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Report on the Science-
driven Evaluation of
Large **Research Infra-**
structure Projects
for the **National Roadmap**
(Pilot Phase)

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Preamble

Aside from researchers and institutions, large research infrastructures are an indispensable requirement for an efficient scientific system. In many cases, science depends on the employment of such research infrastructures to deal with complex scientific subjects and engage in top-level research at international standards. Research infrastructures are essential in all disciplines of research and teaching as well as in the fostering of new generations of academics. As a result of applications which go beyond the original purpose, they often act as a structuring force in the scientific system. Research infrastructures also tie up considerable amounts of resources, not only during the investment phase but for operation and regular modernisation across their entire life-cycle.

Because research infrastructures have this far-reaching importance, in respect of research and funding policy there is a growing need to coordinate decisions concerning the establishment, operation, and use of large-scale research infrastructures in the national and European research context. To ensure the best possible preparation of the political prioritisation processes from a scientific point of view, deliberation and decision-making by policy-makers should be based on the results of a science-driven evaluation.

More than ten years ago the European Strategy Forum on Research Infrastructures (ESFRI) |¹ initiated a coordination process of this kind and began to draw up research infrastructure roadmaps at the European level. It thereby triggered similar processes in the individual European countries. The ESFRI process is driving the European coordination, prioritisation, and implementation of research infrastructure projects. To support the ESFRI process, the majority of European countries have now produced national roadmaps.

In this context, in the summer of 2011 the German Federal Ministry of Education and Research (BMBF) launched a pilot process for a national roadmap in Germany. As part of this roadmap pilot process, the BMBF asked the German

|¹ Cf. http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri of 24 August 2012.

Council of Science and Humanities to develop and implement a process for the science-driven evaluation of large-scale research infrastructures. In the pilot phase, only those research infrastructure projects were evaluated for which a funding contribution from the BMBF was sought and which at the same time were sufficiently well substantiated without any decision having been taken concerning their funding. The projects evaluated were at different stages of maturity. Together with a parallel cost assessment, which was not carried out by the Council, the science-driven evaluation provides the basis for the political prioritisation of the projects by the BMBF. This, in turn, leads to the national roadmap.

In July 2011, the Council established a specially appointed committee for the “Science-driven evaluation of large-scale research infrastructure projects for a national roadmap (pilot phase)”, which was tasked with designing a science-driven evaluation process and testing it on selected research infrastructure projects. Following on from this, the aim is to work on ways of further development of the roadmap process. In January 2012, the research infrastructure proposals were submitted to the Council’s Head Office; the evaluations were finalised by the committee in November of that year.

Many experts – also from other countries – who worked on the committee are not members of the German Council of Science and Humanities. The Council owes them a great debt of gratitude. Particular thanks are due also to the numerous other international reviewers who took part in the differentiated individual evaluations of the research infrastructure projects.

This evaluation report is aimed primarily at the BMBF, but also at hosting institutions in Germany with concrete recommendations for the further development of their research infrastructure projects. In addition, it is intended for the scientific communities as a whole, other political actors in the national and international context, scientific organisations, and a broader public with an interest in science policy.

The evaluation report was approved by the committee on 14 January 2013 and presented to the German Council of Science and Humanities during its meeting from 24 to 26 April 2013.

Summary

As part of the pilot phase of the roadmap process, a science-driven evaluation was performed for nine research infrastructure projects selected by the German Federal Ministry of Education and Research (BMBF). These include two projects in the field of engineering and natural sciences, namely the Cherenkov Telescope Array (CTA) and the European Magnetic Field Laboratory (EMFL). Four projects are based in the environmental sciences: the In-service Aircraft for a Global Observing System (IAGOS), the Cabled Ocean Observing System Frontiers in Arctic Marine Monitoring (Cabled OOS FRAM), the European Plate Observing System (EPOS) and the Global Earth Monitoring and Validation System (GEMIS). A further three projects come from the field of biological and medical sciences: the European Infrastructure of Open Screening Platforms for Chemical Biology (EU-OPENSREEN), the German Research Infrastructure of Imaging Technologies in Biological and Medical Sciences (German Euro-BioImaging – GEBI) and the Integrated Structural Biology Infrastructure (INSTRUCT).

