline research workflows, and promote cross-disciplinary collaboration within NFDI consortia. Implementation will be monitored with use case partners, and feedback collected to refine the dashboard concept (see T2.3). In coordination with WP4,

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<sup>26</sup> RDA PIDINST Working Group (2021).

<sup>27</sup> Plankyté et.al. (2023).

guidelines and training materials on research instruments and material samples will be developed for NFDI users.

## **T2.6 Explore metadata requirements for projects and facility usage awards (Lead: DataCite, TIB)**

Project and award PIDs will be used to track funding outcomes and their impact through resource reuse. In coordination with T1.2, metadata requirements for projects and facility usage awards will be examined<sup>28</sup>. Within NFDI, DMPs and ELNs will be enhanced with Project IDs and Grant IDs, respectively, facilitating integration in SKGs whereby both PIDs can be interlinked as metadata of data and articles. Current practices, standards, and key challenges will be analysed and the results compiled into a report for discussion with experts in the focus groups.

### **WP3 – Technical Implementation of Services in the Coordination Hub**

<b>Responsible</b>	DataCite	GWDG (Lead)	OS Office	TIB
<b>Person months</b>	0	13	0	10

## **Objectives**

PID services will be integrated into the Coordination Hub to ensure centralised, barrier-free access for NFDI researchers. A primary focus will be integration with the authentication and authorization infrastructure (AAI) developed by IAM4NFDI<sup>29</sup>. Access to PID-referenced information, (i.e. data and resources identified and linked using PIDs) will be enhanced through technical developments, either via a dedicated solution (e.g. PIDINST) or by incorporating metadata into a PID Graph.

## **T3.1 PIDs for research instruments: Advancing the infrastructure (Lead: TIB)**

The PIDINST metadata schema<sup>30</sup>—developed by the Research Data Alliance’s PIDINST Working Group that includes GWDG, DataCite, and TIB—is currently supported by DataCite, ePIC, and B2INST<sup>31</sup>. Discovery of instrument PIDs and related metadata will be facilitated through a unified framework integrating data from such providers. Future implementations will be guided by this architecture, which will serve as a blueprint for discovering other resource types (e.g. material samples) through a PID Graph approach. B2INST will be established as a low-barrier service with enhanced community support and metadata extensions for research instrument registration. Instruments will be crosslinked in graphs connecting research outputs. Datasets from instrument

<sup>28</sup> See, for example, Award DOI Service of U.S. Department of Energy: <https://www.osti.gov/award-doi-service/faqs#what-is-an-award>.

<sup>29</sup> <https://base4nfdi.de/projects/iam4nfdi>

<sup>30</sup> Krahl, et al. (2021).

<sup>31</sup> <https://b2inst.gwdg.de/>

measurements, literature citing used instruments, individuals and organisations operating instruments, and instrument calibrations are of particular relevance<sup>32</sup>. To ensure comprehensive integration, instrument PIDs will be linked with related PIDs through the development and publication of best practices and in collaboration with PID providers (c.f. T2.5). The Sensor Management System, developed for managing sensor metadata within the Earth system science community (notably NFDI4Earth), will serve as a key use case for instrument identifiers.

### **T3.2 Prefix registration service (Lead: GWDG)**

A simple prefix registration service will be implemented to promote rapid PID adoption, offering free PID services for around 10 use cases during the project. Test prefixes, useful for technical integration and testing, will be available in larger quantities without persistence guarantees. For ePIC-based prefixes, persistence will be assured under standard contracts. Dedicated contracts with PID service providers will be needed to continue PID generation after the project ends.

### **T3.3 Technical integration of the services (Lead: GWDG)**

The Coordination Hub will integrate technical services including DTR, Prefix Registration Service, and PIDMR. Authentication will be required for the registration of new types (e.g. BasicType or Profiles) and new PID service providers, which will be implemented through the NFDI AAI solution developed by IAM4NFDI. This will enable group specific entries in DTR and for domain specific profiles. Additionally, the user interface will be customised to meet NFDI specific requirements. DTR will facilitate the registration of types and profiles, enabling community-specific metadata schemata and validation of metadata against registered profiles to enhance metadata quality.

## **WP4 – Training and Support**

<b>Responsible</b>	DataCite	GWDG	OS Office	TIB (Lead)
<b>Person months</b>	4	1,2	0	11

### **Objectives**

A modular, multilevel training service will be provided for various user groups—including infrastructure managers, researchers, and institutional administrators—to effectively utilise PIDs. Existing materials from PID providers and projects will be evaluated for compatibility with NFDI requirements, and additional resources and tools will be developed with partners as needed. This scalable model aims to increase PID awareness, adoption, and integration across NFDI services.

