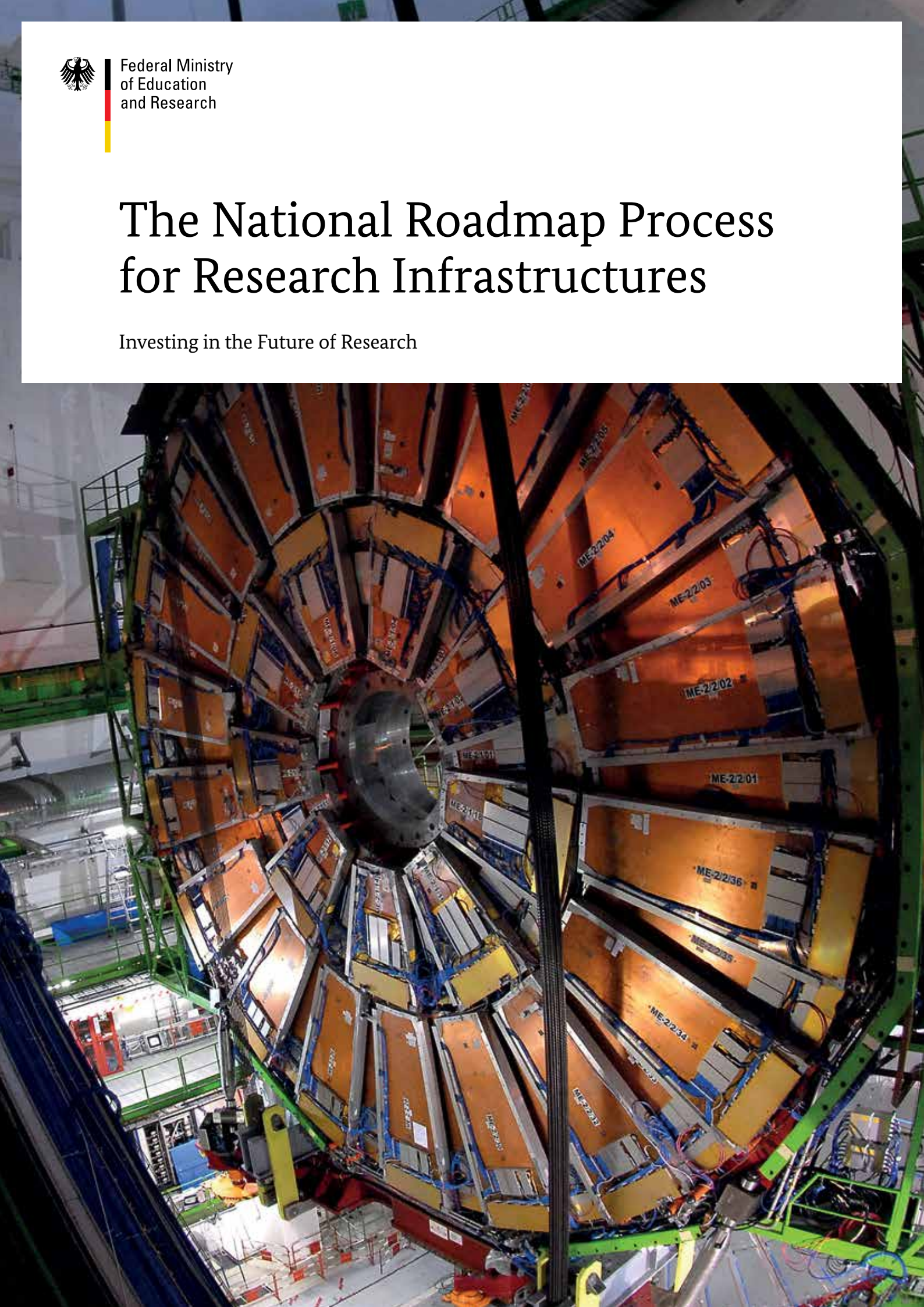
Federal Ministry
of Education
and Research

The National Roadmap Process for Research Infrastructures

Investing in the Future of Research



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Foreword

Research Infrastructures are one of the main prerequisites for excellent basic research, important technological advances and the development of new research areas. Research Infrastructures are therefore the key to Germany's performance as a location for research and economic activities. Examples of such high-performance infrastructures include the marine and polar research vessels funded by the German Federal Ministry of Education and Research (BMBF), particle accelerators for materials research and particle physics, telescopes and longitudinal studies in the social sciences and medicine.

In recent years, the BMBF has provided significant funding for the expansion of Research Infrastructures, and it will continue to do so in the future. The establishment and expansion of Research Infrastructures involve extremely high investments. The BMBF implemented a "National Roadmap Process for Research Infrastructures" from 2011 to 2013 in order to make efficient use of the available funding and plan new Research Infrastructures with a long-term perspective. Building on the experience obtained in this pilot phase, the National Roadmap Process will now be established as a strategic instrument for setting research policy priorities for future investments. With this process we will ensure that investments in Research Infrastructures are made responsibly.

The primary objective of this process is to evaluate new concepts using a coordinated, fair and transparent procedure. High scientific quality, resilient economic planning and major societal relevance are among the benchmarks applied. By including projects in the Roadmap, the BMBF confirms its fundamental intention to provide funding. The Roadmap Process thus provides increased planning certainty and enhances the strategic focus of research and research funding with the aim of establishing ideal conditions for basic research in Germany.

This brochure provides an overview of the Roadmap Process. It is also intended to motivate researchers to contribute their proposals in the long term.

Johanna Wanka

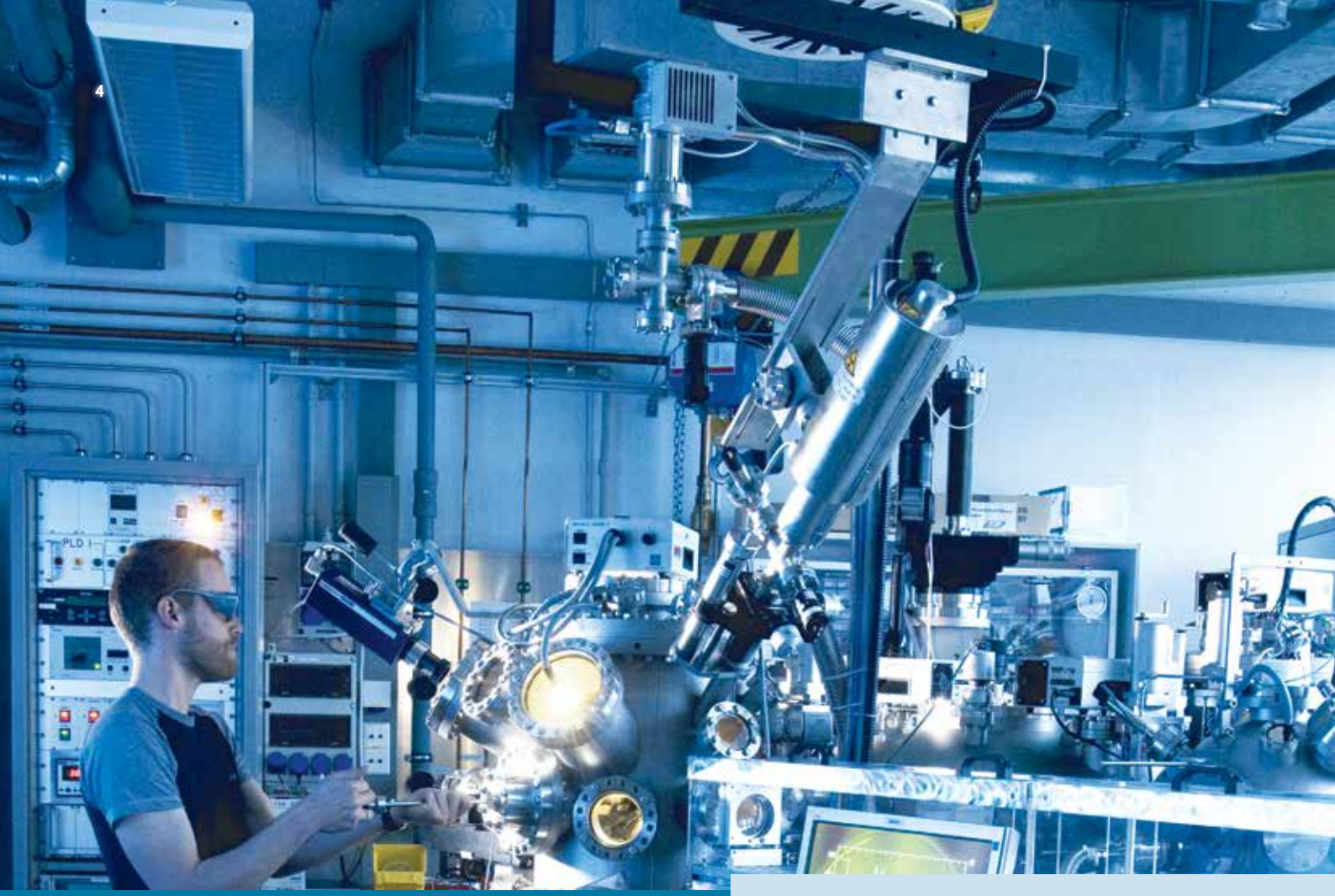
Prof. Dr. Johanna Wanka
German Federal Minister of Education and Research