Science-driven evaluation

The German Council of Science and Humanities mandated the committee “Science-driven evaluation of large-scale research infrastructure projects for a national roadmap (pilot phase)” to carry out the science-driven evaluation, which was based on standardised proposals. These were drafted by the scientists involved with the aid of a set of guidelines. |² The science-driven evaluation process took place in two successive phases: a qualitative individual evaluation of each project and a comparative overall evaluation. Both evaluations follow four evaluation dimensions. The dimensions are “scientific potential”, “utilisation”, “feasibility”, and “relevance to Germany as a location of science and research”.

In the first evaluation phase, with the assistance of mostly international reviewers, qualitative individual evaluations of the research infrastructure pro-

|² Cf. Wissenschaftsrat: Appendix to the Concept for a Science-driven Evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilot Phase) (Drs. 1766-11), Cologne December 2011, pp. 25 ff.

jects were produced. The scientists in charge of the projects were given the opportunity to discuss their proposals with the reviewers and with the committee members. The result was a set of detailed evaluations which consider the maturity and urgency of the projects as well as the four dimensions. |³

The second phase consisted of a comparative evaluation by the committee. In this phase, all projects which were assessed as having sufficient scientific justification were evaluated across scientific disciplines and fields. Eight of the nine projects in the pilot phase satisfied the requirements for being included in the comparative process. Each project underwent a separate comparative evaluation in each of the four evaluation dimensions. There were five quality levels or “stars”. The results – summarised in a table – cover the full range of quality levels. |⁴ It should be pointed out, however, that no overall ranking of the research infrastructure projects can be derived from this.

Overall challenges

During the science-driven evaluation process, the committee and the international experts identified overall challenges faced by different research infrastructures. The most important ones are mentioned here since the committee sees an urgent need for analysis and action on this point in order to optimise the operation of research infrastructures.

– The **field of research infrastructures** has become more differentiated. Whereas, at first, only large-scale facilities such as accelerators or research vessels were regarded as research infrastructures, today the term includes not only distributed research infrastructures but also such things as collections, databases, e-infrastructures and social research infrastructures. Each of these research infrastructures goes through different phases in its life. The roadmap process follows one of these phases in the **overall life-cycle of a research infrastructure**, namely the preparation phase through to the beginning of its implementation. But to do justice to the growing importance of research infrastructures for the scientific system, the different characteristics and all phases in the lives of the research infrastructures should always be taken into consideration.

– The **financing of research infrastructures** is complex and unclear. The actual challenge here is to achieve sustained financing over the entire lifetime for the utilisation of research infrastructures. The hosting institutions cannot al-

|³ Short summaries of the individual evaluations appear on a coloured background and precede the detailed evaluations.

|⁴ The results appear in section B.IV, pp. 83 ff.

ways cover the operating costs and often considerable modernisation costs which arise during the lifetime of the research infrastructure. Hence, when deciding whether to fund a research infrastructure, it is essential to take the financing over its entire lifetime into consideration. Moreover, path dependencies should be considered because the long-term commitment of considerable resources will influence the entire scientific system.

- _ The importance of **data management** for a research infrastructure, i.e. the challenges associated with data collection and archiving, access to data and data processing, are often underestimated. Above all, research infrastructures should develop clear goals for their data concept at an early stage and also ensure its technical feasibility, taking legal and ethical implications into account. In addition, the scientific communities should push ahead with the development of common standards.
- _ The development of **governance structures** often takes second place to elaborating the research question of a research infrastructure, despite these being critical to success in many respects. There is a lack of adequate standards or sufficient models – for access to research infrastructures, for their staff and management, or for future evaluations (keyword: impact) – which offer guidance in the design and evaluation of a research infrastructure.

The roadmap process that has been initiated is complex. The committee welcomes the approach taken in the German process, in which inclusion in the national roadmap shall announce the funding of the projects. Following on from the pilot phase, the current roadmap process in Germany should be continued and developed further.

