Data Production

Data Usage

Data Provision

DAPHNE4NFDI
NFDI4Microbiota
DataPLANT
FAIRagro
KonsortSWD
NFDI4Immuno
NFDI4BIOIMAGE
NFDI4Culture
Text+
NFDI4Chem

Data Science & AI
Data Integration
META(DATA), TERMINOLOGY, PROVENANCE
FAIR Digital Objects
Data Protection and Research Ethics
Multi Cloud
Electronic Lab Notebooks
PUNCH4NFDI
Identity & Access Management
EDUCATION & TRAINING
Persistent Identifiers
NFDI4Health
INDUSTRY ENGAGEMENT
Metadata Schemata
Training Modules
Licensing & Copyright
BERD@NFDI
Terminology Harmonisation
Research Software
NFDI4Earth
Data Management Plans
COMMON INFRASTRUCTURES
Anonymising & Pseudonymising
NFDI4Objects
Long Term Archiving
Error Culture
ETHICAL, LEGAL & SOCIAL ASPECTS
Knowledge Graphs
Search & Harvesting
NFDI4Ing

GHGA
MaRDI
NFDIxCS
NFDI4Cat
FAIRmat
NFDI4Energy
NFDI-MatWerk
NFDI4Biodiversity
NFDI4DataScience
NFDI4Memory

Application of a
Joint Collaboration of NFDI Consortia
on Basic Services

Base4NFDI

Basic Services for NFDI

Revised Community Release
November 2023

Base4NFDI Proposal – revised version November 2023

This version reflects the DFG funding cuts of 50% to flexible funds and the updated term of the project, which runs from 01/03/2023 to 29/02/2028.

Base4NFDI Proposal – revised version November 2023

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List of Abbreviations

AAI	Authentication and Authorisation Infrastructure
AARC	Authentication and Authorisation for Research Collaboration
AI	Artificial Intelligence
ARDC	Australian Research Data Commons
ARK	Archival Resource Key Identifier
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
CARE	Collective benefit, Authority to control, Responsibility, and Ethics
COBIT	Control Objectives for Information and Related Technologies
CODATA	Committee on Data for Science and Technology
CA	Consortia Assembly
CO	Coordination Office
eduGAIN	EDUcation Global Authentication INfrastructure
DFG	German Research Foundation (Deutsche Forschungsgemeinschaft)
DFN	German National Research and Education Network (Deutsches Forschungsnetz)
DMP	Data Management Plan
DOI	Digital Object Identifier
ELN	Electronic Lab Notebooks
ENVRI-FAIR	Environmental Research Infrastructures FAIR
ePIC	Persistent Identifiers for eResearch
ERIC	European Research Infrastructure Consortia
EOSC	European Open Science Cloud
ESCAPE	The European Science Cluster of Astronomy & Particle Physics
FAIR	Findable, Accessible, Interoperable, Re-usable
FB	Funding Building Block
FIM4R	Federated Identity Management for Research
FTE	Full-time Equivalent
GDPR	General Data Protection Regulation

GWK	Joint Science Conference (Gemeinsame Wissenschaftskonferenz)
HIFIS	Helmholtz Federated IT Services
HPC	High Performance Computing
IaaS	Infrastructure-as-a-service
IAM	Identity Access Management
IG	Interest Group
IGSN	International Geo Sample Number
ISNI (IA)	International Standard Name Identifier (International Authority)
ISO	International Organization for Standardization
IT	Information Technology
ITIL	Information Technology Infrastructure Library
KPI	Key Performance Indicator
LEI	Legal Entity Identifier
LOI	Letter of Intent
LTA	Long-term Archiving
M	Measure
MC	Management Committee
MS	Milestone
NFDI	National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur)
NIH	National Institutes of Health
NHR	National High Performance Computing (Nationales Hochleistungsrechnen)
OLA	Operational Level Agreement
OLS	Ontology Lookup Service
OWL	Web Ontology Language
PaaS	Platform-as-a-service
PANOSC	Photon and Neutron Open Science Cloud
PURL	Persistent Uniform Resource Locator
PID	Persistent Identifier
RAiD	Research Activity Identifier
RDA	Research Data Alliance
RDC	Research Data Commons
RDM	Research Data Management

RfII	German Council for Scientific Information Infrastructures (Rat für Informationsinfrastrukturen)
ROR	Research Organisation Registry
RRID	Research Resource Identifiers
SaaS	Software-as-a-Service
SDO	Standards Developing Organisation
SIRTFI	Security Incident Response Trust Framework for Federated Identity
SKOS	Simple Knowledge Organisation System
SL	Service Level
SNCTFI	Scalable Negotiator for a Community Trust Framework in Federated Infrastructures
SRIA	Strategic Research and Innovation
SSHOC	Social Sciences and Humanities Open Cloud
SSO	Single sign-on
TA	Task Area
TEC	Technical Expert Committee
TRL	Technology Readiness Level
TS	Terminology Service
URI	Uniform Resource Identifier
URN	Uniform Resource Name
UUID	Universally Unique Identifiers
WDCC	World Data Center for Climate
WDS	World Data System
WG	Working Group
WISE	Wise Information Security for Collaborating e-Infrastructures

Glossary of NFDI- and proposal-related terms

The **AI Competence Centres** are a mainstay of German AI Research and are funded by the Federal Ministry of Education and Research (BMBF). Together they form a network for the exchange of expertise and research results. The aim is to further strengthen Germany as an AI location and to make German AI research internationally visible. [https://www.plattform-lernende-systeme.de/map-on-ai-map.html]

The **Alliance of Science Organisations** in Germany is a union of the most important German research organisations. It issues statements relating to research policy and funding and the structural development of the German research system.
 [https://www.dfg.de/dfg_profil/allianz/index.html, translated]

Cross-cutting topics address socio-technical questions or tasks that are relevant across consortia and need to be addressed and solved jointly. [15]

The **FAIR Data Spaces** project is funded by the German Federal Ministry of Education and Research (BMBF) from May 2021 to May 2024. In this project, the Gaia-X federated and secure data infrastructure and the National Research Data Infrastructure (NFDI) are connected to a common, cloud-based data space for industry and research in compliance with the FAIR Principles, i.e., to share data in a findable, accessible, interoperable, reusable way. [https://www.nfdi.de/fair-data-spaces/?lang=en]

GAIA-X is a project for a federated data infrastructure in Europe. It is a platform for storing data in external data centres. It aims to guarantee performance and competitiveness, as well as security and trustworthiness. The German Federal Ministry for Economic Affairs and Energy (BMWi) has taken over the lead role within the Federal Government for GAIA-X.[https://www.eu2020.de/eu2020-en/news/article/gaia-x-common-digital-infrastructure-for-europe/2401076]

The **Gauß-Allianz** is a non-profit association for the promotion of science and research. To this end, it supports the scientific community in Germany by creating the conditions for sustainable and efficient use of supercomputing resources of the top performance classes, in particular through the coordination and pooling of complementary skills and diversified computer architectures and the associated access structure. The mission of the Gauß-Allianz is to coordinate the HPC related activities of the members. [https://gauss-allianz.de/en/about_ga/]

German Council for Scientific Information Infrastructures (RFII) In November 2013, the Joint Science Conference resolved to establish a "Council for Information Infrastructures" for an initial pilot phase of four years. The task of the Council is to increase the level of transparency of developments and processes in the area of information infrastructures in the scientific system and beyond and support the development and communication of German positions in European and international debates. [https://rfii.de/en/the-council/]

The **German Council of Science and Humanities** is the most important science policy advisory body in Germany and advises the Federal Government and the governments of the *Länder* on issues relating to the further development of the higher education system in terms of content and structure as well as the state funding of research institutions.

The **Base4NFDI International Advisory Board (IAB)** is a body created by Base4NFDI. It ensures external and international strategic advice to Base4NFDI's Management Committee. It consists of a speaker and four members, all highly distinguished, international, external to Base4NFDI and representing different international perspectives and stakeholders (e.g. research data/software centres, information infrastructures, infrastructure providers, industry, state and public interests). The board reviews the overall status of Base4NFDI and gives recommendations for the development and strategic operation. [cf. p. 31]

The **Joint Science Conference (GWK)** deals with all questions of research funding, science and research policy strategies and the science system which jointly affect the Federal Government and the *Länder*. Whilst preserving their own competences, the members of the GWK strive for close coordination on questions of common interest in the field of national, European and international science and research policy with the aim of strengthening Germany's position as a location for science and research in the international competition. [https://www.gwk-bonn.de/en/]

The **Management Committee (MC)** is a body created by Base4NFDI. It consists of the 12 Base4NFDI co-spokespersons. This proficient group of co-applicants and named co-spokespersons will manage the Task Areas (TA) and assume shared responsibility for the overall work programme. The MC coordinates the activities of all TAs. It is in charge of interlinking the strategic decisions made by the NFDI Association bodies with the operative elements in

Base4NFDI. In particular, it is responsible to ensure compliance of all financial decisions with the DFG's guidelines for disbursement of funds. [cf. p. 27]

In the **NFDI** (German National Research Data Infrastructure), valuable data from science and research are systematically accessed, networked and made usable in a sustainable and qualitative manner for the entire German science system. Up to now, they have mostly been available on a decentralised, project-related or temporary basis. The NFDI aims to create a permanent digital repository of knowledge as an indispensable prerequisite for new research questions, findings and innovations. Relevant data should be made available according to the FAIR principles (Findable, Accessible, Interoperable and Reusable).
 [https://www.nfdi.de/association/?lang=en]

NFDI Association The non-profit Association German National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur (NFDI) e.V.), based in Karlsruhe, was founded to coordinate the activities for establishing a national research data infrastructure. Together, the Association and the NFDI consortia are shaping the future of research data management in Germany. In addition, the NFDI will also be linked to international initiatives such as the European Open Science Cloud (EOSC) and participate in its development.
 [https://www.nfdi.de/association/?lang=en]

The **NFDI Board of Trustees** is the administrative-strategic supervisory body of the Association. Its main tasks are the appointment and supervision of the Directorate, the approval of the admission and exclusion of members as well as the approval of major financial and organisational decisions affecting the Association as such. The Board of Trustees is composed of nine members, three of whom are delegated by the Federal Republic of Germany, three by the federal states and three by the Association's Members Assembly. [https://www.nfdi.de/association/?lang=en]

NFDI Consortia are associations of various institutions within a research field, working together in an interdisciplinary manner to implement the goal. NFDI Consortia are already being funded in the first or second round. [https://www.nfdi.de/association/?lang=en]

The **NFDI Consortia Assembly (CA)** is a body of the NFDI Association. It determines the content-related and technical principles for the work of the consortia. On the one hand, it submits proposals to the Scientific Senate for decisions on cross-consortia standards; on the other hand, it defines the framework conditions for the implementation of the standards determined by the Scientific Senate in the consortia. It is thus a central coordinating body for coordination between the various consortia. It consists of the speakers of the consortia.
[https://www.nfdi.de/association/?lang=en]

NFDI Consortia-initiatives have submitted their proposals for funding as part of the NFDI and are currently still under review. Funding for the third and last round of consortia commences in January 2023.

The **NFDI Directorate** is the Executive Board of the NFDI Association. It coordinates the bodies of the Association, supports the strategic cooperation across the consortia and represents the Association externally. It consists of the Director and the Administrative Director. The Directorate is supported by the NFDI office. [https://www.nfdi.de/association/?lang=en]

The **NFDI Members Assembly** is a body of the NFDI Association. It is responsible for typical tasks according to German association law, such as receiving the annual accounts and the activity report. As of March 2022 the Association has 203 members, including the Federal Republic of Germany and its 16 federal states as founding members as well as other legal entities that are involved in consortia or from which a significant contribution to the realisation of the Association's purpose can be expected. [https://www.nfdi.de/association/?lang=en]

The **Scientific Senate** is a body of the NFDI Association. It determines both the substantive and the strategic direction of the Association. The main tasks of the Scientific Senate include advising on the project progress of the consortia, deciding on cross-disciplinary standards and metadata standards, and deciding on the inclusion and integration of cross-disciplinary services. The Scientific Senate is chaired by the Director of the Association and consists of twelve other experts. Four of them are nominated by the Joint Science Conference (GWK), as well as by the Alliance of Science Organisations and the Consortia Assembly.
[https://www.nfdi.de/association/?lang=en]

NFDI Sections are the loci bridging the standards and service needs between domains and therefore play an important role for building consensus on common standards and workflows in the NFDI. Currently there are the four sections (1) Common Infrastructures, (2) Ethical, Legal, and Social Aspects, (3) Metadata, Terminologies, Provenance, and (4) Training & Education.

NHR (Nationales Hochleistungsrechnen) is an association dedicated to national high performance computing. It was founded on August 23, 2021. Founding members are eight universities/centres that have been jointly funded by the German federal and state governments to operate an NHR centre since January 1, 2021.

Section Liaison Officers directly support the work of the Sections in matters directly related to basic services. One central task will be to assist with coordinating discussions on similar topics across Sections. They also monitor needs for complementary activities and collaboration between working groups. [cf. p. 30]

A "**service**" is understood as a technical-organisational solution, which typically includes storage and computing services, software, processes and workflows, as well as the necessary personnel support for different service desks. A service is usually provided by one or more organisations for a certain period of time and for a defined target group. An **NFDI-wide basic service** would have the potential to serve most or all consortia and thus have a significant impact on the efficiency of the German research community. [cf. p. 11]

Service stewards are positions implemented in Base4NFDI. They will ensure a smooth interplay between the Sections, participating consortia and partner organisations involved in the development of a service. They scout the infrastructure landscape with regard to certain service candidates and corresponding requirements from the researchers in the different domains. They consolidate this information according to criteria defined by the Sections. At later stages of the process they support the rollout of services and the integration of services into the existing infrastructure landscape. They are critical to efficient adaptation of basic-services as the consortia will often need additional support for integrating a basic service with their existing service portfolio or do not have the resources and or expertise for adopting a new service. [cf. p. 29-30]

The **Technical Expert Committee (TEC)** is a body created by Base4NFDI. It will ensure the overall coherence, robustness and scalability of services developed within Base4NFDI. It consists of a group of infrastructure professionals from the consortia's co-applicant and participant organisations and will be appointed by the Consortia Assembly. It will be in charge of evaluating proposals for basic service candidates in terms of technical quality, interoperability with existing solutions, suitability of the partner organisations suggested and the financial calculations provided. [cf. p. 28-29]

The **ZKI (Zentren für Kommunikationsverarbeitung in Forschung und Lehre/ centres for communication and information** processing**)** is the German association of Higher Education IT centres and public funded research organisations. The members represent all research driven universities, many of the universities of applied sciences and other kinds of universities. En masse they educate nearly 90% of all students at German universities. ZKI is focussing on bilateral knowledge transfer and support between Higher Education IT and companies as well as public organisations. [https://www.zki.de/english/]

Proposal

1   General information

Name of the joint collaboration in English and German

Basic Services for NFDI / Basisdienste für die NFDI

Summary of the proposal in English and German

Basic Services for NFDI

Efficiency and seamless user experience in research data management within and beyond the NFDI can be greatly improved through NFDI-wide basic services. Base4NFDI is a unique joint effort supported by all consortia to develop and deploy such services. Base4NFDI involves institutions from all relevant infrastructure domains and from all major research organisations in Germany. Its resulting NFDI-wide basic service portfolio will benefit all these communities and domains. The target group for basic services is the wider NFDI-community and, in particular, operators of specialised community resources.

Base4NFDI builds on two core pillars: 1) organisationally, a community driven co-design of basic services via the NFDI Association and, 2) technologically, a common framework establishing quality assured and coherent models for continuous identification, fostering, development, operation and evaluation of NFDI-wide basic services.

True to its mission of supporting NFDI, all strategic and financial decisions on basic services will be made by all consortia in the bodies of the NFDI Association. A basic service needs to be useful to *potentially all* existing and future consortia. In Base4NFDI a *service* is understood as a technical-organisational solution, which typically includes storage and computing services, software, processes and workflows, as well as the necessary personnel support for different service desks. To generate proposals for basic services, Base4NFDI will draw on the expertise in the NFDI Sections. They are the loci for exchange between consortia on cross-cutting topics, provide infrastructural and technological expertise in combination with domain knowledge and act as incubators for identifying potential basic service.

For development it will rely on a three-stage process of 1) initialisation of potential basic services 2) integration of basic services candidates and 3) ramping-up for operation and becoming part of the NFDI basis service portfolio. Base4NFDI's basic services will foster interoperability and efficiency within the NFDI. Development will commence with services for Identity and Access Management (IAM), Persistent Identifiers (PID) and Terminologies. Through this process, Base4NFDI will bring up to five basic services to operation-readiness by 2028.

Basisdienste für die NFDI

NFDI-weite Basisdienste können Effizienz und eine naht- und reibungslose Nutzung der Angebote des Forschungsdatenmanagements innerhalb und außerhalb der NFDI in außerordentlichem Maß verbessern. Mit Base4NFDI unternehmen alle Konsortien der NFDI die einzigartige und gemeinsame Anstrengung, solche Dienste zu entwickeln und anzubieten. An Base4NFDI beteiligen sich Institutionen aus allen wichtigen Bereichen der wissenschaftlichen Infrastrukturversorgung und aus allen großen Forschungsorganisationen in Deutschland. Das NFDI-weite Basisdienstportfolio wird somit all diesen Communities und Domänen zugute kommen. Die Zielgruppe der NFDI-weiten Basisdienste ist die gesamte NFDI-Gemeinschaft, insbesondere den Betreibern community-spezifischer Dienste.

Base4NFDI baut auf zwei Säulen auf: 1) organisatorisch auf der partizipativen Mitgestaltung der Basisdienste-Entwicklung durch die Communities im NFDI Verein; 2) technologisch auf einem gemeinsamen Rahmen, der qualitätsgesicherte und kohärente Modelle für die kontinuierliche Identifizierung, Förderung, Entwicklung, den Betrieb und die Bewertung von NFDI-weiten Basisdiensten schafft.

Getreu der Mission, die NFDI zu unterstützen, werden alle strategischen und finanziellen Entscheidungen über Basisdienste gemeinsam von allen Konsortien in den Gremien des Vereins getroffen. Ein Basisdienst muss für *potenziell alle* bestehenden und zukünftigen Konsortien nützlich sein. Dabei versteht Base4NFDI unter einem *Service* eine technisch-organisatorische Lösung, die Speicher- und Rechenleistungen, Software, Prozesse und Workflows ebenso umfassen kann, wie die notwendige personelle Betreuung für unterschiedliche Service-Desks. Um Vorschläge für Basisdienste zu generieren, wird Base4NFDI auf die Expertise in den NFDI-Sektionen zurückgreifen. Sie sind Orte des Austauschs zwischen den Konsortien zu Querschnittsthemen, vereinen Fachwissen zu den Themen Infrastruktur und Technologie und fungieren als Keimzellen für potenzielle Basisdienste.

Die Entwicklung von Basisdiensten erfolgt in einem dreistufigen Prozess: 1) Initialisierung potenzieller Basisdienste, 2) Integration von Basisdienstkandidaten und 3) Hochfahren für den operationellen Betrieb und Aufnahme in das Basisdienst-Portfolio der NFDI. Die durch Base4NFDI geschaffenen Basisdienste werden Interoperabilität und Effizienz innerhalb der NFDI nachhaltig stärken. Die Entwicklungen werden mit Diensten zu Identity and Access Management (IAM), Persistent Identifiers (PID) und Terminologien beginnen. Bis 2028 wird Base4NFDI auf diese Weise bis zu fünf Basisdienste zur Einsatzreife bringen.

Coordinating institution

Applicant institution	Location	Acronym of existing consortium
Technische Universität Dresden	01062 Dresden	NFDI4Earth

Coordinator

Spokesperson	Institution, location	Acronym of existing consortium
Prof. Dr. Lars Bernard	TU Dresden, 01062 Dresden	NFDI4Earth

Joining consortia

Applicant institutions	Location	Acronym of existing consortia
Akademie der Wissenschaften und der Literatur | Mainz	Geschwister-Scholl-Straße 2, 55131 Mainz	NFDI4Culture
Albert Ludwig Universität Freiburg	79104 Freiburg	DataPLANT
DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.	Theodor-Heuss-Allee 25, 60486 Frankfurt am Main	NFDI4Cat
Deutsches Elektronen-Synchrotron (DESY)	Notkestraße 85, 22607 Hamburg	DAPHNE4NFDI, PUNCH4NFDI
Deutsches Krebsforschungszentrum	Im Neuenheimer Feld 280, 69120 Heidelberg	GHGA
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	Hansastraße 27 c, 80686 München	NFDI4DataScience, NFDI-Matwerk
Friedrich Schiller Universität Jena	Fürstengraben 1, 07743 Jena	NFDI4Chem
GESIS - Leibniz Institut für Sozialwissenschaften	B6 4-5, 68159 Mannheim	KonsortSWD
Humboldt-Universität zu Berlin	Unter den Linden 6, 10117 Berlin	FAIRmat
Leibniz-Institut für Deutsche Sprache (IDS)	R5 6-13, 68161 Mannheim	Text+
MARUM – Center for Marine Environmental Sciences, Universität Bremen	Leobener Str. 8, 28359 Bremen	NFDI4Biodiversity
RWTH Aachen University	Templergraben 55, 52062 Aachen	NFDI4Ing

Technische Universität Dresden	Helmholtzstraße 10, 01069 Dresden	NFDI4Earth
Universität Mannheim	Mannheim Center for Data Science, 68131 Mannheim	BERD@NFDI
Weierstraß-Institut für Angewandte Analysis und Stochastik (WIAS)	Mohrenstraße 39, 10117 Berlin	MaRDI
ZB MED Information Centre for Life Sciences	Gleueler Straße 60, 50931 Köln	NFDI4Health, NFDI4Microbiota

Joining co-applicant institutions

Co-applicant institutions (shortcut)	Location	Acronym of existing consortia	Responsibility for Task area in this proposal
Deutsches Elektronen-Synchrotron **(DESY)**	Notkestraße 85, 22607 Hamburg	PUNCH4NFDI	TA3: Service Coherence Processes and Monitoring
GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel **(GEOMAR)**	Wischhofstr. 1-3, 24148 Kiel	NFDI4Earth	TA2: Service Integration and Ramping-up for Operation
Georg-August-Universität Göttingen Niedersächsische Staats- und Universitätsbibliothek Göttingen **(SUB)**	Platz der Göttinger Sieben 1, 37073 Göttingen	Text+	TA4: Project Governance
GESIS – Leibniz-Institut für Sozialwissenschaften in Mannheim **(GESIS)**	B6 4-5, 68159 Mannheim	KonsortSWD	TA2: Service Integration and Ramping-up for Operation & TA4: Project Governance
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.; Fraunhofer Institut für Offene	Hansastraße 27 c, 80686 München	NFDI4Data-Science	TA1: Service Requirements, Design and Development

Kommunikationssysteme (FOKUS)			
Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V. Max Planck Computing & Data Facility **(MPCDF)**	Hofgartenstraße 8, 80539 München	FAIRmat	TA2: Service Integration and Ramping-up for Operation
Stiftung Preußischer Kulturbesitz - Staatsbibliothek zu Berlin **(SPK)**	Unter den Linden 8, 10117 Berlin	NFDI4Culture	TA3: Service Coherence Processes and Monitoring
Technische Universität Dresden **(TUD)**	Helmholtzstraße 10, 01069 Dresden	NFDI4Earth	TA4: Project Governance
Technische Informationsbibliothek **(TIB)**	Welfengarten 1 B, 30167 Hannover	NFDI4Ing	TA1: Service Requirements, Design and Development
Universität Bielefeld, Bielefelder Institut für Bioinformatik Infrastruktur **(BiBi)**	Universitätsstraße 25, 33615 Bielefeld	NFDI4Microbiota	TA1: Service Requirements, Design and Development
ZB MED Information Centre for Life Sciences **(ZB MED)**	Gleueler Straße 60, 50931 Köln	NFDI4Health	TA3: Service Coherence Processes and Monitoring

Joining co-spokespersons

Co-spokespersons	Institution, location	Acronym of existing consortia	Responsibility for Task area in this proposal
Reinhard Altenhöner	Stiftung Preußischer Kulturbesitz - Staatsbibliothek zu Berlin, Unter den Linden 8, 10117 Berlin	NFDI4Culture	TA3: Service Coherence Processes and Monitoring
Prof. Dr. Lars Bernard	Technische Universität Dresden,	NFDI4Earth	TA4: Project Governance

	Helmholtzstraße 10, 01069 Dresden		
Prof. Dr. Juliane Fluck	ZB MED Information Centre for Life Sciences, Glueler Straße 60, 50931 Köln	NFDI4Health	TA3: Service Coherence Processes and Monitoring
Axel Klinger	Technische Informationsbibliothek (TIB), Welfengarten 1 B, 30167 Hannover	NFDI4Ing	TA1: Service Requirements, Design and Development
Sören Lorenz	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Wischhofstr. 1-3, 24148 Kiel	NFDI4Earth	TA2: Service Integration and Ramping-up for Operation
Dr. Brigitte Mathiak	GESIS – Leibniz-Institut für Sozialwissenschaften in Mannheim, B6 4-5, 68159 Mannheim	KonsortSWD	TA2: Service Integration and Ramping-up for Operation
Dr. Bernhard Miller	GESIS – Leibniz-Institut für Sozialwissenschaften in Mannheim, B6 4-5, 68159 Mannheim	KonsortSWD	TA4: Project Governance
Dr. Raphael Ritz	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V., Max Planck Computing & Data Facility (MPCDF) Hofgartenstraße 8, 80539 München	FAIRmat	TA2: Service Integration and Ramping up for Operation
Dr. Sonja Schimmler	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., FOKUS Hansastraße 27 c, 80686 München	NFDI4DataScience	TA1: Service Requirements, Design and Development

PD Dr. Thomas Schörner-Sadenius	Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg	PUNCH4NFDI	TA3: Service Coherence Processes and Monitoring
Prof. Dr. Alexander Sczyrba	Universität Bielefeld, Bielefelder Institut für Bioinformatik Infrastruktur Universitätsstraße 25, D-33615 Bielefeld	NFDI4Microbiota	TA1: Service Requirements, Design and Development
Regine Stein	Georg-August-Universität Göttingen Niedersächsische Staats- und Universitätsbibliothek Göttingen, Platz der Göttinger Sieben 1, 37073 Göttingen	Text+	TA4: Project Governance

Prospective institutions or individuals to become participants in existing consortia for the purpose of basic services

Participating institutions **(shortcut)**	Location	Assignment to an existing consortium
Verein zur Förderung eines Deutschen Forschungsnetzes e. V. **(DFN-Verein)**	Alexanderplatz 1 10178 Berlin	NFDI4Ing

Contribution of DFN-Verein

DFN-Verein will contribute to Base4NFDI in two ways. First, by connecting the envisaged NFDI Community AAI to the national identity federation DFN-AAI, which is operated by DFN-Verein. This way, users from German research and higher education institutions plus approx. 4,500 home organisations worldwide will be able to access services and other resources provided by the NFDI Community AAI. Through its modular architecture and participation in the international interfederation eduGAIN, the DFN-AAI also enables international, cross-federation, and cross-community usage scenarios.

Second, DFN-Verein will contribute to various aspects of the NFDI Community AAI which might serve as blueprints for other basic services. These aspects cover technical elements as well as

operational and service models, policies and data protection practice, based on decades of experience in serving the needs of the German research and education community.

Participating individuals	Institution, location	Assignment to an existing consortium
Dr. Christian Grimm	Verein zur Förderung eines Deutschen Forschungsnetzes e. V. Alexanderplatz 1 10178 Berlin	*Nominated as individual expert*
Dr. Simone Rehm	Universität Stuttgart Keplerstraße 7 70174 Stuttgart	*Nominated as individual expert*
Prof. Dr. Ramin Yahyapour	Gesellschaft für wissenschaftliche Datenverarbeitung mbH Göttingen Burckhardtweg 4 37077 Göttingen	*Nominated as individual expert*

Contribution of Dr. Christian Grimm, Dr. Simone Rehm, Prof. Dr. Ramin Yahyapour:

Dr. Christian Grimm, Dr. Simone Rehm and Prof. Dr. Ramin Yahyapour will serve as team of acting co-chairs for the Technical Expert Committee (cf. chapter 3.4) until the committee is formally established by the NFDI Consortia Assembly.

2   Scope and objectives

2.1   Domains or methods addressed by the consortium, specific aim(s)

Base4NFDI is a **joint initiative of all consortia within the National Research Data Infrastructure (NFDI) to foster and establish reliable NFDI-wide basic services**. These basic services shall enable synergy, interoperability, seamless user experience for all researchers and efficient use of the resources within the NFDI, across all domains and all partnering institutions. Base4NFDI's basic services will thus profoundly improve research data management and the research that so crucially depends on it.

NFDI-wide basic services are crucial for the development of an NFDI which harnesses the full potential of Research Data Management (RDM) becoming more than only the sum of its domain-specific parts. Therefore, Base4NFDI was brought into being by the NFDI consortia as a joint and

broadly supported initiative that implements "Performance through Diversity" as outlined and encouraged by the German Council on Scientific Information Infrastructures [1].

The **immediate target group for basic services is the wider NFDI-community and, in particular, operators of specialised community resources** in need of stable hosting or computing infrastructure and providers who will connect their resources to the NFDI. Basic services are thus an additional, crucially important building block for the NFDI, which is grounded on the idea that infrastructure providers create a foundation for domain-specific resources (a) in support of science and (b) in tight cooperation with scientific communities.

Base4NFDI is the further development of the principles on basic services, which were already laid out in the position paper published by all consortia and 13 consortium initiatives in February 2022. It showcases the applicants' ability to effectively work together to shape the NFDI [1]. The **decision to join forces for Base4NFDI was taken unanimously by the NFDI Consortia Assembly** [2] (cf. chapter 3.2 and glossary). Base4NFDI is therefore strongly supported by consortia from all areas of science, consequently covering a plethora of research data types, topics and data cultures [3].

Basic services are necessary across consortia. A **structure to coordinate, develop and deploy such services across Germany requires funding which is currently not budgeted** either in the NFDI consortia or at the NFDI Directorate. Some consortia are in the early stages of establishing agreed data management workflows and community repositories and could adopt NFDI-wide basic services right from the start. Others already address services that bridge different domains through existing infrastructural networks. There are a number of consortia using established services which may take substantial integration efforts. **Base4NFDI addresses the needs of all NFDI consortia – including those currently in the application process – for NFDI-wide basic services in a structured manner. The resulting NFDI-wide basic service portfolio will therefore benefit all communities and domains**.

In preparing the Base4NFDI proposal, the NFDI consortia identified **two core pillars** for the successful development and establishment of NFDI-wide basic services; first, the **community driven co-design of basic services via the NFDI Association** and second, a **common framework establishing quality assured and coherent models** for continuous identification, fostering, development, operation and evaluation of NFDI-wide basic services.