Introduction

The German Federal Ministry of Education and Research (BMBF) regularly invests in cost-intensive and sophisticated Research Infrastructures. These infrastructures are an essential prerequisite for Germany's performance and international competitiveness as a research location.

However, planning and establishing new Research Infrastructures require considerable levels of public sector funding. These investments must be well-considered as it is not possible to implement all of the proposals submitted. As Research Infrastructures are highly relevant to both research policy and the national economy, their development and establishment require a strategic plan. The prioritisation of new Research Infrastructures should be a transparent and open process. The German Federal Ministry of Education and Research has therefore initiated the "National Roadmap Process for Research Infrastructures", which is dedicated to this important task. The German Council of Science and Humanities is also extensively involved in this process.

The National Roadmap Process for Research Infrastructures serves to prepare and prioritise – in terms of research policy – future and long-term investments in national and international scientific infrastructures with German involvement. The process was established in August 2015 as a follow-up to the "Roadmap for Research Infrastructures Pilot Process", which was implemented from 2011 to 2013. All interested universities and non-university research institutions which are planning to establish new Research Infrastructures can participate in this process.



1. Research Infrastructures

Research Infrastructures (RIs) are an essential component of every scientific system and are of particular importance for Germany as a research location. They provide extensive, long-term research resources, such as laboratories, large-scale equipment, instruments, collections of materials, databases and service facilities.

In the context of this brochure, Research Infrastructures are either new and extensive Research Infrastructures or substantial upgrades of existing infrastructures.

Specific examples of Research Infrastructures can be found in the blue information panels of this brochure. Germany's natural, technical and life sciences have been making use of efficient Research Infrastructures for many years now, whereas the need for Research Infrastructures in the humanities and social sciences has only begun to emerge in recent years. This development is due among other things to the increasing complexity of collections and databases.

Research Infrastructures help to advance basic research and provide access to new research areas and new types of cooperation. They facilitate work on complex research issues, promote the transfer of knowledge and technology and serve the recruitment and training of young researchers. Research Infrastructures generally build on long-term experience in the particular subject area and on the existing strengths of the German science system.

They thus form the basis for an efficient, forward-looking science and research system. At the same time, they strengthen Germany's international attractiveness as a research location. This applies especially to transnational Research Infrastructures, which attract both established and junior researchers from all over the world.

Investments in Research Infrastructures are therefore always an investment in a society's future.

Research Infrastructures serve to obtain excellent scientific findings that could not be achieved with

traditional methods of project funding, regardless of whether these were programme-oriented or not.

The cost of establishing the infrastructures is so high that extensive national public resources are necessary which would exceed the scope of conventional research funding. Research Infrastructures also link up with the existing strengths of the German science system and make it possible to close basic knowledge gaps.

It is therefore necessary to evaluate concepts for new Research Infrastructures in a transparent process and prioritise them according to research policy criteria. After all, research policy decisions on investments in cost-intensive Research Infrastructures do not only have to take specific research-based needs into account. They also have to consider academic and practical benefits and financial feasibility during the establishment, operation and close-down phases – in other words, over the infrastructure's entire lifecycle. The National Roadmap Process for Research Infrastructures (see page 12), which was introduced by the German Federal Ministry of Education and Research in 2015, makes an important contribution to this goal. As a strategic instrument for the research policy prioritisation of future investments, it ensures the necessary investments in Research Infrastructures and their appropriate and careful implementation.

1.1 Categories of Research Infrastructures

In the past, only large-scale facilities such as particle accelerators or research vessels were referred to as Research Infrastructures. Today the term is defined more loosely and includes databases, collections as well as social science Research Infrastructures. A new form of Research Infrastructures has also been developed as a result of advances in information and communication technologies. These include IT infrastructures (so-called e-infrastructures) such as high-performance data centres and computer grids, which are mainly required for data analysis.

Definition of Research Infrastructures in the National Roadmap Process

Research Infrastructures for the purposes of the BMBF's National Roadmap Process are comprehensive, long-term resources that benefit research in all fields of science. These include laboratories, equipment, instruments, collections of materials and databases as well as service facilities.

Research Infrastructures for the purposes of the National Roadmap Process are characterised by the following features:

- They are of national importance for research policy.
- They have a long utilisation period – generally of at least ten years.
- Access to them is generally open, and their utilisation is regulated on the basis of scientific quality standards.
- The cost of establishing and installing the infrastructures is so high that considerable national public funding is necessary, justifying a comprehensive national decision-making process.
- They must have an extensive governance system that is adequate for the relevant task. In cases involving various locations with complementary tasks, they must form a functionally integrated Research Infrastructure with common standards that can be regarded as a single entity.

INFRAFRONTIER – Mouse models for research into complex diseases

www.infrafrontier.eu

The increased incidence of diseases resulting from changes in lifestyle and higher life expectancy represents a major societal challenge. Both genetic and epigenetic influences induced by the environment are important factors in diabetes mellitus, for example. A broad approach that considers the organism as a whole is necessary in order to understand the complex effects of genetic and epigenetic changes. The so-called "mouse clinics" of the pan-European INFRAFRONTIER Research Infrastructure are pursuing this type of systematic approach.

As 99 percent of human genes can also be found in mice, mouse models can provide important insights into the functional causes of human diseases. INFRAFRONTIER is using the latest technologies to study mouse models for human diseases in all the relevant organ systems and disease areas. INFRAFRONTIER is also developing the capacities of the European Mouse Mutant Archives (EMMA) to ensure that scientifically valuable mouse models are available to the entire research community. INFRAFRONTIER is thus providing transnational access to a comprehensive characterisation of mouse lines in mouse clinics (so-called systemic phenotyping).

Currently there are four basic categories of Research Infrastructures*):

Instruments are items of large-scale equipment that are directly available for conducting research projects. Examples in the natural sciences include the "FAIR" particle accelerator or the "CTA – Cherenkov Telescope Array" (see page 7). The research vessel SONNE (see page 11), for example, belongs to the environmental and engineering sciences category, and the "INFRAFRONTIER – Mouse models for research into complex diseases" (see page 6) to the category life sciences and medicine.