A. The roadmap process in the pilot phase

A.1 RESEARCH INFRASTRUCTURES

The term “research infrastructures” used in the pilot phase of the roadmap process means large-scale instruments, resources or service facilities for research in all areas of science. |⁵ In the context of the national roadmap process, only those research infrastructures were considered which meet the following criteria: |⁶

- 1 – Research infrastructures are of national strategic importance for the respective area of science. They are used not only by the hosting institutions but to a considerable extent are also available to external (international) users. Research infrastructures of national importance also make key contributions to enabling top-level research in the respective research areas.
- 2 – Research infrastructures are characterised by a long lifespan (generally in excess of 10 years).
- 3 – Research infrastructures involve significant investment and/or operating costs, with the publicly funded national share of total costs generally amounting to more than EUR 15 million in the first ten years. |⁷
- 4 – Management of the use of research infrastructures is conducted via an evaluation of the scientific quality of the submitted projects in a science-

|⁵ Wissenschaftsrat: Concept for a Science-driven Evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilot Phase) (Drs. 1766-11), Cologne, December 2011, p. 7.

|⁶ Ibid., pp. 7 f.

|⁷ This explicitly includes the humanities and social sciences for which no limit on the investment costs should be set; however, operating costs of EUR 1.5 million p. a. are a requirement, *ibid.*, p. 7.

driven and transparent assessment process with external reviewers (peer review).

Many countries use similar definitions for their national roadmap processes. Efforts at definition have been substantially influenced by the term used in the ESFRI process.

In Germany, it is primarily the centres in the Helmholtz Association of German Research Centres (HGF) which are the major research institutions responsible for the construction and operation of large-scale facilities. As the research infrastructure projects on hand and those evaluated by the Council in the past show, however, universities and other non-university research institutions are also involved in the design and operation of research infrastructures. |⁸ In this context, the non-university sector, in addition to the departmental research institutes of the federal ministries and the HGF mentioned above, also includes the other three major national research organisations which operate research infrastructures in their institutes: the Max Planck Society (MPG), the Gottfried Wilhelm Leibniz Scientific Association (Leibniz Association, WGL) and the *Fraunhofer-Gesellschaft* (FhG). |⁹

An overview of existing research infrastructures does not yet exist for Germany. However, efforts are being made in Europe to produce such surveys systematically both at the level of countries |¹⁰ and at European Union level, as the MERIL initiative |¹¹. For Germany, the initiative by the German Research Foundation (DFG) |¹² and the creation of a map of research infrastructures at departmental research institutes of the federal ministries |¹³ should be mentioned.

|⁸ Cf. Wissenschaftsrat: Statement on nine large-scale facilities for basic scientific research and on the development of investing planning for large-scale facilities (Drs. 5385/02), Berlin July 2002, p. 68 f. One example is the research aircraft HALO (High Altitude and LOng range research aircraft).

|⁹ HGF is an association of 18 centres. Their core tasks to date have included the operation of large-scale facilities and national research for prevention. MPG comprises approximately 80 institutes which primarily conduct basic research. WGL is currently an organisation of 86 institutions with different profiles. They perform a variety of research and service tasks with widely varying emphases. FhG comprises approximately 60 institutes which primarily conduct application-oriented research.

|¹⁰ Cf. for example: National Research Infrastructure Register (NEKIFUT) in Hungary, https://regiszter.nekifut.hu/en/ki_kereses/results of 4 September 2012.

|¹¹ Cf. <http://www.esf.org/activities/science-policy/research-infrastructures/meril-mapping-of-the-european-research-infrastructure-landscape.html> of 30 August 2012.

|¹² Cf. http://www.dfg.de/foerderung/info_wissenschaft/info_wissenschaft_12_14/index.html of 30 August 2012.

|¹³ Cf. Wissenschaftsrat: *Empfehlungen zur Rolle und künftigen Entwicklung von Bundeseinrichtungen mit FuE-Aufgaben*, (Drs. 7702-07), Cologne January 2007, p. 131 and Wissenschaftsrat: *Empfehlungen zur Profi-*

The science-driven evaluation is part of an extensive pilot project which also includes an economic cost assessment and a subsequent political prioritisation of the projects by the relevant ministry. The process of the science-driven evaluation was developed by the committee “Science-driven evaluation of large-scale research infrastructure projects for a national roadmap (pilot phase)”, which was set up by the German Council of Science and Humanities. The committee published a corresponding concept in the autumn of 2011, |¹⁴ which it began testing immediately thereafter.

The BMBF selected nine projects for a shortlist and asked the hosting institutions to develop a proposal following the guidelines produced by the committee. The nine projects met the criteria described above for research infrastructures in the roadmap process. A crucial factor for selection by the BMBF was that the decision concerning funding or participation by Germany at the European or global level was pending.