Figure 1: Overview of Base4NFDI's structure and general approach

The Base4NFDI structure and approach combines both pillars: The **NFDI Sections as exchange hubs between consortia on cross-cutting topics, provide infrastructural and technological expertise in combination with domain knowledge and act as incubators for identifying potential basic services**. The NFDI Sections' role is to accompany requirement analyses, to guarantee that evolving basic services are driven by demand and linked back (a) to cross-cutting topics [4] [5] [6] [7] and (b) to specific usage scenarios within the different consortia (figure 1). Complementarily, **Base4NFDI will provide a framework to ensure the overall coherence of the emerging basic services from a sociotechnical perspective, to guarantee streamlined and efficient development, to ensure neutral evaluations, and to organise models for long-term operation**. Infrastructural and technological experts will develop this common framework for basic services (TA3). It will lay the foundation for monitoring and controlling the progress and effectiveness of the service developments. Also, it will provide the score cards for budget decisions and the basis for decisions on whether and how to proceed with the services' developments and where and how to appropriately intervene. All decision-making processes will be seamlessly embedded in the NFDI Association's governance and supplemented by a Base4NFDI Technical Expert Committee (TEC) to ensure the overall coherence, robustness, scalability and acceptance of services developed within Base4NFDI (cf. chapter 3.4 for details on decision-making processes and bodies, figure 4).

In Base4NFDI a "service" is understood as a **technical-organisational solution**, which typically includes storage and computing services, software, processes and workflows, as well as the necessary personnel support for different service desks. A service (cf. chapter 4.3) is usually provided by one or more organisations for a certain period of time and for a defined target group. **An NFDI-wide basic service would have the potential to serve most or all consortia and** thus have a significant impact on the efficiency of the German research community.

From idea to production **Base4NFDI differentiates three service stages: potential basic services, basic service candidates and basic services** ramped-up for operation. Identifying and suggesting potential basic services within the NFDI Sections and working groups driven by the consortia's needs will kick-off their further development within Base4NFDI. The technical **development process will be divided into three process steps: (1) service initialisation**, spanning requirements analysis and design to prepare basic service candidates (TA1), and **(2) service integration**, spanning scaling-up, development, testing, deployment and maintenance, as an incremental and fast-moving process (TA2) to prepare basic service candidates, and **(3) ramping-up for service operation** launching sustainable and reliable long-term provision (TA3 and TA4) of basic services, which will then become part of the NFDI basic service portfolio. Each process step requires an application and can only be funded after a rigorous review procedure, considering whether user needs are fulfilled and technical quality as well as coherence criteria are met (cf. chapter 4.3 and TA3). **A well-defined and transparent budget scheme will be applied to allocate funds to each of these process steps**, thus also supporting transparent allocation of the flexible funds requested by Base4NFDI (cf. chapter 4.3 and TA4). Flexible funds will also enable the participation of new actors, especially the successful consortia from the 3rd round of applicant domains.

The **Base4NFDI application involves institutions from all relevant infrastructure domains and from all major research organisations in Germany**. Therefore, Base4NFDI is in a unique position to achieve the following overarching technological and organisational goals within the next five years:

- Fostering interoperability and efficiency within the NFDI by establishing NFDI-wide basic services, kicking-off with services for identity and access management, persistent identifiers and terminologies.
- Ensuring alignment and effective decision-making between stakeholders by operating an organisational structure that ensures (1) user-driven development, adoption and long term operation models for NFDI-wide basic services, (2) incorporating all relevant NFDI stakeholders in an efficient and already agreed-upon manner and (3) the ability to respond and adapt to existing and future needs.

2.2   Objectives and measuring success

Base4NFDI's key objectives and measures of success for each of these objectives are summarised in the table below (table 1). They do not only address the general requirements from the call for proposals and the DFG's NFDI expert committee. They also include significant factors for a successful implementation of NFDI-wide basic services identified by the NFDI consortia in their joint statement, p.5 f. [1] (cf. chapter 3.1). Additionally, the table serves as a guide to the respective chapters and Task Areas (TA) of the work programme (cf. chapter 5) of this proposal, providing more details on how Base4NFDI plans to achieve its objectives, will measure the success of the respective objectives and how to proceed with deviations.

Table 1: Key objectives of Base4NFDI and corresponding measures of success

Base4NFDI Objective	Measure of Success
Continuously identify and **review** the need for a proposed basic service	● NFDI Sections closely cooperate with Base4NFDI. ● Service Stewards are appointed who continuously review and consolidate user needs for basic services (cf. chapter 3.4, TA1, TA2 and TA3). ● Basic services are developed in a 3-step process, integrating reviews assuring that user requirements are addressed (cf. chapter 3.4, TA3).
Ensure that NFDI **consortia will accept** the agreed-upon NFDI-wide basic service(s) and **use them reliably**	● The basic service development process integrates an overarching review of the coherence of the NFDI basic service portfolio (TA1, TA2 and TA3). ● Service developments, operations and usages are continuously monitored and reported to the NFDI community (TA3). ● Established Service Stewards support consortia with the uptake of (new) basic services (TA1 and TA2). ● Commitment by consortia is integrated into the decision-making process (approval by Consortia Assembly, (cf. chapter 3.4, figure 4). ● Parallel existence of several services during the development stage is tolerated if necessary but appropriately addressed with measures to converge these in the medium or long term (cf. chapter 3.4).
Setup and **launch of basic services** that meet the **common needs** of the consortia through an **agreed-upon process**	● Base4NFDI comprises all NFDI consortia. ● Basic services successfully relieve domain-specific services from generic tasks allowing for a user-oriented NFDI service landscape that meets needs from all domains. ● Base4NFDI decision structure (cf. chapter 3.4, figure 4) and the process model (figure 5) are successfully established and provide the means to channel user needs in a structured manner into the basic services' developments and operation. ● Initial services tackling particularly pressing topics – as identity and access management – are prioritised in an agreed-upon process by the NFDI consortia at the start of Base4NFDI.

Base4NFDI Objective	Measure of Success
Achieve seamless **structural integration** by building on **decision-making bodies** of the **NFDI Association**	• Base4NFDI's processes build on the NFDI Association's structures and involve them at all critical decision-makings of the development process (cf. chapter 3.4).
Assure **state of the art** development and following the **principle of best fit**	• The Technical Expert Committee (TEC, cf. chapter 3.4) assesses proposals along with technical criteria, provides recommendations on appropriate infrastructure and technical expertise. It recommends appropriate partners for service provision. • Basic services are provided by those organisations that can offer the necessary elements in the best possible way.
Develop **long-term operation models** for NFDI-wide basic services	• Each service ramped-up as operational basic service within Base4NFDI provides a long-term operation model (TA2 and TA4). • Base4NFDI engages with the Alliance of Science Organisations in Germany, national and international infrastructures and initiatives (e.g. EOSC, ERICs, NHR, cf. tables 2, 3) and with science policy bodies to jointly develop long-term models for operation of the NFDI basic service portfolio.
Integrate with existing services and/or establish basic services as an integral part of **international research data infrastructures and associations** and be at the forefront within international developments.	• Base4NFDI builds a strong network to assure international visibility – profiting from the international networks of all NFDI consortia (cf. chapter 3.3). • Base4NFDI strongly contributes to international infrastructures, initiatives and bodies such as EOSC, ISO, RDA, W3C, etc. (cf. chapter 3.3). • Benefiting from several Base4NFDI partners contributing to the EOSC, NFDI basic services are developed, provided and deployed in close cooperation with the EOSC, assuring synergies and usage of existing solutions at both ends.

3   Basic service initiative

3.1   Composition of the initiative and its embedding in the community of other consortia

The Base4NFDI initiative is a joint proposal of the 19 consortia funded in the NFDI to date, represented by their applicant organisations and speakers.[1] The initiative is also supported by the majority of consortia initiatives in the third round of the DFG calls.[2] The initiative is rooted in practical research data management practices from all scientific domains in NFDI and unites efforts of the consortia's infrastructure partners to provide basic services for the communities.

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[1] Members of Base4NFDI is used throughout this proposal as a term for all the following: applicants, co-applicants and participants of the joining consortia including joining co-spokespersons and joining participants as listed in chapter 1.

[2] A process has already been foreseen to integrate the applicant institutions of successful consortia soon after their projects start in 2023.

Specifically, major scientific computer centres and research infrastructure providers across Germany bring in a broad range of pre-existing work on basic service development for different scientific communities and initiatives (tables 2, 3, 4). In this way, Base4NFDI will extensively contribute to the massive harmonisation efforts NFDI provides for the research data services landscape in Germany.

Table 2: Representation of members of large long-term infrastructure programmes in NFDI consortia

Programme/initiative	Representation of members in NFDI consortia
German NHR Association – National High Performance Computing (HPC Tiers 2) (Nationales Hoch- und Höchstleistungsrechnen)	7 of 9
German Gauß-Allianz (HPC Tier 1-3)	12 of 13
German AI Competence Centers (Nationale Kompetenzzentren für KI)	6 of 6
ERIC – European Research Infrastructure Consortia	9 of 23[3]
EOSC Association – European Open Science Cloud	12 of 19[4]

The basic structures of NFDI are consortia, i.e. partnerships between infrastructure providers and scientific communities which aim to ensure systematic and sustainable research data management (RDM) for scientific communities and to provide long-term data storage, backup and accessibility for important community resources[5] in accordance with the FAIR guiding principles. These partnerships tackle a notorious problem in the research data service landscape: Many valuable resources are being developed in scientific projects and/or institutions, which have a dedicated user community. Yet, after having been maintained successfully over a decade or more, they often become endangered or unmaintainable due to institutional change or technological obsolescence. At the same time, infrastructures, which can offer the urgently needed sustainability, strive to build attractive resources for researchers.[6] NFDI is built on the idea that professional infrastructure providers help support the domain-specific resources in the

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[3] Based responses from 113 out of 200+ participating institutions. Numbers therefore likely underrepresented strengths of Base4NFDI's network ties to ERICs [8].

[4] Of the 19 EOSC Association members (status including observer and mandated organisation) from Germany, 12 are members in NFDI consortia and therefore part of Base4NFDI. [9].

[5] Resource definition adapted from EOSC rules for participation: digital object or process such as data and metadata, publications, software, workflows, services, and training materials [10].

[6] For a detailed analysis of sustainability issues in the German data landscape cf. [4] (further information in chapter 4.4).

interest of the whole scientific community. To this, Base4NFDI adds a foundational layer of cooperation for the organisation of NFDI-wide basic services, so that interoperability, cost-effectiveness and a seamless user experience can be achieved across scientific domains.

The NFDI-wide workshops on basic services and the requirement analysis for common infrastructures that were conducted in late 2021/early 2022 (cf. chapter 4.1) confirmed an assumption that was made very early on in the process of designing the National Research Data Infrastructure in Germany: In terms of services, consortia have very different starting points, levels of maturity, and development speeds. Existing support and service structures for scientific communities are highly distributed and (at best) federated (like identity and access management (IAM), and cloud computing services). Routine operation of services exists in some communities, but in others, community services are still in a conceptualisation or initiation phase, with unsolved issues of data culture, adaptations to scientific methodology, and community-specific standards. In some domains, services are currently in development, some of which might prove to have generic value or be more aptly suited to generic RDM tasks than existing services.

The consortia are currently at the beginning of their initial five-year funding period. Their target communities have high expectations, and the time to deliver results is limited. They are challenged to create tangible added value for the everyday practice of scientific users within a short period of time and need to build trust in the sometimes very complex partnerships and the collaborative use of research data. Where consortia already use established basic services, potentially on the international level, introduction of an NFDI-wide approach can mean a substantial effort and may also be perceived as risky. Other consortia are in the early stages of establishing agreed data management workflows or community repositories and could adopt NFDI-wide basic services right from the start. Cross-consortium basic services are considered to be of direct benefit where they facilitate the provision of planned services for the specialist communities or achieve synergies.

Currently, it is already demonstrable that many domain-oriented services would benefit from well-established concepts such as Infrastructure-as-a-Service (IaaS), Software-as-a-Service (SaaS) and Platform-as-a-Service (PaaS), in combination with structures that enable easy access for users and interoperability of services in NFDI, such as a joint identity and access management (IAM), persistent identifiers (PID) and common strategies for establishing terminology services (for further examples cf. chapter 4.1, 4.2).

Given the nature of basic services, the **main target community of Base4NFDI** are currently the operators of specialised community resources in need of stable hosting or computing infrastructure or providers who wish to connect their resources to the NFDI. It is worth noting that

– in addition to such distributed technical needs – jointly branded services such as an NFDI helpdesk, a legal clearinghouse and an infrastructure for training have been mentioned in the discussions within the Sections as potential candidates for NFDI-wide basic services. Such services would target the wider NFDI community and be designed to directly benefit researchers and scientific support staff as end users.

Consortia and consortia-initiatives (cf. glossary) have published a list of **key factors for the successful implementation of NFDI-wide basic services** as part of their joint statement in February 2022 [1]:

- **Set up needs identification over the medium term**
  NFDI basic services require a step-by step identification, development and establishment. Prioritisation of needs for basic services is determined by how they support the scientific and methodological objectives of the consortia.
- **Tight interlinking with NFDI Sections**
  According to NFDI Association statutes, Sections are the hub for bridging standards and service needs between domains and therefore, play an important role for building a consensus on common standards and workflows in the NFDI. Basic service needs identified in the Sections are thus likely to reflect actual needs of the NFDI communities.
- **Architectural decisions mandated by NFDI bodies**
  Decision proposals for NFDI-wide basic services, as well as overarching standards and formats, are discussed in the Consortia Assembly on recommendation of the Sections and decided on by the Scientific Senate. This established process can be adapted to identifying basic services.
- **Agile and multi-year planning together with the target community**
  Governance must involve the respective users. Needs assessment and the moderation of negotiation processes take time and must follow professional standards. Planning must be able to respond to existing and future needs.
- **Parallel existence of different solutions in the development phase**
  If necessary, tolerate parallel existence of several services during development, but aim to converge in the medium or long term.
- **Principle of best fit**
  For service provisioning, partner with those organisations that can offer the necessary elements in the best possible way.
- **Support for implementation**
  The integration of basic services into different scientific-methodological processes and technical environments requires personnel resources and expert support.

- **Periodical evaluation**
  Basic services must be evaluated regularly. In this way, it is possible to react to changes in technical standards, user requirements and the market, and more cost-saving and efficient solutions can be adopted.
- **Integration with existing services**
  Preferably, existing services – from the consortium partners or from other initiatives such as EOSC – should be used as basic services.

These factors are the conceptual baseline for the joint Base4NFDI initiative. The main motivation is to build a solid foundation for service delivery across consortia that is sustainable, practical and self-organised (cf. criteria for prioritisation of basic services in chapter 4.3). Base4NFDI aims to achieve this by joining forces on developing projects in parallel, effective planning closely tied to actual use cases for the services, a thorough technology review for the solutions in progress (cf. chapter 4.3, figure 8) and consequent coupling to the governance structures of the NFDI Association (cf. chapters 3.2 and 3.4).

The initiative is in a unique position to achieve these tasks: The **consortia joining Base4NFDI** as expert networks bring the perspective of experienced scientific infrastructure providers and different research practices to the joint initiative. They also contribute a large portfolio of pre-existing work on basic services. They are represented in the Consortia Assembly of the NFDI Association, which decides on joint technical-operational baselines for the work. The **spokespersons of the joining consortia** will ensure the overall strategic fit of the basic service development with the work programs of the domain-specific consortia. Their applicant organisations will act as grant recipients and organise the distribution of funds among their co-applicants and participants (procedures already in place for the existing consortia).

A proficient sub-group will **join as "co-applicant institutions"** (formal term for lead-institutions of existing consortia)**,** manage the task areas and assume shared responsibility for the overall work programme. The **joining co-spokespersons** (formal term for groups of experts responsible for running work-packages within the task-areas, cf. chapter 1) are renowned experts representing infrastructure perspectives and different scientific domains, methods and data cultures. They have been unanimously elected by the Consortia Assembly. Additional IT expertise from the **larger partner network** of the consortia is mobilised in a managed bottom-up process, using a flex-funds mechanism for individual basic service development projects (cf. chapter 3.4, chapter 4.3, TA1-3). As a **new participant,** the German National Research and Education Network (DFN-Verein) will join this initiative. DFN-Verein operates the communication backbone and several other large scale IT infrastructure services for science in Germany.

Management of such a broad provider network is a challenge that will be successful only through tight coupling with the governance structures of the NFDI Association (cf. chapter 3.2, figure 3). The cross-domain Sections of NFDI and their working groups (cf. chapter 3.2, figure 2) provide an excellent basis for user-oriented negotiations of features and thus a high level of acceptance for candidate services. The technical governance within the Base4NFDI project will add a professional requirements engineering layer and channel funding into the agreed development projects (cf. chapter 3.4, chapter 4.3).

Effects on the science system in Germany

Unprecedented in both nature and scope, Base4NFDI believes that Base4NFDI has the potential to profoundly consolidate the service landscape for research in Germany. The initiative will encourage smart specialisation of providers, the allocation of responsibilities[7], and a sensible division of labour.

Existing cooperation contracts of the NFDI consortia stipulate that project results are shared and software can be re-used in the long-term. In this same spirit, the Base4NFDI initiative will deliver open source solutions, common standards, workflows and policies that can be reused anywhere in the research system. Base4NFDI also complements and builds on initiatives for the European Open Science Cloud (EOSC) and the Research Data Alliance (RDA), where key partners are already engaged (cf. chapter 3.3).

All non-university research associations – Fraunhofer Society, Helmholtz Association, Leibniz Association and Max Planck Society – are represented, as well as large university IT Centres and State Libraries. The Helmholtz incubator platforms for information and data science[8] and, in particular, the Helmholtz Federated IT Services (HIFIS)[9] are represented through their main actors. Synergies will be created with other infrastructure programmes in Germany, such as e.g., the National High Performance Computing (NHR), the Gauß-Allianz, Academic Clouds and the National Research and Education Network in Germany (DFN-Verein) as well as similar entities abroad. Through the respective partner institutions in the consortia Base4NFDI can build on links to the Gauß-Allianz of Tier 1 to Tier 3 computing centres as well as to the Tier 2 centres and the National AI Competence Centres (table 2). Likewise, further initiatives and departments from partner organisations have been co-opted to get the providers that fit best on board and include

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[7] This has been specifically recommended for the task of long-term archiving for research data, cf. [11], p. 39 ff.

[8] The Helmholtz Information & Data Science Incubator was initiated in 2016 in order to network and to strengthen the association's digitalisation expertise and enormous stores of data [12].

[9] The Helmholtz Federated IT Services serve as a common infrastructure across the six research fields of the Helmholtz Association. Quite similar to Base4NFDI the aim is to provide "a seamless, functioning, and extremely powerful" generic service infrastructure, in this case for researchers of the Helmholtz Centers [13].

pre-existing work on basic services, e.g., from RDA and EOSC (cf. chapter 3.3, tables 3, 4). Of the infrastructure partners involved, 17 institutions are participating institutions of 9 European Research Infrastructure Consortia (ERICs) and 18 are actively involved in one or more EOSC projects.[10]

Harmonising such a large stakeholder network in Germany is a challenge from which there is much to learn. A scientific study will be conducted as part of the work programme, to assess the impact of Base4NFDI on research infrastructures and research in Germany and to inform science policy actors (cf. M4.3).

3.2   The initiative within the NFDI

Within barely 18 months, the NFDI Association has grown to be the largest network in the German science system. It is also its most diverse, comprising both research institutions and infrastructure providers representing all domains and addressing the various digital needs within these domains. The DFG-funded consortia integrate partners including major infrastructure providers in Germany crucial to their domains in order to develop and provide domain-specific standards, processes and services.

NFDI has a clear mission:

> [It] aims to ensure systematic and sustainable research data management (RDM), to provide long-term data storage, back-up and accessibility, and to embed these efforts into other national and international structures. This is achieved through a coordinated network of consortia tasked with providing science-driven data services to the research communities within their domains. [14].

The NFDI Association as an independent legal entity provides the procedural framework to aggregate, articulate and converge those needs. This setting provides a unique basis to negotiate a generic backbone for RDM services across Germany and for linking resources both nationally and internationally.

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[10] For a dataset with results from a survey on Base4NFDI infrastructure networks cf. [9].
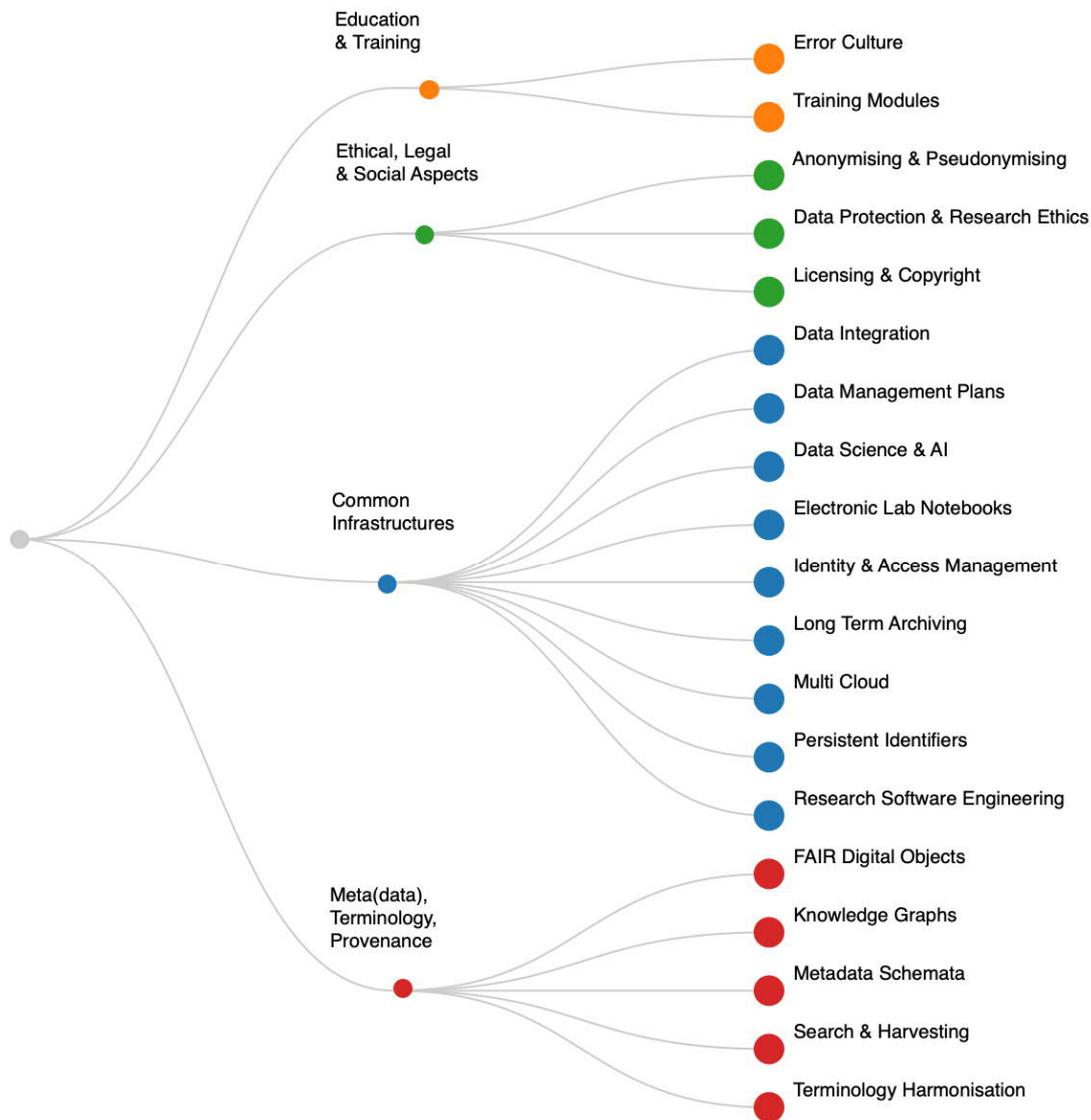
Figure 2: NFDI Sections with their current topics and working groups

Within the NFDI Association, consortia collaborate in Sections. Sections have the status of autonomous (but not legally independent) departments in the NFDI Association and are thematically organised. They are the place to discuss the consortia's cross-cutting topics [15] [16] and their main role is to develop recommendations for common standards, procedures and joint actions of the NFDI stakeholders. Four Sections with a total of more than 17 working groups have been established since May 2021. During the preparation of this proposal, they have already become interest groups for NFDI-wide basic services that will help move RDM forward. Figure 2 below shows a current snapshot of the Sections with their topics and working groups.

Base4NFDI briefly outlines this process set forth in the NFDI Association's statutes (figure 2). **Sections** are the hubs bridging the standards and service needs between domains and therefore play an important role for building a consensus on common standards and workflows in the NFDI. They support the **Consortia Assembly** in the preparation of its decision proposals. Decision

proposals approved in the Consortia Assembly are submitted to the NFDI's **Scientific Senate**, a panel of external experts and elected consortia representatives. The Senate has the final vote on which proposed standard or workflow is to be adopted. The agreed standards and workflows will then be implemented by the **consortia**. The **Directorate** coordinates all of the Association's activities and a **Board of Trustees** with representatives of the funders oversees all operations of the Association and the Directorate.
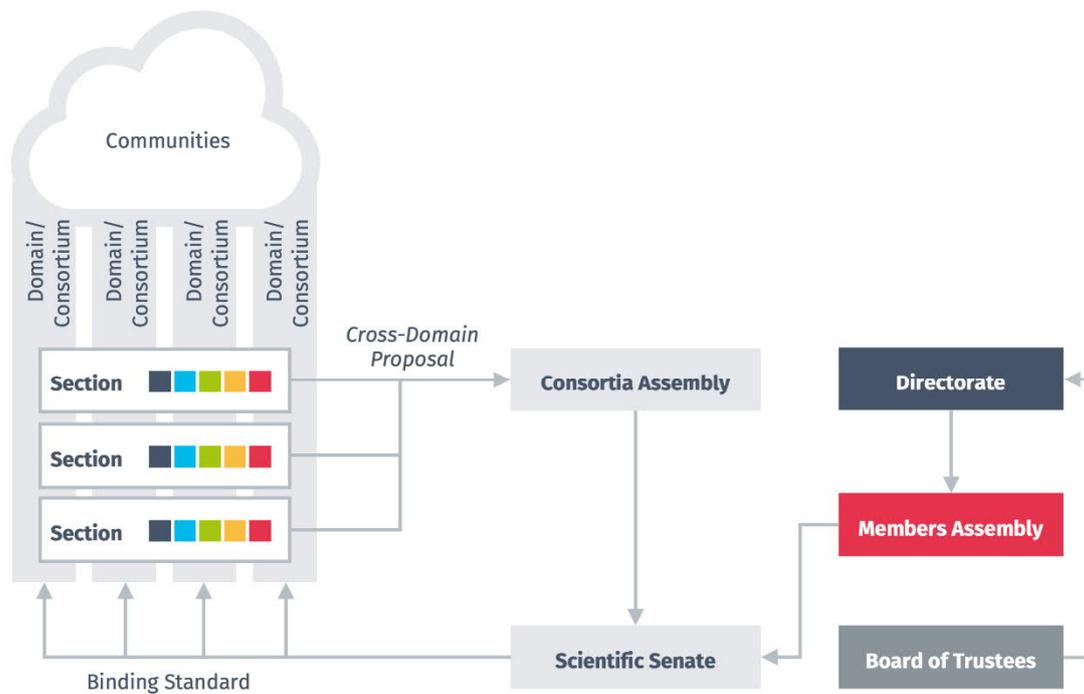
Figure 3: NFDI Governance and process for cross-domain standards: a blueprint adaptable for basic services

This structure provides an excellent blueprint to negotiate consensus on standards, workflows and architecture for NFDI-wide basic services. Base4NFDI will make full use of these established processes and complement them with the capacity to develop agreed-upon NFDI-wide basic services.

Similar to cross-domain standards and workflows, needs for NFDI-wide services are identified and described in the Sections. Base4NFDI will provide the processes and structures to determine which of these needs qualify for an NFDI-wide basic service and the means to implement them. Crucially, a basic service must be of interest to potentially all consortia (cf. complete set of criteria in 4.3). This definition of an "NFDI-wide basic service" is important as several consortia already run their own basic services – for example community-specific authentication and authorisation infrastructures (e.g. in PUNCH4NFDI, the Life Sciences or Text+) or computing services (e.g. in NFDI4Earth). In many cases they are already connected to international research infrastructures

(ERICs, EOSC, other domain specific services such as World Data Center for Climate (WDCC), cf. chapter 3.3) Thus, a central part of the Base4NFDI work programme focuses on how these existing domain-specific services or other existing service portfolios (cf. chapter 3.1, table 2) can be integrated into NFDI-wide basic services or serve as blueprints for further developments (cf. chapters 3.5 and 5).

As any NFDI-wide basic service will require a formal agreement and NFDI-wide approval, Base4NFDI will plug into the decision process depicted in figure 3 above. This means that proposals for basic services will be submitted for approval by the Consortia Assembly and pass through the governance procedures of the NFDI Association (cf. chapter 3.4, figure 4).

Given this integrative process is based on already agreed-upon structures, it is to be expected that the consortia and their domains will accept, use and/or implement the basic services provided by Base4NFDI.

Preparation of Base4NFDI

The integrative model of Base4NFDI presented here as a joint proposal of all NFDI consortia is the result of a series of workshops held with NFDI stakeholders between December 2021 and March 2022 [16]. Each workshop attracted between 80-100 participants from all research domains, funded NFDI consortia and consortium initiatives applying for the third round of funding to begin in 2023. Thus, feedback from the different communities – consent but more importantly also reservations and constraints – are reflected in this proposal.

The first milestone towards the preparation of the Base4NFDI proposal was a joint statement with agreed general guidelines for the development of NFDI-wide basic services. The statement was endorsed by 32 consortia and consortium initiatives [1]. The paper lists several factors which are key to a successful implementation of NFDI-wide basic services (cf. chapter 3.1), which now serve as guidelines in the design of the Base4NFDI initiative.

The second milestone was the decision of the consortia's spokespersons to engage in a joint basic services proposal. This decision was extensively prepared with the consortia's main infrastructure partners and stakeholders. An editorial team consisting of 19 persons from 14 different consortia[11] and all four Sections were mandated and tasked with the development of the general concepts and strategy of Base4NFDI. Four consortia provided the initiative with a Coordination Office and resources to support the joint proposal throughout the proposal phase.[12]

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[11] NFDI4Biodiversity, NFDI4Chem, NFDI4Culture, NFDI4DataScience, NFDI4Cat, NFDI4Earth, NFDI4Health, NFDI4Ing, DataPLANT, DAPHNE4NFDI, FAIRmat, MaRDI, KonsortSWD, PUNCH4NFDI, Text+.

[12] NFDI4Chem, NFDI4Culture, Text+, NFDI4Datascience.

