



Digital Research Practice and Cooperative Information Infrastructures

A DFG discussion paper on the funding
and financing of scientific information infra-
structures

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The discussion paper was drawn up by the Committee on Scientific Library Services and Information Systems (AWBI).

Further information at: www.dfg.de/lis/en

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1 Introduction

For some time now, the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) has been exploring the question of what specific consequences the use of digital technologies has for research and how the research community can shape the digital turn in its own interests.¹ Given that the digital turn affects the infrastructures needed by researchers on a systemic level, it is only natural that the DFG has addressed this impact in recent years by advancing its programmes dedicated to the funding of information infrastructures. The portfolio under the responsibility of the Committee on Scientific Library Services and Information Systems (AWBI) offers funding instruments² that enable the establishment and development of information infrastructures to support digital research practice: these are relevant to all stages of the research lifecycle – including information and literature research, the analysis and evaluation of data and information, and the dissemination of a diverse range of research findings.

In order to ensure that the information and tools needed for research can be used as efficiently as possible, the DFG consistently aims to develop a coordinated, nationwide system of information infrastructures. As set out in the DFG position papers published in 2012 and 2018, such a system requires close cooperation between various stakeholders.³ In view of the current challenges in terms of establishing and developing information infrastructures and operating them on a long-term basis, it will not be enough simply to refine the DFG's existing funding portfolio. What is in fact needed – more than ever before – in order to establish a nationally coordinated system, is close dialogue between all parties involved so as to mutually align the various roles and responsibilities within an evolving framework. Ideally, this dialogue will ensure that information infrastructures meet the dynamic needs of the research communities, that the research process is efficiently supported at all its various stages, and that long-term provision is secured in the case of those services that are indispensable to researchers.

In order to promote the necessary discourse with all relevant stakeholders, the quintessential points of the present discussion paper are first set out in the form of five theses (section 2). Subsequently, existing challenges are analysed (section 3) and overarching fields of action are defined that are to be addressed collaboratively by different parties (section 4). Directly

¹ For an in-depth overview of the DFG's engagement in this field, see: www.dfg.de/digital_turn.

² For the relevant details, see the programme guidelines at: www.dfg.de/lis/forms.

³ DFG position paper (2012): Die digitale Transformation weiter gestalten. Der Beitrag der Deutschen Forschungsgemeinschaft zu einer innovativen Informationsinfrastruktur für die Forschung [“Continuing to shape the digital turn. The DFG's contribution to an innovative information structure for research”], www.dfg.de/re-source/blob/170622/c9807e83bb07c64667b0287a115e5232/positionspapier-digitale-transformation-data.pdf, p. 2–4 (German only); DFG position paper (2018): Förderung von Informationsinfrastrukturen für die Wissenschaft [“The funding of information infrastructures for research”], www.dfg.de/re-source/blob/173200/66e1e4296848c5f700b83898f7f48995/positionspapier-informationsinfrastrukturen-data.pdf, p. 13 (German only).

derived from the analysis, measures relating to the DFG's area of responsibility are outlined in the section on how DFG funding activities are impacted (section 5). Unlike in previous DFG position papers on scientific information infrastructures, the measures set out here are not intended to be exhaustive: rather, the DFG invites information infrastructure institutions, relevant funding bodies, research organisations and research funding organisations, as well as researchers and other stakeholders who wish to meet their responsibilities within the system to engage in discussion of the further joint development of this system, including the DFG's funding activities (section 6).

2 Five theses on the future of information infrastructures

Solutions to the key challenges involved in creating an overall system of scientific information infrastructures can only be developed through a dialogue involving research policymakers, institutions and individual stakeholders. In the view of the DFG – and in particular the AWBI, which is responsible for this report – the following theses provide a suitable starting point for this dialogue.