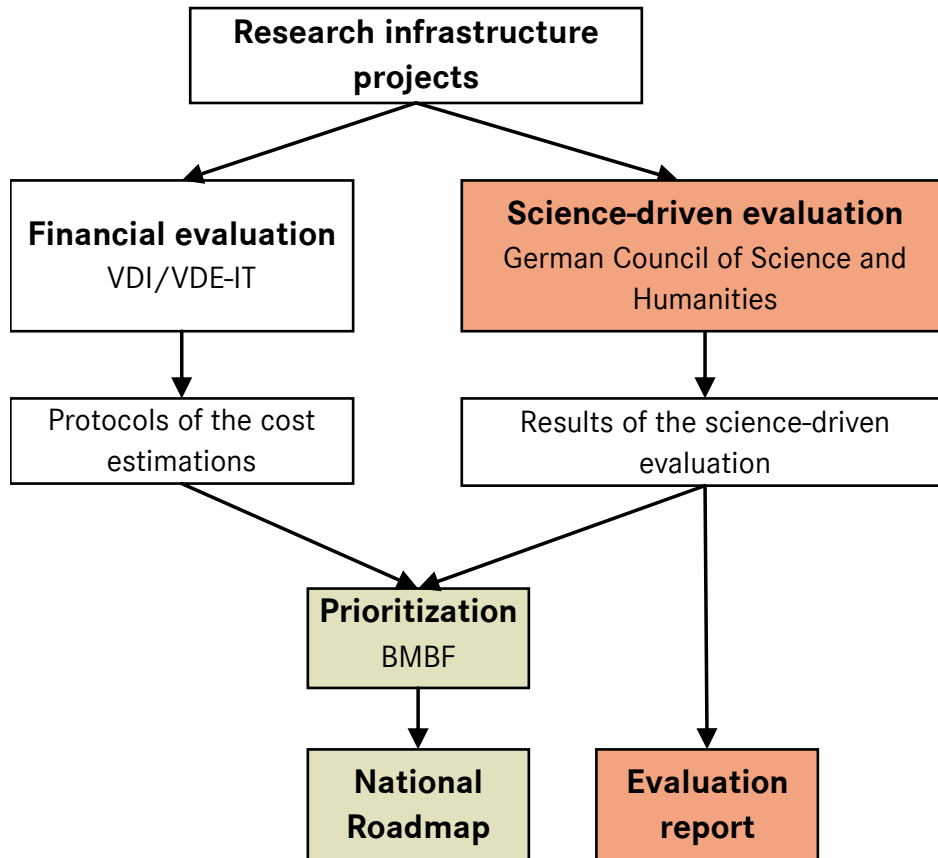
The research infrastructure proposals submitted for evaluation were assigned to three areas of science. Two projects were in engineering and natural sciences, four in environmental sciences and three in biological and medical sciences.

Parallel to this, and independently of the science-driven evaluation of the projects by the Council, each project underwent an economic assessment of the expected costs by the project management agency *VDI/VDE Innovation und Technik GmbH* (VDI/VDE-IT). The BMBF will prioritise the projects based on the results of the science-driven evaluation and economic assessments, and by also taking their socio-political relevance into account. In the pilot phase, inclusion in the roadmap indicates a willingness in principle to fund further development of the project or its implementation. The overview in Figure 1 shows the basic structure of the roadmap process as a whole during the pilot phase.

lierung der Einrichtungen mit Ressortforschungsaufgaben des Bundes (Drs. 10295-10), Cologne November 2010, p. 51.

| ¹⁴ Wissenschaftsrat: Concept for a Science-driven Evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilot Phase) (Drs. 1766-11), Cologne December 2011.

Figure 1: Overview of the roadmap process



The science-driven evaluation of the projects took place in two phases: the detailed individual evaluation and the comparative evaluation of the research infrastructure projects. In terms of content, in both phases the evaluation was based on four evaluation dimensions: “scientific potential”, “utilisation”, “feasibility”, and “relevance to Germany as a location of science and research”. Each of the submitted research infrastructure proposals initially went through an extensive individual evaluation with the assistance of international reviewers. At the same time, the proposals were placed within the international landscape of existing and/or planned competing or complementary research infrastructures. To cover the full spectrum of relevant research infrastructures and efforts necessary for classification purposes, the research infrastructures compiled for this purpose in Appendix 2 are in some cases based on a wider definition of research infrastructure than the definition described above for the national roadmap process (cf. section A.I).