Eight teams with more than 50 persons across all participating consortia and the Section working groups drafted requirements, design principles and development strategies for potential basic services to be developed by Base4NFDI.

All major steps in the Base4NFDI proposal were fed back to the Consortia Assembly in order to ensure the mandate and assure that all consortia retain ownership of the work programme, the structure of the process and Base4NFDI's strategy. Over the course of March and April 2022, Sections and their working groups contributed initial analyses for more than a dozen cross-domain needs for basic-services (cf. chapter 4.1) in order to support and exemplify the case for a joint approach made in this proposal. Thus, the development of this proposal also was a successful trial-run for the coordination within the NFDI governance that Base4NFDI intends to deploy for the development of basic services (cf. chapter 3.4).

3.3   International networking

Base4NFDI will speed up the collaboration in NFDI towards integration with the EOSC ecosystem and supports building and interconnecting infrastructure services, e.g. compute and storage, of broader European and international research infrastructures. Networking entails the organisation and orchestration of existing activities by individual members of Base4NFDI in task forces, working groups, steering committees and advisory boards of EOSC, RDA, CODATA, ERICs, etc. Major engagements in EOSC and RDA are illustrated in tables 3 and 4. Facing interdisciplinary international structures on the one hand and the task to concentrate on domain-specific service portfolio building on the other hand, the joint Base4NFDI initiative unburdens single NFDI consortia to concentrate on both ends. In Base4NFDI they are able to consolidate their approaches, increase forces and free resources for community-specific solutions.

NFDI consortia are well aware of the endeavour of scientific discovery not being limited to national research communities. In fact, most if not all of the scientific domains Base4NFDI serves operate internationally running networks. Therefore, Base4NFDI is committed to scientific information infrastructures accessible across borders. Base4NFDI will apply Open Science principles [17]. to the establishment of basic services. In practice this means federating German services with international initiatives will support trans-national data access. Many members of Base4NFDI are already connected to or even part of provider-communities such as EUDAT-CDI [18] or OpenAIRE and facilitate access to their domain-specific data repositories or generic services in Europe and internationally.

Thus, international networking of Base4NFDI serves three objectives. **First** it aims to enable mutual learning, as scientific communities abroad encounter similar challenges for managing and analysing research data. International networks help in learning about existing solutions in other

countries and evaluating them with respect to the needs of scientific communities in Germany. **Second**, it facilitates alignment with parallel national and international initiatives. Joined international forces are needed to build, maintain and provide trusted and reliable basic services used in a federated landscape. To avoid redundant or incompatible services competing at the international and national levels, Base4NFDI will contribute to alignments especially between German NFDI and EOSC but without neglecting other, often more domain-oriented initiatives. On the one hand, the consortium will encourage domain-specific NFDI consortia to adopt existing international services, standards and policies; and Base4NFDI itself will integrate and contribute to existing services, especially the newly established core services from the EOSC, also potentially GAIA-X [19] or the Global Open Science Cloud. On the other hand, the Base4NFDI initiative will enable coordinated contributions to the development of technical and organisational solutions in these international initiatives. Many actors involved in the consortium are already active in projects establishing the EOSC, participate in the worldwide Research Data Alliance's (RDA) working groups or contribute to international standards on information infrastructures (e.g. ISO or W3C). A good example of this is the complex interaction between RDA working / interest groups e.g. regarding PID [20] or IAM [21] and EOSC activities (PID Implementation and Policy Task Force [22] or Authentication and Authorization Infrastructure Architecture (AAI) Task Force) [23]. This is possible because of long standing engagement of Base4NFDI members in RDA and EOSC (tables 3, 4 below). The consortium will additionally use existing partnerships within international organisations like RDA (e.g., for adopting its standards [24] where appropriate), CODATA and GO FAIR (some members of Base4NFDI are also involved in GO FAIR Implementation Networks [25]) to contribute to the development of recommendations, best practices, and policies regarding the FAIRification of research data.

Third, Base4NFDI will foster knowledge transfer with domain specific international support infrastructures such as the Virtual Observatory for Astronomy and Astrophysics, the Worldwide LHC Computing Grid for High Energy Physics or the World Data Center for Climate (WDCC). Those are established international disciplinary infrastructures composed of basic services (HPC, PID, etc.) to which members of Base4NFDI have been contributing for a long time.[13]

Integration with the European Open Science Cloud (EOSC)

As the NFDI is one of the rare nationwide RDM strategies, it is expected that Base4NFDI can be a role model also for national contributions to EOSC, among EU member states. EOSC is a central building block for the European Research Area.

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[13] See DKRZ as service provider for WDCC: [26].

The integration of the NFDI service landscape with the EOSC core services that are proposed in the Strategic Research and Innovation (SRIA) agenda of EOSC [27] might be one of the main challenges in the long run for Base4NFDI. The EOSC core services need direct partners to reach the national level for connecting to science clusters (ENVRI-FAIR [28], EOSC-Life [29], ESCAPE [30], PANOSC [31] and SSHOC [32]) and beyond. Base4NFDI shall be suited to answer this challenge. Members of Base4NFDI are engaged in the numerous EOSC task forces to take part in policy making as well as in crucial activities such as defining the interoperability framework [33]. Service providers on the national level which are going to build the basic services for the NFDI are simultaneously collaborating in the various ERICs, science clusters and EOSC projects.

Reciprocally, Base4NFDI closely monitors and connects to current and future developments specifically with respect to EOSC core services (for instance as they are developed and integrated currently in EOSC Future [34] and in FAIRCORE4EOSC in the following years). Basic services will be developed and provided by Base4NFDI in close cooperation with EOSC to assure the use of existing solutions, to profit from experiences, synergies and the federation of services and to contribute own developments to the EOSC community. Integration with EOSC will enable smaller communities and international partners to use complex and cost-intensive services that would normally not be able to provide themselves. Also, better visibility of community-specific resources can be achieved by facilitated access to global indices and registries provided by EOSC and others.

The integration of NFDI-wide basic services into European and international initiatives has been highlighted as being of high importance [35], p. 4. Table 3 therefore details connections between members of Base4NFDI and EOSC on the level of the association and its boards (the continuous and ongoing collaborations in EOSC would be too numerous to list). All consortia and their members have also sought to include expertise from pertinent standard-setting bodies, like ISO or W3C. While links between these bodies and Base4NFDI are numerous (e.g. the German National Library participates in W3C), table 4 focuses on connections to RDA for which the most systematic data were available (again at the level of boards and chairmanship of interest groups).

Table 3: Exemplary connections of Base4NFDI to the EOSC Association and Advisory Boards

EOSC Association / Advisory Board	Base4NFDI member	Status in EOSC
Association-board	ZBW	Director
Authentication and Authorization Infrastructure Architecture (AAI) Task Force [23]	DFN-Verein, FZ Jülich, GWDG, Helmholtz Zentrum München, KIT, MPCDF	Member
Data stewardship, Curricula and Career paths Task Force [36]	TIB	Member

FAIR metrics and Data Quality Task Force [37]	DKRZ, DLR	Member
Infrastructures for Quality Research Software Task Force [38]	DLR, FIZ Karlsruhe, HZDR, ZB MED, University of Stuttgart, MPCDF	Member
Long-Term Data Preservation Task Force [39]	DKRZ	Member
PID Task Force [22]	GWDG, TIB	Chair, Member
Research careers, recognition and credit Task Force [40]	SUB	Member
Rules of Participation Compliance Monitoring Task Force [41]	KIT, SUB	Member
Semantic Interoperability Task Force [42]	DKFZ, DKRZ, TIB	Member
Technical Interoperability of Data and Services Task Force [43]	DKFZ, FZ Jülich, GWDG, HU Berlin,	Member
Association-member	DESY, DFN-Verein, DLR, DKRZ, EMBL, FZ Jülich, Fraunhofer, GWDG, KIT, SUB, TIB, ZBW	Member

Table 4: *Exemplary connections of Base4NFDI to key RDA positions*

RDA – Boards	Base4NFDI member	Status
Technical Advisory Board	KIT	Member
Organisational Advisory Board	MPCDF	Member
RDA - Interest Groups	**Base4NFDI member**	**Status**
Data for Development IG	GESIS	Chair
Data Versioning IG	GFZ	Chair
Education and Training on Handling of Research Data IG	HU Berlin	Chair
Ethics and Social Aspects of Data IG	University of Cologne	Chair
FAIR Digital Object Fabric IG	KIT	Chair
Libraries for Research Data IG	SUB	Chair
RDA Privacy Implications of Research Data Sets IG	University of Würzburg	Chair
RDA for the Sustainable Development Goals IG	GESIS	Chair
Research Data Management in Engineering IG	RWTH	Chair
Research data needs of the Photon and Neutron Science community IG	DESY	Chair

3.4   Organisational structure and viability

Base4NFDI's organisational structure follows **three guiding principles**: 1) **consistent and inclusive participation** of all relevant stakeholders, 2) rigorous **process-orientation** on all levels, and 3) **efficient reuse of existing structures** within the NFDI Association.

Organisational units of Base4NFDI

Figure 4 shows the organisational units of Base4NFDI and core elements of the NFDI Association.
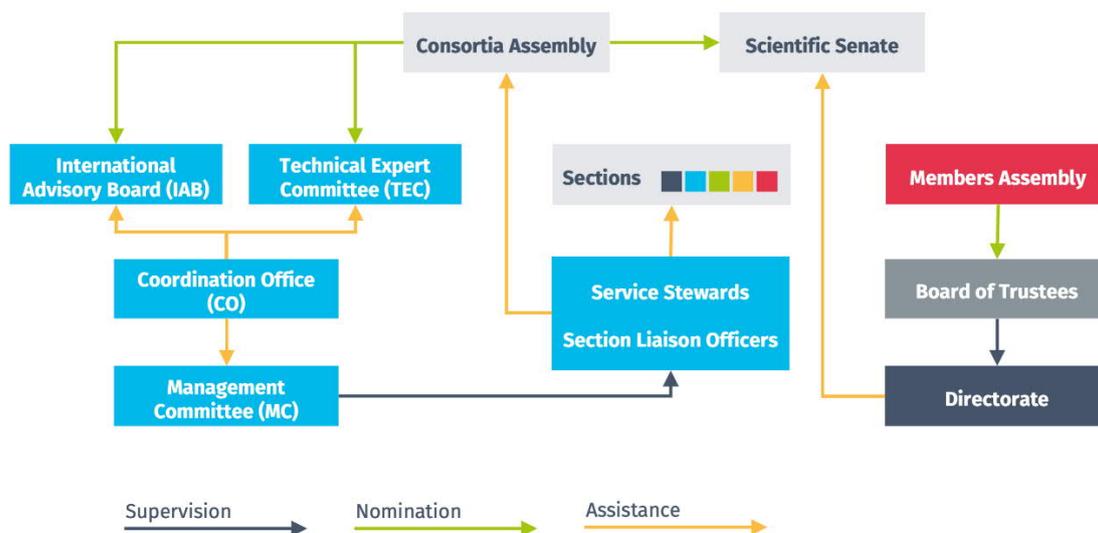
Figure 4: Organisational units of Base4NFDI (blue) and NFDI Association bodies (grey and red)

Structures established by Base4NFDI

The **Management Committee** (MC) consists of **12 co-spokespersons** including the coordinator of the proposal: A proficient group of co-applicants and named co-spokespersons (cf. chapter 1) will manage the Task Areas (TA) and assume shared responsibility for the overall work programme (cf. chapter 5, table 7). The co-spokespersons are experienced experts representing infrastructure and different scientific domains. They are mandated by the Consortia Assembly. Appropriate gender balance will be observed. The MC coordinates the activities of all TAs (cf. chapter 5). It is in charge of interlinking the strategic decisions made by the NFDI Association bodies with the operative elements in Base4NFDI. In particular, it is responsible to ensure compliance of all financial decisions with the DFG's guidelines for disbursement of funds. The MC will decide by simple majority. In addition, the MC is responsible for resolving conflicts of interest in the sense of an escalation instance if no decision is reached in the TEC.

The **Technical Expert Committee** (TEC) will ensure the overall coherence, robustness and scalability of services developed within Base4NFDI. It consists of a group of **infrastructure professionals** from the consortia's co-applicant and participant organisations and will be appointed by the Consortia Assembly.

It will be in charge of evaluating proposals for basic service candidates in terms of technical quality, interoperability with existing solutions, suitability of the partner organisations suggested and the financial calculations provided (figure 4). Through its guidance, it assures an orderly development processes and a professional evaluation of the results of development in Base4NFDI.

The TEC will explicitly assess which organisations within Base4NFDI would be the best partners to implement the proposed service. If partners outside of Base4NFDI are recommended, they will be added to one participating consortium.

TEC members are dedicated experts in infrastructure services. The membership will be determined by the Consortia Assembly and consist of 12-15 infrastructure experts whose expertise shall cover the perspectives of all domain-specific consortia and of all Sections. The TEC will invite ad-hoc members with special expertise depending on the topics at hand. Candidates must be prepared to act in a pro bono capacity for a defined workload, but will be supported by Base4NFDI staff. In order to prepare recommendations, the TEC can set up subgroups for, e.g. certain technology stacks. Recommendations by the TEC need to pass with a two-thirds majority of members present in the TEC plenum.

The committee assumes a central role in the process of approving basic service candidates for development. Its advice and recommendations will help the NFDI Consortia Assembly and the NFDI Scientific Senate to govern Base4NFDI developments. To avoid potential conflicts of interest, the TEC is managed by TA4 *Project Governance*, but receives its decision papers from TA3 *Service Coherence Processes and Monitoring* to clearly separate decision-preparation and decision-making. This will help in a situation where infrastructure providers may be both a recipient of funding and involved in the evaluation of proposals and in strategic decision-making.

For initialising the TEC three well-recognised experts have been pre-nominated and are willing to commit themselves on an honorary basis to serve as a team of acting co-chairs for the TEC until the committee is formally established through the NFDI Consortia Assembly at the start of Base4NFDI: **Dr. Christian Grimm** is joint Chief Executive Officer of the DFN-Verein, the National Research and Education Network in Germany whose aim is to foster the development of digital infrastructures in research and higher education. **Dr. Simone Rehm** is chief information officer of the University of Stuttgart and served on the RfII during the time when the concept of the NFDI

was being developed. **Prof. Dr. Ramin Yahyapour** is Managing Director of the GWDG, which works in conjunction with the University of Göttingen and the Max Planck Society as a data and IT service centre. He is also Chief Information Officer of the University of Göttingen and serves on the RfII as representative of information facilities.

A **Coordination Office** (CO) will support both the Technical Expert Committee and the Management Committee in day-to-day operations. It ensures smooth transition of proposals through the decision processes, oversees financial decisions and prepares all necessary reports for the MC and the TEC (more details in chapter 5, TA4).

Service Stewards will support the service development process through all stages of the development (TA1 and TA2). They will ensure a smooth interplay between the Sections, a specific set of participating consortia and partner organisations involved in the development of a service. They are responsible for interfacing with the consortia in both the NFDI Sections and Base4NFDI's development operations. They scout the consortia's infrastructure landscape with regard to certain service candidates and act as requirement engineers in specific domains. They consolidate this information according to criteria defined by the NFDI Sections and Base4NFDI. In later stages of the process they support the rollout of services and the integration of services into the existing infrastructure landscape. They are critical to efficient adaptation of basic services as the consortia will often need additional support for integrating a basic service with their existing service portfolio or do not have the resources and/or expertise for adopting a new service.

To facilitate these crucial tasks, Service Stewards form a network of in-person interfaces across all consortia and all Sections. They will network weekly in virtual meetings and through quarterly in-person meetings. This will help develop tight liaisons within the large network of NFDI partners and especially between the consortia's infrastructure providers, who are typically involved in several consortia. In this Service Stewards are supported by the MC and the Coordination Office.

Service development and operation is a multifaceted process. The Service Stewards will take care of domain specific and technical-organisational requirements as well as management and communication tasks.

In the *initialisation* phase Service Stewards
- catalyse the NFDI Section's discussions on basic services in their domain as well as the decisions on potential candidates, i.e. by providing information about and / or prototypes of existing community solutions and their broader usability,
- aggregate, consolidate and monitor needs and requirements for basic services across several consortia, and help synchronise basic-service related discussions between different Sections,

- assist Section working groups with their domain-specific knowledge in developing proposals for the initialisation phase,
- with their domain-specific knowledge support evaluation and reporting during the initialisation phase.

In the *integration* and *ramping-up for operation* phase Service Stewards

- support integration of services into the NFDI consortia's service landscapes. They will assist with (1) fixing commitments from institutions necessary for the operation of a service, (2) implementing compliance requirements and – where necessary – (3) providing or arranging training,
- assist Section working groups with their domain-specific knowledge in developing proposals for service integration and service operation,
- support evaluation and reporting during the integration and ramping-up-for-operation phase,
- supervise service levels and propose service adjustments.

Service Stewards through their contacts to (potential) users in the different domains also help to maintain the quality of Base4NFDI's processes in close cooperation with TA3, which establishes the common quality framework (cf. chapter 5).

All Service Stewards will be employed in full time. In order to achieve maximum impact in the shortest possible time, a number of consortia agree to cooperate with one or more Service Stewards to promote and speed-up development. The Coordination Office will provide a template for this application to the Consortia Assembly. It will include information on funding available in a given year and the subsequent years. The request will be decided by the Consortia Assembly. Service Stewards are employed at an institution associated with the cooperating consortia, thus allowing long-term contracts to create attractive positions in a competitive market. Attractiveness can be increased further by pooling Base4NFDI's resources with consortia and or institutional funding. Service Stewards' responsibilities for domains can change over time: At the beginning of the project Service Stewards will primarily focus on scouting and communicating across consortia, later they will concentrate increasingly on the adoption of and support for established basic services.

Section Liaison Officers directly support the work of the Sections in matters directly related to preparing basic services development strategies, decisions and monitoring (cf. TA3). Central tasks will be (1) to assist with coordinating discussions on similar topics across Sections and (2) monitor needs for complementary activities and collaboration between working groups, and (3) support TA3 in coordinated monitoring and reporting of the service developments within all

development phases and across all developers. Section Liaison Officers are administered by TA3.

The **International Advisory Board (IAB)** provides external and international strategic advice to Base4NFDI's Management Committee. It consists of a speaker and four members, all highly distinguished, international, external to Base4NFDI and representing different perspectives and stakeholders (e.g. research data/software centres, information infrastructures, infrastructure providers, industry, state and public interests). The board reviews the overall status of Base4NFDI and gives recommendations for the development and strategic operation. It also advises on the lessons Base4NFDI should draw from its external evaluation. The NFDI Consortia Assembly will nominate Advisory Board candidates and vote to appoint the Advisory Board members for a three year term (which can be extended by a second voting). The International Advisory Board meets annually in conjunction with Base4NFDI's user conference (cf. Quality Management, below).

NFDI Association structures central to Base4NFDI processes

To ensure the long-term viability of structures it is essential that Base4NFDI's governance is closely linked to the **existing NFDI Association bodies**. It is through those bodies that all relevant strategic and financial decisions within Base4NFDI are made:

The **Sections** of the NFDI Association serve as the main collaboration structure for the negotiation and incubation of existing or new candidates for basic services in accordance with the needs and requirements of participating consortia. They provide the ideal platform for preparing proposals for basic service candidates along defined needs and criteria for a successful adaptation and monitoring of a suggested basic service. Sections are organised in working groups, each responsible for one topic. Sections can issue proposals for basic service candidates and will prioritise proposals along the maturity of the candidates. In doing so, they organise the identification process and initialise the service initialisation phase. In later stages, they are kept informed about basic service development progress and get particularly involved in the evaluation cycles, which are organised by TA3. Section leads and co-leads, assisted by Section Liaison Officers (above), will synchronise activities on similar potential basic services across Sections.

The **Joining Consortia** represent the providers and users of scientific domains and identify cross-domain service needs. Through cooperation contracts and work programmes they create ownership and assure usage rights for jointly developed services in later stages of the service design.

The **Consortia Assembly** is composed of the spokespersons of all consortia in the NFDI Association. As such it represents all domains within the NFDI and determines the "substantive

and technical principles for the work of the consortia" [44], Section 10. The Consortia Assembly acts as an Executive Board for Base4NFDI. It mandates the Base4NFDI co-spokespersons and appoints the members of the Technical Experts Committee. Based on recommendations from Base4NFDI's Task Areas it determines if a service candidate is initialised for development, put forward to integration stage or suggested as candidate for the operational stage.

The **Scientific Senate** is the final authority in the acceptance chain for an NFDI-wide basic service. The Scientific Senate is responsible for the overall operational strategy of the NFDI and shall decide on the "admission and integration of cross-cutting services into the NFDI" [44], Section 11.

Procedures for the development of basic services

Any basic service development will necessarily start in one or more Section working group(s). Based on criteria (cf. chapter 4.3) a basic services candidate can apply to enter the basic service process: (1) service initialisation, (2) service integration and (3) ramping up for service operation (figure 5). Phase (1) is based in TA1 *Service Requirements, Design and Development*, phases (2) and (3) are based in TA2 *Service Integration and Ramping-up for Operation*. The precondition to enter phase 2 and 3 ist to document the results of the previous phase.

To launch into the (1) initialisation phase, a Section's working group – likely in collaboration with Service Stewards – submits a proposal to the related Section. Proposals are presented and discussed during Section meetings, commented on and – if necessary – negotiated between other interested Sections. When submitted, the proposal will be prepared for evaluation (TA3). The proposals need to pass the TEC which may provide advice and / or state technical concerns. Subsequently, the NFDI Consortia Assembly decides on whether to fund the service initialisation based on a decision memo prepared by TA3. The memo summarises a) TA3's evaluation according to the criteria (cf. chapter 4.3), b) a vote and statement from the Section's meeting, c) recommendations stated by the TEC and d) an assessment of the Managing Committee. The vote in the Consortia Assembly reflects the degree of support and commitment for a basic service candidate among the consortia.
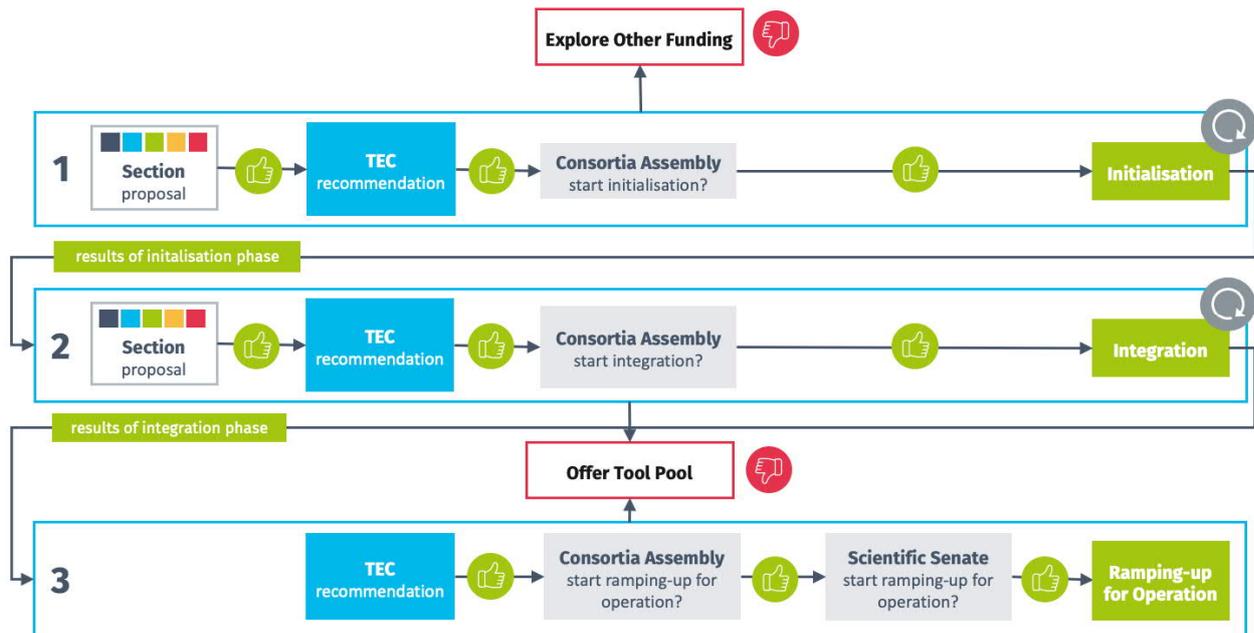
Figure 5: Selection and development process for basic services: proposal to operation

For launching a service in the (2) integration phase or the (3) ramping-up for operation phase, a proposal is submitted. It involves partners, usually involved in the initialisation phase in collaboration with the respective Service Steward(s) and the Section's working group. The proposal will be evaluated by the TEC. Like in the initialisation phase It is accompanied by a decision memo prepared by TA3, which includes a) TA3's evaluation according to the criteria (cf. chapter 4.3), b) a vote and statement from the Section's meeting, and c) an assessment of the Management Committee. The TEC's evaluation of a proposal may include the expertise of further experts involved on an ad-hoc basis. The Consortia Assembly decides on funding service integration phases based on a decision memo prepared by the TEC. The vote in the Consortia Assembly reflects the degree of support and commitment for a basic service candidate among the consortia. Proposals for the service operation phase require approval by at least 75% of the Consortia Assembly and will be submitted to the Scientific Senate for a final strategic vote.[14]

A decision not to fund further a developed service can be supplemented with the recommendation to let the respective service become part of a "tool pool" for which the service might then be sustained through other funding (cf. TA2, M2.2).

Disbursement of funds

To allow maximum flexibility while the NFDI is being shaped in the coming years (additional consortia, development of Sections, etc.) Base4NFDI funds will be allocated to a big share as

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[14] This procedure proposal follows §20(2c) in the Association's statutes.

flexible funds and a moderate share as fixed funds. The co-applicants of Base4NFDI will receive fixed budgets for the workload of the TAs, support for work in the Sections and the Coordination Office staff.

The larger portion of flex-funds is necessary, given the complexity of the task at hand. In order to develop basic services for and/or to integrate them across potentially all scientific domains, the structured process described above ensures that all basic services can be properly negotiated, interlinked, coordinated, and regularly reviewed with respect to the continuously changing needs of the participating NFDI consortia and their scientific communities, while simultaneously guaranteeing inclusiveness and transparency. Domain-specific consortia have already made very good experiences with the flex-funds model during the last two years. Flex-funds are funds that are generally planned in the project's budget but will be allocated later to specific partners during the project's execution after quality-assured processes capable of determining the development needs and allocating the funding necessary for implementation have taken place. Base4NFDI will apply this very procedure to allow for an appropriate and responsible adaptation to not yet fully outlined user needs and implementation plans for NFDI-wide basic services.

As explained in chapter 3.2, Base4NFDI situates the final decisions between consortia on which specific service implementations to fund in the NFDI Association structures which facilitate consensus building. Consequently, the disbursement of flex-funds will be contractually linked to those decisions. Strategic decisions by the NFDI Association bodies on implementation projects will translate directly into budgets for the partner organisations identified in the approved service proposals. All Applicant Institutions will be notified of decisions affecting the global funding plan and disburse funding as additional budgets to the respective consortium partners.

Once a service proposal has passed the Consortia Assembly, funds will be allocated accordingly. Base4NFDI will continuously monitor spending and potentially revise budgets, if necessary. A Coordination Office will issue annual reports to all consortia participating in the project as well as the NFDI Association's structures detailing spending for each development process in comparison to funds budgeted.

The MC is responsible for monitoring the overall financial framework and for performing regular compliance checks with the DFG disbursement rules for the NFDI. It will also coordinate activities of the Task Areas (cf. chapter 5). The applicant institutions of the participating consortia will provide the funds to partners in charge of the respective tasks through their existing consortial cooperation agreements.

Base4NFDI can provide, in accordance with the DFG grant, flexible funds of €13.5 million over a period of 5 years (for financial building blocks, cf. chapter 4.3). In light of the DFG funding cuts to

flexible funds, upon decision of the Consortia Assembly €10.9 million are allocated for service initialisation, integration and ramping-up for operation phases and €2.6 million are allocated for a fix number of 7 service steward positions running from 01.06.2023 to 29.02.2028.

Risk analysis, monitoring and conflict resolution

Base4NFDI will be in a unique position to dynamically and continuously identify needs, develop and pilot basic services because all relevant partners and the mechanisms to aggregate their needs are already organised in the NFDI. Despite all of its advantages, this process entails risks: 1) Bias with regard to partner selection, 2) Insufficient mechanisms for ensuring spending efficiency. 3) An additional risk, specific to developing basic services that need to serve technically and organisationally diverse domains, is to ensure the adaptation of these services. In addition, like other infrastructure initiatives, it faces the challenge of recruiting highly qualified personnel.

Risks 1) and 2) stem from the fact that substantial amounts of unallocated flexible funding meet a structure which places a premium on cooperation and thus might not emphasise competition sufficiently. Yet while there is no other alternative to bringing all relevant players together in the way Base4NFDI proposes, Base4NFDI also wants to establish mechanisms to avoid the risks outlined above as they are particularly undesirable in the endeavour of developing as ambitious an infrastructure as Base4NFDI intends.

Base4NFDI will rigorously address selection biases by maintaining maximum transparency of all decision processes and by establishing an **external ombudsperson** who will document and if required trigger investigations for all complaints against the way Base4NFDI's flexible financial resources are allocated. In addition to the ombudsperson, Base4NFDI will ensure to be accountable and effective through transparency. Base4NFDI's monitoring mechanisms will ensure transparency and document the efficiency of Base4NFDI developments. Also, all actors involved are acutely aware that their performance in Base4NFDI will shape both their perception in other infrastructure contexts but also – and most importantly – in any scenario to perpetuate the services and build a stable long-term National Research Data Infrastructure.

As any other publicly funded initiative, Base4NFDI will face the challenge of recruiting the highly skilled experts needed to develop and deploy the basic services envisioned here. However, because Base4NFDI can rely on the experienced partners of the NFDI network, it will be able to minimise this risk by drawing on the experienced personnel of these partners, but also by having alternatives by replacing the responsible partners as needed and/or appropriate.

An additional risk 3) lies in the substantial complexities of adapting and integrating services into organisationally and technically diverse domains. As any service candidate will need approval from the Consortia Assembly, all consortia giving their approval express their commitment to the

service. This is particularly true for the operation phase where support will mean a commitment to using a service. Yet integrating services will come at costs to the consortia and their domains. Base4NFDI will alleviate some of those costs through Service Stewards. Other support for implementing services will need to be anticipated in the Sections' proposals and provided as part of the integration phase.

The adoption of basic services might further be impeded in situations where existing solutions are already in place. Base4NFDI commits to tolerate parallel existence of several services during development. Commitment to a basic service, however, will mean commitment to converge in the medium or long term. Domains with pre-existing services that will operate parallel to integrated basic services will be able to fund migration and or integration support through Base4NFDI. Base4NFDI also has to acknowledge that in some situations, the benefits of joining a basic service might not outweigh the costs of quitting an existing solution. In such cases, particular domains may remain outside the scope of a given service.