- T 1.** Cooperation, coordination and shared responsibility form the foundation for the successful development and operation of scientific information infrastructures.
- T 2.** Digital research practice in science and the humanities is highly dependent on information infrastructures. It is the responsibility of funding organisations, funding bodies and research policymakers to establish suitable framework conditions so that publicly funded information infrastructures are reliably financed and sponsoring institutions are able to guarantee long-term operation and demand-oriented further development.
- T 3.** In order to successfully negotiate the efficient structuring of a collaboratively operated information infrastructure and secure its long-term funding, it is crucial to start by identifying and mapping services that are of national relevance and will attract widespread use on the part of the research community.
- T 4.** It is only possible to guarantee the efficient, sustainable and long-term operation of a cooperative information infrastructure by optimising the structural compatibility of the institutions and organisations involved. In order for this to happen, funding options and financing structures must be more closely aligned.
- T 5.** The traditional separation between research and information infrastructure is becoming less distinct: this means that newly emerging roles, responsibilities and interests have to be aligned with the institutional, financial and legal possibilities at the sponsoring institutions.

At the level of *research policy*, the relevant stakeholders which the DFG is aiming to address through this discussion paper include in particular the responsible state and federal ministries, the members of the Alliance of Science Organisations in Germany, and the German Council for Scientific Information Infrastructure (RfII). At the *institutional level*, the universities and non-university research institutions are particularly responsible for the development, advancement and operation of information infrastructures, as are the information infrastructure institutions themselves (libraries, archives, museums, research collections, research data centres, computing and information centres). Other stakeholders who are likewise invited to join in the dialogue include the National Research Data Infrastructure (NFDI), the National High Performance Computing Network (NHR-Verbund) and the German National Research and Educa-

tion Network (DFN-Verein). At the *individual level*, this paper is aimed at anyone who contributes to digital research practice based on scientific information infrastructures (in addition to researchers themselves this includes archivists, librarians, data stewards and research software engineers, for example).

3 Challenges

The DFG's 2018⁴ position paper on its funding of information infrastructures undertook an analysis of the challenges and opportunities that arise from the use of digital technologies in research.⁵ The fundamental point remains true that the results yielded by the research process (publications, data, software and other resources) are to be made available, searched, processed, analysed and re-distributed as digital objects via information infrastructures. The following are some of the developments which now prompt broader consideration, associated with the invitation to engage in dialogue:

In the current phase of digital transformation, research and information infrastructure must be increasingly viewed in conjunction with one another: after all, the digital technologies used by researchers determine the research process itself, thereby greatly influencing shifts in methodology. The resulting challenges can often only be overcome through cooperation and functional task-sharing.

What is more, the practices and processes associated with the demands of open science⁶ require reflection on the institutional framework conditions underlying information infrastructures. Research findings are to be openly accessible in the long term to enable better reusability by the research community itself as well as by industry and society. The scope and objectives involved here are the subject of negotiation processes at the institutional, national and international level.

Another challenge here is the scale on which researchers generate and access information and data. Having to some extent been adapted in terms of its focus since 2018, the funding programmes created by the AWBI offer a wide range of opportunities for aligning the development and advancement of information infrastructures with digital research practice. However, they now require updating again in some respects.

The RfII defines scientific information infrastructures as “technically and organisationally networked services and offerings for accessing and preserving data, information and knowledge. According to the RfII, they primarily serve research purposes, they are often the subject of research themselves, and they always have an enabling function.”⁷ The RfII definition is to be

⁴ As in note 3.

⁵ Cf. DFG impulse paper (2020): Digitaler Wandel in den Wissenschaften [“The digital turn in science and the humanities”], <https://doi.org/10.5281/zenodo.4191345> (German only).

⁶ Cf. DFG position paper (2022): Open Science as Part of Research Culture, <https://zenodo.org/records/7194537>.

⁷ German Council for Scientific Information Infrastructures: Enhancing Research Data Management: Performance through Diversity. Recommendations regarding structures, processes, and financing for research data management in Germany, Göttingen 2016, <https://rfii.de/?p=2075>, p. A-15.

extended: Information infrastructures are able to make a vital contribution to the digital sovereignty of research.⁸ Ideally, they should be supported by the research community as a whole and be freely accessible to all researchers. In line with this idea, information infrastructures should be established and developed in collaboration with research and infrastructure institutions (section 3.2), operated under cooperative structures (section 3.3), and transparently financed in the long term by funds generated by the research system (section 3.4).