Based on the detailed individual evaluations, which also include recommendations for the further development of the respective research infrastructure proposals, the committee performed a comparative evaluation across all areas of science in each of the four evaluation dimensions. Both of these process steps are described in more detail below.

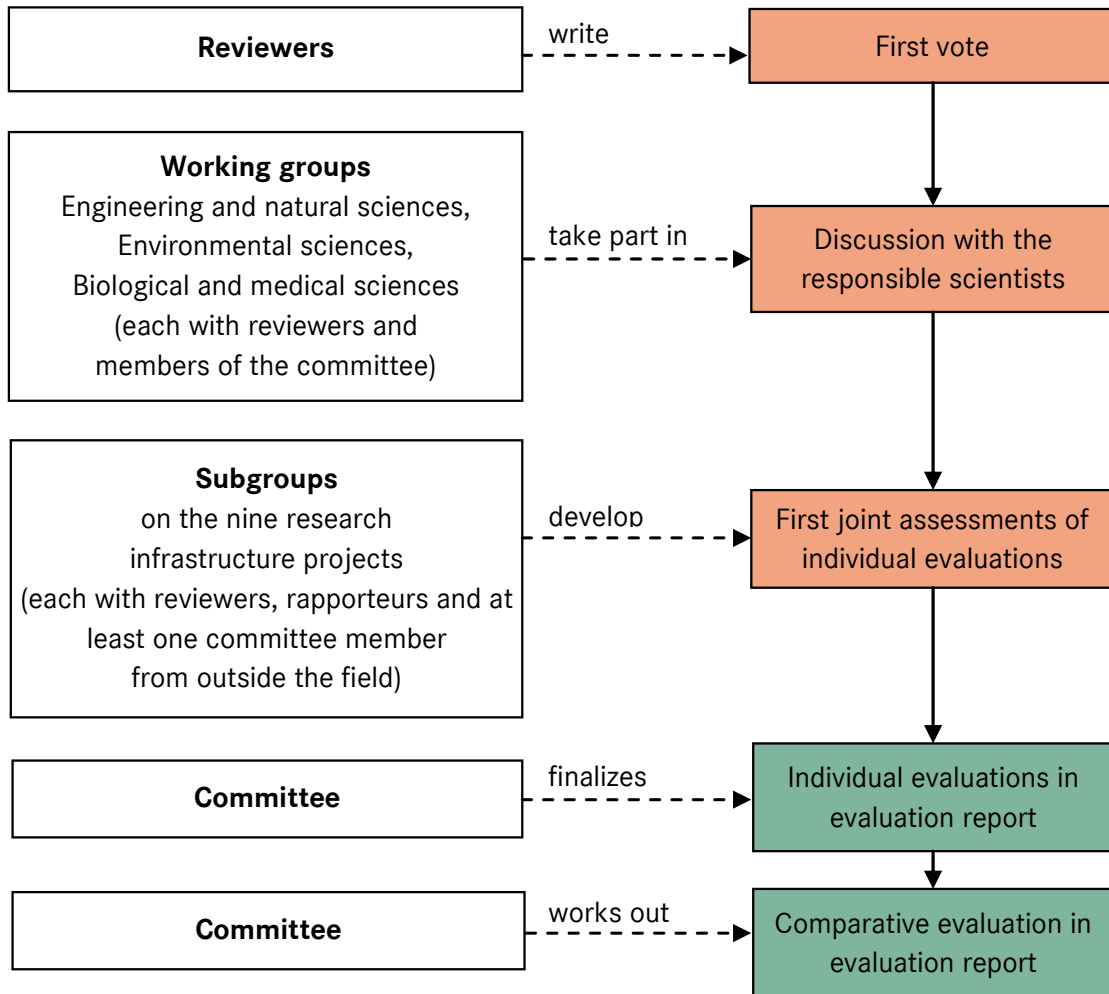
At the start of 2012, detailed proposals were submitted for all nine research infrastructure projects in the pilot phase. These were produced by the relevant hosting institutions following a standardised set of guidelines |¹⁵ previously drawn up by the committee. In addition to the basic data and the state of implementation, the research infrastructure proposals contain extensive information on aspects of the four evaluation dimensions, which was obtained by means of detailed questions.