Many risk factors can be mitigated if identified in time: Base4NFDI will employ NFDI's OpenProject Project Management platform for monitoring all measures (funded with fixed- as well as flexible-funding) and administrative processes. Under the regular observation of the Management Committee and process-monitoring experts in TA1 and TA2, the platform will deliver regularly updated overviews of both overall processes (how many services at which stage of process) as well as on more detailed components (such as project risks). Furthermore, regular automated reports will be generated from this data and will offer an easily accessible overview of the most relevant processes.

Beyond process monitoring Base4NFDI will propose key performance indicators (KPI) for each service at each stage of maturity (e.g. acceptance and usage across communities) (cf. chapter 4.3 and M3.1, M3.4). This endeavour will be able to draw on the consortia's joint expertise in the NFDI Association Task Force Monitoring. Base4NFDI also commits to documenting reference usage statistics (e.g. from similar services) to assess the competitive weaknesses and strengths of Base4NFDI's services.

Information on performance and use of the services will also be central to overall quality management. A second pillar of quality management is based on observing the criteria for service selection (cf. chapter 4.3) and technical quality. The latter is the responsibility of the TEC).

The **resolution of conflicts** and mediation of controversial topics at the governance level is the responsibility of the Management Committee. Base4NFDI's co-spokespersons assess the opposing positions, mediate between the parties and decide on which measures need to be taken to appropriately resolve the conflict. For substantial controversies that might affect the progress

of Base4NFDI as a whole, the Management Committee can request advice from the Technical Expert Committee and the Scientific Senate and bring about a solution in the Consortia Assembly. Conflicts relating to the disbursement of funds can be directed to an external and independent ombudsperson.

Quality management and evaluation of Base4NFDI Structures

Base4NFDI expects to process a substantial number of proposals for basic services from the NFDI Sections. In order to ensure these proposals are fit to be an NFDI-wide basic service, a substantial amount of coordination is necessary. Given this high degree of specificity, most proposals will not lend themselves to external review because relevant competence resides among the partners of Base4NFDI.

Base4NFDI therefore proposes an alternative system of quality assurance to make sure the best possible decisions are made. Next to a high degree of transparency Base4NFDI proposes:

1) An **ombudsperson** will hear and transparently document complaints against the decision processes within Base4NFDI. In particular, claims that challenge the criteria-based decision-making or the selection of partnering institutions for the implementation, integration or the piloting of basic service candidates.

2) At **annual user conferences** all of Base4NFDI's decisions and resulting developments will be presented and researchers will be able to comment on the degree to which they help in their research.

3) Given both its complexity but also the novelty of the mechanisms employed here, Base4NFDI commits to an **external evaluation of the decision-making processes and its governance mechanisms after two years**. This evaluation will be conducted externally by a professional evaluation agency. It will draw on feedback from stakeholders in the NFDI process. Base4NFDI's International Advisory Board will issue recommendations which lessons should be drawn from the evaluation.

4) The **International Advisory Board** reviews the overall status, gives recommendations and advises on the lessons Base4NFDI should draw from its external evaluation.

Quality management will also benefit from a systematic analysis of Base4NFDI's impact and its reception in the wider academic community which will provide empirical evidence to inform the evaluation. Preliminary results will be available for the German Council of Science and the Humanities (Wissenschaftsrat) evaluation of NFDI's overall structures, to which the capacity to engage in basic-service development is critical (cf. chapter 5.4, M4.3). Results from the quality assurance will be communicated to the DFG and the NFDI with the project´s interim report due after project year 3.

Viability of structures

The Base4NFDI work program lays the groundwork for an infrastructural backbone which is meant to serve NFDI in the long run. To prepare for the long-term provision of the services Base4NFDI is launching as NFDI-wide basic services, Base4NFDI will employ two strategies (cf. also chapter 4): 1) A sustainable operating model for each basic service candidate passing the threshold to enter the pilot phase for operation. 2) building on the strongest possible network of cross-domain infrastructure providers in Germany.

Base4NFDI is in a unique position to enable the integration of existing services of these providers into a sustainable technical backbone for NFDI. Services that fail to qualify as NFDI-wide basic services but prove valuable to a more limited number of scientific domains can be sustained by the respective consortia or be submitted to a common "tool pool" for re-use and/or joint maintenance.

The joint initiative will prove its capability for this endeavour through up to five service implementations and a pipeline of tools in the initial funding phase of 5 years (cf. chapters 4.3 and 4.4). The organisational structure and processes it provides can be continued in the NFDI Association after the project ends (cf. chapters 3.4 and 3.5).

Material results (software, documentation, training materials, etc.) by Base4NFDI will be made available as open-source or open-access products free of charge. (Co-)applicants and participants work in their capacities as consortium partners, governed by the respective cooperation contracts. This means they will operate on their own account and according to the requirements of their respective legal status. As participation in Base4NFDI does not constitute membership in a new legal entity, service provision will be organised in a way that is independent of the initiative and viable also after the end of the project. In line with DFG funding requirements, (Co-)applicants and participants work in their capacities as consortium partners, governed by the respective cooperation contracts. This means they will operate on their own account and according to the requirements of their respective legal status. As participation in Base4NFDI does not constitute membership in a new legal entity, service provision will be organised in a way that is independent of the initiative and viable also after the end of the project. In line with DFG funding requirements, financial transfers will be made only to allow recipients to create new services by scientific means or involving scientific expertise.

Organisational structures implemented in the project to support the management of basic services development can be continued by the NFDI Association after the Base4NFDI project ends, for example the Technical Expert Committee. The necessary support for the Sections, coordination and back office support provided by the Operation Committee and the Coordination Office could

be continued by the directorate, provided that appropriate resources are included in future budgets for the NFDI Association.

The viability of the structures created by Base4NFDI (and basic services) beyond 2028 will strongly depend on the outcome of the NFDI structural evaluation scheduled for 2025 by the German Council for Science and the Humanities, which delivers recommendations for funding decisions for NFDI post-2028, when the current programme ends. Base4NFDI aims to contribute to this evaluation and the general success of the NFDI through the implementation of efficient, integrative and well-balanced processes that lead to the development of broadly negotiated, robust and highly scalable basic services across the NFDI. Independent of this, Base4NFDI expects the harmonisation efforts of the Base4NFDI project to have decidedly positive effects for the German science system that go well beyond other existing infrastructure projects.

3.5   Operating model

Base4NFDI operates along a structured process for managing basic service development across consortia (cf. chapter 3.4, with illustration of process). The process is closely linked to the NFDI Association bodies, is based on sets of criteria for basic services and is thus sustainable even after the end of the Base4NFDI project (cf. chapter 3.4, viability). Moreover, the **Base4NFDI project will develop sustainable business models for each service as part of its work programme** (cf. chapter 4.4 and TA2).

Service development will be **sustained by different stakeholders in Germany, unless international infrastructures can be used**. In cases where **existing services are integrated or extended**, basic services could be provided as an extension of established activities, i.e. in scientific computing centres in Germany. Such services would be **viable later on through a mandate of the respective organisations' funders**. In other cases, self-sustained, fee-based, service provision may be needed. Base4NFDI sees such models i.e. in the field of Persistent Identifier Infrastructure.

Therefore, partnering institutions play an important role in implementing services and ensuring long-term sustainability. They also provide **substantial in-kind contributions** to service development in the consortia and the Base4NFDI initiative. Further in-kind contributions are made through the participation of partner organisations in the conceptual work of the NFDI Sections. In addition, partners implementing, integrating or piloting a basic service candidate will be expected to make in-kind contributions in their proposal. One crucial type of in-kind contribution will be to bring existing services to the table and facilitate their integration into NFDI-wide basic services.

Once a service is formally established, users will require equally formal commitments of its sustainable operation in order to start using it. NFDI-wide basic services need to be highly reliable.

To support structural decision-making in the science policy sector, **Base4NFDI will provide detailed policy briefings on the issue of basic services** (cf. chapter 5.4, M4.1). These will be addressed particularly to the federal government and the governments of the federal states, who will jointly need to agree on any long-term financial agreement.

In its operations, **Base4NFDI will fully comply with German Research Foundation (DFG) regulations and non-profit requirements** (Gemeinnützigkeit). Contracts between partners will contain DFG's spending conditions and ensure compliance. They will also define the contributions, responsibilities, and the distribution of overhead along the lines of this proposal. All participant institutions receiving funds through their co-applicant institutions are required to be non-profit entities. Base4NFDI will limit other transactions to avoid paying value-added tax through contract work.

4   Basic service(s) strategy

To provide basic services with NFDI-wide acceptance, Base4NFDI will follow a straightforward strategy: From idea to production Base4NFDI differentiates three service stages: potential basic services, basic service candidates and basic services ramped-up for operation. The process starts with proposals for potential basic services drawn up with Base4NFDI's support by the Sections and reflecting their discussion on cross-cutting topics and thus the consortia's needs (cf. chapter 4.1.). Given the breadth of topics, this approach assures that proposals with substantial potential for basic services will emerge (for examples cf. chapter 4.2). Based on a set of agreed-upon criteria (cf. chapter 4.3), these proposals are closely examined with respect to their technical validity and their correspondence to the consoritia's needs. Once vetted, Base4NFDI will employ a three phase process for each potential basic service: 1) service initialisation, 2) service integration, and 3) ramping-up for service operation (cf. chapter 2, figure 1). Each proposal will iteratively pass through these steps, with phase 3 becoming part of the NFDI basic service portfolio (cf. chapter 4.3). Before entering each next step, proposals are again evaluated against predefined criteria. Some parts of development might need to be repeated at later stages, e.g. to refine a specification. To reflect this setup, Base4NFDI employs a matrix structure. As efforts to pass the development steps will vary substantially between Basic-Service candidates (e.g. Long-Term Archiving and IAM) and because not all candidates might successfully pass each stage, funds are allocated flexibly based on predefined funding-blocks (cf. chapter 4.3). This strategy thus continuously involves consortia as the representatives of their domains and end-users and assures both NFDI-wide acceptance and state-of-the art technical readiness of its services through core-processes (cf. chapter 4.3). It furthermore specifies crucial elements for long-term sustainability (cf. chapter 4.4) and clarifies that, given the complexities of this endeavour, a transparent communication strategy is highly relevant to success (cf. chapter 4.5).

4.1   Detailed needs analysis and a matching strategy

Base4NFDI tackles a **subset of cross-cutting topics** in the NFDI, i.e. those that concern the joint operation of basic services[15] to provide essential infrastructures for potentially all consortia and ensure interoperability. These "NFDI-wide basic services" are conceptually distinct from other cross-cutting topics.[16]

In identifying basic services, Base4NFDI can build on stable commitments for collaboration on cross-cutting topics, achieved in the course of a three-year preparation phase for NFDI. Since 2019, several workshops involving stakeholders across domains – including in particular researchers as end users – have been carried out in order to consolidate ideas. Results were consolidated in joint publications, namely the Berlin Declaration [15], the Leipzig-Berlin Declaration [46], and the NFDI Cross-Cutting Workshop report [47]. These documents are the basis of the current NFDI Sections and their concepts (cf. chapter 3.2, figure 2).
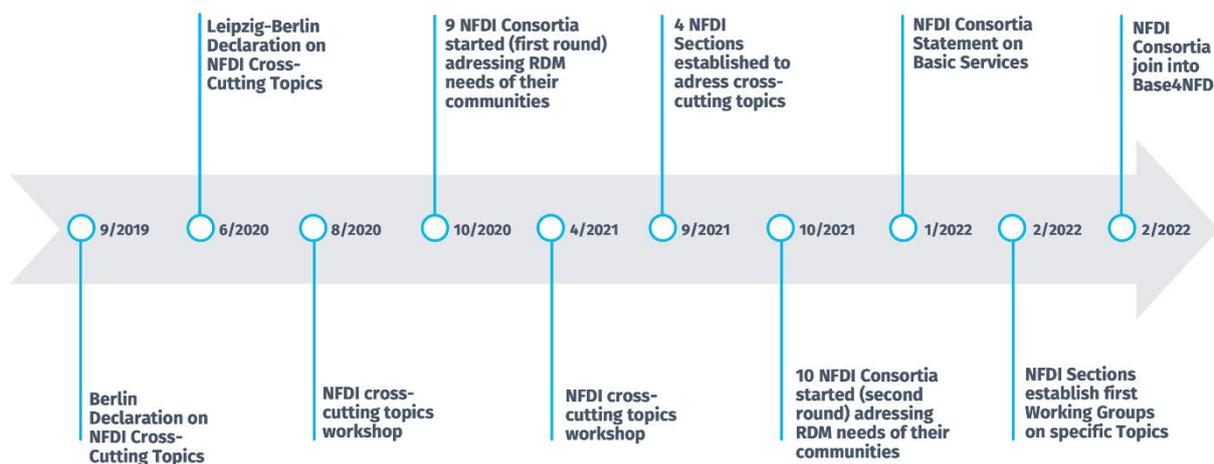
Figure 6: Laying the groundwork for Base4NFDI. A brief history

The Leipzig-Berlin declaration identified six areas for basic services: (1) interlinked research data platforms for data publication, data discovery and (meta-)data exploration; (2) harmonised and networked ontologies/terminologies and data annotation; (3) support structures and service portfolio management; (4) long time archiving, PIDs and data provenance; (5) research software management; (6) identity and access management [46], p. 4.

Subsequent – yet still initial – more detailed analyses on cross-domain needs can be found in **concepts for the first four NFDI Sections**, published in mid-2021: Common Infrastructures [4],

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[15] Whereby the term "service" is understood as a technical-organisational solution usually provided by one or more organisations for a certain period of time and for a defined target group.
[16] The distinction between types of cross-cutting topics was introduced in the 2nd statement of the NFDI expert committee [45].

(Meta)data, Terminologies and Provenance [5], Training & Education [7], and Ethical, Legal & Social Aspects [6].

Following the Berlin Declaration, the Section Common Infrastructures in particular emphasised the development of a joint Research Data Commons (RDC) as an overarching, holistic concept along the lines of the EOSC, the ARDC [48] or the NIH Data Commons [49]. Such constructs, in line with Platform-as-a-service (PaaS) approaches, can prove useful to the operators of specialised community resources in need of stable hosting or computing infrastructure or providers who wish to connect their resources to the NFDI. They can provide the ultimate end user community targeted by NFDI consortia – researchers and other legitimate users of research data and services – with data, applications and computing infrastructure.

Survey on common infrastructure needs of the consortia

In autumn of 2021, Section Common Infrastructures launched a survey on topics for basic services, spanning consortia and end users. The consortium proposals of the first and second round – in particular service descriptions, and work programmes – were used as additional sources of information, followed by discussions with the consortia and within several NFDI Section workshops and meetings. 17 topics with more than 100 technologies, tools and governing policies were identified. This impressively demonstrates the scope of basic services and the possibilities for harmonisation within the NFDI.

Clear **priorities** were Identity and Access Management (IAM), Persistent Identifiers (PID), and search technologies. A large majority referred to Terminology Services (TS) as a highly relevant type of service. A majority of the consortia either already rely on or intend to use cloud infrastructures for storage and computing. Furthermore, services for federated user support desks were brought forward in several responses. Other topics only appear to be essential for some of the consortia, e.g. tools for pseudonymisation and anonymisation, documentation tools such as electronic laboratory notebooks as well as platforms and tools for (collaborative) data analysis.

The obtained results **illustrate the common needs** but have **limitations.** Round two consortia were still in their kick-off processes and consortia initiatives for round three were only in the application phase and could not be fully included. Still, important initial information was gathered as a useful starting point for more targeted and in depth needs analysis for basic services within NFDI. Based on this input, the freshly established working groups in the Sections started making their contribution (see below).

Strategy to continuously identify and review needs of consortia

From a technical and strategic point of view, NFDI-wide basic services will have to be organised on **different, possibly nested levels**: a centrally coordinated service (e.g. IAM), a jointly operated networked infrastructure for exchanging and processing data (e.g. a multi cloud as basic component of the Research Data Commons, championed in the Section Common Infrastructures), jointly operated federated based services (e.g. for Long-Term Archiving and Access (LTA)), or support services, technologies and tools that are organised and mediated collaboratively (e.g. federated user support service desks on RDM, a Data Management Planning Tool (DMP) or a joint training platform for RDM that provides NFDI-related educational resources).

These services cannot be seen in isolation. Base4NFDI expects to employ well-known concepts such as **IaaS, SaaS and PaaS**, which are combinations of several generic components. In addition, there will be tools with considerable added value for state-of-the-art research in several domains, but maybe not "all consortia". The available structures in NFDI could serve to drive more generic and solid developments forward, and realise economies of scale, for example in the form of a "tool pool" (cf. TA2, M2.2).

Base4NFDI builds on a close collaboration with the NFDI Association's Sections to **continuously review** the needs of consortia and identify new candidates for basic services (cf. chapter 3.4, figure 4). The Section's working groups will consolidate topics, describe needs for cross-domain basic services and feed them into the Base4NFDI processes. This workflow has been successfully applied during the preparation of the proposal and proved suitable to integrate NFDI members´ expertise as well as consortial needs.

In the four NFDI Sections Common Infrastructures, (Meta)data, Terminologies and Provenance, Training & Education, Ethical, Legal & Social Aspects, several topics for coordinated service development have been identified. The list presented in table 5 is the current pipeline from which concrete proposals for basic services emerge. The range of topics for basic service provision is rather diverse – ranging from technical services that support the services of the consortia in the background to technical services supporting training and consulting. While every potential basic service is linked to one or more of those topics, not every topic will result in one or more basic service candidate(s).

An NFDI-wide basic service needs to be **useful to "potentially all" existing and future consortia**, maintaining the necessary flexibility to react appropriately to future requirement developments. The flexibility is without alternative because funding of the NFDI consortia was staggered, with three consecutive funding rounds, the last round starting in January 2023. This temporal staggering naturally **results in different levels of maturity** in the formulation of

requirements and the development of solutions with respect to services that might be potential NFDI-wide basic services. Additionally, Base4NFDI needs to take into account that domain-specific services also vary greatly in their form, which makes uniform assessment difficult. As a cornerstone of the Base4NFDI strategy Base4NFDI respects that rapid development of technology, new methodologies, and the emerging landscape of the wider international context regularly generate new opportunities for end users and this may impact needs for basic services from NFDI. The step-by-step development process designed for Base4NFDI allows for dynamic adjustments throughout a service´s life cycle (cf. TA1, M1.2).

The Section working groups have prepared **initial analyses on more than a dozen topics** that were identified in the preparation stage for this proposal. The results are shown in table 5 below. Three **featured topics** with advanced concepts are described in chapter 4.2 to illustrate the intended development process for NFDI-wide basic services. The initial analyses serve to illustrate a well-working division of labour between the NFDI Sections and Base4NFDI. The NFDI Sections and their working groups identify and synchronise common interests across the consortia, whereas Base4NFDI drives selection and development of NFDI-wide basic services forward. The prioritisation of basic services will be determined by how they support the scientific and methodological objectives of the consortia (cf. organisation processes described in chapter 3.4). Some asynchrony between the development of NFDI-wide basic services and the corresponding activities in the consortia is likely, and expected to be part of the negotiations. It is one of the challenges all parties will have to negotiate (cf. chapter 3.1).

Substantial expertise on different levels, technical, organisational, and research will be mobilised through the NFDI Association's Sections. So far, **several hundred technical experts and professionals** from all consortia are registered in the Sections and their working groups. The **Service Stewards of Base4NFDI will establish organisational links** with the Sections in order to support negotiation processes in the NFDI Association and ensure that Base4NFDI can respond swiftly to emerging trends and evolving needs (cf. chapters 3.4 and 4.5).

The following initial analyses illustrate the status quo of cross-cutting topics for coordinated service development in the NFDI (table 5). They were prepared by working groups within the NFDI Sections in support of the Base4NFDI proposal.[17]

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[17] Several more detailed concepts are under publication and will be added to
 https://zenodo.org/communities/base4nfdi/

Table 5: *Pipeline of topics for Basic Service development*

Topic: **Anonymisation and Pseudonymisation of Sensitive Information**
Research concerned with living persons usually contains sensitive information. Due to this sensitivity, the processing of this kind of research data requires taking legal regulations as well as ethical standards into account. Anonymization and pseudonymization are central instruments to fulfil these requirements to protect personal rights of research participants, researchers and third persons. Both instruments are therefore common in empirical research with and about humans – independent of subject and discipline. However, protecting research data is only one side of the coin when you think of data sharing and reuse. Hiding, or deceiving information might prevent research or lead to wrong results. Especially if data are supposed to be shared for scientific re-use, researchers must balance two potentially conflicting interests: protecting personal data and enabling further research. To address both – data protection and scientific re-use – the Research Data Center Qualiservice (KonsortSWD) developed the concept of „Flexible Anonymisation", replacing sensitive personal data with more abstract information relevant for further research on different levels of abstraction. To identify the right replacements the user can apply individual or standardised replacements applying (standardised) lists. QualiAnon [50] supports two standardised formats for importing classifications: 1) CLASET/XML format for exchange of classifications, used e.g by EUROSTAT et al. ICSO, NACE, and ClaML/XML, classification markup language, adopted by the WHO to distribute their family of classifications (ICD-10 etc.). The replacements are set on different abstraction levels and kept reversible up to a specific degree. The replacements can be opened up with more specific information on a lower level of abstraction or in the case of pseudonymization with the original information itself. From this topic, one **basic service** can be derived, which will be capable of **(semi-)automatic anonymisation and pseudonymisation**.
Topic: **Data Integration**
Data integration provides users, tools, and applications with unified views on data and metadata originating from different sources. There is no question that data integration is one of the essential building blocks in every NFDI consortium and in the NFDI as an integrated infrastructure. However, while physical data integration has been known from data warehousing for more than 30 years, the NFDI comes with specific requirements, making data integration a challenging task. The reason for this is that NFDI behaves more like a so-called data lake where heterogeneous data sets with various kinds of schema, partly with schema or without any schema, are supposed to be managed within a common cloud-based storage infrastructure. In addition, some data sets with high-volume, e.g. molecular data and satellite data, or with privacy concerns, e.g., medical data, are not physically available instead just virtually via dedicated interfaces. Thus, data integration requires, in addition, a mediator-based approach to support federated architectures, where data remains in the different sources and integration only takes place when access is made. In agreement with the basic architecture of Research Data Commons (RDC) and the FAIR data principles, data integration in the NFDI follows the observation that different users and applications require different schemata depending on the specific context. Therefore, data integration includes the following tasks which collectively yield into a potential **basic service** targeting **Research Data Integration Commons**: (1) Ingestion of different datasets from external providers into e.g., a federated storage either physically or virtually is required. (2) A powerful and comprehensive management of schemas and mappings between them is needed as a basis for data integration services. (3) Targeted and appropriate services for discovering data in the cloud storage will be needed. The foundation of such discovery services are indexes on metadata or link structures among similar data objects or user profiles. (4) Services are required for transforming the technical schemata of the cloud storage via the mediation layer of RDC into semantic schemata most suitable for users and applications. (5) It is essential to check and document data and metadata quality in the various phases of the data integration processes such as data ingestion and schema transformation. Data integration relates to all cross-cutting aspects such as versioning, AAI, and logging that need to be considered when offering data integration services. For example, a comprehensive versioning of data, metadata, and transformations is a prerequisite for a provenance service within the integration process.

Topic: **Data Management Plans** [91]

Data management plans (DMP) are internationally identified and established as a crucial element of data management workflows. At best, DMPs document data before, throughout and beyond the research process. As a tool DMPs could help to establish services to measure research data quality with respect to the application of the FAIR data principles. All researchers face the requirements of funding agencies regarding their data management. Nowadays, DMPs support the communication and early RDM awareness creation in projects, institutes, etc.

A previous survey in the working group "DMPs in the NFDI" in 2021 has shown that some NFDI consortia have adapted the RDMO [51] software for this purpose and that most of the participants from the working group have great interest in the tool. It also became apparent that the topic of DMPs must be considered from both a content (incl. DMP templates, guidance etc.) and technical perspective of DMPs, e.g. seamless integration of DMP tools in research data infrastructures, bidirectional linking of DMP tools and other tools, DMP discovery and publication. Past experience has shown that aligning both perspectives is of high importance to provide a good service to researchers.

A **data management plan tool** for NFDI (DMP4NFDI) as a potential **basic service** related to this topic will bundle generic tasks and features creating both synergies and customisability across the domains thus releasing resources in the consortia to focus on community-specific issues.

Topic: **Data Science and AI** [52]

The main driver of the suggested topic regarding its relevance within NFDI and its foreseen maturity within the NFDI Section relates to the support of the entire Data Science and AI research data lifecycle with an emphasis on infrastructure, processing pipelines and computational workflows. The overall aim is at delivering and sharing benchmarked software solutions in dedicated repositories (or public registries) as well as establishing a notebook platform and the corresponding assessment and evaluation services. The latter should enable research communities to advance their data analytics capabilities to the highest standards, including AI and deep learning approaches based on the various end user communities' own data.

The relevance and maturity of the services will be demonstrated through a reality check of the services *by and with end user communities*, which will help reduce the gap between new functionality to be implemented and the ability to execute it through a basic service.

From this topic, a multitude of **basic services** may arise, spanning from tools that are dedicated to data science & AI, including **tools for transparent, reproducible and FAIR data science & AI** on the one side, and tools that are enabled by data science & AI, including a **tool for FAIRness assessment** on the other side.

Topic: **Electronic Lab Notebooks** [54]

Electronic Lab Notebooks (ELNs) play an important role for many disciplines with respect to digitalisation of scientific workflows. ELNs provide the appropriate environment to collect information and data at an early stage of the research data lifecycle (e.g. data acquisition in a laboratory) and can be used for the management of original data along with edited and annotated data. Additionally, ELNs can be used to collect and link data from different sources. They provide a significant contribution to securing research results in line with FAIR data principles through supporting functions for data visualisation, storage, discoverability and re-use. ELNs offer the option to organise information in a structured way, to standardise processes and data and to efficiently annotate data. This makes ELNs a highly valuable tool for the NFDI since ELNs could be used to embed the results of the NFDI consortia for standardisation, metadata schemes, ontologies/taxonomies and different other topics. Thus, the use of ELNs for scientific documentation can lead to a direct adoption of the standardisation efforts of the NFDI at a very early stage of the scientific work. While many other tools for research data management are often seen as an additional burden, ELNs are in general widely accepted in the scientific community due to the manifold functionality that supports scientific work, facilitates the management of data and increases the scientists' efficiency. In the end, ELNs are tools to prepare data in a suitable way for further applications in the NFDI infrastructures. As an example, data captured and managed by ELNs could serve as a source for a seamless, effortless transfer of the data to repositories. A systematic use of ELNs is likely to be a crucial factor for the success of the NFDI. Nevertheless, this requires the awareness of scientists to select

suitable ELNs. Suitable solutions should allow a systematic standardisation of data as well as clear and appropriate data structures and the adoption of ELNs to the achievements of NFDI working groups and their results. While a focus on discipline-specific work and needs is important for the acceptance of ELNs, the standardisation efforts need to be defined and discussed by NFDI as a whole. An **ELN assessment** as well as **ELNs** and their interoperability will arise as potential **basic services** from this topic.

Topic: **Ethical, Legal and Social Aspects: Data Protection and Research Ethics, Licensing and Copyrigh**t

A number of legal and research ethics issues arise from the planned basic services, especially from the ones that arise from the current topics data science & AI, data integration, identity management, long term archiving, persistent identifiers, multi cloud and research software engineering. Further topics are to be added in the future. The topics are addressed in an inter- and intradisciplinary manner, links legal theory and research-related practice, and is distinguished by close exchange with the NFDI consortia and NFDI Sections. Ethical issues inform the legal review of topics; they are relevant across the entire data lifecycle of sensitive and personal data. In order to work through stated and future issues and to make them accessible to the scientific community, a variety of methods will be used. These include digestible overviews and detailed legal opinions, flowcharts, best practices or statements on political processes. Based on these, NFDI consortia can develop basic services in a legally compliant manner and balance existing uncertainties in science and research. So far, the following sub-topics have been identified:

The protection of personal rights as a key subject of **data protection and research ethics** is central to proper scientific practice. In order to guarantee this for research participants and also the researchers themselves, further instruments such as informed consent are available in addition to technical and organisational measures. Frequently, the uncertainty of researchers begins with the identification of relevant data sets, the legally compliant information of data subjects, or the understanding of special legal exceptions for research. The goal is to reduce these obstacles and to sensitise researchers to the legal and ethically responsible handling of research data. Central tools are also the pseudonymisation and anonymisation of research data. Their successful implementation in the research process has so far been rare: While pseudonymisation raises fewer questions because of its definition in the GDPR, there is a lack of confident knowledge on anonymisation. For researchers, many questions on this remain unanswered. Furthermore, anonymisation procedures differ with respect to different types of data and data types (quantitative vs. qualitative data of empirical research, video, audio, interview or questionnaire data, etc.). Challenges associated with anonymisation relate in particular to the preservation of scientific re-use value, which must be balanced between privacy-friendly "over-anonymisation" and science-friendly "under-anonymisation". Tools that make anonymisation more comprehensible and easier to adjust are helpful here. For example, the service QualiAnon of the FDZ Qualiservice with its concept of "flexible anonymisation" allows output of data sets anonymised to different degrees by restoring information to a lower level of abstraction. **Anonymisation and pseudonymisation services** and similar **basic services** are likely to originate from this topic.

Researchers' questions about **licensing, data protection, and copyright** have long been handled not only by the legal departments of research institutions, but are increasingly posed by researchers to the personnel who advise on research data (management) and provide support services at scientific institutions. These personnel are usually exposed to uncertainties regarding copyright, data protection, and licensing issues due to a lack of legal training. This has led to the need for an information centre where essential information about the current legal situation is presented in an up-to-date and understandable way (e.g., including case studies). Initial uncertainties are to be eliminated by appropriate information materials and, if necessary, supported by counselling sessions. The latter secure the level of understanding and also identify further, unanswered questions and in-depth needs. However, the discussions do not replace or take over legal advice. Alongside the advisory services, public discussions are initiated and conducted on what science-friendly licences – depending on the requirements of the respective discipline – might look like. A potential **basic service** that could originate from this topic is a **help desk infrastructure** with essential information about the current legal situation, and offering information materials and counselling sessions.