3.1 Data-centred research with machine support

The digital provision of quality-assured information is a typical feature of modern research, as is the intense use of digital technologies; both have led to a significant increase in digital data and information. One essential prerequisite for accelerated scientific progress and economic wealth generation is machine-readable data which is available across disciplinary and sectoral boundaries – and for artificial intelligence (AI) applications. Archives, libraries, research collections and museums, and centres for data, computing and information have a crucial role to play here since they are institutions that are dedicated to the management of data, software and information: they create essential foundations for the extensive use of machine learning and AI, enable new research strategies, and they must simultaneously meet new demands on scientific information infrastructure.

The following aspects require particularly careful consideration when it comes to the cross-disciplinary and cross-sectoral use of data and the targeted development of data spaces for science, industry and society:

- ▶ From a technical point of view, the interdisciplinary compatibility of data and systems in national and international networks is paramount. Software and digital processes are required in order to be able to generate and process data. This is another factor which broadens the range of functions to be performed by information infrastructure facilities.
- ▶ The development of services and structures for digital research practice relies on the networking of different actors and activities. Where there is a need for the various actors' interests and possibilities to be aligned, however, there is frequently still insufficient coordination.
- ▶ The development and, in particular, the operation of an increasingly networked information infrastructure to support research also requires an adequate legal framework, incentives for joint financing – or at least the removal of hurdles, attention to IT security, and the safeguarding of the digital sovereignty of science and research.

⁸ Cf. German Science and Humanities Council (WR): Empfehlungen zur Souveränität und Sicherheit im digitalen Raum. ["Recommendations on sovereignty and security in the digital space"] Cologne 2023 (German only), <https://doi.org/10.57674/m6pk-dt95>.

3.2 Close dovetailing of research and information infrastructure

Information infrastructure is a fundamental condition for research practice: it determines research processes and brings about their transformation.⁹ As a result of this, the mutual dependency between research and information infrastructure is growing. Since research and information infrastructures often coexist at universities, it is primarily the universities – along with non-university research institutions – that can and should define their strategy and engage responsibly as institutions in the digital turn. The operation of information infrastructures for research can be expected to develop into an important element of the performance capability and reputation of universities.

Improved organisation of the interaction between research and information infrastructure should aim to achieve greater precision in serving the needs of researchers with regard to complex platforms that accompany the research process. This is possible if a publicly funded information infrastructure is able to adequately handle a wide range of research outcomes (publications, data, software), consistently support digital working methods, while at the same time meeting increased demands in terms of good research practice, replicability/reproducibility, and the reusability of research results.

In view of this diverse range of requirements, close dialogue between researchers and information experts is an essential prerequisite for the establishment and further development of an information infrastructure that serves the research community. Such dialogue can ensure that platforms are geared towards the (changing) needs of research communities and offer support throughout all phases of the research process. The close dovetailing of the two areas should ensure that the needs of both the subject specialist side and the infrastructure side are met to the very highest quality standards.

3.3 Cooperation between information infrastructure institutions

There is now also increasingly close cooperation between information infrastructure institutions themselves. Since the cooperative running of information infrastructures is not a new phenomenon, there are various instruments that can be used to develop joint responsibility on a binding basis. In view of the international character of science and the necessity of long-term financing – and given the way public budgets are developing in times of multiple crises – it will be necessary to re-assess which information infrastructures can or must be operated at the regional, national, European or international level.

⁹ Cf. Petra Gehring: Viele Fronten. Digitale Methoden fordern neue Prozesse: Wie kann Forschungspolitik Qualität und Verknüpfbarkeit von Daten sowie Datensouveränität sichern? In: Forschung & Lehre 9/2018, www.forschung-und-lehre.de/forschung/viele-fronten-985.