The first of the four dimensions is the **scientific potential**, which encompasses the importance of the project in opening up new fields of research or developing existing fields, and places it in relation to the performance of competing and complementary research infrastructures. Another dimension to be evaluated is the **utilisation** of the research infrastructure, which includes both the size and origin of user groups and the regulation of access to the research infrastructure. The dimension of **feasibility** covers both technical requirements relating primarily to the research infrastructure, and institutional and personnel requirements for the hosting institutions. The fourth evaluation dimension, **relevance to Germany as a location of science and research**, assesses the relevance of the research infrastructure project to Germany's role and interests, and also its impact on the visibility and attractiveness of German science (for more about the dimensions, cf. B.IV).

The differentiation in the presentation of the research infrastructure proposals and their evaluation according to the four stated dimensions also served to achieve better comparability of the projects, which come from different areas of science.

The process of the science-driven evaluation is described in an overview in Figure 2. The steps are explained in more detail below.

| ¹⁵ Cf. Wissenschaftsrat: Appendix to the Concept for a Science-driven Evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilot Phase) (Drs. 1766-11), Cologne December 2011, pp. 25 ff.

Figure 2: Science-driven evaluation process

For each proposal, three reviewers – mostly from outside Germany – were found who were suitable for the technical specifics of the project. First of all, based on the written documentation, they produced a review of the respective project. To ensure the best possible comparability here too, the reviewers were also asked to follow a set of guidelines drawn up for this purpose. In addition, the scientists responsible for the proposal were given the opportunity to discuss their project with the reviewers and committee members. This took place in working groups for the three areas of science, allowed questions to be resolved, and enabled a more differentiated overall impression of the research infrastructure proposal.

Subsequently, the subgroups consisting of reviewers of a project, an expert committee member – who acted as a rapporteur – and at least one other, non-expert committee member agreed on their first joint evaluation of the project. This coordinated, confidential review, which was produced in writing by the respective subgroups for all nine projects, formed the basis for all subsequent evaluation processes by the committee. The individual evaluations, which can be found in sections B.I to B.III, and the respective associated short summaries

of the evaluations, are based on it. The individual evaluations also contain recommendations for the further development of the proposals.

II.2 Comparative evaluation

For the comparative evaluation, which formed the second phase of the evaluation process, only those research infrastructure projects were included which met certain minimum requirements. If a research infrastructure project was judged by the reviewers to be insufficient with regard to its scientific potential or the research question, the minimum requirements for inclusion in the comparative evaluation were not met. In such a case, only the individual evaluation was carried out.

The evaluation scale for the pilot process was set at one to five stars. A scale with five stars allows clear differentiation at the upper end of the evaluations. A score of one star means that the project is considered to be just sufficient for inclusion in the comparative evaluation. The number of stars can be expressed in words as sufficient (*), satisfactory (**), good (***), very good (****) and outstanding (*****).

The comparative science-driven evaluation was conducted separately within each dimension across all projects. First of all, they were ranked in each dimension via pairwise comparisons. As a second step, the projects were then grouped into “classes” which each had the same number of stars. In particular, it should be noted that it was not necessary to use the full range of stars. The project with the best evaluation did not necessarily have to receive five stars, nor was the worst necessarily given one star. The results appear in section B.IV.

The individual evaluations with the comparative evaluation and the recommendations for the further development of the proposals together constitute the result of the science-driven evaluation process.

Finally, it should be emphasised that the science-driven evaluation of research infrastructure proposals, while important, ultimately takes into account only one stage in the overall life-cycle of a research infrastructure. Neither the process of idea generation and agreement by the community on the need for a particular research infrastructure project, nor the implementation process and operation of a research infrastructure are taken into consideration. The structural significance of research infrastructures for the scientific system, their high resource requirements over their lifespan, and the path dependencies which are

18 created as a result |¹⁶ mean that independent, science-driven accompanying processes of these phases should also be developed and tested.

| ¹⁶ In other words, the expected long-term commitment of resources will limit decision-making freedom in the future; therefore, these consequences should be systematically taken into account.

B. Individual and comparative evaluation

As mentioned before the nine research infrastructure projects of the evaluation can be assigned to three areas of science: (1) engineering and natural sciences, (2) environmental sciences as well as (3) biological and medical sciences. All three areas encompass very large fields of science. Within the range of the evaluation report these cannot be presented in their entire complexity. For giving an insight into the possible applications of the research infrastructures within their area to those who do not belong to the scientific community there is a short introduction to the areas of science before the descriptions of the projects and their evaluations. These introductions focus on the environment of the presented research infrastructures and their relevance to the development of their respective area. Due to the heterogeneity of the area of engineering and natural sciences it had to be divided into the field of astrophysics (B.I.1) and that of materials research (B.I.3).