Topic: **FAIR Digital Objects Architecture**

FAIR digital objects address major challenges for data interoperability providing the fundamental data and service architecture models for a scalable federative core of hyper infrastructures such as NFDI or EOSC. The FDO approach implies the adoption of several key components involving globally-unique, persistent and resolvable object identifiers, a standardised set of object-related metadata records including a typed classification of the object itself and a specification of valid operations on the object bitstream. The specifications of operations and corresponding registries are essential to one of the major aims in the FDO context: Machine actionability, which refers to self-contained selection of actions from a set of options by machines as well as subsequent operation decision-relevant in a given context (e.g. represented by a named graph). This enables the development of highly automated methods for mobilising, aggregating and combining the data encapsulated in FDOs, which thus embody actionable knowledge units for the knowledge resources of concern. It is of particular emphasis that the actionable knowledge units have to be embedded in a FAIR ecosystem of services for creation and maintenance of those units including registries with minimum metadata describing (domain-specific) FDO types, services to mint PIDs or provide cross-references and mappings to terminologies. Interplay and optimal functioning of these infrastructures are supposed to leverage the core objective of a global data ecosystem, processed independently by machines and allowing to open up all the vast amounts of research data. The FDO Data Refinery is a cloud-based platform combining and providing models, corresponding workflows, FAIR metadata, rich provenance data for seamless integration in diverse service networks and encapsulation of this data in domain-specific FDO types. The integration into the FDO framework will consider profiles for various types of FDOs involved, accordingly different requirements for (self-contained) machine operations and computational tasks as well as disparate and heterogeneous data sources in different communities. The FDO Type Registry is a community-based service or network of services comprising relevant information on structure, core and optional metadata elements on (domain-)specific FDO substantiations referred to as FDO types. Communities are expected to endorse those FDO types, NFDI might provide a central index and search service for relevant FDO types. From this topic, **basic services** may be derived, spanning an **FDO data refinery** provided as a cloud-based platform, and an **FDO type registry** as well as **FDO data repositories** provided as cloud-based services.

Featured Topic: **Identity and Access Management –** *featured in detail in chapter 4.2*

Topic: **Knowledge Graphs**

Knowledge graphs are widely used technologies for the flexible description of entities and their linking enabling advanced information modelling, exploration, and use. Since the establishment of the Google Knowledge Graph, these technologies have gained momentum in industry and in research, where knowledge graphs are used in infrastructures to organise and publish information about articles, datasets, software, samples, instruments, contributors, organisations, etc. and their interrelations in a machine-interpretable way. OpenAIRE Research Graph, GESIS Knowledge Graph Infrastructure, TIB Open Research Knowledge Graph, Springer Nature SciGraph, Research Graph Foundation, and PID Graph are established infrastructures that connect research. Besides this, Wikidata contains a large number of research related items and several domain specific Wikibase instances are used by several research communities. Knowledge Graphs provide established design principles for implementing FAIR principles and ensuring interoperability for both machine and human access through the use of a joint data model, adoption of established and interlinked schemas and vocabularies and reliance on consistent PIDs across the entire data space. Given the highly structured, machine readable data model, the identification of data at its atomic level, their seamless linking with terminology providing data semantics, their web-based data exchange protocols, knowledge graphs are a key technology for the implementation of the FAIR principles. Given the increasingly interdisciplinary use of resources, e.g. datasets, methods or models, transparent metadata about resources across individual disciplines and their dependencies is crucial and lays the foundation for transdisciplinary discovery. This is even more important given the widespread use of computational methods (e.g. NLP or ML models) across various disciplines and their dependencies with data resources.

To enable the integrated discovery of assets across all consortia, it is critical to provide a technologically consolidated single entry point to NFDI assets. The NFDI Knowledge Graph will provide such an entry point and make disciplinary assets discoverable in the whole NFDI. Such a knowledge graph will build

upon several harmonisation and standardisation activities such as shared concepts, terminologies or the usage of identifiers to represent entities. This leads to a need for FAIR and machine-interpretable representations of resources and their dependencies across the NFDI. From this topic, an **NFDI Knowledge Graph** will arise as a potential **basic service**.

Topic: **Long Term Archiving and Access** [92]

Long Term Archiving and Access (LTA) for digital resources has been a recurring problem for well over 30 years and has not been conclusively solved to date, gaining urgency with the exponential growth of research data, whether due to funder requirements – the DFG requires 10 years of retention – or digital artefacts that must be preserved indefinitely as digital cultural heritage. Against this background, the integration of **Long Term Archiving and Access** into the NFDI Research Data Common (RDC) is an urgent **basic service** for research data management to guarantee sustainable archiving and access, to ensure data provenance and to provide interoperability and reuse [11]. This basic service should enable fast provisioning and data protection compliant de-provisioning. A distinction must be made between the archiving of digital objects as bitstreams (this can be numeric or textual data or complex objects such as models), which represents a first step towards long-term usability, and the archiving of the semantic and software-technical context of the digital original objects, which entails far more effort. Beyond the technical embedding of the LTA in the system environment, a number of technically differentiated requirements of the domain-specific NFDI-consortia are part of the development of LTA as a basic service. Against this background, the objectives of the topic are to identify suitable common processes and standards for archival purposes such as PREMIS, the comprehensive establishment of know-how for the various tasks in the context of LTA and an organisation and cost model based on existing technical solutions. Thus, the basic service makes an important contribution to the traceability and reproducibility of research.

Featured Topic: Mapping, Harmonisation and Overall Management of Terminologies – *featured in detail in chapter 4.2*

Topic: **Metadata Schemata and Application Profiles**

Metadata schemata and application profiles facilitate consistent and standardised documentation of research data and are a necessity for quality control and validation of metadata. By making use of terms form controlled vocabularies, metadata generated according to application profiles is highly machine-actionable and interoperable, which is a prerequisite for many tasks, including highly relevant topics such as automation of data-related tasks in research processes or using data in cross-domain applications like machine learning or knowledge graphs.

Although some scientific domains already apply subject- and application-specific schemata and profiles, many other scientific domains are at an earlier stage of their wide application. Therefore, challenges range from long-term curation and interlinking of existing solutions to services for finding schemata and profiles enabling queries via subject- or application-specific criteria. Also, there is a lack of subject- and application-specific schemata and profiles, and the existing services for finding schemata and profiles do not enable searching via subject- or application-specific criteria. In addition, for most scientific domains there are no tools for the easy generation, curation and sharing of metadata schemata or application profiles.

Application profiles offer a means to build metadata schemata from controlled terms taken from ontologies, resulting in highly interoperable and machine-actionable metadata. However, the definition of application profiles requires knowledge of semantic technologies, e.g. RDF-serialisations and SHACL or ShEx, that typical domain scientists do not possess. An application profile service could aid this technical process by offering a graphical user interface allowing intuitive generation of application profiles via, e.g., a drag-and-drop assembly of suitable ontology terms identified via a connected terminology service. In addition, the service would serve as a platform for sharing of application profiles, indexing them via suitable fields and making them available for reuse and adaptation, and offer a means for community-based curation and quality control of application profiles.

Application profiles are a domain-agnostic technology applicable to virtually any scientific discipline and application and therefore useful to all NFDI consortia. While there are first prototypes of such services available within some consortia, e.g. the NFDI4Ing Metadata Profile Service, there is currently no service

offered with a cross-consortium scope, although due to the generality of the approach this would be possible and an efficient means to bundle the ongoing efforts towards development of a common service with a larger scale.

Potential **basic services** originating from this topic include a **metadata schema registry** as well as an **application profile service** for applications handling data in the NFDI.

Topic: **Multi Cloud**

The key objective of all NFDI consortia is to systematically register data in a sustained manner in order to make them openly and consistently accessible at the national or even international level. The overall goal of the NFDI is to interconnect resources to enable a community-wide and cross-community access to data and applications in order to facilitate the exchange and reuse of data and hereupon established collaborations. The foundation for such an overarching common infrastructure builds a federated multi cloud providing unified access by a federated Identity and Access Management (IAM) to compute resources and data.

To date, it is common practice in many scientific disciplines for users to locally store data and work with it. Cloud computing, in contrast, offers an economic and scalable solution by pooling compute and storage resources and providing a model in which public data is integrated or hosted by data providers so that users can perform their analyses close to where the data resides. Virtual compute environments allow, beyond that, for maximal flexibility in terms of software stacks, and portable containers enable scientists to share environments or workflows with colleagues, facilitating reproducible research. Consequently, the development of new or the integration into existing cloud-based infrastructures is already a formulated goal of many NFDI consortia. In order to bundle and consolidate these efforts and to promote compatibility and interoperability on multiple levels, a common decentralised yet federated platform is needed. This platform is based on the ideas introduced by the Research Data Commons (RDC) concept initially supported by a number of NFDI consortia and the BMBF FAIR DS project [55]. By further adapting and extending the concept according to the requirements of each consortium, a decentralised yet federated cloud computing platform, i.e. a multi cloud, allows consortia to either operate their own systems, that in turn are federated and form a cloud of clouds, or use a shared cloud system that integrates into the federated system.

Following this architecture, involved NFDI centres provide the necessary capacity and expertise for hosting the decentralised parts of this platform, storing the actual data and providing information about available services and computing resources. This way, fast provisioning and data protection compliant de-provisioning can be assured. Access to sensitive or otherwise protected data can be tightly controlled by and restricted to a single data centre. Associated non-critical metadata and generally non-restricted data should be made publicly available in accordance to FAIR principles either physically or virtually in the multi cloud storage, that interconnects and integrates the heterogeneous data landscape of the different data centres and other public resources. This topic covers the **NFDI multi cloud** itself as a potential **basic service**. To optimally utilise the cloud resources this platform will also provide a set of additional basic services for the development of scalable analysis procedures.

Featured Topic: **Persistent Identifiers (PID)** – *featured in detail in chapter 4.2*

Topic: **Research Software Engineering** [93]

Software is fundamental to open, reproducible and data-driven research with results complying to the FAIR guiding principles. The development and use of software for research purposes has multiplied over the last two decades. The research software available today ranges from small, helpful scripts to robust software products and complex software systems. In a wide variety of forms, research software supports the work of local working groups, small scientific communities and large global research networks. With its range of variation and abundance, findability of research software has become a challenge. Effectively using research data goes hand in hand with the use of research software. In addition to the research data, the software required for its use must thus be equally available – so it can also be used with other research data of the same type.

Software is an essential component not only in research but also in digital infrastructures. Digital infrastructures consist of hardware, communication networks, and distributed software systems with components that work in coordination with each other. The functionality, connectivity, compatibility and

security of the infrastructure as a whole and of the individual components depend on agreed interfaces, standards and conventions. The development of a networked infrastructure, as envisaged in the Research Data Commons (RDC) concept, requires solutions implemented under a community-based agreement; ideally, involving NFDI consortia as well as other national and international partners. Community agreements facilitate harmonisation and efficient use of resources as well as re-usability. Contributing to a software ecosystem potential **basic services** derived from this topic may include a **research software marketplace** and a **catalogue of standardised training and workshop opportunities.**

Topic: **Search and Harvesting**

This topic focuses on how to find, and (re)use (meta)data provided and maintained by the NFDI consortia, both for consumption by humans (search/discovery) and by machines and service providers (harvesting). For search and harvesting queries to be efficient, i.e. for them to deliver optimal results, metadata has to be complete, adequate, and connectable/interoperable. However, what "adequate" means depends on the specific research questions in the related scientific communities, which cannot be known a priori, i.e., they have to be inferred by analysing users' behaviour or interviewing them. Ideally, we need to strive for an optimum in flexibility on the one hand, while ensuring efficient search-and-harvesting of metadata on the other. When considering the consortia's requirements, we need to distinguish between the requirements from the content side (e.g., how data are described, which scientific tasks need to be supported) and requirements from the IT side (how metadata are re-used for interoperable search and harvesting in distributed repositories). It is important to ensure a FAIR-compliant usage of research data in modern research infrastructures while keeping the "big pictures" set out by the consortia and NFDI e.V. In order to achieve all these goals, we need services that make sense of the heterogeneous ecosystem of search and harvesting both metadata and data in the NFDI present and future databases, as well as services that leverage their synergies. The first stage are services that take stock, measure, and identify synergies of search and harvesting systems in the NFDI. We also identified that granularity (i.e., establishing a hierarchy at increasing levels of resolution and detail) of metadata is of particular interest for (human) searches. Different disciplines use different granularity levels for their data and these come with unique, but comparable challenges. Findability on the web is important as search systems that cannot be found in that way fade into obscurity as well as the data they represent. Based on the foundation of a thorough stocktaking, we will propose **basic services** derived from this topic that close the gaps, such as a **cross-domain authority file service** or a **federated search and harvesting infrastructure** thus fostering harvesting, granularity and findability in the NFDI.

Topic: **Training & Education: Training Modules, Error Culture**

Training data literacy from the very beginning is of utmost importance for all stakeholders in research and education. Training in data literacy will help to ensure that formal qualifications to use "data" as a modern resource can be improved for new knowledge and for sustainable solutions to societal challenges. This is achieved by means of transparency and traceability for all stakeholders in an open or also protected data space. Data literacy paves the way for the sustainability of research data management (RDM) and contributes to the advancement of scientific methods and good scientific practice.

Data literacy plays a key role in solving societal challenges, and in shaping the digital culture. Data literacy is the prerequisite for evolving the scientific method; for industry, it has become a prerequisite for employment, and the Stifterverband also defined it in the data literacy charter as an "indispensable component of general education". Coordinated and targeted training in data literacy is of great importance for the competitiveness of Germany as a centre of research and industry and hence, for all NFDI consortia.

In an active dialogue with all NFDI consortia and other relevant stakeholders, a target group- and requirements-analysis as well as regular exchange is already taking place. The specific aspects of the individual consortia will be recorded, combined and compared. From this, target group profiles which are independent of discipline will be derived and educational goals specified for each of these.

One central **sub-topic** is the provision of requirement-based and target group-specific **training modules** on data literacy. The basis for this is a modular and scalable training concept as an overall framework. In addition to the development of new teaching materials, existing offers will also be transferred to the concept and disseminated with the help of the knowledge base being funded and developed in parallel.

With the development of new teaching materials, aspects not yet addressed are covered. From this task, a **basic service** that provides a **training infrastructure** may arise [56].

Another **sub-topic** is the **quality assurance of training modules**. One goal is to develop a quality assurance concept for the individual modules as well as for the resulting teaching and training courses. In addition to the quality of the content, the formal quality of the materials and courses will also be considered. An additional goal is to create the framework for a course which certifies data stewards based on existing programs. The certificate course led by the NFDI e.V. ensures standardisation and quality. It contributes to personal development. From this task, a **basic service** that provides a **certificate infrastructure** may arise [57].

Latest RDM training sessions have shown that many scientists see the absence of an appropriate error culture as a hurdle to providing all data as FAIR data. Hence, a further crucial **sub-topic** for the cultural change towards FAIR data in sciences is the establishment of an **error culture** in all branches of sciences. After a root-cause analysis within all NFDI consortia, a round-table will be initiated to come into a dialogue with all stakeholders (e.g. funding organisations, researchers, publishers). Publications and talks on this topic will be organised. From this task, a **basic service** to address **error management and no-blame culture** may arise [58].

4.2   Basic Service(s)

This section will present three topics for basic services in more detail and illustrate the development process designed for Base4NFDI.Featured Topics for potential basic services

From the topics described by the Sections' working groups the **Consortia Assembly has nominated three** that are already eligible for the start of the initialisation process of potential basic services and are documented here as examples. Specifically, these three topics serve the needs of the large majority of consortia, while being sufficiently mature to start initialisation in the short term. Furthermore, they represent a wide range of services models and technological and organisational characteristics which will hold valuable lessons for ensuring development processes. These topics are

- a federated **Identity and Access Management** (IAM) [53] that provides unified access to the services and data of the consortia,
- a system for **Persistent Identifiers** (PID) to support FAIR data infrastructures and to make (meta-)data referenceable,
- a federated **Terminology Service** (TS) that manages, curates and makes terminologies accessible (both for human users and machine-based services) for aligned research data management and uniform vocabularies for the content-related networking of research.

For these topics the process described in chapter 4.3 will start with the initialisation of services as soon as the project begins. Base4NFDI will apply the same process to all topics for which service proposals will emerge in the work of the Sections as long as funding is available. The three topics already identified above as candidates for being initialised with the start of Base4NFDI are presented hereinafter in more detail.
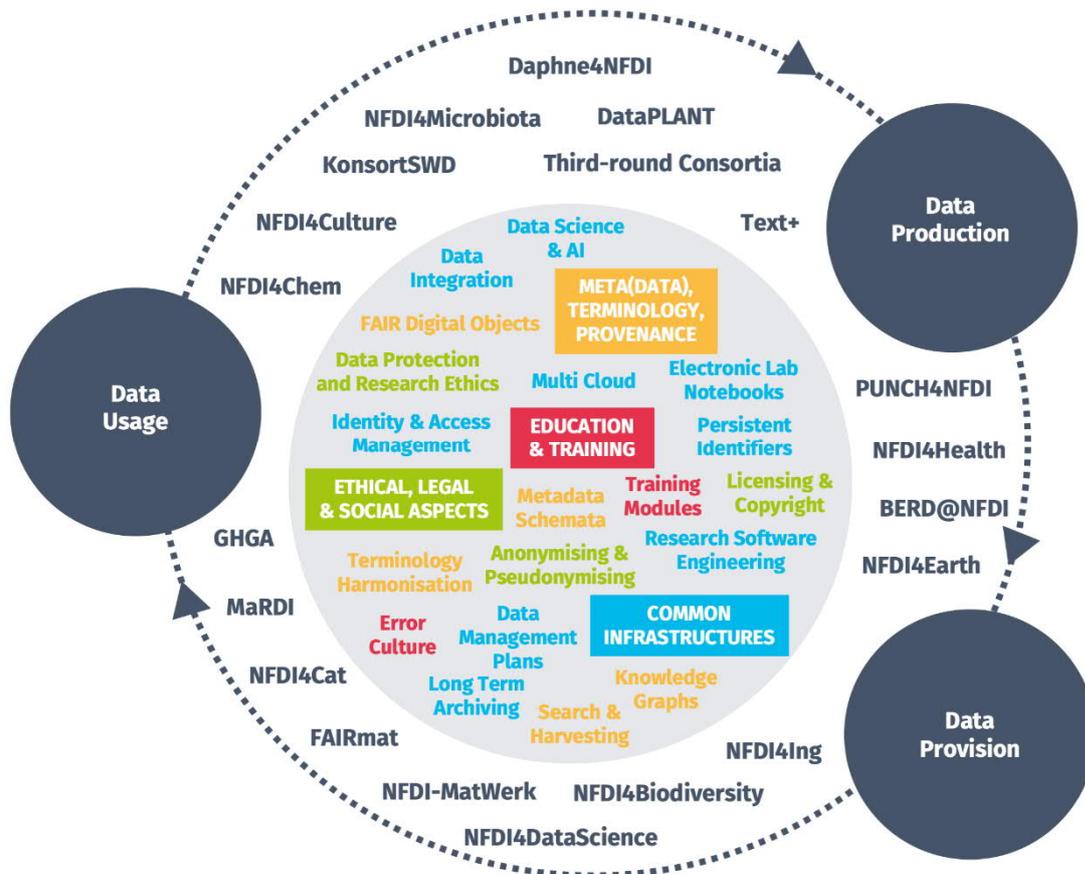
Figure 7: Potential Basic Services serving the Data Life Cycle along the consortia's needs

Featured Topic: Identity and Access Management

Identity and Access Management (IAM) [53] is concerned with the processes, policies and technologies for managing digital identities and their access rights to specific resources. The function of IAM is to ensure that a user – either a human or a machine – obtains access rights to this specific resource.

A central goal within NFDI is to enable unified access to data, software, and compute resources as well as sovereign data exchange and collaborative work. In order to achieve this, it will be necessary to **connect and expand existing and emerging IAM systems** in a way that researchers from different domains and institutions are able to access digital resources existing within NFDI as easily as possible, yet in a secure manner. Interoperability is therefore a central requirement on multiple levels. Those include services within the NFDI, access to and exchange with external infrastructures such as the European Open Science Cloud (EOSC), national resources such as NHR (National High Performance Computing), HIFIS (Helmholtz Federated IT Services), and, potentially, the GAIA-X ecosystem (e.g. FAIR Data Spaces). In order to manage the complex relationships between identity sources (e.g. from home institutions), national identity

federations (e.g. DFN-AAI, eduGAIN), virtual organisations (e.g. NFDI consortia), and other access management solutions, a decentralised, federated Identity and Access Management is required. The technical and organisational framework for a federated IAM is a so-called Authentication and Authorisation Infrastructure (AAI).

Potential basic service related to this topic: Identity and Access Management (IAM)

In terms of basic services, it is planned to provide a state of the art AAI, that fosters cross-consortial collaboration, while providing the maximum freedom to cater to the individual needs of the domain-specific consortia, while complying with regulations such as the GDPR.

Needs addressed by this potential service: Federated Identity and Access Management allows to manage who may access a consortium' services using Virtual Organisations (VOs). Compared to conventional approaches, the suggested IAM basic service integrates existing solutions to provide a more scalable solution. It will be better suited than existing solutions for authorisation for three reasons: First, the use of federated identities allows scientists to use their home organisational accounts, rather than creating new accounts for individual services. This simultaneously unburdens service operators and users. Second, the Virtual Organisation approach introduces an authorisation concept that is decoupled from the services. This allows services to authorise groups of federated identities rather than individual ones. The benefit for users is that their VO membership can be organised along structures of their scientific communities. It is thus independent of structures imposed by an employer or a service. Another user benefit is the single sign-on experience. Finally, IAM will create a reliable trust framework and enhance the general security of connected systems, by following established recommendations by international bodies, such as FIM4R, WISE, and AEGIS (i.e. the AARC community). This will also ensure compatibility with currently partly adopted IAM solutions for some consortia, such as DARIAH AAI, Helmholtz AAI and Life Science AAI (formerly ELIXIR AAI). Crucially, compatibility with EOSC services will be ensured.

State of the art for this potential service: As for research community AAIs, the AARC Blueprint Architecture (BPA) [59] has established itself as a best practice solution over the last years in several research communities and projects, e.g. in Life Science AAI (formerly ELIXIR AAI). Many research communities and projects participating in EOSC are based on this model. Furthermore, several recommendations of the AARC community define a set of common widely-accepted baseline standards enabling international cross-community interoperability. Lower level standards such as SAML2, OIDC, OAuth2 or X.509 are well established and well integrated into the above.

The **service initialisation strategy** contains the collection and an update of the actual state and requirements of NFDI consortia. In order to validate the work results and to gather further feedback, the IAM-Team will conduct Infoshare meetings within the Section Common Infrastructures on a regular basis. Infoshares will focus on a particular aspect of the IAM service. Their interactive nature allows for gathering further feedback from the consortia. The basis for the Infoshares will be the minimum viable product of the NFDI IAM. These Infoshares will be conducted in collaboration with the Section Training & Education.

As a part of the **service integration strategy**, a clear organisational scheme will be developed to identify responsibilities, regulations, and guidance for interaction with domain specific consortia, regarding

- Delegation of authorisation management

- Implementation of essential policies to establish trust and common procedures

- Integration of services of consortia

- Integration of global users (e.g. from other countries and trust domains)

- Integration of guest users (e.g. citizen scientists)

- Authorisation management for subject-specific, generic and cross-consortia resources (e.g. communication services)

This work will implement the recommendations of WISE, Sirtfi, and Snctfi, as it will be based on the AARC Policy Development KIT, to ensure interoperability with international initiatives, such as EOSC. These activities will lead to the establishment of an appropriate governance structure and processes for the access and rights management of the NFDI IAM that will implement the topics listed above in a sustainable way. Clearly defined structures and responsibilities in terms of IAM will help to connect NFDI with the above mentioned international initiatives.

The NFDI Community AAI will be connected to the national identity federation DFN-AAI, which is operated by the German DFN-Verein. This way, users from more than 360 German research and higher education institutions plus approx. 4500 home organisations worldwide will be able to use services provided by the NFDI Community AAI. Through its modular architecture and participation in the international interfederation eduGAIN, the DFN-AAI also facilitates international, cross-federation, and cross-community usage scenarios.

The **ramping up for service strategy** involves development and maintenance of an overall architecture and the technological basis to keep the state-of-the-art level for supporting consortia and their services. Federated IAM is an evolving field with new developments addressing more requirements and extending the possibilities for users to collaborate on distributed services. The

continuous extension of technology and the evolving international context in which users and services operate require constant adaptation of the AAI architecture and its core services.

- Integration within an international context

- Integration of services from the domain-specific consortia

- Monitoring of and continuous adaptation to new technologies and standards

- Continuous development to keep up with the state of the art of international identity and access management.

The IAM basic service operational model works in two ways. Two core components will establish connectivity with the identity federations (via DFN-AAI and eduGAIN), as well as an intermediary that enables cross-community collaboration. These core services are extended, and made available to the consortia via specific, so-called "Community-AAIs". These Community-AAIs are based on existing technical components that may be customised to the specific needs of individual NFDI consortia. Among the partners (from PUNCH4NFDI, DAPHNE), there is already experience in such community specific adoption processes of AAI, for example, the adoption of the Helmholtz AAI (via HIFIS) and subsets of connected cloud services. The same applies for DARIAH AAI (Text+) and ELIXIR/Life Science AAI (partners from NFDI4Biodiversity). The operational model foresees a general coordination of the central services by the base-consortium, which maintains a close collaboration with the Community-AAIs.

Possible challenges and risks:

- AAI and IAM service not mature enough for production, low acceptance by the consortia

  - Likelihood: Very unlikely, because multiple similar software exist

  - Impact: Not all features may be available

  - Mitigation: Analyse the available options early, and provide prototypes, so that problems can be detected ahead of time and alternative products may be used or the deployed open source products may be extended

- AAI and IAM service implementation phase underfunded

  - Likelihood: Possible

  - Impact: Some AAI features may not be available in time; consortia may have chosen different / incompatible solutions

  - Mitigation: Iterative approach to provide limited functionality early. Extend later.

Potential partners with existing expertise:

DAASI International (NFDI4Culture), DFN-Verein (to join NFDI4Ing), FIZ Karlsruhe (MaRDI, NFDI4DataScience), FZJ (NFDI4Ing, NFDI-MatWerk, PUNCH4NFDI), GWDG (Text+,

NFDI4Biodiversity, NFDI4Ing), KIT (NFDI4Chem, NFDI4DataScience, NFDI4Earth, NFDI4Ing, NFDI-MatWerk, PUNCH4NFDI), RWTH (NFDI4Ing, NFDI-MatWerk, NFDI4DataScience), TUD (GHGA, NFDI4Chem, NFDI4Ing, NFDI4Earth, NFDI-MatWerk, NFDI4DataScience, PUNCH4NFDI, FAIRmat, Text+), ZKI (Section Common Infrastructures)[18]

Featured Topic: Persistent Identifiers (PID)

In recent years, the use of persistent identifiers (PIDs) [94] to identify data objects, general research outputs, or researchers themselves has become widely accepted in the scientific community. Every existing and every proposed NFDI consortium uses one or more PID systems in its everyday handling of research objects. Furthermore, **reliable PID systems are the backbone** for many additional services, such as knowledge graphs or portfolio analytics services. Thus, persistent identifiers are a fundamental building block of research data management and a mandatory element of FAIR data infrastructures.

Globally operating organisations and consortia such as DataCite [60], the DOI foundation [61], or the ePIC consortium [62] already offer trustworthy, mature, and well established infrastructures that are used for research data identification by almost all NFDI consortia. Furthermore, systems for the persistent identification of individual entities such as persons, organisations, places, events, or for general terms (like ORCID [63], ROR [64], GND [65], or VIAF [66]) are well established. Nevertheless, the assignment of identifiers in all NFDI consortia at the moment is scattered and heterogeneous in terms of actors, services, scope, quality, and costs involved. Having the crucial role of PIDs in RDM in mind, it is essential to **analyse existing gaps and develop joint solutions** in order to serve the needs of individual communities and the NFDI as a whole. This implies finding answers to questions such as: How can the existing infrastructure of PID services be optimally used and interoperability with global research infrastructures like EOSC ensured? What interfaces and licences are needed? Which specific needs of consortia should be addressed? Where are central solutions – e.g. for support and training – needed?

Potential Basic Service related to this topic: PIDs4NFDI

The resulting service, PIDs4NFDI, will provide an integrated offer for the whole NFDI to close the aforementioned gaps. This offer contains, but is not limited to, the following deliverables and functions. (1) Requirements engineering: An in-depth analysis of user requirements and existing (inter)national service offers resulting in specific, implementable requirements. (2) Community integration: Implementation of community-specific requirements such as specific PID types, PID-related metadata, or service integrations. (3) Common interfaces: Conceptualisation of common

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[18] ZKI is not yet a member of any consortium but participates in Section Common Infrastructure as a member institution of the NFDI Association.

interface requirements and communication with PID provider communities to include the German perspective in ongoing development and standardisation efforts and to enable equal access to PID infrastructure across the globe. (4) Marketplace: Development of a marketplace comprising all existing PID type-specific offers and missing functions required by the communities. (5) Support and training: Combined best practices, training programmes, and a concept for an NFDI-wide PID support infrastructure.

Needs addressed by this potential service: Persistent identifiers are a central component of a FAIR and quality-oriented research data management. The current state of integration of such PIDs into RDM workflows, subject-specific repositories, or services is very heterogeneous with respect to the individual NFDI consortia and, like RDM itself, strongly dependent on the common practices of the respective community as well as its approach towards and prioritisation of topics such as data re-use, data sharing, reproducibility or collaborative research. Furthermore, subject-specific metadata adaptations strongly depend on the research resource types and content that are relevant for the respective community.

A joint and cross-domain PID service offer as outlined in this proposal will improve the status quo and provide significant added value to communities, but also to the NFDI as a whole. Implementing the requirements of the consortia will result in an integrated service offer that makes use of existing robust, secure, and scalable globally-available infrastructures. This will improve the overall FAIRness of research data management in the NFDI, ensure interoperability of distinct PID schemes across disciplines, and, in general, save resources by exploiting synergies and by brokering knowledge and expertise. This increases the findability of resources across disciplines and repositories, promotes the standardisation of metadata as a means of contextualising research results and thus increases their quality and re-use potential along the lifecycle of research data. Finally, PIDs4NFDI will contribute to and, wherever possible, coordinate efforts to standardise results from PID-related developments within the NFDI to increase sustainability and international re-usability of its service offer.

State of the art for this potential service: A persistent identifier is a persistent, unique, and globally resolvable identifier based on an openly specified PID scheme [67]. The global PID ecosystem relies on many persistent identifier standards (e.g., ARK, DOI, Handle, or URN) to identify a reference point: a digital object or a digital representation of an entity. Whatever the chosen scheme is, the PIDs' basic features ensure global uniqueness, persistent identification, and long-term resolvable function to locate the reference point. These functionalities enable unambiguous and unique referencing and citation and improve the object's visibility and findability.