Coordinating functional task-sharing, continuously maintaining standards and transferring project outcomes into permanent services can only succeed in a system that is geared towards cooperation and will often require strategic decisions to be made at the management level of the institutions. For this reason, information infrastructure organisations must arrive at a sustainable agreement on the effective distribution of responsibilities. Here it will be important to define and address potential hurdles to cooperation more clearly, including those of a legal nature.

3.4 Financing of long-term operation

The establishment and further development of an existing information infrastructure is often financed by third-party funds that are subject to a time limit. Many issues, such as the curation of data and software, the development of infrastructures for diamond open access and the longer-term financing of the operation of information infrastructures, have to be resolved in the long term, however.¹⁰ Meanwhile the operating institutions are faced with cost increases as more and more digital objects are created, curated and made available for a variety of use cases in the interests of open science. The fact that planned budgets do not correlate with growing demands exacerbates the problem of financially safeguarding the ongoing operation of scientific information infrastructures. This also raises the question of how research policy can provide the necessary resources for digital and open research

¹⁰ Cf. DFG impulse paper (2018): Stärkung des Systems wissenschaftlicher Bibliotheken in Deutschland. Ein Impulspapier des Ausschusses für wissenschaftliche Bibliotheken und Informationssysteme der DFG [“Strengthening the system of academic libraries in Germany. An impulse paper issued by the DFG Committee on Scientific Library Services and Information Systems] Bonn 2018, <https://zenodo.org/records/6375861>, p. 9f. (German only).

4 Fields of action

4.1 Optimising technical, organisational and social compatibility

The compatibility of information infrastructures is essential to digital, data-centred research practice. This discussion paper takes a comprehensive view of compatibility, emphasising that *the technical, organisational and social dimensions of information infrastructures* are to be developed as three closely interlinked aspects.

From a *technical* point of view, the compatibility of platforms, portals, services, software, apps, etc. is to be advanced by placing increased demands on their systemic interaction – thus making sure that the numerous publicly funded scientific information infrastructures in Germany are even more closely interlinked in the future. This will ideally enable further compatibility: 1.) with other public information infrastructures, 2.) with initiatives of the open-source community, and 3.) with commercial offerings. From an *organisational* point of view, the aim is to increase the structural compatibility of institutions and organisations in order to achieve more efficient and sustainable use of resources (personnel, hardware, software, etc.). From a *social* point of view it is important to take into account the increasing emergence of new job profiles and roles (e.g. data librarian, data steward, research software engineer) – a factor which impacts on the recruitment and development of personnel at research and information infrastructure institutions.

In order to facilitate the use of digital objects beyond their initial context of creation, it is essential to design their compatibility accordingly:¹¹ after all, the ready accessibility of digital objects is the essential basis for increasingly data-driven research, and therefore also for scientific AI applications. Descriptions that include metadata, ontologies and thesauri ensure that digital objects can be contextualised not just by humans but by machines, too.

4.2 Promoting and functionally aligning cooperation

Cooperation is essential in the establishment, further development and long-term continuity of information infrastructures. The stakeholders involved have differing abilities, interests and possibilities, however – and they cooperate in different ways, too. Some information infrastructures are supported exclusively by institutions such as libraries, archives, research collections

¹¹ The term “digital objects” includes research data, software and publications as well as digital collections, holdings and archives. Cf. also the priority initiative of the Alliance of Science Organisations in Germany “Digital Information” (2021): Digitale Sammlungen. Eine Handreichung der Arbeitsgruppe Digitale Sammlungen (AG 3) der Allianz der deutschen Wissenschaftsorganisationen, <https://doi.org/10.48440/allianz0a.043> (German only).

or museums, while others are operated exclusively by research communities or research institutions.¹² In between there is a wide range of different information infrastructures featuring diverse forms of organisation and governance in which both institutions and researchers perform different tasks that are distributed among the various participants.¹³ This means that not only operating frameworks and business models are designed differently and have been established in different ways, but also processes such as rule-setting, standardisation and decision-making. Here it will be necessary to constantly re-assess and re-define which actors can take on which roles and tasks, and determine the relevant areas of responsibility to be assigned.