Resource and Information Infrastructures are information infrastructures that pool, process and provide data for specific research purposes; such as the German Socio-Economic Panel (SOEP) (see page 9), archives and libraries as well as object-related collections such as the "Deutsches Museum" in Munich.

Information Technology Infrastructures are so called e-infrastructures such as the high-performance computer for climate studies "HLRE 3" (see page 10) or high-performance communication and computer grids such as the "GCS – Gauss Centre for Supercomputing".

Social Research Infrastructures are, for example, centres for research and academic exchange that have been recently established in order to facilitate exchanges on or the development of new research topics – mainly in the humanities and social sciences – such as the Institute for Advanced Sustainability Studies and the Oberwolfach Research Institute for Mathematics.

Some Research Infrastructures may fit into a number of categories at the same time. For example, technology centres that work with large-scale equipment such as particle accelerators may also serve as social science Research Infrastructures or information infrastructures.

*) German Council of Science and Humanities: Report on the Scientific Evaluation of Large-Scale Research Infrastructure Projects for the National Roadmap (Pilot Phase), Cologne 2013, p. 88 ff.

In recent years, "distributed" Research Infrastructures that draw on a range of instruments at various locations have also been developed alongside conventional "centralised" Research Infrastructures. One example is the Cherenkov Telescope Array (see page 7). Furthermore, existing laboratories in the life sciences have joined together to form distributed infrastructures under a common roof. These structures are characterised by a uniform governance system which, among other things, regulates the use of the Research Infrastructures. This allows participating research groups to work together on complex research issues and to access technologies and infrastructures at various locations.

1.2 Lifecycle of Research Infrastructures

Research Infrastructures are characterised by a long development period prior to their establishment, a long utilisation period and, in some cases, a complicated deconstruction and removal phase. It is therefore important to consider the entire lifecycle when planning a Research Infrastructure.

The lifecycle of a Research Infrastructure covers the following five phases (see the diagram on page 8):

1. Initialisation phase

The project initialisation phase takes place before concrete planning for a new Research Infrastructure can begin. This phase is used to identify the need for the particular Research Infrastructure within the scientific community, specify areas of responsibility, outline goals, and discuss and refine initial plans for the Research Infrastructure.

2. Definition phase

Once the new proposal for a Research Infrastructure has been accepted within the scientific community, it is refined further before the actual planning begins. Among other things, the definition phase is used to specify goals and milestones, explore the project environment and stakeholders, analyse possible risks and evaluate feasibility.

3. Planning phase

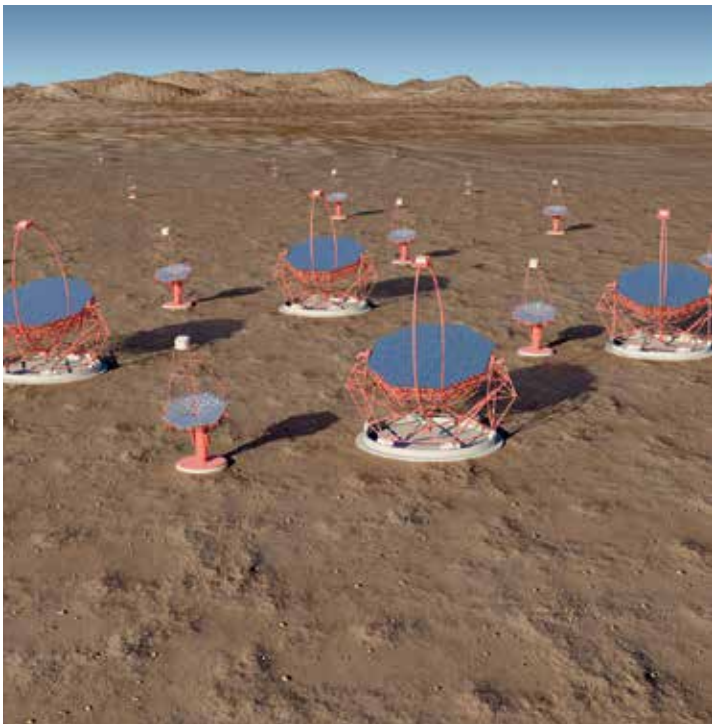
The planning phase is used to specify project measures and goals; for example, risk minimisation measures are planned, project structure plans, schedules and financial plans finalised and quality assurance measures developed. A detailed proposal for a Research Infrastructure should emerge by the end of this phase. Implementation then takes place in the next phase – the steering phase.

CTA – Cherenkov Telescope Array

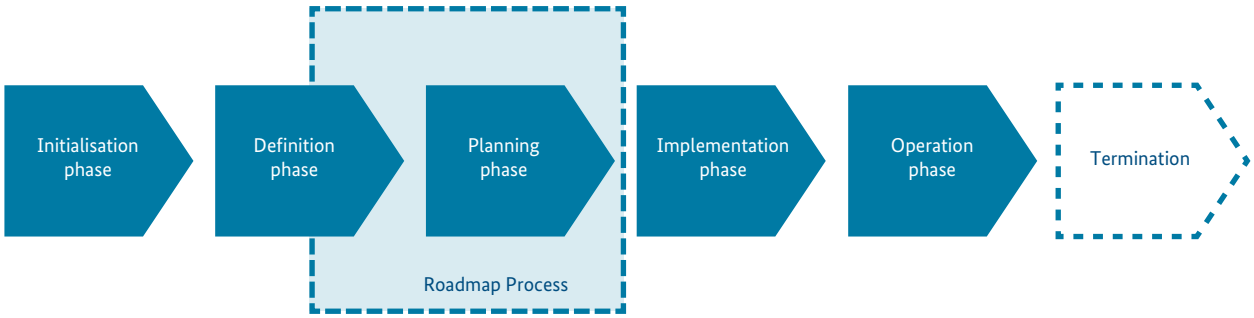
www.cta-observatory.org

The Cherenkov Telescope Array (CTA) astrophysics project – a ground-based network of telescopes that specialises in the detection of gamma rays – aims to detect highest-energy rays that originate far away in the universe and are absorbed in the upper layers of the earth's atmosphere. Thanks to its previously unattainable sensitivity and spatial resolution, the CTA will help to provide answers to a range of fundamental questions about the structure of the centre of the Milky Way, the nature of dark matter and the formation of the stars and black holes.

The CTA will be built by a worldwide consortium of almost 30 countries as a distributed Research Infrastructure with two observatory locations that together cover both the northern and southern hemispheres.



Phases in the life of a Research Infrastructure



The BMBF MAP Process

The National Roadmap Process for Research Infrastructures – introduced by the German Federal Ministry of Education and Research in 2015 – focuses on the crucial early phases in the lifecycle of a Research Infrastructure, which comprises the end of the "Definition Phase" up to the completion of the "Planning Phase" (see graphic above). These phases include the stages from the initial development of a research infrastructure project up to a more detailed RI proposal that can be implemented in principle.

The German Federal Ministry of Education and Research provides a structure called 'minimum requirements for projects' (in German: 'Mindestanforderungen an Projekte', MAP) for the implementation of large-scale projects; this structure is the basis for the lifecycle phases described here. The terminology used is based on the BMBF's key management process of controlling.

The MAP process was developed on the basis of the relevant DIN standards (DIN 69900 and DIN 69901), and in accordance with the Lehman process (US DOE Order 413.3A). Its aim is to ensure an efficient project management structure within a project that among other things enables quick orientation and is relatively independent of the individual persons involved.

Detailed information on the BMBF MAP process and the relevant key management processes can be found in German at www.bmbf.de under the heading "Über uns" by selecting "Haushalt" and then "Controlling von Großprojekten".