The general introduction to the areas of science is followed by a brief description of the project, a summarized evaluation of the project (highlighted in colour) and a detailed evaluation which also includes recommendations on the further development of the proposal.

Competitive and complementary research infrastructure projects are referred to within the introduction as well as in the context of the evaluations. Further information about these existing or planned projects is in Appendix 2.

Moreover the detailed descriptions of the research infrastructure projects are in Appendix 1. These descriptions were agreed upon with the hosting institutions in the English version. They were compiled on the basis of the submitted proposals.

The area of engineering and natural sciences encompasses a plurality of scientific disciplines including physics, astronomy, chemistry, biology, and engineering. Objects of research cover the whole range from the smallest building blocks of matter to the largest structures of the universe as well as the fundamental forces.

An enormous number of different fields of research constitute this heterogeneous area of science. At the boundaries of these fields, there might be overlap and collaborations. In the following, the focus will be on the two fields of research related to the two proposed research infrastructures in the roadmap process, i.e. astrophysical and materials research.

1.1 Scientific landscape for research infrastructures in astrophysics

The terms astronomy and astrophysics are frequently used interchangeably and this convention will be adopted here. Generally speaking, astrophysical research deals with fundamental questions concerning the universe, which encompasses the origin, properties, and evolution of the universe and of all its constituents.

Historically, astrophysical research was based on observations and limited until the first half of the last century to the optical wavelength range only, by this, restricted to stars and interstellar gas emitting their continuous brightness or spectral lines in this range of the electromagnetic spectrum. With the opening of further non-optical wavelength ranges, ground-based by means of detector developments in the radio and near-infrared spectral range and of space-born telescopes, different subfields of astrophysics were defined according to the wavelengths to which they are related. Therefore, the astrophysics community was divided into researchers working in the radio, infrared, optical, X-ray, or gamma-ray wavelengths. Today, this categorization has changed according to the research focus on targets and processes. Because most astronomers are focussing their research on objects, i.e. work target-oriented, as e.g. massive stars, galaxies, etc., they use information from the whole electromagnetic spectrum, gamma-rays at its highest-energy end, and also cosmic-ray particles. Basically, theoretical and computational astrophysics complete the astrophysical research tools, thus allowing the fullest possible understanding of the phenomena that are studied. In the recent past, modern astronomy has developed to higher interdisciplinarity not only connecting with physics but also chemistry, biology, mineralogy, as well as affecting engineering, materials sciences, and electronics.

Examples of current questions of interest are the discovery and closer examination of planets outside our solar system and the investigation of black holes that are known to exist in the centres of most galaxies. Furthermore, the age and

evolution of structures in the universe, and its expansion are studied. Astrophysicists also strive to reveal the nature of the so-called dark matter, i.e. matter in the universe that is invisible but indirectly detectable through its gravitational effect. Together with the dark energy, an unknown force that drives the universe apart in an accelerated expansion, dark matter belongs to the most mysterious research questions in astronomy and physics in general.

The relatively young field of high-energy gamma-ray astronomy (photon energies in the giga-electron volt to multi-tera-electron volt range) at which the most energetic end of the electromagnetic spectrum is investigated developed over the last twenty years. The detected gamma rays allow for a complementary view on some of the research objects mentioned above but also open new fields such as the study of active galactic nuclei.

It is vital that observations of the phenomena of interest are conducted using complementary instruments. Also, new techniques or approaches of observation need to be tested comprehensively. For high-energy gamma-ray astronomy, research infrastructures can be either satellite-based or ground-based. The latter rely either on the technique of imaging atmospheric Cherenkov telescopes, on water Cherenkov experiments, or on air shower arrays which investigate mostly the origin of cosmic rays. The project **Cherenkov Telescope Array (CTA)** aims at constructing an array of ground-based imaging atmospheric Cherenkov telescopes. It is designed to study high-energy cosmic rays to gain insights into their origin in the universe and into related astronomical questions. Furthermore, e-infrastructures for handling the observational data are essential parts of the research landscape. This described categorisation of research infrastructures is also used in Appendix 2.1 where the most important complementary research infrastructures to the CTA in the field of astrophysics are collected.