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<sup>32</sup> Hackel et al. (2017).

#### **T4.1 Collect and evaluate training material, identify gaps (Lead: TIB)**

On the basis of the initialization phase, the collection and evaluation of PID training materials— including videos, slides, manuals, and wikis—will be expanded. Materials from PID providers, project partners, and existing NFDI services will be assessed, focusing on research instruments, material samples, and highly granular entities<sup>33</sup>. Usability, best practices, and gaps in training resources will be identified to enhance PID training across NFDI. Initial recommendations for exploratory PID resource types, such as projects and awards, will also be developed.

#### **T4.2 Develop material to fill the gaps (Lead: TIB, DataCite, GWDG)**

Targeted training materials will be developed to address identified gaps, aligned with WP2 and WP3 requirements. This collection will cater to NFDI needs through a multilevel approach coordinated with EduTrain section activities, including train-the-trainer concepts<sup>34</sup>. Introductory materials such as short videos (2–4 minutes) will raise awareness of PID utility in FAIR data management for infrastructure managers, researchers, and data managers. The second level will cover integration of multiple PIDs, including PID Graph concepts, API usage, and examples of successful PID implementations and their impact. The third level will include comprehensive documentation from PID providers, including those outside of the PID4NFDI project. Modular materials will address our use cases of research instruments, material samples, and highly granular entities by employing the EduBricks<sup>35</sup> concept for customizable learning experiences. This approach ensures scalability for diverse users and use cases during the ramp-up phase.

#### **T4.3 Testing of material as feedback loop (Lead: TIB)**

Training materials will be validated by testing with ELN and DMP focus group members. Qualitative feedback will be gathered through workshops and surveys to prioritise user satisfaction and capture additional requests. This feedback will inform T4.4., ensuring alignment with NFDI expectations and requirements.

#### **T4.4 Integration of developed material in PID Coordination Hub and NFDI training material infrastructure/collection (Lead: TIB)**

Training materials will be integrated into the PID Coordination Hub. In WP 5, the web platform will be expanded to offer open-source training materials to NFDI users and the public. Material descriptions will align with EduTrain requirements and the DALIA<sup>36</sup>

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<sup>33</sup> Such as base services, section working groups or the NFDI4Ing Schulungsplattform:

<https://education.nfdi4ing.de/>.

<sup>34</sup> Biernacka et al. (2023).

<sup>35</sup> See living document of the EduTrain section on a modular training concept:

<https://docs.google.com/document/d/1XpHsC6HmEXGLpGOrdwu-szg5WTkb8-Q9NQ47cr14dhY/edit>.

<sup>36</sup> Data Literacy Alliance - DALIA, <https://dalia.education/>

knowledge base, and will be linked with other knowledge hubs, such as NFDI4Ing Schulungsplattform<sup>37</sup>.

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<sup>37</sup> <https://education.nfdi4ing.de/>

## WP5 – Outreach and Community Engagement

<b>Responsible</b>	DataCite	GWDG	OS Office (Lead)	TIB
<b>Person months</b>	3	6	17	1

### Objectives

This WP will coordinate outreach and dissemination to maximise the impact of PID4NFDI outputs. The goal is to raise awareness of the value of PIDs and foster community engagement surrounding PID implementation within NFDI. Support will be provided for other WPs to effectively reach target audiences and engage PID experts and stakeholders.

#### **T5.1 Expand project website as entry point to Coordination Hub and communication channels (Lead: OS Office)**

In the initialisation phase, a project website was set up<sup>38</sup>. The required maintenance of the website will continue, both in terms of technical management and content editing. The website will be further expanded to provide an access point to the Coordination Hub, including developed guidelines and best practices (WP1), tools, and training materials (T4.4). It will also feature information on outreach events and community engagement activities, with emphasis on use cases and focus groups. A help section will be added with frequently asked questions. In coordination with WP2, resources such as templates, toolkits, and examples will be produced to support infrastructure operators in developing and managing high-quality metadata (including the best practices and guidelines developed in T.2.2). Moreover, the Coordination Hub will expand access to PID-referenced information through technical developments (WP3).

#### **T5.2 Determining stakeholder needs (Lead: OS Office)**

Enhanced community engagement and a stakeholder needs assessment will be achieved by monitoring consortia activities, attending consortia meetings<sup>39</sup>, reviewing websites and outputs, and consulting with NFDI sections. Consultation hours will be offered in collaboration with WP4 and a contact form (D5.2) for structured PID-related inquiries will be added to the website.