4. Implementation phase (project establishment phase)

The implementation phase is the phase during which the project is established. The beginning of the implementation phase can be defined more or less precisely depending on the type of Research Infrastructure. For example, the implementation of a singular, local, large-scale research facility can be defined precisely from ground-breaking ceremony to commissioning. It may be more difficult to define the beginning of the implementation phase in distributed Research Infrastructures, however, because existing and new large-scale facilities and platforms are incorporated step by step.

5. Operation phase and termination

The Research Infrastructure is used during the operation phase, with a utilisation period of at least ten years. The operation phase is subsequently followed by the termination phase, which involves the renewal or subsequent use as well as the removal of the Research Infrastructure.

1.3 Operation and Utilisation of Research Infrastructures

Research Infrastructures that are set up using public funds must produce an exceptional research benefit in order to justify the high costs of establishing and operating these infrastructures. This benefit is achieved among other things when the given infrastructure is used intensively by a large number of researchers.

The **utilisation concept** is thereby of great importance as it must identify a sufficiently large circle of users

with a high level of research potential and must regulate access arrangements. This also includes questions regarding the infrastructure's capacity utilisation or international networking with other user groups.

In principle, the Research Infrastructure is intended to be available to the entire scientific community in the relevant research area. If this is not possible, access must be regulated on the basis of transparent, scientifically-based procedures.

The **governance** of a Research Infrastructure has a significant effect on its successful operation and effectiveness. Guidelines that define tasks and decision-making competences (e.g. of a scientific advisory board, board of directors and management) as well as details of incorporation in supranational consortia are elements of the governance of a Research Infrastructure. They are evaluated in detail within the framework of the National Roadmap Process. The basic elements of a governance concept include the designation of the organisation responsible for the Research Infrastructure, the related choice of location, as well as arrangements governing the use of the Research Infrastructure.

Data management is an important challenge for many Research Infrastructures. In addition to ensuring reliable and secure data acquisition and storage for researchers, the conditions for general access to primary data must also be regulated for national and international researchers.

1.4 Cost-Effectiveness of Investments

The cost-effectiveness of investments is always an important criterion when employing public funds. The efficiency of a project is initially calculated by analysing costs and benefits. Further scaling options (e.g. alternative features and equipment) and their impacts in terms of costs and benefits on research itself and on Germany's strength as a research location also play an important role. An economic benefit can be achieved by supplying the funds for establishing infrastructures from various complementary sources (e.g. the German Federal Government, EU, partner countries).

SOEP – The German Socio-Economic Panel

www.diw.de/en/soep

How satisfied are German citizens? How much time do fathers spend with their children every day? These are just two of the issues on which the German Socio-Economic Panel (SOEP) provides information.

The SOEP is Germany's oldest multidisciplinary long-term study, which the German Institute for Economic Research (DIW Berlin) has been conducting since 1984. 30,000 people from around 15,000 households in Germany are currently participating in this representative longitudinal study. The data gathered provides information on issues such as income, employment, education and health. The same people are surveyed once a year. This means that it is not only possible to follow long-term societal trends, but also to document specific developments in the life courses of certain population groups.

Along with the long-term monitoring of societal changes, new measurement methods are continually being added to the SOEP. In particular, these include geo-referenced context data, biomarkers and the results of psychological measurements. A number of cohort studies have been established by introducing age-specific questionnaires. The data from the SOEP is made available to researchers all over the world.

The grip strength test shown below provides reliable information about the current state of health of those surveyed. Together with the SOEP data, the grip strength test not only provides information about state of health, but also about socioeconomic status and future risks of disability und mortality.

The ability of the operator or the operating consortium to bear the operating costs is also assessed when evaluating the cost-effectiveness of a Research Infrastructure. The calculations can take into account revenue such as fees and reimbursements of costs (e.g. utilisation fees or as part of project funding).

The cost-effectiveness of a research vessel, for example, results from its high potential for obtaining new knowledge and from its multidisciplinary usage (natural and life sciences).

A High-Performance Computer for Earth System Research (HLRE 3)

www.dkrz.de/Klimarechner-en

At the German Climate Computing Center (DKRZ), processes and interactions which play an important role for the climate can be reproduced using climate simulations in order to investigate past, current and future climate behaviour.

As a disciplinary high-performance computing centre, the DKRZ is an essential service facility for climate research in Germany. It provides high-performance computers and data-storage systems that have been specifically customised for applications in climate and earth system research. It also provides many other services that support work with highly complex computational models. In addition, the DKRZ operates one of the largest, most powerful data archives worldwide: a total capacity of up to 500 petabytes (equivalent to $5x10^{15}$ bytes) is available to users in seven libraries with over 77,000 magnetic tapes.

Another important factor is that the same goal could not be achieved through conventional funding of individual projects at various locations.

1.5 Internationality

Many major innovative and interdisciplinary research projects in Germany are already being implemented in close cooperation with partners from Europe and all over the world. Research Infrastructures involving cross-border cooperation attract a large number of international researchers as well as junior researchers. The ongoing development of the European Research Area and, in particular, the pan-European establishment of major Research Infrastructures play an important role in German research policy. The Research Infrastructures that Germany is operating are already demonstrating features which are relevant for international cooperation as well as for Germany's international competitiveness as a research location:

- The organisations responsible for the Research Infrastructures fulfil the highest international research standards.
- The Research Infrastructures contribute to establishing and maintaining international competitiveness in the respective field by building on existing national strengths.
- The Research Infrastructures enhance Germany's international profile and attractiveness as a research location in the medium and long term.
- The Research Infrastructures are generally organised internationally. The form in which international cooperation is regulated is thereby irrelevant. For example, there are Research Infrastructures that consist of a number of locations in various partner countries. On the other hand, a Research Infrastructure may also be located in just one partner country with all the costs being shared on the basis of a contractual agreement. Decisive is the contribution to the excellence of German research and whether the costs remain economical.

The great international importance of Research Infrastructures is reflected in the fact that there is a separate Roadmap Process (see also page 15) at European level. The "European Strategy Forum on Research Infrastructures" (ESFRI) promotes the integration of the European Research Area with this process.

The European Strategy Forum on Research Infrastructures (ESFRI) was founded in 2002 at the behest of the European Council. ESFRI is a strategic instrument enabling EU Member States to agree on which large-scale Research Infrastructures are to be planned and implemented together. The main task of ESFRI is to identify and prioritise new Research Infrastructures that are required to strengthen and develop Europe as a research location.

In 2006, ESFRI introduced a Roadmap for the most important Research Infrastructure projects at European level. Since then, this Roadmap has been updated a number of times.

The ESFRI roadmap is essentially a list of priority projects which are being supported by a number of European states and, in certain cases, by associated non-European states such as the United States, China and Japan.

Further information on the ESFRI roadmap is available at www.esfri.eu under the heading "Roadmaps".

New Research Vessel SONNE

www.portal-forschungsschiffe.de/schiffe/sonne

Marine researchers plan to use the high-tech vessel SONNE to study climate change in more detail, assess the impacts of human activity on eco-systems and search for maritime raw materials.

The SONNE research vessel offers ideal conditions for this work thanks to its working area of 600 square metres, state-of-the-art equipment and up to 25 twenty-foot research containers. The vessel was completed in 2014 and provides room for 40 researchers. The SONNE was constructed in accordance with the latest environmental standards, is highly energy-efficient and thus particularly environmentally friendly.

The SONNE is available as a research and working platform for all marine and related scientific disciplines. It will be used mainly for research work in the Indian and Pacific Oceans. It is becoming increasingly important to carry out research on both of these oceans as they have a major influence on the world's climate. The research vessel collects data on issues such as climate protection and global warming, and thus makes an important contribution to climate change research. In addition, deep-sea research will provide new findings on geodynamics and georisks such as earth movements and tsunamis and will study the ecological impacts of possible future deep-sea mining.