4.3 Promoting reusability and organising long-term sustainability

In order to ensure a functioning overall system, it is essential for information infrastructures to be operated and evolved by those responsible on a medium-term and long term basis in a way which is geared towards demand. The increasingly close dovetailing of research and information infrastructure must be taken into account here: if libraries, research data centres and research collections can actively manage the digital turn by merging their own research and development work with input from the research community, they will be able to inherently align their services with researchers' needs, thereby ensuring that the services they create are up to date, while also making a significant contribution to the digital sovereignty of science.¹⁴

In view of the fact that information infrastructures are increasingly operated on a collaborative basis, overarching governance structures are needed – also in view of differing institutional capabilities – in which clear responsibilities for a functioning information infrastructure can be agreed on, technical standards can be set, and if necessary the transfer of services and responsibility can be organised. Reliable operating models should be available early on in the development and design of information infrastructures and services so as to ensure that the costs of maintaining subsequent operations can be covered.

The DFG believes that the level of active commitment on the part of universities and other research institutions to the long-term financing of nationwide information infrastructures in particular will depend not only on whether federal and state governments allocate dedicated resources for this purpose but also – if not more so – on the extent to which the long-term adoption of such services enhances performance capacity, institutional profile and reputation. This

¹² Examples of the first type include the comprehensive catalogues of printed works published in the German-speaking world (VD 16, VD 17, VD 18), and the citation tool for research data repositories re3data. An example of the second type is the bioinformatics platform for the genome-based taxonomic classification of bacteria Type (Strain) Genome Server.

¹³ The NFDI consortia are examples of both distributed roles and their embedding in a higher-level governance structure.

¹⁴ Cf note 8.

goal seems most likely to be achieved if a broader perspective is established in which recognition is established within the research community that goes beyond research activity in the narrower sense.¹⁵

¹⁵ Cf. on this point the comprehensive approach adopted by the Coalition for Advancing Research Assessment, <https://coara.eu>.

5 Impact on the DFG's funding activities

Measures for the DFG's funding activities in the field of information infrastructure can be derived directly from the three above-mentioned fields of action. The catalogue listed below is not intended to be exhaustive but is to be supplemented, expanded and specified in dialogue with other stakeholders.

5.1 Compatibility

In its provision of clear guidelines relating to alignment with national and international standards, the DFG is already specifically promoting the aspect of technical compatibility in its current funding activities. The following mechanisms can be applied in addition to ensure the compatibility of information infrastructures:

- 1) Increasingly require the establishment and implementation of standards, e.g. for technical interfaces, documentation, and rules relating to practice and process.
- 2) Expand funding programmes to increase the compatibility of digital objects, e.g. by promoting the curation and annotation of data using established formats, schemas, standards and norms. This can also include the preparation of digital objects for machine learning or AI applications.
- 3) Further develop the interplay between different data models and classifications through targeted funding programmes so as to be able to align specific organisational systems with each other more closely across disciplines and sectors.
- 4) Promote national and international regulations and standards for designing compatibility, also with a view to the demands of open science.

5.2 Cooperation

The DFG's funding is not aimed solely at selecting the best in a competitive context but also at creating conditions for the successful implementation of research projects and establishing fundamental quality standards.¹⁶ Framework conditions and standards can only be developed and implemented on a broad scale through joint action, so there is clearly a need for cooperative approaches in the development and expansion of information infrastructure. It is also the

¹⁶Cf. on this point DFG position paper (2022): Rolle und perspektivische Entwicklung der Deutschen Forschungsgemeinschaft im deutschen Wissenschaftssystem ["The role and development of the DFG in the German research system in the medium term"] Position Paper issued by the DFG Executive Committee, www.dfg.de/re-source/blob/175812/4c40128a9bcff67f362605b709f997e5/220629-positionspapier-rolle-entwicklung-dfg-data.pdf, cf. p. 8 (German only).

case that from a functional point of view, digital research practice itself enables – if not necessitates – a distribution of responsibilities. In line with this idea, DFG funding of information infrastructures can make an essential contribution to establishing cooperative responsibility structures and ensuring their functional alignment.