PIDs are the backbone of a FAIR research information infrastructure since they connect people, places, and objects [68]. Identifiers for *researchers* include ORCID, ResearcherID, and Scopus IDs. For *organisations* in the research community, standard identifiers are Ringgold IDs, International Standard Name Identifiers (ISNIs), International Authority (ISNI-IA ISNI), Legal entity identifiers (LEIs), and Research Organisation Registry (ROR IDs). Identifiers for *objects and research* outputs are Digital Object Identifiers (DOIs), Archival Resource Key identifiers (ARKs), the Handle system (governed by the independent Swiss DONA Foundation and used by DOI, ePic and many other service providers), International Geo Sample Number (IGSNs), Uniform Resource Name (URN), Persistent Uniform Resource Locators (PURL), Research Activity identifier (RAiD), Research resource identifiers (RRID), Uniform Resource Identifier (URI), and Universally Unique Identifiers (UUID).

The European Open Science Cloud (EOSC) is an integrated infrastructure to create a web of FAIR data [69]. The development of EOSC is a significant and ongoing multi-stakeholder initiative with a large number of associated projects that build services integrated into the overall EOSC landscape. The EOSC persistent identifier (PID) policy [67] establishes service and infrastructure requirements for potential services providers. Additionally, the PID technical architecture document[3] details guidelines on the implementation of compliant PIDs and related services with EOSC persistent identifier policy. It also identifies opportunities for interoperability between PID services and the EOSC framework. In this sense, these policy-related and technical guidelines shape the high-level aligning of PIDs4NFDI with EOSC. Example projects contributing to PID services for ESOC are FREYA, which built innovative PID-related services as a building block for EOSC, DICE, which offers i.a handle-based PID services for European researchers, and the upcoming FAIRCORE4EOSC project, which will develop i.a. a PID graph, metadata schemata, and a PID registry. Within all projects, PIDs4NFDI partners are contributing to the European service development.

The cited examples are trusted and reliable PID systems that deliver PID services which vary in maturity levels, landscape characteristics, object types, and domain particularities; hence, it is necessary to assess those requirements to assemble a suitable PID strategy for the NFDI. PID services should assure interoperability within PID service providers and across NFDI consortia infrastructures. Considering the multi-standard landscape, local and global PID qualities, open or proprietary rights licences, the PIDs4NFDI service offer must integrate well with NFDI research infrastructures to provide an open infrastructure, supporting NFDI research community needs.

The first step of the **service initialisation strategy** envisions reviewing the NFDI PID landscape in detail, collecting requirements of the consortia of all three rounds, and analysing requirements as well as gaps. Furthermore, requirements from other Sections, e.g. metadata, terminologies

and provenance, and working groups, e.g. on knowledge graphs, will also be taken into consideration. This step will be carried out based on the initial survey that led to the foundation of the Persistent Identifiers working group. It is acknowledged that Base4NFDI will bring about a community- and demand-driven process in close collaboration with the Sections, which will result in changes and evolution also related to the PIDs4NFDI service offer. Service-specific development and decision processes will be therefore closely synchronised with the overall Base4NFDI process and service characteristics will be adopted according to the evolving requirements. The output of this stage will be a requirements and gap analysis (to be updated dynamically in parallel to executing the next stages).

As a part of the **service integration strategy**, PIDs4NFDI will develop the foundation for an NFDI-wide governance model to establish a representative for PID-related issues within the NFDI and as an accepted partner for international PID stakeholders like EOSC. Furthermore, licence models will be designed to enable seamless and easy access to PID resources for all NFDI consortia.

Based on the input from the initialisation stage, technical solutions will be implemented to fulfill the requirements of the domain-specific consortia as well as of the Sections and their working groups, respectively. These developments include the implementation of specific PID-types for, e.g., samples from collection processes or measurements or large-scale instruments, integration of community-specific, PID-related metadata, or the integration with services from individual consortia. Furthermore, PIDs4NFDI will develop a concept for common interfaces for the usage and integration of PIDs within the NFDI. The goal of this task is to code generally applicable functions into APIs and provide them independently of the respective specific PID system. This input will be shared with international stakeholders to incorporate the German perspective into ongoing development and standardisation efforts that will enable common access to PID infrastructure across the globe.

These enhancements and integrations of the PID service offer will be based on existing, globally operated infrastructures (cf. above, state-of-the-art). These infrastructures constitute robust fundamental technologies with proven operation and licence models. PIDs4NFDI's service offer for the whole NFDI will integrate these and report the results back to the respective technology owners, service providers, and standardisation bodies.

The **ramping-up strategy for service operation** for PIDs4NFDI will combine the developments from the integration stage into a marketplace comprising all existing PID type-specific offers as well as developing further missing functions required by the communities. The marketplace complements the common interfaces, which are primarily provided for service developers and integrators, with functionality for easy access to and registration of PIDs. Another essential part

of this stage is the preparation of support and training material for consortia as well as individual users. This includes best practices, training programmes (in collaboration with the Section Training & Education), and a concept for an NFDI-wide PID support infrastructure.

This stage will also be used to specify service level agreements and implement operational level agreements with potential providers of (parts of) the PID service offer. Furthermore, an operation model and GDPR-related contracts will be prepared based on the templates from Base4NFDI. Last, but not least, concise monitoring of service performance and usage will be prepared.

Possible challenges and risks: a lack of responsibility for metadata maintenance is a risk for persistence and sustainability. To ensure persistence in the availability of metadata and thus in the availability of research resources, it is necessary to ensure the long-term maintenance of metadata to avoid dysfunctional or orphaned PIDs which lack important metadata information or do not resolve at all. The governance structure of the PID service(s) should mitigate these risks by clearly defining metadata maintenance responsibilities among NFDI network stakeholders beyond funding periods and contexts. Since PID assignment is a cross-cutting task, it requires a highly scalable service that can provide an interdisciplinary technical infrastructure and metadata schema that enables global resolution of PIDs, and already has a certain technology readiness level, to create the conditions for sustainable research data management. In addition, to ensure interoperability and secure provenance of data, a strategy must be devised to link discipline-specific metadata to generic schemas in a way that enables reuse by humans and machines.

Legal issues are relevant in the area of PIDs: It is necessary to clarify licensing options for metadata (e.g., free availability of metadata for patents, from publishers, etc.) and for the subsequent use of developed tools. A lack of awareness of the importance of PIDs and to PIDs being used superficially without realising their full potential (e.g., providing contextual information about the described object or related objects, provenance, citation information, etc.). Rich metadata is a prerequisite for a high quality description of research resources. Meaningful use of metadata requires that metadata are mapped according to international standards (adaptation of best practices) and user requirements, that interfaces between different systems are available, that awareness of their importance is created through training, that licences regulate their re-use, etc.

The objectives and measures described above address these challenges and risks and the partners are able to manage them. However, the assignment and efficient use of PIDs requires the participation and engagement of all stakeholders in the NFDI. A close exchange with other actors within the NFDI is therefore a prerequisite for a functioning PID service.

Potential partners with existing expertise:

DNB (Text+, NFDI4Culture, DKRZ (NFDI4Earth), FIZ Karlsruhe (MaRDI), GESIS and ZBW (KonsortSWD, BERD@NFDI, NFDI4DataScience), GFZ (NFDI4Earth), GWDG (NFDI4Biodiversity, NFDI4Ing, Text+), IPK (NFDI4Biodiversity, FAIRAgro), SUB (Text+, NFDI4Biodiversity, NFDI4Culture), TIB (NFID4Chem, NFDI4Culture, NFDI4DataScience, NFID4Ing), DataCite (NFDI4Ing)

Featured Topic: Mapping, Harmonisation and Overall Management of Terminologies

The FAIR principles explicitly state that a formal and common terminology must be used for knowledge representation. An important task for each NFDI consortium is therefore to identify and align – through mapping and/or harmonisation activities – their relevant terminologies within the designated communities and beyond to achieve the broadest possible applicability and acceptance. Currently, each branch of science and each consortium in the NFDI works with their own set of terminologies, at different stages of maturity, and at different levels with respect to FAIRness. Accordingly, ontologies and controlled vocabularies evolve in different time-frames and for different purposes. They are prone to have conceptual overlaps and – as in natural language – there are different ways of expressing the same concept. In consequence, interoperability of the different approaches is significantly compromised. Mappings between equivalent representations of the same concept are thus essential for the federation of data that are structured with domain ontologies. The creation and machine-readable documentation of such mappings needs to be guided by common standards. Additionally, the use of upper level ontologies and mechanisms for the re-use of terms from existing terminologies need to be promoted within the entire NFDI community and beyond. In addition to mapping equivalent terms, disambiguation between terms "overloaded" with different meanings in different disciplines, is another key task. Therefore, there is a **need for terminology mappings, and various other harmonisation activities, between the different consortia's terminologies** as well as on the intra-consortium level. Besides the communication aspect of this work – which is ongoing within the Section (Meta)data Terminologies and Provenance – there is also the need for shared and standardised technical services to facilitate the overall management of interoperable terminologies.

Potential Basic Service related to this topic: NFDI Terminology Service

A terminology service implements precisely this requirement, as a web-based service that manages terminologies (i.e. vocabularies or ontologies) represented through semantic web specifications (OWL, SKOS, etc). Several NFDI consortia have allocated resources to set up a terminology service relying on established open source software, such as *Ontology Lookup Service* (OLS) or *BioPortal.* However, no NFDI consortium itself has enough resources and

expertise for the implementation of all necessary features and services for all NFDI consortia. A cross-consortium terminology service offer, which forms a consolidating interface across all consortia, is the only way to achieve comprehensive interoperability across the various consortia. It is therefore necessary to establish a higher-level service that integrates the existing distributed services. Among other things, to make federated requests or to get access to mappings between domain-specific ontologies. Unlike other more general knowledge graph services (which may also be proposed as basic services in the future), the focus of a terminology service is on the ontologies themselves and not on assigning specific values to them.

The overarching goal of a terminology service is an alignment of the existing terminology services across NFDI consortia to counteract siloed solutions and to assist in efficient cross-domain terminology use in RDM. The topic of mapping, harmonisation and overall management of terminologies encompasses most of the key aspects related to the scoping and provision of this potential basic service, but further cooperation with working groups in Section Common Infrastructures and the topic search and harvesting will be necessary to specify the precise needs for access and curation of a broad set of structured terminology resources across different disciplines.

This topic and the potential basic service envisioned for it is concerned with the introduction of **service alignment processes** across the NFDI consortia. This will include a federated architecture agreed upon by the consortia to enable consistent terminology access, maintenance of terminologies, and subscription to terminologies, as well as best practices and tools to evaluate and improve the consistency and usability of terminologies in a feedback loop with the participating consortia.

To reach this objective the following sub-objectives must be met:

- Provision of a consortia-agreed, federated terminology service architecture to align the various services on an infrastructure level.
- In cooperation with the Section Common Infrastructures and WG "Search and Harvesting": provision of requirements for terminology services to be used in NFDI for access and curation of a broad set of structured terminology resources. Base4NFDI assumes a heterogeneous situation for the different disciplines.
- Implementation and deployment of the federated terminology service architecture
- Introduction of service alignment processes across the NFDI consortia
- Implementation of general functionalities
  - uniform terminology access, curation of terminologies, and subscription to terminologies

○ Semantification of unstructured (e.g. tabular) data and semantic enrichment of textual (automatic annotation/tagging/indexing)

○ Provide best practices and tools for assessing and improving the correctness and validity of terminologies. This includes, in particular, processing quality metrics such as those of consistency, comprehensiveness, conciseness, and usability of terminologies, in a feedback loop with the involved consortia.

Needs addressed by this potential service: The Base4NFDI terminology service will serve as a consolidated entry point that bundles the needs of all NFDI consortia. The different requirements of all consortia for the terminology service will be captured, sorted by relevance and development efforts. In addition, the development of a terminology service agreed on in different consortia can be carried out in a coordinated manner. The service addresses various stakeholders' needs, e.g., knowledge workers will find a place that bundles community-specific knowledge for data markup with metadata, providing important overviews (search, browse, and filter bundles of terminologies of specific research fields) and insights (e.g. statistics about their usage and alignment). Data curators will find aligned metadata standards for their data holding. Also, the basic terminology service will fulfil requirements of an overarching NFDI infrastructure and provide a central service that can federate queries to the domain specific underlying services. There might be a number of different services supported by the domain NFDIs, but it is necessary that they can interact through common interfaces with an overarching service. Their robustness and security as well as the scalability of the technology will improve through joined forces and resources in the NFDI Terminology Service. Furthermore, mapping needs between consortia terminologies can be coordinated as well and results integrated accordingly. Finally, consortia which do not have a service planned in their proposal can use one of the solutions provided by the commonly guided solutions offered by Base4NFDI.

State of the art for this potential service: A number of Terminology Service solutions have been developed and deployed already within different NFDI consortia, e.g. NFDI4Biodiversity uses a service developed for their community [70], GESIS (KonsortSWD), hosts TheSoz [71], a thesaurus for the social sciences or DNB (Text+) hosts GND as a general thesaurus including mapping services to various thesauri. NFDI4Chem [72], NFDI4Health [73] and NFDI4Ing [74] provide domain-specific terminologies based on the Ontology Lookup Service (OLS), part of ELIXIR infrastructure [75] and and open source solution with a broader user community and part of the ELIXIR infrastructure. Examples of further terminology services for the various disciplines are BioPortal [76], MatPortal [77], and Skosmos [78]. BioPortal and OLS offer a number of features and widgets for UIs supporting autocompletion, search and result visualisation. Although they provide these functions and a large user community, they lack federation functionalities that are needed for an overarching service which can communicate with different domain-specific

services through defined interfaces and offers overarching searches. Also a number of additional functional needs have already been identified by consortia based on evaluations of existing services.

The **service initialisation strategy comprises** a comprehensive overview of all consortia; how terminologies are used and applied, what services are developed or needed. What goals are formulated in the proposals of the consortia and what is the current status of progress. All requirements for domain-specific services as well as for an overarching service will be gathered and sorted according to relevance through the organisation of workshops and surveys. The strategy will ensure the verification of compatibility with national and international terminology service development / infrastructure initiatives such as EOSC or ELIXIR.

The **service integration strategy** will elaborate an agreement on a common federated architecture for the Base4NFDI terminology service and on a software development plan for supported services. Steps include the introduction of development groups for the suite of tools agreed upon, the implementation of the Base4NFDI terminology services federation core architecture, the implementation of new features coordinated by the development groups, and regular releases and user feedback. These activities are complemented by the integration of ontology mappings and alignments from other working groups or ongoing national cross-domain initiatives, e.g. HMC [79].

The **ramping up for service strategy** will take into account the following aspects. First the coordination between different cross-domain subgroups. The subgroups will organise testing sessions to evaluate and document the current status of the different software services. With the cross-domain subgroups being involved very early in the development, it is possible to harmonise approaches directly which ensures short feedback loops between different developers. These feedback loops also support knowledge exchange and skill sharing. Another important part of this stage is the direct discussion with Section working groups, NFDI consortia, and user groups to get feedback. In addition to the regular testing sessions, regular presentations and workshops are planned to receive feedback. It is also planned to publish a white paper summarising the activities.

Possible challenges and risks: a low risk exists that the consortia cannot agree on a common infrastructure for the Base4NFDI terminology service. An early integration of all consortia in the working groups and a capture of all requirements would mitigate this risk. By using a federated system with common infrastructure definitions, different preferred solutions can be integrated and work together. Additionally, there is a medium risk that there is not enough funding or there are not enough development resources to implement all relevant features. If Base4NFDI identifies

requirements and commonly used tools very early, Base4NFDI can join forces to develop the most relevant features together. Due to this coordination it should be possible to use development resources more efficiently. Nevertheless, if Base4NFDI identifies major development gaps which cannot be filled using Base4NFDI funding alone, Base4NFDI will identify additional funding opportunities.

Potential partners with existing expertise (list the potential partner institutions, their consorti(a) and their roles):
ZB MED (NFDI4Health, NFDI4Microbiota, NFDI4DataScience), TIB (NFDI4Ing, NFDI4Chem, NFDI4Culture, NFDI4DataScience), InfAI (NFDI4Biodiversity), GESIS (KonsortSWD, NFDI4DataScience, BERD@NFDI), DNB (Text+), ZBW (BERD@NFDI, KonsortSWD, NFDI4DataScience), GEOMAR (NFDI4Earth)

4.3   Strategy for development and implementation of Basic Service(s) as well as their integration and acceptance by other consortia

The strategy to achieve the overarching technological and organisational goals of Base4NFDI rests on two core pillars: 1) **community driven co-design** of basic services via the governance structures of the NFDI Association (social governance) and 2) a **common framework establishing quality assured and coherent processes** for continuous identification, fostering, development, operation and evaluation of NFDI-wide basic services (technical governance).

Those two pillars are connected by a **set of criteria** that govern which potential services identified in the Sections become basic-service candidates and later may progress to an NFDI-wide basic service.

Criteria for the selection of Basic Services and strategy for prioritisation

Base4NFDI defines an initial set of criteria for accepting a proposal for initialisation, integration or ramping-up for operation. It shows different types of criteria – some relating to the backing for service candidates across NFDI, others exploring their technical soundness. Base4NFDI considers these criteria to be initial and subject to review and recalibration (by TA3). Any potential service needs to pass four criteria to commence initialisation. There are five criteria to enter the integration phase and four more requirements for a service to achieve "basic service status" during ramping-up for operation. Proposals should also provide further information on items listed below to allow for a prioritisation of proposals.

Table 6: Initial criteria for the selection of basic services

Mandatory criteria for the initialisation phase
1. Approval of 25% of consortia.
2. Compliance with Technical Readiness Level [80] TRL 3-4.
3. Presentation of strengths and weaknesses through a SWOT analysis and transparent reflection on opportunities and risks, with particular attention to existing solutions.
4. Concept for implementation or instantiation of services with technologies that have open licences to ensure transparency and to avoid lock-in scenarios. The software of the service itself has to be licensed under an open source software licence.
Additional mandatory criteria for the integration phase
5. Approval of 50% of consortia.
6. Compliance with Technical Readiness Level TRL 5-6.
7. Provision of a firm calculation of financial support needed from Base4NFDI for reaching the operational phase including a detailed work plan indicating in particular, until when the service can be provided
8. Demonstration of interoperability with NFDI services
9. Demonstration of ability to integrate with other national and international infrastructures, in particular EOSC (compliance with EOSC's Interoperability Guidelines [81]).
Additional mandatory criteria for the ramping-up for the operation phase
10. Approval of 75% ("potentially all" [82]) consortia.
11. Compliance with Technical Readiness Level TRL 7-8.
12. Provision of sufficient evidence TRL 9 will be reached at the end of the funding phase.
13. Provision of sufficient evidence that the operational phase is sustainably supported by commitments from participating or further institutions.

In addition, proposals must provide information on items characterising added quality and acceptance (specific criteria are subject to further development), e.g.,

- Number of interested consortia / communities (above the minimum threshold as defined as mandatory criterion above),

- Number of potential users and if the service is essential for a list of specific use cases,

- Proposals for indicators of service use (cf. chapter 4.4),

- Estimates of resources saved by potential service,

- Estimates of financial support needed for service roll-out and long-term maintenance,

- Ease of adaptation for consortia / user needs,

- Particular results of the SWOT Analysis.

The requirements mentioned above are a minimum set for the services to be included in the Base4NFDI process. At the same time, it will be necessary to adapt this list in the future to include altered or new criteria. The design and dynamic adaptation of the service evaluation toolkit, including the selection of relevant criteria, is part of the work programme (cf. TA3, M3.1). Once approved for development, services can be supported to progress with respect to the criteria. For

example, services that have been developed within one or more consortia can be supported by funding for a generalisation of the service, or improvements regarding robustness, security or performance.

Prioritisation of service candidates

Requirements from the scientific communities represented by consortia will be acquired and collected as described in chapter 4.1. The multitude of potential services, both from NFDI stakeholders or from external providers, are screened and evaluated (TA3) against the criteria above.

To this end, a prioritisation schema will be developed, allowing to weigh the multiple facets and derive a priority list in a transparent and accountable manner. By evaluating the service proposals according to and using weighting criteria (cf. TA3, chapter 5), the value of the individual services is determined. The aim is to allow for an optimal and timely allocation of resources to reach the overall goals of this proposal (cf. chapter 2).

Since some of the criteria influence each other, Base4NFDI is aware that the evaluation of the services will be complex, and dependencies exist that will need to be factored in. Presumably, there will be services that are needed to provide other services. Therefore, such services should be rated higher in the course of the criteria evaluation.

In order to maintain a maximum of objectivity, the prioritisation schema including measurable indicators will be specified before the first complete set of basic service candidates is evaluated. The evaluation processes are designed to be applied in the same way to all service candidates. Therefore, service candidates become comparable, yet TEC involvement in decision processes (figure 8) can also serve as a corrective in cases where indicators offer an incomplete picture. As the primary definition of the prioritisation schema is the base for a sustainable, high-quality and comprehensive portfolio, it becomes part of the core processes (see below): Establishing a regular review of the portfolio's services also allows to incorporate an altered (updated or extended) prioritisation schema to already existing basic services and preserve compatibility with service candidates under review.

Strategy for development of Basic Services

The development process for basic services encompasses **the three process steps (1) service initialisation**, spanning requirements analysis and design strongly tied to the Sections (TA1), and **(2) service integration**, ramping-up/scaling-up, spanning development, testing, deployment and maintenance, as an incremental and fast-moving process (TA2), and **(3) ramping-up for service operation** launching sustainable and reliable long-term service provision (TA2 and TA4). Each

process step requires an application which clearly considers based on a set of criteria whether user needs are fulfilled and technical quality as well as coherence criteria are met. The criteria presented above serve as the initial set which is continuously refined in TA3. If approved by the NFDI Consortia Assembly according to the process described in chapter 3.4, potential basic services reach basic service candidate status and will get funded.

As the needs analysis – such as the shape and nature of NFDI as a whole – is still progressing and will be ongoing in the Sections, Base4NFDI relies on flexible funds for service development. How costs for service development are calculated and how these funds are assigned is thus of utmost importance for the development strategy.

Base4NFDI rests its calculation and allocation schema for flexible funds on its three above-mentioned process steps (for the process description cf. chapter 3.4). **Funds will be allocated based on "building blocks"**. A funding building block (FB) reflects cost- and duration-based average calculations based on exemplary reference development processes (see below). It will assign full-time equivalent positions to a particular process step. The funding for staff is based on the DFG personnel cost rates [83]. Proposals must use and match these building blocks but need to specify how many or which share of each building block they request.

(FB1) Service Initialisation Phase comprises a budget for two postdoctoral researchers or comparable and one doctoral researcher or comparable, resulting in a budget of **226.500 € per year**. It involves the consolidation of definitions, requirements, design and technical foundations and develops a work plan for one specific basic service, resulting in a technical document according to the common framework. It also includes to a limited extent prototyping, piloting and user testing. In this phase typical scenarios might be the exploration or generalisation of potential basic services, e.g. in-depth requirement analysis, a feasibility study or specification for moving forward an existing domain-specific service or a basic service deployed in one or just a few consortia.

(FB2) Service Integration Phase comprises a budget for three postdoctoral researchers or comparable and three doctoral researchers or comparable, resulting in a budget of **447.300 € per year**. It involves ramping-up, development/enhancement, testing, deployment and maintenance, as an incremental and fast-moving process with a growing user base, resulting in a scale-up prototype service and operation reports. In this phase typical scenarios are the adoption or convergence of shared services, e.g. consortia apply or switch to a service while retaining partial solutions which match their specific requirements. A particular challenge will be to deal with dependencies on existing services and infrastructures. Basic services can only succeed if they are properly integrated into the environments of the domain-specific consortia. Work towards

integrating and maintaining such dependencies will necessarily need to be addressed in this phase.

(FB3) Ramping-up for Service Operation Phase comprises a budget for four postdoctoral researchers or comparable, resulting in a budget of **309.600 € per year**. It involves preparing the operational running of a basic service and the set up of an operation model with dedicated service providers. The development work for a service will then be largely completed and it will go through an initial operating phase in which necessary resources for support, maintenance, coordination and ongoing further developments will be validated. In this phase typical scenarios are scalability work, development efforts for revisions and the actual operation effort.

These blocks were compared as a proof of concept with the funding requests for the service development of the featured topics IAM and PID (cf. chapter 4.2). For each of these two topics, one block (FB1) service initialisation and two blocks (FB2) service integration are needed. For IAM, phase (1) for consolidating service specifications and the integration phase (2) can start in parallel and the service would move on in year 3 to the operational phase with block (FB3) over 3 years. For PID, the service development will start with block (FB1), followed by block (FB2) and block (FB3) each over two years. The planning for these two topics confirms that the figures provide a sound basis and that the budget for these blocks can be used as an overall cap for each service phase. Each application for a funding phase must, however, specify the expenses incurred and a funding block can also be allocated proportionally if necessary. In parallel to the service funding, the consortia can apply for Service Stewards who support the consortium-specific implementation of one or more services. In particular, they facilitate the communication between service providers on both sides, the basic service provider and the providers of domain-specific services in order to control dependencies between services. Service Stewards are calculated as postdoctoral researchers and can be activated for TA1, TA2 and TA3.

Model scenario of the original bid for the development of Basic Services

Base4NFDI initially applied for flexible funds of €27.1 million over a period of 5 years. Assuming typical basic service development may require one or more blocks (FB1) for the initialisation, one or two blocks (FB2) for the integration and two blocks (FB3) for ramping-up for operation. Base4NFDI is fully aware that there are no "average" services, particular in light of the variety that might arise from the Sections (cf. chapter 4.1). Yet for setting up a work-plan, assumptions are necessary. Based on these, the following scenario calculation allows Base4NFDI to conduct 34 initialisation phases, 20 integration phases and 20 operation phases, each with a duration of one year. In this budgeted scenario Base4NFDI would also fund 54 person-years for Service Stewards.

As an illustration, the following scenario can be considered: Base4NFDI funds a first round of six initialisation phases in 2023, including the featured topics IAM, PIDs and TS, and one integration phase as IAM is likely to be able to enter the second phase swiftly. In 2024, with the project picking up speed, nine further initialisation phases and six integration phases could follow. At this point, all three featured topics move on to or with integration. Another nine initialisation phases, eight integration phases, and two ramping-up for operation phases, the latter including IAM, could follow in 2025, the expected peak year for using the flexible funds to develop basic services. From 2026, the number of initialisation phases would decrease to six and finally four in 2027. Those four would primarily focus on gathering and consolidating requirements from additional consortia adopting a basic service. In this scenario up to five integration phases would be funded in 2026 while ramping-up for operation phases would increase to nine in 2026 and 2027. As this scenario implies, the funding can very flexibly adapt to new service candidates as well as requirements from communities that have not previously been considered in the development process.

In parallel with basic service developments, service stewards are allocated to ensure optimal interfacing between the consortia and the developers of basic services. The number of service stewards is projected to increase from five at the beginning in 2023 to 13 in 2025 and will remain at this level. Service stewards starting in 2023 will primarily focus on scouting and communicating across consortia, they will later – together with those joining over time – concentrate increasingly on the adoption of and support for established basic services.

This scenario was taken as a rationale to calculate the distribution of flexible funds across Task Areas and years. Based on this rationale, **Base4NFDI expected up to ten services to be fully developed to the operational phase with the requested budget.**

Figure 8: Scenario for basic service candidates moving through three phases of development

Updated scenario for the development of Basic Services

In light of the DFG funding cuts of 50% to the flexible funds, Base4NFDI can provide flexible funds of €13.5 million over a period of 5 years. Upon decision of the Consortia Assembly €10.9 million are allocated for service initialisation, integration and ramping-up for operation phases and €2.6 million are allocated for a fix number of 7 service steward positions running from 01.06.2023 to 29.02.2028. Based on the above rationale with the same budget amount per funding block, **Base4NFDI expects up to five services to be fully developed to the operational phase with the available budget.**

It is crucial that the development processes are implemented in a transparent and stable manner and are simultaneously able to tolerate specific requirements. The processes developed for service portfolio and life-cycle management in the context of Helmholtz Federated IT Services (HIFIS) [84], whose services are already partly in use by some of the consortia, can serve as a blueprint for some of the considered aspects (cf. M2.2).

Strategy for implementation of Basic Services

Base4NFDI's strategy for implementation of basic services builds on a process framework for the service portfolio. This includes a **service portfolio management** (M2.2) with key processes for service recruiting, onboarding, reviewing, offboarding procedures (cf. TA3, chapter 5); they are accompanied by rules for the operation of the services. The purpose of service portfolio management is to enable basic service candidates to become basic services for NFDI. Given the substantial number of potential services, services have to be managed according to established service-life-cycle standards. The maintenance of the service portfolio goes hand in hand with the validation of existing services and a regular review of the portfolio. These regular reviews particularly allow for the incorporation of altered/updated technical and/or prioritisation criteria. The acceptance and added value of the portfolio is monitored both quantitatively (i.e. monitoring active users and service usage, yielding a quantitative measure of added value, cf. TA3), as well as qualitatively by obtaining feedback from user communities (M2.3). This explicitly includes the possibility of offboarding of services if requirements are not met (anymore).

A **process framework** for the service portfolio shall comprehensively establish the rules by which the services are provided (M2.2). These processes define common rules for all roles involved. Adherence to the processes is an indispensable basis for the federated provision of services.

The trustworthy and constructive cooperation of the participating research institutions will be underpinned by contractually secured commitments between institutions employing a service in the consortia and the provider(s). For similar use cases involving multiple services, the extent to which bilateral agreements can be avoided and instead merged at some points through joint

agreements will be explored. In extension steps, the aim is to further reduce the number of additional service level and usage agreements. Regarding the diversity of participating entities in NFDI, a set of contractually secured commitments focuses on what is feasible, prioritising the seamless use of basic services. These joint agreements consider both a) the provision, and b) the use of services. They create the conditions for organisational and fair use requirements. Legal aspects such as liability, warranty, confidentiality, duration and measures in the event of violations are also taken into account (cf. M2.1, chapter 5). This enables participating research institutions to use the services of different providers in a secure and simple manner.

The individual service is described in terms of its service level (SL). A service can be offered on several service levels, which differ in quality or quantity. Service providers and service recipients agree to a certain service level and other contractual aspects. Templates for both, service levels and service level agreements are developed and made available along with exemplary suggestions (cf. TA2, M2.1).

Templates will also cover different use cases regarding GDPR compliance. Three prominent examples are users who decide to use a service and can self-consent to the data protection policies of the services or a research institution which decides to use the service. In the latter case, the GDPR requires an agreement between the service recipient and the provider – a situation for which useful templates already exist. A third use case is if the user group is composed of employees of different research institutions. In that case a joint controller agreement must be agreed on. This is also the case if the user group contains employees of the providing institute.

Core processes, regulations, contractual commitments and policies are the basic pillars for a trusting cooperation. They form the framework and the manual for the collaborative offer and the use of services. Changes and adaptations can have significant technical, administrative, legal and collaborative implications. A review and approval by the governance structures should be foreseen.