In 2015, the new high-tech vessel SONNE replaced the old "Sonne" vessel, which had been underway in the service of research for 36 years.

2. The National Roadmap Process for Research Infrastructures

2.1 The Pilot Process 2011-2013

The BMBF conducted a pilot process to establish a National Roadmap for Research Infrastructures between 2011 and 2013. This involved examining and prioritising concepts for new Research Infrastructures based on a standardised, transparent procedure consisting of two coordinated processes: a science-driven evaluation and an economic evaluation. It was supplemented by an evaluation of the societal relevance of the proposals and followed by a prioritisation based on research policy aspects.

The Pilot Process demonstrated that this instrument is particularly suitable for preparing strategic decisions on cost-intensive research infrastructure projects.

Further information on the "Roadmap for Research Infrastructures" Pilot Process can be found in German at www.bmbf.de under the heading "Forschung" by selecting "Das Wissenschaftssystem" and then "Forschungsinfrastrukturen".

2.2 Establishment of the Roadmap Process

Building on the experience gained within the pilot process, the National Roadmap Process for Research Infrastructures was established in 2015 as a strategic instrument for prioritising future investments based on research policy criteria. The primary objective of this process is to evaluate new Research Infrastructure proposals according to a standardised, fair and transparent procedure. The Roadmap Process sets out to ensure that all proposals for Research Infrastructures that are ultimately included in the National Roadmap distin-

guish themselves through the high quality of their research, resilient economic planning and high societal benefits.

The process thus strengthens Germany's competitiveness as a location for research and innovation and enhances the quality of wide ranging decisions regarding research policy.

2.3 Aims of the Roadmap Process

The Roadmap Process supports the research policy decision-making process on a national level in the context of major investments in comprehensive, long-term Research Infrastructures. It involves all areas of research and all research organisations and institutions in Germany. By establishing this process, the BMBF wishes to ensure that the necessary investments are made sensibly and responsibly.

The Roadmap Process serves both as a map and a timetable. The map shows which Research Infrastructures should be located where and in which contexts. The timetable, on the other hand, indicates the timeframe for and the steps involved in developing the Research Infrastructures. The Roadmap Process is not a new funding programme as such, but rather a strategic instrument for research policy prioritisation.

As some Research Infrastructures can only be implemented as part of European or international cooperation schemes, the BMBF also aims to use the Roadmap Process to prepare and support political decisions concerning German participation in European or international research infrastructure projects.

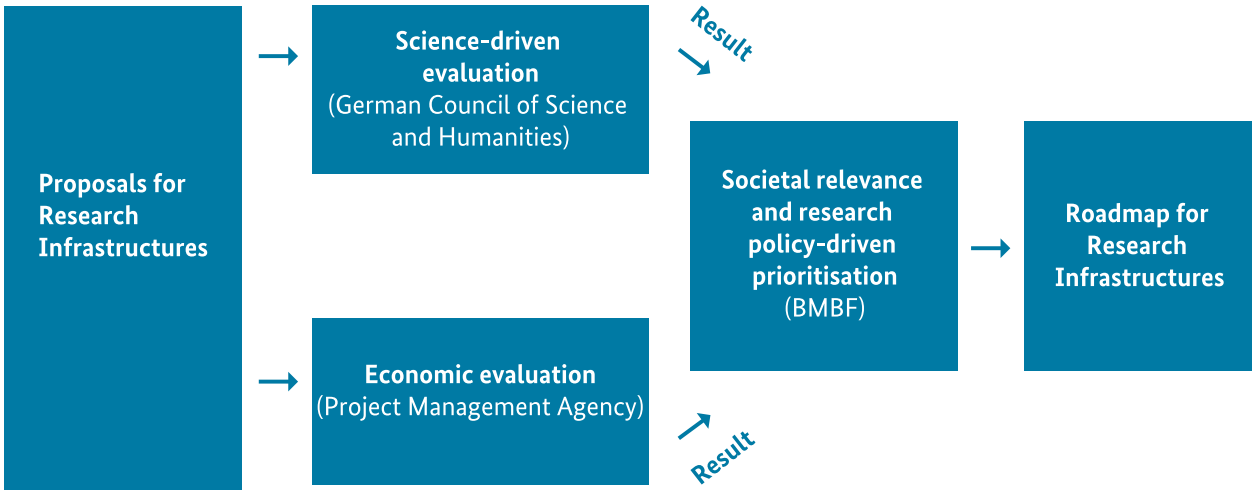
2.4 Benefits for the Research Landscape

Researchers who participate in the National Roadmap Process by presenting proposals for infrastructures provide a vital contribution to a long-term national research strategy. Their involvement introduces new topics into research policy discussions. This enables the researchers concerned to participate in the long-term strategic positioning of research topics in the context of setting an agenda. Although it may not always be viable to implement all new Research Infrastructures in the short term, it is nevertheless possible that the intensive substantive discussions initiated by the Roadmap Process will lead to success in the long term.

An additional positive aspect of the Roadmap Process for all the proposals presented is that the work to prepare the proposals and the subsequent evaluation processes foster the creation of networks in thematically related areas. Concepts that cannot be included in the National Roadmap to begin with are also able to benefit in this context.

Furthermore, there are a number of other advantages for all the proposals for Research Infrastructures included in the Roadmap Process, for example:

Roadmap Pilot Process – Procedure within the Pilot Process 2011-2013



XFEL – X-Ray Free Electron Laser

www.xfel.eu/en

The X-Ray Free Electron Laser (XFEL) is a unique facility in Europe that generates ultrashort flashes in the X-ray range. These X-ray flashes open up a lot of opportunities in many research areas: As well as helping to reveal the atomic details of cells, viruses, biomolecules and nanomaterials, they can also be used to film chemical reactions and biological processes at a molecular level and to investigate processes that cannot be directly observed, such as those in the interior of planets.

Free electron lasers in the X-ray wavelength range can revolutionise this research area and provide key inspiration for innovations within the context of developing efficient and environmentally friendly chemical production processes, producing effective drugs and developing new resource-efficient materials.

The world's most up-to-date and most powerful X-ray laser system runs mainly underground in tunnel systems. It has a 4,500 square metre underground experimental hall, underground engineering halls as well as a laboratory and office building.

XFEL is being implemented jointly with a large number of partners. The construction costs for the facility, including commissioning, are expected to amount to 1.225 billion euros (price basis: 2005). Germany, as the host country, is bearing 58 percent of the construction costs; Russia will pay 27 percent and the other international partners will be responsible for between one and three percent each. Construction began in early 2009, the start of the first experiments is planned for 2017.

Intention to fund successful proposals

There is a basic intention to provide funding for all Research Infrastructures that are included in the National Roadmap. The actual implementation of funding takes place following the Roadmap Process. Unless infrastructures are funded under institutional budgets, funding is provided by the relevant ministries – such as the German Federal Ministry of Education and Research – within the framework of a regular application procedure and depending on the budgetary funds available.

"Quality mark" strengthens ability to promote own infrastructures

Inclusion in the National Roadmap serves as a kind of "Quality mark" for the respective Research Infrastructures, which they can then use to promote their work in the future. This increases their chances of acquiring additional funding as well as new partners and users. The "Quality mark" also guarantees researchers wishing to use the infrastructure that it fulfils the highest possible quality standards and that they will be able to conduct their research under excellent working conditions.

External cost validation raises planning certainty

External evaluators draw up a detailed and independent estimate of the expected investment costs for every proposal involved in the Roadmap Process. This provides transparency for funding bodies and greater planning certainty for all stakeholders.