It will therefore be necessary to explore the following aspects in terms of the further structuring of the DFG's funding activities in the area of information infrastructures:

- 1) which steering mechanisms can be used to define roles, functions and responsibilities more clearly, and which funding principles can be applied to further promote cooperation
- 2) which further incentives (including those of a financial nature) can be created to enhance cooperation in the context of project funding
- 3) which methods can be used to identify successful examples of collaboratively developed or collaboratively operated information infrastructures and, where applicable, to recognise these as best practices
- 4) to what extent it can be ensured in the review, evaluation and decision-making process that clearly recognisable cooperative approaches within funding proposal submissions impact positively on the chances of securing funding

5.3 Reusability and long-term sustainability

Always limited in terms of duration, project-based funding is known to be at odds with the need for a long-term, functional information infrastructure. In third-party funding, greater attention must be paid to mechanisms that enable a more effective transition from project-based information infrastructures to regularly operated structures that are securely maintained by third parties. In order to achieve this, answers are needed to the question of which attributes can be incorporated into an information infrastructure project via third-party funding in order to ensure its ongoing financing once the project funding period has come to an end. Such attributes could include the following: development of lean and functional structures from a technical and organisational point of view; encouragement of intrinsic motivation on the part of users, thereby enabling them to contribute to the targeted further development of the information infrastructure with minimal effort; ensuring clear commitment on the part of universities and institutions to become long-term sponsors of the information infrastructure.

As such, an assessment should be carried out of how the following fields of action – aimed at the long-term preservation of a functioning information infrastructure – can be given even greater emphasis in the context of the DFG's funding activities:

- 1) Encouragement of the reusability and actual reuse of existing technologies based on incentive systems that may still need to be developed – to this end, the reuse of services should be made eligible for funding to the same extent as their initial development

- 2) The requirement of governance structures that enable the clear definition and implementation of responsibility and of potentially differing roles and duties, particularly in the collaborative management of information infrastructures
- 3) The creation of mechanisms and the description of conditions required for transferring services from one lead institution to another operating institution if necessary
- 4) The early drafting and development of operating models, which are to be outlined at the proposal submission stage and consistently addressed and taken into account in the review, evaluation and decision-making process
- 5) The development of reputation at both the individual and institutional level based on activities to establish, expand, maintain and evolve information infrastructures that are geared towards demand.

6 Looking ahead to the future

Simply emphasising that (funding) measures must be developed in dialogue with various stakeholders does not in itself guarantee that this dialogue will actually take place. For this reason, the publication of this discussion paper by the DFG is to be combined with the launch of a dialogue process. The aim here is not only to communicate the content of this paper to the groups relevant to the establishment and development of information infrastructures: the DFG will also seek to make targeted use of existing communication channels – and establish new ones – in order to obtain feedback both on the theses on the future of information infrastructures and on the funding measures outlined in section 5 in particular. The intention is to build on these ideas through dialogue with universities, the NFDI consortia and the relevant sections of the German Library Association, for example, and discuss approaches to tackling the challenges facing information infrastructure – also involving research policymakers. The DFG wishes to avoid a situation in which it only engages in bilateral communication with other stakeholders: instead it would like to encourage dialogue between the other stakeholders themselves, particularly in areas where such interaction is not (yet) established or is only in its infancy.

The success of the envisaged dialogue process will be measured primarily by whether it enables the development of mechanisms and procedures that enable scientific information infrastructures to be developed on a demand-oriented basis and maintained in the longer term. The focus of such considerations should be on information infrastructures that either have a unique selling point, are compatible with commercial services, or can be positioned as a genuine alternative to commercial offerings. At the core of this is a shared interest in secure funding, governed by the primacy of digital sovereignty in science.



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