Strategy for integration

One of the most crucial factors for success will be how well the **collaboration with existing platforms and services** can be organised. Base4NFDI will provide a number of services whose sole purpose is to be integrated with existing portals and infrastructures such as data portals and research information systems used widely in particular communities, for example the DBLP computer science bibliography [85] or da|ra [86] for social science research data, etc. In other instances, integration will have a number of substantial dependencies. A terminology service will rely on and integrate with existing vocabularies/terminologies, an IAM service will have to be

integrated into existing portals/services. The success of basic services will depend on their ability to be properly integrated into the environments where "the users are".

Considering the aforementioned, the role of competent technical service integration is of utmost importance. It needs to specify e.g. how collaboration with existing services will take place and how Base4NFDI will make sure it has the necessary resources to work towards integrating and maintaining any dependencies. Service Stewards will support this process (cf. chapter 3.4).

The first aim of service integration is that the service provider makes the services available in such a way that seamless access and use by the users of all interested consortia as well as the respective cooperation partners is possible (cf. chapter 4.4).

Once it is verified that a service can be integrated, the customisation to the specific needs of a community will commence. In this phase, the services will be made available by the providers, tested and activated for the users after approval. The required depth of integration will vary from service to service. With the release of the service and enablement for use, the transition to the operational phase is planned for all components.

In addition to the provision of the service with the agreed service level, the operation mode includes the permanent monitoring of the service quality, the recording and accounting of the use of the services as well as the support of the users in the sense of technical support.

Being an intrinsic component of technical service integration, the collection of quantitative service usage data is integrated and corresponding data is continuously and centrally collected to derive service KPI. These data are further processed for service review (cf. M3.1 and M3.2, chapter 5).

4.4   Sustainability and operation of Basic Services

Reliability of NFDI-wide basic services will be a critical prerequisite for the consortia to use and support (procedurally, logistically and financially) a service in the long-term. Thus, sustainability of NFDI-wide services is mainly one of economic viability. Additional factors for sustainability are impact, adaptability and the capacity to deliver added value to the designated target community (in this case: mainly providers of community-specific resources and the wider NFDI community).

The Base4NFDI project will develop sustainable business models for each service as a part of its work programme (cf. TA2, chapter 5). For this purpose, Base4NFDI can draw on existing case studies and literature on the operation of scientific information infrastructures [87].

In cases where existing basic services are integrated or extended, their provision for NFDI consortia could be organised as an extension of established activities, which are already in place within and across institutions – nationally and internationally. In other cases, self-sustained

service provision may be necessary. In both cases, the NFDI Association can play an important role in organising mandates and sustaining operations by entering into service agreements (cf. M2.1) with providers. Costing models can (but need not) be part of such agreements. Base4NFDI expects that the economic viability of basic services will partly depend on the willingness of the federal government and the federal states to enter into long-term financial agreements for the National Research Data Infrastructure and its various elements after the current initial funding phase ends in 2028.

On a final note, Base4NFDI is aware that basic services will only add value if they are properly integrated with existing platforms and/or portals (such as PID or IAM). Therefore, a considerable part of Base4NFDI's sustainability approach will be devoted to managing these dependencies and the integration of the basic service into the overall ecosystem.

Approach to service sustainability

The viability of the structures created by Base4NFDI beyond 2028 will strongly depend on the **outcome of the NFDI structural evaluation** scheduled for 2025 by the German Council for Science and the Humanities, which delivers recommendations for funding decisions for the NFDI post-2028, when the current programme ends. Base4NFDI aims to contribute to this evaluation and the general success of the NFDI through the implementation of efficient, integrative and well-balanced processes that lead to the development of broadly negotiated, robust and highly scalable basic services across the NFDI.

The Base4NFDI work program will lay the groundwork for an infrastructural backbone which is meant to serve NFDI in the long run. Base4NFDI is in a unique position to enable the integration of existing services of these providers into such a technical backbone. An additional avenue for assuring long-term viability is that services that fail to qualify as NFDI-wide basic services but prove valuable to a more limited number of scientific domains can be sustained by the respective consortia or be submitted to a common "**tool pool**" for re-use and/or joint maintenance.

Generally, Base4NFDI will increase the sustainability of its services by including a broad range of relevant stakeholders as a part of the development process. This will help to improve not only the technological, but also the business and market maturity of the basic service offerings.

To this end, Base4NFDI follows a strategic development process that leverages the capacity and expertise of the service providers of all consortia, while ensuring the necessary engagement of the operators of the basic services, as part of an open and iterative process that takes into account the entirety of the process steps and builds on the end users and 'target' communities of the respective NFDI consortia.

Additional to the strategies on viability (cf. chapter 3.4) and the operating model (cf. chapter 3.5), the following development principles constitute Base4NFDI's approach towards sustainability:

1. Base4NFDI intends to proactively ensure risk mitigation and avoid potential lock-in effects. Base4NFDI shall achieve this by building on existing standards, technologies and solutions.

2. Define clear rules for an open, fair, and transparent functioning of the basic services, including how these would be guaranteed in the long term through a suitable governance structure and business model. Base4NFDI shall achieve this by promoting and preferring Open Source solutions which are supported by a dedicated developer community and for which a high quality is assured (TA2).

3. Adopt appropriate governance models to ensure the proper supervision of NFDI-wide basic services, potentially within the NFDI Association, fostering interconnections with existing initiatives, e.g. EOSC. Base4NFDI shall achieve this by fostering the engagement of the respective NFDI consortia by providing them with appropriate business and operating models that can convince through the value and, where appropriate, longevity of the relationships between the end-user communities and them as service providers (M2.1).

4. Deploy the technical infrastructure of basic services, with a strong focus on the needs of the end user communities. Base4NFDI will achieve this by actively engaging in service usage monitoring and accounting (where applicable).

Sustainability of service operation

As of today, users of almost all types of IT-based services expect high service availability, concise information about the status of operation, and professional, user-oriented support. This demand is independent of the function of the requested service, the payment model, or the community a service is provided for. It is therefore evident and a clear goal for the operation of the Base4NFDI services, that, in addition to meeting the aforementioned technical (cf. chapter 4.3) and sustainability criteria, the specific expectations of the NFDI community are met by prov iding professionally operated services with adequate support.

The foundations for the successful operation along those lines inherently lie in the construction of the NFDI where many renowned academic IT centres and infrastructure providers contribute in their respective consortia. In Base4NFDI, they contribute their expertise and existing IT service management processes to ensure that NFDI-wide basic services can be swiftly deployed and rolled out to targeted users. In case further capabilities will be required or suggested by basic service providers, procedures will be in place to add new participants to Base4NFDI.

Special emphasis is placed on comprehensive operating models for the NFDI-wide basic services. They will include information about governance, service levels, support contact points, and technical interfaces for service monitoring and management. Standard templates for such models are provided to guarantee that all services are operated according to equal standards and that communication as well as governance are equally enabled. Furthermore, standard templates for contracts and agreements between service providers and service consumers will be developed to assure a consistent level of service quality and data protection. Such a set will include templates for service contracts, operational level agreements (OLAs), data protection concepts and agreements, technical and organisational measures, and more. A general legal verification of the documents will be conducted to ease the process for the individual basic service providers and to provide a common legal foundation for service operation within Base4NFDI.

During operation, procedures will be established for continuous monitoring of services (TA3). Such monitoring has multiple dimensions including health status, events, performance, usage accounting, and resource prediction. The respective providers of basic services will ensure that the necessary technical infrastructure is in place to gather the respective monitoring data and make it available to stakeholders such as users, who e.g. want to get information about the health status of a service to judge their individual problems, or to system administrators, who need to adjust infrastructure resources in case of growing demand. This monitoring information will be centrally maintained and will also serve as input to measuring KPIs (cf. TA3, chapter 5 and chapter 3.4).

4.5   Organisational and communication strategy

Organisationally, Base4NFDI is built on the collaboration of all NFDI consortia (domain-specific) and commits to continue this practice which is crucial to its success. As a key principle, Base4NFDI avoids any parallel governance structures between Base4NFDI and the NFDI Association. Base4NFDI is therefore tightly integrated into the NFDI. In fact, it is the NFDI consortia that will – within the NFDI Consortia Assembly, make all decisions of consequence for Base4NFDI (development strategy and finances). For a detailed description cf. chapter 3.4

Given that Base4NFDI is setting out to organise an unprecedented harmonisation process for research infrastructure services in Germany, the **communication strategy** is key (M4.2 and M4.3). This is because the process holds opportunities for many service providers and the communities they serve, but might also elicit reservations from others who already operate successful services. Good and transparent communication will be essential to ensure acceptance. Opportunities to participate in and shape the process must be clearly communicated. Even more importantly, the criteria for the selection of a service candidate to enter implementation, integration and finally the stage of operation must be actively communicated to

all interested parties. A **publication policy** will set out how project results and policies will be published on a regular basis (cf. chapter 5 M4.3). The Base4NFDI Coordination Office will be equipped with a professional communication officer assisting in the task. Base4NFDI's operation will make many processes in RDM easier and more efficient also for researchers as end users. Base4NFDI's communication strategy will also aim to make the various scientific communities aware of the added value that the NFDI brings to them.

Reporting will be a key factor to keep all stakeholders informed. NFDI's OpenProject project management platform will be used by the Coordination Office to generate monitoring reports for the Base4NFDI management committee and the NFDI Consortia Assembly. The platform also serves as an open information tool for all stakeholders within the NFDI including, of course the sections and the boards simply because everyone active within the NFDI is entitled to access to the common OpenProject instance (cf. chapter 5, M4.2).

Dissemination of results: The process of developing NFDI-wide basic services following a bottom-up approach is likely to hold many lessons to be learned for science and science policies. Base4NFDI acknowledges that itself will certainly experience a steep learning curve that will lead to continuous improvements of its processes. The **scientific study** (cf. chapter 5.4) to assess the impact on research infrastructures and research will be the basis for **policy briefings** (cf. chapter 5 M4.3). Policy briefings serve to communicate insights on structures, processes and financing of basic services at an early stage to stakeholders in the NFDI Association bodies, the DFG and the Joint Science Conference (GWK).

Capacity building: The initiative will provide training and practical hands-on support of basic service users. Consultancy will be available to consortia wishing to implement services as part of their work programmes.

5   Work programme

Overview of Task Areas

Table 7: Overview of Task Areas

Task Area	Measures	Co-Spokesperson(s)
TA1 Service requirements, design and development	**M1.1** Coordination and coherent service landscape **M1.2** Support for user-driven requirements analysis, piloting and testing **M1.3** Support for technical software evaluation, design and development **M1.4** Service initialisation (flex-funds)	Fraunhofer Society (FOKUS) **Dr. Sonja Schimmler** Engineering Sciences Leibniz Association **Axel Klinger** Engineering Sciences University of Bielefeld **Prof. Dr. Alexander Sczyrba** Life Sciences
TA2 Service integration and ramping-up for operation	**M2.1** Procedural framework for service integration and operation **M2.2** Service portfolio management and tool pool **M2.3** Quality assurance for usability and software sustainability **M2.4** Service integration and ramping-up for service operation (flex-funds)	Leibniz Association **Dr. Brigitte Mathiak** Humanities & Social Sciences Helmholtz Association **Sören Lorenz** Natural Sciences Max-Planck Society (MPCDF) **Dr. Raphael Ritz** Natural Sciences
TA3 Service coherence processes and monitoring	**M3.1** Defining, setting up and continuously adjusting the operation of the Base4NFDI decision-making process **M3.2** Monitoring overall basic service progress **M3.3** Preparing decision dossiers and decision-making templates for entry of the basic services in the three different basic service phases	Leibniz Association **Prof. Dr. Juliane Fluck** Life Sciences Prussian Cultural Heritage Foundation **Reinhard Altenhöner** Humanities & Social Sciences Helmholtz Association **PD Dr. Thomas Schörner-Sadenius** Natural Sciences
TA4 Project Governance	**M4.1** Coordination Office **M4.2** Outreach, coordination of user training and support **M4.3** Systematic assessment of impact of Base4NFDI	University of Göttingen **Regine Stein** Humanities & Social Sciences TU Dresden **Prof. Dr. Lars Bernard** Natural Sciences Leibniz Association **Dr. Bernhard Miller** Humanities & Social Sciences

NFDI4Base is organised in **Task Areas (TA)**, three of which are responsible for the processes of service-development at the various stages of maturity (figure 9):

1) **TA1 Service Requirements, Design and Development** supports NFDI sections in identifying potential basic services and accompanies potential basic services from when they are first conceived until they successfully enter the service initialisation phase. Subsequently, it coordinates the individual steps of the service initialisation phase – requirements analysis; software evaluation and service design; service development (enhancement/adaption); and piloting and testing. In all these steps TA1 strongly crosslinks with the NFDI Sections.

2) **TA2 Service Integration and Ramping up for Operation** takes basic service candidates – having successfully passed the initialisation step in TA1 – forward to service integration and service operation ramp-up and provides a procedural framework for both phases. Measures on software quality and user acceptance support service improvements. Approved basic services become part of the Base4NFDI service portfolio, managed in TA2.

3) **TA3 Service Coherence Processes and Monitoring** coordinates the decision-making workflows between Base4NFDI and the NFDI Association bodies and lays the foundation for the decisions on continuation of service developments, allocations of related resources, involvements of external partners or even discontinuations of services or developments and ensures that decisions are traceable and transparent. TA3 establishes an evaluation framework, monitors the development of the basic service candidates carried out in both TA1 and TA2 and thus ensures that processes stay on track and alerts for action in case of derivations. TA3 dynamically adapts this framework to the different needs of upcoming basic service categories.

4) **TA4 Project Governance:** TA4 is responsible for coordinating and managing Base4NFDI activities, maintaining networks within but especially outside the NFDI, evaluating, monitoring and reporting, and systematically assessing the impact of the basic service development process in support of science policy. In addition, it is in charge of contract management, onboarding new partners and outreach.
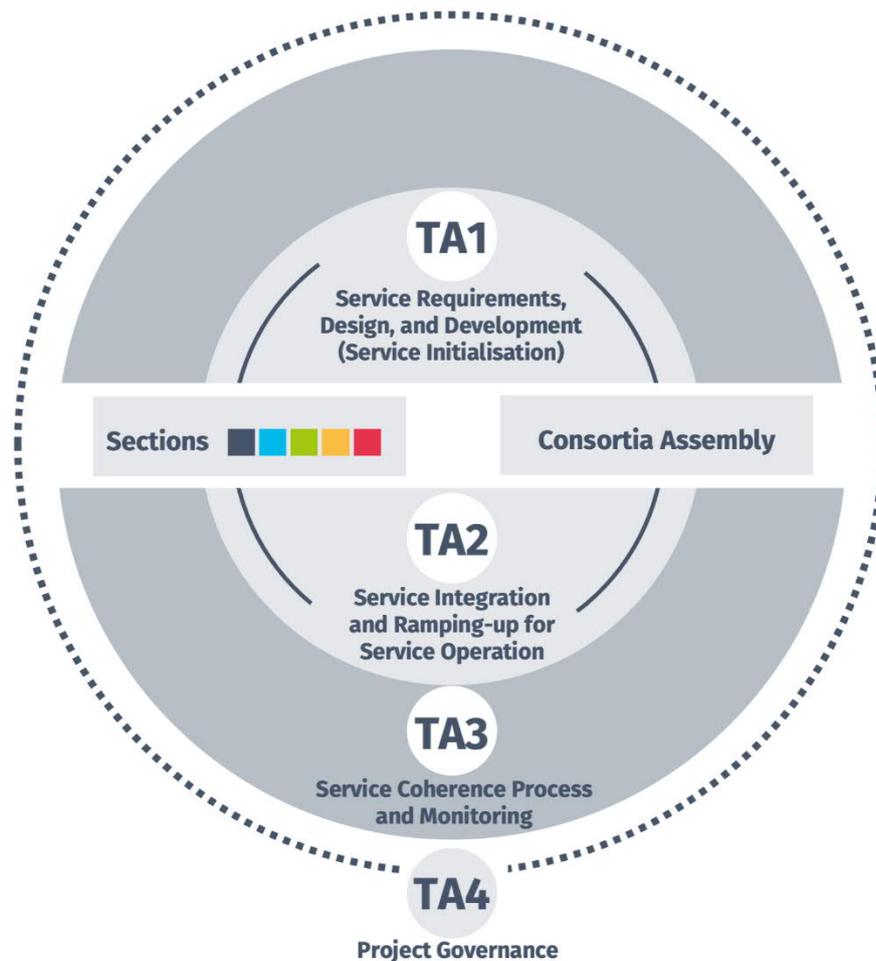
Figure 9: Task Areas in Base4NFDI's iterative development process

5.1   TA1 - Service requirements, design and development

Given that many cross-cutting issues in the NFDI are only beginning to emerge, Base4NFDI can expect a significant number of proposals to be considered for a baseline service, many of which merit in-depth consideration. TA1 will support all activities in the NFDI sections and its WGs related to identifying potential basic services and preparing proposals for service initialisation. The actual selection of basic service candidates that enter the initialisation phase follows the decision, evaluation and prioritisation procedures as outlined in chapters 3.4 and 4.3. TA1 will be supported by the frameworks and reporting measures developed in TA3.

After a potential basic service passes the formal criteria for acceptance (cf. chapter 4.3, figure 8), it enters the initialisation phase. TA1 supports the first steps in establishing a basic service candidate. It will initiate a requirements analysis across consortia and prospective users. Based on its results, a software evaluation will be carried out and a design proposal will be put forward. Subsequently, the basic service will be developed, piloted and tested. Once the basic service is

ready for integration, it will be handed over to TA2. All these steps are progressed in close collaboration with the related NFDI sections.

Measure 1.1 (M1.1): Coordination and coherent service landscape

Contributors: BiBi (lead), FOKUS, TIB

The objective of this measure is to oversee all basic services that are in the initialisation phase. This measure ensures that all steps within the initialisation phase – requirements analysis; software evaluation and service design; development; and piloting and testing – are carried out in accordance with a common framework. It further oversees all potential basic services, basic service candidates and the NFDI basic service portfolio (in cooperation with TA2) and their interdependencies, to assure that a coherent service landscape evolves.

Action 1 Coordination of Service Initialisation Phase The action keeps track of the status of all basic services that are currently running through the initialisation phase, and intervenes in case of deviations. Accompanying this, a common framework is developed that covers all steps of the initialisation phase – requirements analysis; software evaluation and service design; development; and piloting and testing. It is further ensured that, for each basic service that runs through the initialisation phase, all steps are carried out in accordance with the developed common framework.

Action 2 Coherent Service Landscape The action oversees all basic services and their interdependencies, to assure that a coherent service landscape evolves. It especially examines all basic services that are currently being set up, keeps track of the global design and architecture, and uncovers inconsistencies and blind spots.

Action 3 Service Stewardship A flexible number of service stewards cooperate closely with the NFDI sections and the consortia to support the setup of a coherent service landscape, especially by overseeing the potential basic services that are currently being set up and the needs brought forward from the NFDI sections and the consortia.

Table 8: Deliverables and Milestones in M1.1

Mile-stone	Delive-rable	Type*	Description	Due end of
MS1.1.1		S	Preparations for framework fo initialisation completed	8/23
	D1.1.1	SP, R	Common framework for initialisation phase	8/23
MS1.1.2		S	Collect data on current status of services	02/24 02/25 02/26 02/27 02/28
	D1.1.2	R	Yearly report on current status of services in initialisation phase	02/24 02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 1.2 (M1.2): Support for user-driven requirements analysis, piloting and testing

Contributors: BiBi, FOKUS (lead), TIB

The objective of this measure is to support the user-driven parts of the initialisation phase of a basic service candidate with the preparation of templates and guidelines for all steps from requirements analysis to piloting and testing. These templates and guidelines will be developed and continuously improved by a specialist for software development.

Action 1 Supporting Potential Basic Services The action supports all activities in the NFDI sections related to identifying potential basic services and preparing related proposals for service initialisation. It will support service providers to get in contact with an appropriate NFDI section and WG. In case such a WG does not yet exist, it supports service providers in writing a proposal for a WG. It will further accompany the WG and service providers in writing a proposal for the envisioned basic service.

Action 2 Supporting Requirements Analysis The action supports the user-driven requirements analysis by setting up a standardised toolkit, comrising qualitative and quantitative methods such as surveys, interviews and workshops. It further supports the requirements analysis by supporting the application of this toolkit. The goal is a user-driven requirements analysis that covers a wide range of prospective consortia and its user bases.

Action 3 Supporting Piloting and Testing This action supports the user-driven piloting and testing by setting up a standardised toolkit, harmonising piloting and testing strategies. It further supports the piloting and testing by applying this toolkit. The goal is the integration into the first

services of the consortia, and testing with first prospective users. In the next phases, i.e. integration and ramping-up, the service will be rolled out for wider dissemination (cf. TA2).

Action 4 Events for Requirements Analysis, Piloting and Testing Workshops, hackathons, and other events will be organised for the services during different phases of the service development life cycle, especially during the requirements analysis and piloting and testing. For instance, within the requirements analysis phase, this includes the organisation of coachings that introduce methods to gather personas, epics and user stories and the organisation of workshops to apply them to the individual basic services. Within the piloting and testing phase, this may include events to foster a dialogue between existing and new service providers and to foster service distribution.

Action 5 Service Stewards A flexible number of service stewards support the requirements analysis and the piloting and testing, especially by establishing links to the consortia and its user bases.

Table 9: Deliverables and Milestones in M1.2

Mile-stone	Delive-rable	Type*	Description	Due end of
	D1.2.1	R	Requirements analysis strategy	5/23
	D1.2.2	R	Piloting and testing strategy	02/24
	D1.2.3	SP	Events for initialised services	4,6,8,10,12/23 2,4,6,8,10,12/24 2,4,6,8,10,12/25 2,4,6,8,10,12/26 2,4,6,8,10,12/27 2/28
MS1.2.1			Support for requirements analysis completed, for each service	02/24 02/25 02/26 02/27 02/28
MS1.2.2			Support for piloting and testing completed, for each service	02/24 02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 1.3 (M1.3): Support for technical software evaluation, design and development

Contributors: BiBi, FOKUS, TIB (lead)

The objective of this measure is to support the technical parts of the initialisation phase, including software evaluation, design and development. This measure will support detailed inspections of each potential basic service running through the initialisation phase (M1.4).

Action 1 Supporting Software Evaluation and Service Design This measure will support software evaluation by monitoring the service landscape and ensuring that there are no blind spots. It will also support the design of the services according to the requirements, while taking into account the technical framework.

Action 2 Supporting Service Development This action supports the service development, i.e. enhancement and adaption, by establishing standards for Base4NFDI software development and by fostering agile and open source software development. The action will build on existing standards, and will be in close exchange with TA2.

Action 3 Events for Software Evaluation, Service Design, and Service Development If deemed necessary during development, events will be offered to support the development of services, e.g. in terms of quality and sustainability. Coachings to support the development of services will be run by NFDI partners or external experts.

Action 4 Service Stewards A flexible number of Service Stewards support the software evaluation and service design, especially by picking up current technological trends within the consortia and its user bases.

Table 10: Deliverables and Milestones in M1.3

Mile-stone	Delive-rable	Type*	Description	Due end of
	D1.3.1	R	Software evaluation plan and service design template	8/23
	D1.3.2	R	Service development guidelines	02/24
	D1.3.3	SP	Events depending on initialised services	5,11/23 5,11/24 5,11/25 5,11/26 5,11/27
MS1.3.1			Support for software evaluation and service design done, for each service	02/24 02/25 02/26 02/27 02/28
MS1.3.2			Support for development done, for each service	02/24 02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 1.4 (M1.4): Service initialisation (flex-funds)

Contributors: BiBi, FOKUS, TIB

As soon as a basic service has been thematically checked by the corresponding NFDI Section, formally checked by TA3 and approved by the Consortia Assembly to enter the initialisation phase, a measure is created for this service, and initial funding is awarded for up to one year. After a successful start, the service receives further funding for up to two years. Following the completion of the initialisation phase (checked by TA3), the service will enter the integration and ramping-up phase, and thus be handed over to TA2. All basic services that do not successfully complete the initialisation phase will be included in the tool pool (cf. TA2, M2.2)

The initialisation phase starts with a requirements analysis to gather the needs of the community, preceded by a software evaluation to choose the most appropriate tools. The basic service will then be designed and implemented based on the outcomes. Finally, it will be piloted and tested in cooperation with a selected number of consortia and users.

Action 1 Requirements Analysis for Topic X A requirements analysis will be carried out to assess the needs of the community. The requirements analysis is done both from the bottom up, by having the services in the consortia present their needs for solutions to common issues to the NFDI sections and their working groups, and from the top down, by systematically bringing

together all the services in the consortia and exploring possible commonalities in relation to the issues already identified in the working groups.

Action 2 Software Evaluation for Service X A software evaluation is carried out, which ensures that the most suitable software solutions are chosen. When evaluating existing solutions for basic services, the possible service candidates for a topic are collected and compared with the requirements. In addition to the requirements, the criteria mentioned in chapter 4.3 are also taken into account in the selection process in order to ensure a stable, secure, sustainable and sufficiently scalable basic service.

Action 3 Design of Service X Based on the software evaluation, the action fosters a profound service design. The design includes the fulfilment and, if necessary, the improvement of the requirements for basic services as well as the calculation of costs for funding of the initialisation and integration phases.

Action 4 Development of Service X The development, i.e. enhancement and adaption, of basic services builds on existing software solutions, which are extended within the NFDI for the broadest possible use by the services of the consortia. In the development phase, the basic service providers are supported by software architects in order to ensure high quality and scalability of the services according to recognised rules of software development.

Action 5 Piloting and User Testing of Service X In the piloting and testing phase, the basic service will be provided as a prototype and integrated into two or three services of the consortia as a proof of concept to demonstrate its applicability. It further comprises user testing with a selected group of users.

Table 11: Deliverables and Milestones in M1.4

Mile-stone	Delive-rable	Type*	Description	Duration after start
	D1.4.1	R	Documentation of requirements analysis	3M
	D1.4.2	R	Documentation of software evaluation	6M
	D1.4.3	R	Documentation of service design	6M
	D1.4.4	S	Service prototype	12M
	D1.4.5	S	Service piloting and user testing	12M
MS1.4.1			Service ready for integration	12M

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

5.2   TA2 - Service integration and ramping-up for operation

Basic service candidates that are determined to be ready for integration and ramping-up and that meet the criteria as outlined in chapter 4 will be managed and receive flexible funds and will be supported through this Task Area. As such, TA2 will support basic service candidates to progress smoothly through the phase **(2) Service Integration** and – ideally – subsequently, through the phase **(3) Ramping-up for Service Operation** (cf. chapter 4.3). A procedural framework for service integration and for ramping-up will guide basic service candidates through these phases, supported by service stewards, and accompanied by quality measures for user acceptance and software sustainability. If successfully integrated and ramped-up, basic services can be approved as basic services for NFDI consortia and be included in the Base4NFDI service portfolio. TA2 will provide an operational frame for service portfolio management including service-life-cycle management. A tool pool will be provided for the re-use of these services or components that do not reach the necessary maturity to become an NFDI-wide basic service.

Measure 2.1 (M2.1): Procedural framework for service integration and operation

Contributors: GEOMAR (lead), GESIS, MPCDF

Basic services for NFDI are intended not only to relieve consortia from dealing with generic aspects that distract them from the efficient development of the intended domain-specific services, but also to enable cross-domain collaboration at the technical-organisational level (cf. chapter 2). Therefore, this measure aims to ensure that basic service candidates are integrated with or are at least interoperable with the domain-specific consortial service landscape on an operational level, to ensure the NFDI-wide access and reuse of knowledge, data, tools and other resources. Additionally, basic services shall be compatible with (or even part of) already existing (partial) solutions of other national or international initiatives (cf. chapter 4.3). In the event of recommendation for the operational ramp-up by the TEC (cf. chapter 3.4), basic service candidates must prove their suitability as useful, durable and reliable services in ramping-up for operational services phase (cf. chapter 4.3 and chapter 4.5). This ramp-up phase addresses issues such as user experience, scalability, capacity to provide the service to users, service level descriptions and templates for agreement, financing needed for rollout, operation, user support and long-term maintenance, and an appropriate business and operation model. The development, adaptation and application of integration and operation procedures to basic service candidates will be supported by service stewards. Additionally, service stewards will support the evaluation of the integration and ramping-up phases, applying the procedures as designed and conducted by TA3. This measure will be conducted in close communication with the NFDI sections.

Action 1 Procedures to support service integration Action 1 develops and establishes transparent procedures to support the integration of basic service candidates along predefined criteria, as outlined in chapter 4 and defined by TA3. Each basic service will be evaluated according to these procedures, although individual procedural adaptations might be necessary.

Action 2 Procedures to support ramping-up for operational services Action 2 develops and establishes procedures to control the ramping-up for service operation for each given basic service candidate and to test one or more operating scenarios to allow for an evaluation of the candidate's potential for the inclusion in the Base4NFDI service portfolio.

Action 3 Business models Action 3 develops a set of exemplified business models for basic services compliant with predefined criteria by TA3 (e.g. non-profit, as exercised by NHR, Helmholtz, EOSC; cf. chapter 4.4). These models will serve as blueprints for each given basic service candidate and service.

Table 12: Deliverables and Milestones in M2.1

Milestone	Deliverable	Type*	Description	Due end of
MS2.1.1		F	Procedures for service integration described and applicable	08/23
	D2.1.1	R	Report on service integration procedures	08/23
MS2.1.2		F	Procedures for service operation ramp-up described and applicable	11/23
	D2.1.2	R	Report on procedures for service operation ramp-up	11/23
MS2.1.3		W	Workshop on suitable business models	02/24
	D2.1.3	R	Recommendation of a set of appropriate business models	11/24
MS2.1.4		S	Application and adaptation of procedures and business models	05-02/25
	D2.1.4	R	Report on Experiences of initial procedure application	02/25

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 2.2 (M2.2): Service portfolio management and tool pool

Contributors: GEOMAR (lead), GESIS, MPCDF

The goal of TA2 is to enable basic service candidates to become basic services for NFDI. Assuming multiple candidates are successful in this endeavour, services must be managed according to established service-life-cycle standards. Additionally, they should be compiled into a service-portfolio, to provide a comprehensive overview and access to NFDI basic services, although services are mainly decentralised by established or upcoming providers. That some services may succeed implies that others may not. To preserve valuable resources built within finally not established or phased-out services, such as (meta)data, processes, software, and users, which can be redirected to similar services, end-of-life-scenarios have to be found for services that were not selected to be continued from both TA1 and TA2. Therefore, the aim of this measure is to establish both, a service-portfolio and life-cycle management for those services, that succeed in the process of basic service evaluation and a tool pool for reusing even parts of previous service developments from other contexts.

Action 1 Define Base4NFDI service-life-cycle standard The action will define a service-life-cycle standard e.g. ITIL, COBIT, ISO 20000. The service life cycle standard serves as a policy and can in some cases supplement the standards practised by potential providers. For Base4NFDI and related coordination procedures – both building on common standards.