Ongoing optimization process

The experts involved in the Roadmap Process suggest ways to optimize the proposals received. Proposals that are not yet included in the Roadmap can also benefit as they can take the suggested improvements into account, thus enhancing their chances of being included in the next Roadmap Process.

2.5 Organisation of the Roadmap Process

The National Roadmap Process, which was established in 2015, is organised centrally by the German Federal Ministry of Education and Research and enables all research organisations, universities, states and relevant institutions in Germany to participate. The Roadmap Process is implemented within the framework of a public announcement.

The Roadmap Process helps to identify future needs for new Research Infrastructures as early as possible and to prioritize them in a strategic decision-making process. This ensures Germany's steady development as a research location, taking into account the international competitiveness of German basic research. As this task needs to be tackled in cooperation with the entire scientific community, the latter is given the opportunity to provide relevant input. At the same time, a transparent procedure ensures that the need for new Research Infrastructures is justified scientifically. The Roadmap Process allows stakeholders from universities, research organisations, non-university research institutions, academies as well as industry to participate.

2.6 National and International Relevance of the Roadmap Process

In terms of content, the Roadmap Process for Research Infrastructures is closely connected with the processes and strategies of the BMBF and of the science and research community in Germany. For example, the BMBF has been using foresight processes since 1992 to assess at regular intervals which developments and topics expected to be relevant in ten to fifteen years' time and will therefore play an important role in research. The national relevance of new Research Infrastructures is derived from the findings of these foresight processes as well as from strategy discussions such as those conducted within the framework of the High-Tech Strategy (HTS) or the Joint Initiative for Research and Innovation.

At the same time, the German Roadmap Process is closely linked with developments in the European Union (EU). For example, Germany – as the largest research nation in Europe – plays a leading role in the ongoing development of the European Research Area.

In 2014, the German Federal Government published its National Strategy on the European Research Area, which, among other things, foresees the establishment of major Research Infrastructures on a pan-European basis. Germany plays a leading role in the EU in this context. One example here is the X-Ray Free-Electron Laser (XFEL) in Hamburg – a 3.4-kilometre-long X-ray laser. In total, twelve European countries are involved in building this facility on German soil.
Furthermore, Germany participates in ESFRI - the European Strategy Forum for Research Infrastructures – which was founded in 2002 at the behest of the European Council.

IAGOS – In-service Aircraft for a Global Observing System

www.iagos.org

There are still a lot of gaps in our current knowledge about climate change and its complex consequences for the climate system. We need to know more, for example, about the amplification of the CO_2-induced greenhouse effect by water vapour, the effect of aerosols on the formation and properties of clouds, or changes to biological cycles. These uncertainties make it difficult to provide an accurate forecast of the future climate, particularly at a regional level.

IAGOS is being set up and operated as a world-leading Research Infrastructure. It will make it possible to measure the composition of the atmosphere on a global scale. The monitoring of the atmosphere using passenger aircrafts represents the best method of obtaining detailed information, particularly in the boundary zone between the troposphere and the stratosphere at an altitude of 9-13 kilometres. The IAGOS research infrastructure is based on automated measuring equipment that will be installed on a fleet of up to 20 passenger aircraft belonging to international airlines, thus closing the gap between satellite-supported remote sensing and ground measurement stations.

ESFRI is the central forum where member states can contribute their thoughts and ideas on Research Infrastructures in accordance with their national priorities and jointly discuss, identify and prioritise new Research Infrastructures.

The major benefit of the ESFRI process is that it provides an opportunity to use the potential of the European Research Area and takes advantage of the complementary cooperation and financing methods at a European and potentially even at a global level.

Germany plays a leading role in providing and using Research Infrastructures and benefits from close networking with its European neighbours. Germany has been actively involved in ESFRI since it was founded. Early coordination with European and non-European partners regarding common interests in the planning, construction and operation of Research Infrastructures will become even more important in the future. For this reason, the BMBF aims to continue its active involvement in the Member State-driven ESFRI process in the future and to ensure that it dovetails with the National Roadmap Process.

Further information on the ESFRI roadmap is available at www.esfri.eu under the heading “Roadmaps”.

2.7 Roadmap Process Workflow

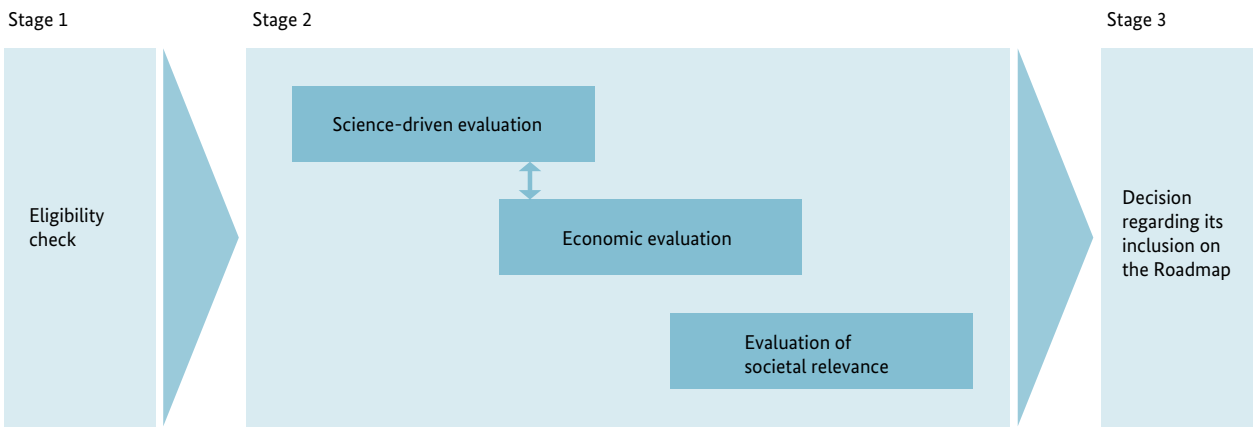
Research Infrastructures play an extremely important role in both research policy and the national economy. Therefore it is essential that the establishment of new Research Infrastructures is planned strategically and prioritised in a transparent and open procedure. To ensure this, the National Roadmap Process has been structured as a three-stage assessment process (see the diagram at the bottom of page 16):

- In **stage 1**, the proposals submitted are checked for eligibility.
- In **stage 2**, independent experts evaluate the proposals on the basis of scientific and economic criteria. These evaluations are then supplemented by an appraisal of the societal relevance of the proposals.
- In **stage 3**, the BMBF or other relevant ministry makes a decision on the inclusion of Research Infrastructures in the Roadmap based on the evaluations in stage 2.

Stage 1: Eligibility check on incoming documentation

Before proposals are accepted for assessment in the Roadmap Process, they are reviewed to ensure that they fulfil the formal prerequisites. Thus only proposals for very large, cost intensive Research Infrastructures can be accepted. Another essential requirement is that the submitted proposals must be ready for

Course of the Roadmap Process



assessment, i.e. projects must already be at the concrete planning stage. This is necessary for the science-driven and economic evaluations as well as for the timely implementation of the Research Infrastructure. Accordingly, the proposals must be planned in sufficient detail and include specific information and planning documentation.

The BMBF provides all the relevant information on documentation criteria – such as the thresholds for development costs– in guidelines for outlining proposals prepared specifically for the Roadmap Process (see page 19).

Stage 2: Science-driven and economic evaluation process and evaluation of societal importance

The BMBF involves independent experts in the second phase of the assessment process; they assess the scientific quality and the financial feasibility of the proposals submitted. The BMBF – or another ministry if appropriate – then evaluates the societal relevance of the proposals presented. All three evaluations are carried out separately. Their results are then summarised and serve as a basis for the decision on inclusion in the Roadmap.