#### **T5.3 Community engagement and facilitation of outreach events (Lead: OS Office)**

Building on the initial communication strategy and stakeholder workshop, problem- or needs-specific workshops will be organised to facilitate exchanges among consortia PID experts, PID4NFDI staff, and external stakeholders. Training resources (WP4), best

<sup>38</sup> <https://base4nfdi.github.io/pid4nfdi/>

<sup>39</sup> We expect it necessary to participate in online-only, hybrid and in-person events, respectively.

practices, use cases, and general topics at the consortia level will be presented<sup>40</sup>. Existing PID liaisons and stakeholders within consortia, including repository managers and project members, will be engaged to strengthen our network<sup>41</sup>. Collaboration with PID Network Germany will be prioritised, aligning our efforts with their activities and the EOSC framework. Community engagement will be supported through the development and use of communication channels, including social media.

#### **T5.4 Outputs management and curation (Lead: OS Office)**

Ongoing management, curation, and publishing of various project outputs (e.g. training materials, outreach resources, and scientific publications) will be coordinated to ensure consistency. Open Science principles will be followed, with a commitment to making all results publicly available. This will ensure resources are accessible and usable by stakeholders, encouraging collaboration and enhancing impact within the NFDI initiative.

#### **WP6 – Project Management**

<b>Responsible</b>	DataCite	GWDG	Helmholtz	TIB (Lead)
<b>Person months</b>	0	4 as in-kind contribution	0	9 as in-kind contribution

#### **Objectives and tasks**

The accomplishment of defined KPIs and quality indicators will be monitored, technically supported by OpenProject, which is used to constantly evaluate objectives, deliverables, milestones, and tasks to be achieved. Team meetings are held every 14 days (online); project meetings including PIs are held every six months. Project management also includes coordination with NFDI stakeholders: Base4NFDI (TA meetings and jours fixes), sections, the PID Working Group within NFDI, as well as other working groups.

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<sup>40</sup> Possible topics of workshops and presentations are PID choice strategies in DMPs, the integration of PIDs within ELNs, and the relevance of PIDs for research practices, research integrity, data quality and collaboration (see also paragraph 3.1 Service Integration Concept).

<sup>41</sup> Possibly to be developed into a network of PID ambassadors in the ramp-up phase (see paragraph Transition to ramp-up phase and vision of operative service under 3.2).



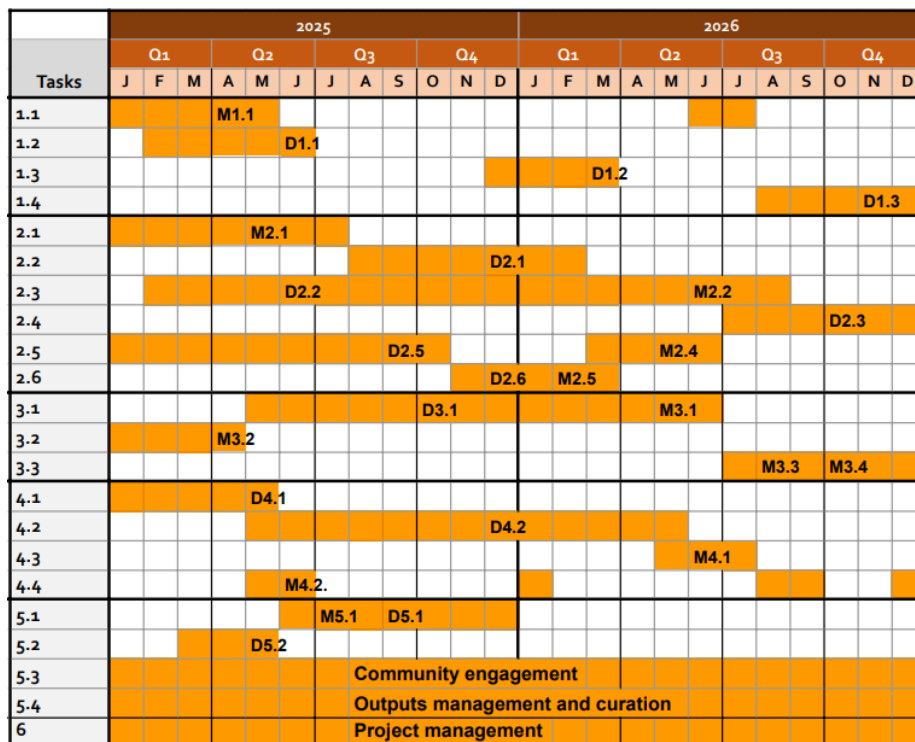


Figure 2: Gantt chart of PID4NFDI integration phase.

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