Action 2 Establish and maintain service portfolio framework Development, implementation and maintenance of a service portfolio management for Base4NFDI. Here, concepts and solutions as HIFIS (cf. chapter 4.3) and/or the EOSC marketplace are considered as starting points and/or potential integration frameworks for this action.

Action 3 Establish and maintain a tool pool Development, implementation and maintenance of a tool pool to allow for re-use of elements developed in the context of Base4NFDI that did not get promoted to basic services.

Table 13: Deliverables and Milestones in M2.2

Milestone	Deliverable	Type*	Description	Due end of
MS2.2.1		F, R	Concept for a service lifecycle management for Base4NFDI developed	08/23
	D2.2.1	R	Publication of Base4NFDI service life cycle management	11/23
MS2.2.2		F	Concept for a service portfolio framework for Base4NFDI	11/23
	D2.2.2	R	Publication of Base4NFDI service portfolio framework	11/23

MS2.2.3		F	Concept for a tool pool framework and publication	11/23
	D2.2.3	R	Publication of tool pool concept	11/23
MS2.2.4		S	Implementation, and yearly adaptation and maintenance of developed concepts	02/25 02/26 02/27 02/28
	D2.2.4	R	Yearly report on usability of implemented concepts	02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 2.3 (M2.3): Quality assurance for usability and software sustainability

Contributors: GESIS (lead 1), MPCDF (lead 2), GEOMAR

Basic service candidates, processed through TA2, will profit from this quality assurance measure that addresses two dimensions: (1) user acceptance and (2) software quality. The measure will support improving basic service developments, especially in the phase of ramping-up for service operation.

Usability of services is crucial for their acceptance and broad use. User studies will be conducted via user panels, i.e. focus groups to evaluate the current strengths and weaknesses of the services. Participants correspond to prospective end-users from a wide range of consortia and can either be researchers, data managers or technical personnel working at repositories or computing centres. This methodology is suitable for both software and non-digital services [88]. In technical terms, this can be considered "acceptance testing" [89], as part of a user-centred design process [90]. The requirements analysis from TA1 forms the basis for choosing the user panel. There is a strong link to the requirements process in TA1 and the evaluation process to be defined in TA3.

Software quality is essential for long-term maintainability, but often a secondary concern for research prototypes. Therefore, the goal is to assist the services to reach higher software quality to (1) increase reliability and stability (2) enable extensibility, (3) reduce maintenance costs, (4) keep up-to-date with current technological developments, in particular security requirements, and (5) adopt an Open Source approach, if applicable, and establish or increase engagement with Open Source projects related to the service. In addition, requirements already identified by TA1 and TA3 will be taken into account. Identification and application of quality measures will be conducted together with a pool of specialised experts among the consortia to directly integrate existing knowledge and expertise into the Base4NFDI software quality measures, e.g. on software

metrics, or continuous integration test suites, which are already used by one service, and which could be shared with or transferred to other services.

Action 1 Designing and conducting user studies To form the panels, user groups for services have to be identified, working with TA1 and TA3. Of particular interest are user groups that are relevant for multiple services or prospective services. For these, a recruiting strategy will be developed that allows for synergies between the user studies to be conducted. Protocols to conduct the user studies themselves have to be developed and will be refined based on feedback from the services and the commissioning measures. Once protocols are in place, they serve as guidelines for the user studies. The decision on which studies will be conducted will be made in conjunction with TA1 and TA3 and the services in question.

Action 2 Designing and conducting software quality measures To identify potential software quality measures and their suitability for Base4NFDI services, a "crowd-sourcing" approach will be adopted within NFDI communities. Identified quality measures will be compiled and exemplified by practical scenarios, derived from expertise collected.

To apply software quality measures for basic service candidates, hands-on events such as bootcamps, hackathons, workshops, etc. will be organised, to leverage existing expertise of the partners and relevant third parties and to test service candidates against the quality measures.

Gaps in software quality of particular basic service candidates identified within this action will be analysed and specific improvement measures will be proposed to the developers and the potential service providers.

Table 14: Deliverables and Milestones in M2.3

Milestone	Deliverable	Type*	Description	Due end of
MS2.3.1		S	Definition of recruiting strategy	08/23
	D2.3.1	R	Publication of recruiting strategy and protocol templates	08/23
MS2.3.2		S	Recruiting and user study protocols	02/24 02/25 02/26 02/27 02/28
MS2.3.3		S	Conduct user panel studies	02/24 02/25 02/26 02/27 02/28
	D2.3.2	R	Report on each conducted user panel study	02/24 02/25 02/26

				02/27 02/28
MS2.3.4		W	Workshop on identification of quality measures	08/23
	D2.3.3	R	Publication of identified quality measures	08/23
MS2.3.5		W	1st event on practical knowledge exchange	11/23
	D2.3.4	R	Report on 1st practical knowledge exchange	11/23
MS2.3.6		W	Repeated specialised training events	02/24 02/25 02/26 02/27 02/28
	D2.3.5	R	Report on each training event	02/24 02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 2.4 (M2.4): Service integration and ramping-up for service operation (flex-funds)

Contributors: GEOMAR, GESIS, MPCDF

For each basic service candidate which enters TA2 (after passing TA1) and which gets approved for entering the respective development process step (cf. chapters 3.4 and 4.3), this measure implements the **(2) service integration phase** and the subsequent **(3) ramping-up for service operation phase**. Each service candidate will be processed through the procedures of the above given M2.1 to M2.3. Albeit the measures for a particular service may be of varying depth and duration depending on the maturity and development progress. The steps per service resulting from this approach will be coordinated by service stewards (cf. chapters 3.4 and 4.3).

Action 1 Support for service integration phase This action supports basic service candidates in the integration phase in applying the integration procedures defined by M2.1. Service stewards will coordinate the discussion and testing of interoperability with the consortial service landscape as well as the integration of existing solutions and will mediate operational issues between the NFDI sections, consortia and potential basic service providers.

Action 2 Support for ramping-up for service operation phase In this action, Service stewards support basic service candidates in the ramping-up for operation in applying the ramp-up procedures defined by measure 2.1. Service stewards will help potential service providers to conduct the tests of operating scenarios together with the NFDI sections and consortia and will mediate operational issues between the stakeholders.

Action 3 Service Stewards will provide support for elaborating on quality and sustainability measures of basic service candidates reflecting the feedback from user panel studies (M2.3) and software quality and sustainability studies (M2.3) to facilitate basic services acceptance and overall quality.

Action 4 Admission to service portofolio or tool pool Following approval of basic service candidates by the respective procedures and bodies (cf. chapter 3.4), service stewards will support the admission of a service to the Base4NFDI service portfolio and will monitor the service-lifecycle management, conducted by the providers. Should a service candidate be rejected, the service stewards will support the inclusion of developments into the tool pool.

Table 15: Deliverables and Milestones in M2.4

Milestone	Deliverable	Type*	Description	Due end of
MS2.4.1		S	Service integration approved	08/23
	D2.4.1	R	Report on conducted service integration	08/23
MS2.4.2		S	Service operation ramp-up approved	03/24
	D2.4.2	R	Report conducted service operation ramp-up	03/24
MS2.4.3		S	Quality and sustainability studies	03/24
	D2.4.3	R	Report on results of quality and sustainability studies	03/24
MS2.4.4		S	Admission to service portfolio	04/24
	D2.4.4	R	Report on admission for a given service	04/24

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

5.3   TA3 - Service coherence processes and monitoring

The main goal of TA3 is to set up a coherent process, monitor the progress of the individual services and the appropriateness of the selection process and dynamically adapt it to the needs of providers and users. Therefore, TA3 establishes the process framework for the selection and development of basic services. This framework specifically serves TA1 and TA2 in their tasks of gathering consortia requirements for potential basic services and the subsequent initialisation, integration and ramping-up for operation of NFDI basic services. Within this framework, TA3 ensures the seamless operation of the decision-making process, compiles all necessary information, pre-screens, prepares evaluation reports based on agreed and transparently accessible criteria catalogues, and ensures the quality assurance of the applications in interaction

with the sections in particular and in close cooperation with TA1 and TA2. In particular, TA3 refines the process for selecting potential basic services and the related criteria along the three development steps (cf. chapter 4.3). TA3 thus supports the TEC and the consortia assembly to carry out the required decisions by preparing appropriate decision documents for the services under consideration. Results will be documented in dossiers with all relevant information.

Overall, TA3 oversees a basic service proposal in all steps based on transparent catalogues of general and Base4NFDI-specific criteria (e.g. requirements/gap analysis, expected operational excellence, maturity level of existing software-stacks, criticality, innovation level, risk analysis, investment/financial request, business model, OSS-relevance/support from consortia, fitness of the provider) and prepares the decision-making by the NFDI association's bodies based on a distinctive time management. In this context, TA3 builds an evaluation framework to keep decisions traceable and transparent and ensures the establishment of an efficient documentation and process management system for the benefit of TA1, TA2, TA4 and all basic service candidates. Results in the decision workflow directed to the NFDI association will be documented in dossiers with all relevant information.

In M3.2, TA3 coordinates the decision-making workflows between the initiative and the bodies of the NFDI association and ensures the selection process for basic services is defined and implemented on the basis of a science-driven process. In this respect, TA3 ensures that the individual basic service dossiers have the necessary degree of maturity so that they can be decided upon. This also includes ensuring transferable benchmarks for making decisions based on comprehensible, transparent parameters. Likewise, TA3 is responsible for preparing final decision papers on the inclusion or discontinuation of services in the Base4NFDI basic service portfolio, which are then handed to the decision-making bodies of the NFDI association.

At the same time, TA3 monitors the development of the basic service candidates carried out in both TA1 and TA2 and dynamically adapts this framework to the different needs of upcoming basic service categories (M3.3). To this end, appropriate reporting documents and reporting steps have to be developed in close cooperation with TA1 and TA2. This reporting must also provide information about the consideration of state of the art technology and illustrate how it supports the interconnection with (inter)national infrastructures. Furthermore, the monitoring process must also take into account the heterogeneity of the potential basic services and must not follow a rigid scheme. Here, too, the close involvement of the NFDI committees is essential.

Measure 3.1 (M3.1): Defining, setting up and continuously adjusting the operation of the Base4NFDI decision-making process

Contributors: DESY, SPK (lead), ZB MED

This measure establishes the basic framework for workflow-supporting data acquisition and data management in order to substantially support the decision-making process. It shapes the core decision-making process for Base4NFDI: The selection of basic service candidates at each of the three development phases (cf. chapter 4.3). Given the 15+ working groups in the sections (figure 4), most of which will likely propose one or more potential basic service, structured and well-prepared processes are key to this bottom-up process for shaping the NFDI. This measure prepares and supports the sections and TA1 and TA2 by providing resources and agreed-upon procedures to enable timely, efficient but also balanced decisions on which basic service-candidates should or should not be supported for development. It will set up an overall process model to implement selection and decision criteria for basic services, define key performance indicators (KPIs) for the basic services, document their maturity status based on these KPIs and progress based on those criteria and prepare dossiers for each basic service which will be regularly updated.

Creating a powerful forms structure and data collection toolset is an important prerequisite for a seamless and smooth workflow design. TA3 will provide this framework based on a secure online form, which will also be used to document communication and processing progress. The involvement of all stakeholders is essential for acceptance. Continuous quality management ensures that necessary adjustments and changes resulting from the ongoing process are implemented. The comparability of information will be crucial in this context. Based on continuous feedback from the section liaison officers, TA1, TA2 and TA4 and on the monitoring results of M3.2, the process model will be further consolidated and continuously updated based on the NFDI and community requirements. A preliminary process including relevant reporting will be set up in the first year based on the first services entered into TA2 to allow the first decision rounds to take place. The resulting process model and criteria will be presented to the **TEC** and the **NFDI bodies** and, based on their feedback and the monitoring results of M3.2, the process model will be further consolidated and continuously updated based on the NFDI community requirements.

Action 1 Decision-making support in the sections for basic service initialisation phase
Action 1 will consolidate, evaluate, and refine the selection process for potential basic service candidates within the NFDI sections, which was already initiated as a preparation for the Base4NFDI proposal in close collaboration with the NFDI sections. This work needs strong input from the sections and will be managed by the section liaison officers (cf. chapter 3.4) who will support the sections with the identification and selection process of potential basic services. This includes the integration of additional criteria, and the elaboration of a selection process and decision-making process in the basic services relevant for the initial selection. The section liaison officer also ensures that the points of view and basic service requirements of the third-round consortia are taken into account. This support will also assure that promising ideas for basic

services enter the phase 1 of the overall development process as soon as possible, covered by TA1 and TA2. As part of this process, the initially existing templates to be filled in will be refined and the sections will be assisted by the section liaison officer to collect the appropriate information and identify potential basic service partners.

Action 2 Decision-making support for service integration phase This action will establish a selection- and decision-making process for transferring a basic service candidate towards the integration phase (hand over from TA1 to TA2) or even for discontinuing a basic service development. Relevant criteria of this process have to be elaborated in close interaction with TA1 and TA2. A preliminary process including relevant reporting will be set up in the first year based on the first services entered into TA1 to allow the first decision rounds to take place. The section liaison officer ensures that the sections remain informed about the decision-making process and that it supports the section's goals for a basic service.

Action 3 Decision-making support for ramping-up for operational service phase Analogously to action 2, Base4NFDI will set up a process model and decision criteria to decide on the release of basic service from the integration phase TA2 into a ramping-up for operational service as well as a transfer of a service back to a previous step or into the tool pool.

Table 16: Deliverables and Milestones in M3.1

Milestone	Deliverable	Type*	Description	Due end of
MS3.1.1		F	Concept and implementation for a decision framework for Base4NFDI (phase 1) and publication, regular revisions	08/23 08/24 08/25 08/26 08/27
MS3.1.2		F	Concept and implementation for a decision framework for Base4NFDI (phase 2) and publication, regular revisions	11/23 11/24 11/25 11/26 11/27
MS3.1.3		F	Concept and implementation for a decision framework for Base4NFDI (phase 3) and publication, regular revisions	11/23 11/24 11/25 11/26 11/27
	D3.1.1	R	Initial Report	02/24
	D3.1.2	R	Annual Report	02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 3.2 (M3.2): Monitoring overall basic service progress

Contributors: DESY, SPK, ZB MED (lead)

The objective of this measure is to monitor the progress of the basic service within the development steps on an ongoing basis. Based on the process model and criteria established in M3.1, a standardised reporting schema for the basic service in the different progress status will be set up. A special focus will be to monitor the KPIs defined in M3.1 for each basic service. Action 1 sets up and carries out the monitoring process for the maturity level of the initial services. Action 2 establishes the reporting of TA1 and TA2 necessary to monitor the progress of an individual basic service, ensures regular report submission, and monitors the progress based on the reports. Action 3 creates overall status reports that are the baselines for preparing the basic service dossiers which are prepared in M3.3.

Action 1 Monitoring the maturity level of basic service candidates The maturity level of the potential services will be in a first step evaluated by addressing the completeness of the dossiers prepared for the respective basic service. Appropriate templates will be provided to the sections after the criteria catalogue has been refined (M3.1). The section liaison officer will assist the sections and participating partners in providing the appropriate information. Complete dossiers will be considered as mature and reported to M3.3 for preparation of decision-making.

Action 2 Monitoring the progress of the individual basic services during TA1 and TA2 development phases Working closely with TA1 and TA2, decisions will be made on what information to include in reporting and what information is best reported at the TA1 and TA2 levels and what information is best reported by individual basic service teams. Templates for reporting as well as quality control of the reporting will be set up and the timelines for individual reporting will be established. Furthermore, the reporting will be managed and controlled.

Action 3 Overall status report creation for all basic services Based on the individual reports, the current and target state of services in the pipeline will be assessed and the need for action for the individual services will be identified and reported. In addition, summary overviews and analyses will be created as status reports and presented to the NFDI association bodies and the Base4NFDI consortium (TA4). If necessary, based on the analyses, adaptations of the selection process will be proposed to M3.1.

Action 4 Service Stewards A flexible number of Service Stewards support the processes and contribute insights on the progress in specific services.

Table 17: Deliverables and Milestones in M3.2

Milestone	Deliverable	Type*	Description	Due end of
MS3.2.1		R	Reporting templates are ready	11/23
	D3.2.1	R	Initial monitoring-reports	02/24
	D3.2.2	R	Annual monitoring reports	02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 3.3 (M3.3): Preparing decision dossiers and decision-making templates for the inclusion of the basic services in the three different basic service phases

Contributors: DESY (lead), SPK, ZB MED

To support the transparent decision-making process being organised by TA4, M3.3 prepares templates for the different decision dossiers. The information of the monitoring reports will feed into the dossiers and missing information will be requested by the basic service. The preliminary dossiers for the first decisions will be prepared and updated as soon as the first outputs of M3.1 (preliminary process model for the different selection processes and decision-making) and M3.2 (first reporting) are available. Based on the model and reporting and on the feedback of TA4, the dossier templates will be adjusted and optimised in iterative steps as a continuous process. Overall this measure addresses in Action 1 the preparation of decision dossiers and decision-making templates for potential basic service to enter TA1; in Action 2 the preparation of decision dossiers and decision-making templates for basic service candidates for TA1/TA2 transition or discontinuation; Action 3 involves the preparation of decision dossiers and decision templates for potential basic service in the transition from Phase 2 to Phase 3 (ramping-up for operational) or their termination.

Action 1 Preparation of decision dossiers and decision-making templates for potential basic services to enter TA1 In Action 1, the decision dossiers are created and the templates for the decision on the inclusion of potential basic service in TA1 or their rejection are elaborated, if necessary with qualified feedback for revision.

Action 2 Preparation of decision dossiers and decision-making templates for service integration phase In Action 2, the decision dossiers and decision-making templates for development process continuation or discontinuation in phase 2 (from TA1 to TA2) are elaborated, if necessary with qualified feedback for revision.

Action 3 Preparation of decision dossiers and decision-making templates for ramping-up for operational service phase In Action 3, the decision dossiers and decision-making templates for transition or discontinuation in phase 3 are elaborated, if necessary with qualified feedback for revision.

Table 18: Deliverables and Milestones in M3.3

Milestone	Deliverable	Type*	Description	Due end of
MS3.3.1		F	Reporting concept/ framework	11/23
	D3.3.1	R	Annual Dossiers	02/24 02/25 02/26 02/27 02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

5.4   TA4 - Project Governance

TA4 acts as the coordination and management structure for the NFDI association bodies with a particular focus on decision-making for service initialisation, integration and operationalisation of services identified through the processes in TA1 to TA3. At the same time it is Base4NFDIs conduit to national and international research and infrastructure communities beyond the NFDI. TA4's key tasks encompass the project management including risk-, financial- and contract-management, project monitoring as well conducting regular external evaluations of the project's progress, measuring the project's impact on the NFDI and the German science landscape in general, far-reaching outreach activities, coordinating user training and support and drafting of policy briefings with respect to long-term operating models, durable structures and long-term financing options for basic services.

Measure 4.1 (M4.1): Coordination Office

Contributors: GESIS, SUB, TU Dresden (lead)

This measure establishes a distributed Coordination Office which will **support** both the **Technical Expert Committee (TEC)** and the **Management Committee (MC)** in day-to-day operations. In this capacity it also assists the MC in **resolving potential conflicts** within the governance structures (cf. chapter 3.4). It **oversees financial decisions,** provides **financial management support,** and covers **contract management** for Base4NFDI. To structure and automate reporting, Base4NFDI will employ NFDI's **OpenProject project management** platform. It will cover progress on all measures across all Task Areas. This process will be **centrally supported** through experience in project-planning and -documentation. The **Coordination Office** (CO) assists the MC to **align** its strategy and work programme with **scientific and infrastructure initiatives both nationally** (Alliance of Science Organisations in Germany, NHR, ZKI) but more importantly, **internationally** (EOSC and various large domain-oriented structures such as the World Data System).

The CO will also commission an independent, **external evaluation** of Base4NFDIs decision-making structures after two years. The CO will closely work together with coordinators of the existing consortia.

Action 1 Coordinate with NFDI Association bodies Support CA meetings where they pertain to Base4NFDI matters. Coordinate processes and timetables with other stakeholders – as the consensus-oriented processes in Base4NFDI often also involve other stakeholders in the NFDI association, timetables and other processes need to be closely coordinated. Collect and provide the relevant documents together with TA3, and communicate results. Support MC logistically and financially (travel).

Action 2 Administer Technical Expert Committee Organise the 2-4 annual meetings of the TEC, prepare all relevant documentation in conjunction with TAs 1-3, and document results. It will act as the point-of contact between TEC members and Base4NFDI. Two TEC meetings per year will take place in person. Other meetings will be held virtually.

Action 3 Financial and Contract Management The also provides financial management support and will help with contract issues both regarding the interplay within Base4NFDI but also relating to service development. It manages in particular the flexible funds and their allocation to the consortia whose partners will receive funding for the development of the basic services. Financing for legal expertise, if deemed necessary for service development will come from flexible funds and be approved in the proposal process.

Action 4 Set up and operate monitoring process Discuss with stakeholders, propose and then define – together with the MC – a monitoring process for project performance. Actively support its communication and compliance with it over the course of the project.

Action 5 Support Use of OpenProject across Base4NFDI Establish and maintain reporting processes in OpenProject, provide training on productively using OpenProject in all parts of Base4NFDI and assist the MC in preparing internal and external reports. Implement a support structure, provide training materials, offer in-person- as well as virtual training for all Base4NFDI employees and collaborators to facilitate the systematic use of OpenProject.

Action 6 Internal and External reports Issue quarterly internal performance reports and on-demand reports for external purposes. Templates for these reports will be developed in close coordination with the MC, the sections and the NFDI association.

Action 7 External Evaluation Given the novelty of its approach and to foster continuous adaptation and optimization of its structures, the young age and thus developing nature of the NFDI and its processes Base4NFDI, commits to an external evaluation of its governance and all decision-making processes after two years. The purpose of the evaluation is to objectively assess possible deficiencies particularly with respect to substantive and financial decisions. It will be handled by an external (likely commercial) provider with the appropriate experience in "programme evaluations" and no ties to any partners within Base4NFDI. The evaluation will be able to draw on all data generated in TAs 3 and 4 and gain further insights through interviews with stakeholders both within and outside of Base4NFDI.

Action 8 Facilitate National and International Networking Support managing committee, partner institutions and NFDI association bodies to engage in national and international networks in order to align Base4NFDI's strategy and work programme. Following the establishment, this will be an ongoing task.

Action 9 Policy Briefs Based on its networks and the work on basic services, Base4NFDI will be in a position to issue policy briefings. Policy briefings serve to communicate insights on structures, processes and financing of basic services early on to stakeholders in the NFDI association bodies, the DFG and the Joint Science Conference (GWK). These activities will be coordinated closely with the NFDI Directorate and infrastructure partners in Base4NFDI.

Action 10 Conflict Resolution Issues of disagreement will be documented by the Coordination Office and brought to the attention of the appropriate bodies within or outside of Base4NFDI. Wherever necessary, arbitration will be provided. Cases can be referred to the external ombudsperson.

Table 19: *Deliverables and Milestones in M4.1*

Milestone	Deliverable	Type *	Description	Due end of
	D4.1.1	SP	Support CA meetings, provide relevant B4N documents together with TA3, communicate results.	persist
	D4.1.2	SP	Organise regular TEC meeting, synchronise documents with TA3, provide minutes, communicate results	persist
MS4.1.1		S	OpenProject support structure set up	05/23
	D4.1.3	R	Regular internal quarterly monitoring report (each quarter)	08/23
MS4.1.2		R	Specification of regular monitoring process and template for quarterly internal reports	08/23
MS4.1.3		S	Specification of reporting requirements for unified monitoring in OpenProject (updated annually)	08/23
MS4.1.4		R	Specification of regular monitoring process and template for external reports	11/23
MS4.1.5		S	Strategy for policy briefs	11/23
	D4.1.4	S	Version 1 of training materials for use of OpenProject with Base4NFDI (updated regularly)	01/24
MS4.1.6		S	Database for contact networks	02/24
MS4.1.7		W	Regular Training offer for Open Project (ongoing)	02/24
MS4.1.8		S	First policy brief (updated regularly)	05/24
MS4.1.9		SP	Commission tender for external evaluation	08/24
MS4.1.10		SP	Support external evaluation	08/25

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 4.2 (M4.2): Outreach, coordination of user training and support

Contributors: GESIS, SUB (lead), TU Dresden

Base4NFDI will provide training and practical hands-on support for basic service users. Consulting will be available to consortia wishing to implement services as part of their work programmes. Training as well as consulting will have to be provided by the service operators and their staff. This measure will **assist with coordination, development of formats for training** and **information/rollout events**, as well as **support knowledge exchange** between experts on the basic-service (candidates) at a given phase in development. As both the extent and the nature of training needs cannot be adequately foreseen at this stage, this measure will only budget a base-level support. More resources should then be budgeted as a corollary to the development process.

Outreach is generally of crucial importance for scientific endeavours. Given the unprecedented scope of Base4NFDI's harmonisation process, opportunities to participate in and shape the process must be **clearly communicated**. This reinforces the role of professional outreach.

Action 1 Assist with coordination, development of formats While training and consulting on services will mainly need to be offered by the providers of the services, aided by service stewards, this measure will offer a basic infrastructure for such training. It will develop formats for different target audiences (e.g. power users, users with integration needs) to help providers create bespoke training materials for the respective target groups. This will not need to be done from the ground up, but build on the consortia's substantial experience. It will also collect and share best practices (on locations, tools, content but also on best presenters or moderators). Furthermore, the measure will support interlinking the training with other events, such as the consortia's community conferences or subject specific workshops to help forge synergies and facilitate the adoption of the services. Base4NFDI will use platforms / tools developed by section Edutrain [7] and will cooperate to integrate training on basic services into any standard courses it might be relevant to.

Action 2 Support knowledge exchange The measure collects user needs in terms of training and support, analyses them and discusses suitable strategies for knowledge transfer with the experts and the Management Committee. For clearly delineated needs it will organise workshops and make the materials available for re-use. For recurring needs, the development of more systematic formats (webinars, documentations, ...) will be supported.

Action 3 Draw up publication policy A publication policy will set out how project results and policies will be published on a regular basis. For these capacities a professional communication officer will be part of the Coordination Office.

Action 4 Outreach for Base4NFDI In addition to existing networking among partner organisations in the consortia, the Base4NFDI Managing Committee will build trusted relationships with relevant initiatives to negotiate a mutual understanding on the executive level and raise awareness for the Base4NFDI initiative. Once established, this will be an ongoing task.

Table 20: Deliverables and Milestones in M4.2

Milestone	Deliverable	Type *	Description	Due end of
MS4.2.1		S	Draw up plan for outreach, including user conferences and regular workshops (updated annually)	08/23
MS4.2.2		S	Establish initial collection of best practices (update regularly)	08/23
MS4.2.3		S	Establish list of events linkable with training (update regularly)	08/23
MS4.3.4		S	First regular outreach events held	10/23
MS4.2.5		S	Set up process for collection of user needs for training and support in conjunction with sections and TAs1 and 2	11/23
	D4.2.1	R	Publication policy	12/23
	D4.2.2	R	Document training and support user needs (update regularly)	05/24

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Measure 4.3 (M4.3): Systematic assessment of the impact of Base4NFDI

Contributors: GESIS (lead), FOKUS

The goal of this measure is to systematically assess the impact of Base4NFDI **among users, infrastructure providers**, and the **wider science system**. The systematic assessment of impact will be of relevance by providing information about the process of establishing Base4NFDI services. In addition, it will support decision-making by providing information on how Base4NFDI services are perceived and used. The measure consists of **three actions**, covering different perspectives and levels of Base4NFDI, the **user perspective, provider perspective, and process perspective**. This measure will not only cover the implementation of the services, but also reflect on the perception of governance decisions for research information infrastructures within the scholarly community. The measure will **benefit from specific conceptual and methodological advances of higher education and science studies**. The measure will address each action with a set of both quantitative and qualitative methods (surveys, interviews, document analysis and participatory observation).

Action 1 Exploration of user perspective Action 1 will deliver a systematic assessment of how Base4NFDI services are perceived among end users. To that end, it is planned to design a survey instrument with nation-wide coverage. Within this action, a module within the scientist's survey of the German Centre for Higher Education Research and Science Studies (DZHW) (the largest trend study in Germany) will be designed, assessing awareness, recognition and perception of structures, activities and services for Base4NFDI. The module can be complemented with existing modules about data usage and provision across disciplines. Action 1 will thus approximate the domains covered by the NFDI consortia. Action 1 also links to action 3 (process perspective) of this measure by providing contextual information for process analysis.

Action 2 Exploration of provider perspective Action 2 will deliver an exploration of the impact of the Base4NFDI services on public operators and providers of research data infrastructures. It is aimed to explore perceptions and strategies of infrastructure with a mixture of document analyses and interviews. The action consists of a), a landscaping review of existing infrastructure providers relevant for Base4NFDI, b), a typologisation on the basis of existing dimensions (type of service, domain specificity, user base) via document analysis, c), selection of cases for in depth study, and d), qualitative interview study.

Action 3 Exploration of process perspective Action 3 will deliver an exploration of the process leading to Base4NFDI services. It will reflect on this process taking the open and domain overarching nature of Base4NFDI into account. Using Base4NFDI as an example, the action will examine opportunities and risks arising from the digitalisation and opening up of science, in particular from the establishment of research data infrastructures (including basic services). The aim is to reflect on the current change process and on collaboration patterns and structures. For examination, a mixed-method approach is envisioned, combining quantitative and qualitative methods. Key elements will be surveys, interviews and workshops with different stakeholders. Here, a collaboration with the research group "Digitalisation and Opening Up of Science" at the Weizenbaum Institute is planned.

Table 21: *Deliverables and Milestones in M4.3*

Milestone	Deliverable	Type*	Description	Due end of
MS4.3.1		S	Establish field study design for process perspective	12/24
MS4.3.2		S	Map and systematise research	12/24
MS4.3.3		S	Conduct participatory research for process perspective	02/27
MS4.3.4		S	Organise and evaluate stakeholder surveys, interviews and workshops on process perspective	8/24, 8/25 8/26
MS4.3.5		S	Set up list of Base4NFDI services and connected infrastructures relevant for user assessment	02/25
	D4.3.1	R	Interim report on process perspective	02/26
MS4.3.6		S	Design survey module for assessing user perceptions of Base4NFDI services	02/26
MS4.3.7		S	Map infrastructure providers (exploration of provider perspective)	05/26
MS4.3.8		S	Finish typology of infrastructure providers relevant for provider perspective	08/26
	D4.3.2	R	Report on user perception of Base4NFDI services based on survey results from Scientist's survey	02/27
MS4.3.9		S	Finish qualitative data analysis of infrastructure provider case studies	08/27
	D4.3.3	R	Synthesis report on systematic impact assessment of Base4NFDI services, including opportunities and risks analysis of process development	02/28

* F-Framework, R-Report, S-Service, SP-Support, W-Workshop

Table 21: *Deliverables and Milestones in M4.3*

Appendix

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