Science-driven evaluation

The German Council of Science and Humanities is responsible for the science-driven evaluation of the research infrastructure proposals. An independent, interdisciplinary comparison based on standardised evaluation criteria is required to justify the prioritisation of future investments in new Research Infrastructures according to scientific needs. The German Council of Science and Humanities has therefore appointed a mandated committee consisting of researchers from all major fields of science. This committee is supported by international experts from a wide variety of disciplines who are appointed especially to evaluate the proposals submitted. The experts are selected on the basis of their scientific expertise and international experience. The latter is necessary to judge the importance of planned Research Infrastructures within the global research landscape. Moreover, there are not enough national experts to guarantee an independent evaluation – when one considers the extensive networking between large-scale research infrastructure projects and the potential problem of a lack of impartiality.

The science-driven evaluation of the proposals submitted takes place in two steps: a review of the project proposals and a comparative overall assessment. The term ‘comparative’ here means that planned Research Infrastructures from all fields of science are assessed according to the same criteria and the results are presented in a standardized manner. Key factors for the assessment are the scientific potential of the planned Research Infrastructures– i.e. their importance in initiating new or developing existing research fields – and their relevance for Germany as a scientific and research location as well as their international visibility. However, the success of large-scale Research Infrastructures does not depend solely on their scientific potential. The evaluation therefore includes additional aspects relating to utilisation (e.g. size and origin of user groups and access management), feasibility (e.g. technical requirements and risks), governance and relevance to Germany as a location of science and research.

Qualitative individual assessment, comparative overall assessment and recommendations for the further development of the proposals together form the result of the science-driven evaluation procedure. All results are presented to the German Council of Science and Humanities and published in the form of an evaluation report.

Economic evaluation

Independent experts from industry and science who have specialist economic and technical expertise are appointed to evaluate the proposals from an economic perspective. In addition to specialists in economics, these experts may also include – depending on the subject area of the Research Infrastructure planned – shipyard directors or engineers who specialise in propulsion engines for research vessels or in the load-bearing capacity of large concrete structures for a particle accelerator. Such practical experience and knowledge is essential in order to be able to evaluate whether proposals are in fact sustainable and feasible from a technical and, above all, economic perspective.

Investment cost-effectiveness is a key criterion within the Roadmap Process. In this way the German Federal Ministry of Education and Research faces up to its responsibility to use limited funds optimally.

The primary goal of the economic evaluation is to analyse the funding concept of the Research Infrastructure proposal. The main objective is to obtain an additional independent estimate of the development costs from

multiple experts in a process based on the "Delphi" method. The appropriateness and reasonableness of the expected costs are also evaluated.

The economic evaluation also includes checking the operating costs as well as the planned implementation, realisation and utilisation of the Research Infrastructure with regard to economic and organisational feasibility. The aim is to identify whether the estimated funds will be used in an economically reasonable manner and whether the specified costs are realistic, complete and justifiable. The evaluation considers whether less expensive, but nonetheless equally high-quality alternatives are available for the procurement of research equipment. A further important aspect that is evaluated is the question of whether the operator or operating consortium is in a position to bear the operating costs. The experts focus their attention in particular on potential imponderabilities when setting up the Research Infrastructures, conduct a risk assessment and, where applicable, suggest alternative approaches and methods to those responsible for the proposal.

Evaluation of societal relevance

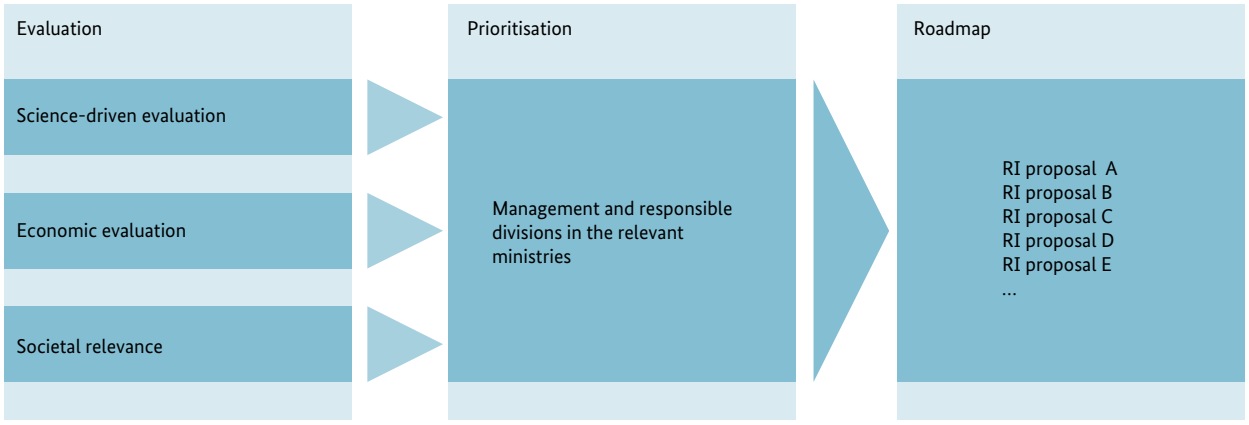
The evaluation of whether a proposal will deliver a societal benefit is carried out internally by the relevant funding body – this will generally involve one or more ministries. Above all, the socio-economic, societal and research policy impacts of the proposals are examined. Detailed consideration is given in particular to the direct economic consequences, the medium and long-term socio-economic benefit and the role of the Research Infrastructure in national value chains and innovation cycles.

An important criterion for the BMBF – or another ministry if appropriate – is the extent to which the proposals deal with major societal challenges: can they help solve global challenges such as climate change, demographic change, health and food security or migration? Other evaluation criteria include questions such as whether the concepts help to maintain and develop an excellent, future-oriented research landscape or foster the next generation of researchers.

Stage 3: Decision on inclusion in the Roadmap

In stage 3 of the Roadmap Process, the BMBF or the relevant ministry decides whether a new Research Infrastructure will be included in the National Roadmap. The Ministry is primarily guided by the results of the scientific and economic evaluations and the evaluation of the societal relevance of the proposals. In addition, decision-making in this phase of the procedure also takes other criteria into account that have deliberately not been considered up to this point – including international obligations, the possible contribution of the planned project to the development of innovative research areas or to the relevant research policy strategy.

Prioritisation process



In view of the scientific and economic importance of the Research Infrastructures and their high investment and operating costs, the BMBF involves the persons responsible for the respective Research Infrastructure in the decision-making and prioritisation process.

As far as the selected proposals are concerned, inclusion in the National Roadmap signifies a fundamental intention to provide funding. The actual implementation of this intention by the relevant ministries is then based on the funds available.

At the end of the assessment procedure, all projects participating in the Roadmap Process receive a validation. This validation is intended to help those responsible to optimise their proposals. Proposals that are not included in the National Roadmap can be resubmitted to the next Roadmap Process.

Further information about the National Roadmap Process

Further information on the "Guidelines for Outlining Proposals for the National Roadmap for Research Infrastructures" can be found at www.bmbf.de under the heading "Forschung" by selecting "Das Wissenschaftssystem", "Forschungsinfrastrukturen" and then "Publikation".

The "Guidelines for Outlining Proposals" provide specific information on preparing proposals and on the scientific and economic evaluations.

DARIAH – Digital Research Infrastructure for the Arts and Humanities

www.dariah.eu

DARIAH-DE, a research network consisting of 14 partners, is Germany's contribution to the European DARIAH-EU project. This network supports scholars in the humanities and arts working with digital resources and methods in teaching and research.

A digital Research Infrastructure for tools and research data is being established for this purpose and materials for teaching and ongoing training in the area of digital humanities are being developed. This Research Infrastructure allows specialists to perform interdisciplinary, collaborative, sustainable and cross-institutional work in an increasingly digital research environment.

The main task of DARIAH-DE is to facilitate the extensive and enduring utilisation of tools and research data in the digital humanities. In addition, DARIAH-DE provides support and advice to specialists and researchers when planning humanities research projects in a digital environment.

The project also aims to ensure the competent utilisation of digital humanities resources, concepts and methods when teaching and training humanities specialists.

3. Frequently Asked Questions

What is covered by the term “Research Infrastructure”?

Research Infrastructures (RIs) are comprehensive, long-term research resources, such as laboratories, equipment, instruments, collections of materials and databases, or service facilities. In the past, only large-scale facilities such as particle accelerators or research vessels were classified as Research Infrastructures. Today, the term is used in a broader sense and includes databases, collections and social Research Infrastructures.

New forms of Research Infrastructures have been developed as a result of improvements in information and communication technologies. These so-called IT infrastructures (e-infrastructures) include high-performance computers and computer grids which are particularly important for analysing data.

Why is the German Federal Ministry of Education and Research investing significant funds in sophisticated Research Infrastructures?

For many years now, the BMBF has been investing significant funds for complex and sophisticated Research Infrastructures as these are an essential component of every scientific system and are particularly important for Germany as a research location.

Research Infrastructures advance basic research in particular and develop new research areas and new types of cooperation. They promote knowledge and technology transfer, facilitate work on complex research issues and help to recruit and train junior researchers. Research Infrastructures generally build upon many years of experience in the relevant subject area and link up with the existing strengths of the German scientific

system. The BMBF aims to further enhance the efficiency and international competitiveness of German research by establishing and expanding Research Infrastructures.

What is the specific objective of the National Roadmap Process?

The National Roadmap Process serves as a strategic instrument for prioritising future investments in Research Infrastructures based on research policy criteria. It sets out to ensure that new RI concepts are assessed on the basis of a standardised, transparent process.

By establishing the Roadmap Process, the BMBF aims to make planning processes more reliable and increase efficiency, improve the strategic orientation of research and research funding, and create optimal conditions for Germany as a research location. The BMBF aims to ensure that public investments are made wisely and appropriately. The BMBF uses the Roadmap Process for Research Infrastructures to prepare the necessary research policy decisions on long-term Research Infrastructures.

Who can participate in the National Roadmap Process, and with which Research Infrastructure?

Interested universities and non-university research institutions which are planning to establish very large, cost-intensive Research Infrastructures can participate in the National Roadmap Process. These infrastructures must fulfil the specified framework conditions and must have reached, among other things, a specific level of planning.

The BMBF specifies all the relevant information regarding eligibility criteria – such as the applicable thresholds for establishment costs – in its guidelines for the Roadmap Process.

At which phase of a Research Infrastructure project does it make sense for the project to participate in the Roadmap Process?

One of the main prerequisites for an application to be admitted to the National Roadmap Process is that the Research Infrastructure should have reached a specific level of planning and thus be ready for assessment. The proposals must be planned in sufficient detail and include specific information and planning documentation in order to be considered for the assessment process.

How are the Research Infrastructure proposals assessed?

The RI concepts are assessed in a three-stage process. In stage 1, the proposals are checked for eligibility. In stage 2, independent experts evaluate the accepted proposals on the basis of scientific and economic criteria. These evaluations are then supplemented by an estimate of the societal relevance of the concepts. In stage 3, the German Federal Ministry of Education and Research or other relevant ministry decides whether or not the Research Infrastructures are to be included in the National Roadmap on the basis of the three evaluations carried out in stage 2.

What role does the German Council of Science and Humanities play in the development of the National Roadmap?

The German Council of Science and Humanities is responsible for the science-driven evaluation of the proposals submitted. It acts independently and autonomously. The evaluation is carried out by a mandated committee of the Council consisting of researchers from all major fields of science. The committee is supported by international experts from a wide variety of disciplines who are appointed especially to review the proposals submitted. The experts are selected on the basis of their scientific expertise and international experience. The latter is necessary to rank the importance

of planned Research Infrastructures within the global research landscape.

How is the societal relevance of the RI proposals evaluated?

The societal relevance of the RI concepts is evaluated internally by the BMBF or the relevant responsible ministry. In this context, the BMBF examines the socio-economic, societal and research policy impacts of the concepts – particularly their direct economic consequences, their medium and long-term socio-economic benefit and the role of the Research Infrastructure in national value chains and innovation cycles.

One important criterion here is the extent to which the proposals help to solve major societal challenges such as climate change, demographic change, food security, migration or economic instability.

Furthermore the proposals are evaluated in terms of their contribution to maintaining and developing a future-oriented, excellent research landscape and whether they can help to promote junior researchers.

To what extent is the German Roadmap Process linked to the European ESFRI Roadmap Process?

The German Roadmap Process is closely linked to developments in the European Union. Germany is a member of ESFRI, the European Strategy Forum for Research Infrastructures. ESFRI's main task is to identify and prioritise new Research Infrastructures of strategic pan-European importance that strengthen and develop Europe as a research location. ESFRI issued a first roadmap for the most important RI projects at European level in 2006. This has since been updated a number of times.

The major benefit of the ESFRI roadmap process is that it utilises the potential of the European Research Area and takes advantage of complementary opportunities for cooperation and funding at European or even global level, where applicable.

Are Research Infrastructures funded directly once they have been included in the National Roadmap?

Inclusion of Research Infrastructures in the National Roadmap signifies a fundamental intention on the part of the responsible ministries to fund the establishment of these infrastructures. At the same time, this paves the way for appropriate coordination with the relevant national and international bodies. The actual implementation of funding takes place following the Roadmap Process. Unless infrastructures are funded under institutional budgets, funding is provided by the relevant ministries within the framework of a regular application procedure and subject to the availability of the necessary budgetary funds.

What are the consequences if a Research Infrastructure is not included in the National Roadmap?

There is no priority intention on the part of the responsible funding body to fund RI projects that are not included in the National Roadmap. However, these RI proposals may be resubmitted to the next Roadmap Process. All institutions participating in the Roadmap Process receive a validation of their research and economic proposals at the end of the process. This can help those responsible for the Research Infrastructures to optimise their ideas and re-apply to be included in the National Roadmap.

Why should the scientific community participate in the process?

By participating in the National Roadmap Process, the German scientific community is making a vital contribution to a long-term national research strategy. The RI proposals submitted and the associated dialogue help to introduce new topics into research policy discussions that significantly enhance the efficiency of German research as well as its international visibility and competitiveness.

What does the consolidation of the Roadmap Process mean?

The German Federal Ministry of Education and Research carried out a Pilot Process to create a National Roadmap for Research Infrastructures between 2011 and 2013. This process involved the evaluation and prioritisation of proposals for new Research Infrastructures based on a standardised, transparent procedure. With the Pilot Process, the BMBF established a solid foundation for prioritising new Research Infrastructures in its research policy of new Research Infrastructures and demonstrated that this instrument is most suitable for preparing strategic decisions on cost-intensive research infrastructure projects.

Based on the experience gained in the Pilot Process, the National Roadmap Process since 2015 has been consolidated and established as a strategic instrument for the research policy prioritisation of future investments in Germany. The Roadmap Process is binding for all new RI proposals which are to be (co-) financed by the BMBF and achieve the applicable thresholds. At the same time, this process is also open to RI proposals without BMBF funding providing that they fulfil the relevant framework conditions.

Are the authors of the proposals informed about the results of the various evaluations and/or are all the results published?

The results of the science-driven evaluation by the German Council of Science and Humanities are published and are thus available to both those responsible for the proposals and the general public. However, the results of the economic evaluation are only sent in writing to those responsible for the proposals as they may contain sensitive or confidential information.

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