Within the German astrophysics community, the internal process to set priorities for large research infrastructures is less well-defined and transparent, while for example in the US and the Netherlands, the communities come up with decadal strategic reports as continuous plans. Hosted by the German Research Foundation (DFG), contemporary reflections of German astrophysical research facilities are compiled by an expert group of the *Rat Deutscher Sternwarten (RDS)* as “*Denkschrift*”. The last “*Denkschrift*” was released in 2003 |¹⁷ and a new one is currently envisaged. This “*Denkschrift*” primarily serves the streamlining of research initiatives in astrophysics. It does not explicitly serve the purpose of research infrastructure planning.

| ¹⁷ *Deutsche Forschungsgemeinschaft: Status und Perspektiven der Astronomie in Deutschland 2003-2016. Denkschrift*, Bonn 2003, http://www.dfg.de/download/pdf/dfg_im_profil/geschaeftsstelle/publikationen/status_perspektiven_astronomie_2003_2016.pdf of 20 June 2012.

1.2 Cherenkov Telescope Array (CTA)

1.2.a Short description of CTA

Astrophysical research has over the last decades developed extremely sensitive instrumentations of increasing high-performance level with always increasing photon sampling areas. Such telescopes make the financing, construction, and administration by international consortia or organizations necessary (e.g. ESO and ESA). Over the past years, high-energy gamma-ray astronomy has developed into a global scientific project, with presently scientists from close to 30 countries world-wide participating in CTA, with German leadership. |¹⁸

CTA is a ground-based telescope array aimed at the investigation of cosmic gamma rays. The research of these high-energy photons allows exploring the most energetic sources in the universe as gamma rays are produced in supernova remnants, black holes, and active galaxies. In addition to optical and radio astronomy, high-energy gamma-ray astronomy opens up a new wavelength window for ground-based astrophysical research.

CTA is based on the two predecessor projects, H.E.S.S. in Namibia and MAGIC on La Palma. |¹⁹ In the realization of these projects, German institutions played a leading role. CTA is to be built on two separate sites not yet determined. One site will be in the southern hemisphere with its unique access to the galactic centre. It should consist of 4 large-size (23 diameter), 23 medium-size (12 m) and 32 small-size telescopes (4-6 m) and is supposed to extend over an area of nearly ten square kilometres. The other site will be in the northern hemisphere with a prime focus on the investigation of extragalactic objects and the early universe. Currently, 4 large-size and 17 medium-size telescopes distributed over an area of one square kilometre are planned.

CTA is constructed by an international consortium of the major expert teams world-wide and will be administrated as an open facility with preferential access by the consortium members. To facilitate the use of CTA and its data also by astronomers from other wavelength ranges and scientists from other physical disciplines, data pre-processing by the CTA observatory staff is envisaged. Although using a mature technique, the CTA will achieve an increase in sensitivity and an extension of the energy range, respectively, both by one order of

|¹⁸ For further details concerning CTA, cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 68.

|¹⁹ For further details concerning the two projects, High Energy Stereoscopic System (H.E.S.S.) and Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes (MAGIC), cf. Appendix 2.1.

magnitude. This way, CTA is aiming at proceeding into a new era of high-energy observations.

Although already more than 100 high-energy sources were detected by the present-day gamma-ray telescope arrays, it is expected that CTA will increase this number significantly and hence allow for a better understanding of physical processes acting at such high energies. Burning questions to be addressed by CTA concern the Milky-Way central massive black hole, possible detection of dark matter, fundamental physics, and energetic processes and consequences for the energetic state in the early universe, as e.g. the formation of massive black holes in the centres of massive galaxies. The detection of new types of sources is also expected as it happened in astrophysics for all newly opened spectral wavelength ranges.

The following German institutions are participating in CTA: DESY, Zeuthen, in the Helmholtz Association, the Max Planck Institute (MPI) for Physics, Munich, the MPI for Nuclear Physics, Heidelberg, the Humboldt University Berlin, the universities of Bochum, Erlangen-Nürnberg, Hamburg, Heidelberg, Potsdam, Tübingen, Würzburg, and the Technical University Dortmund.

Germany is foreseen to contribute 28 % of the previewed total investment costs of EUR 186 million (for the years 2014-2018), corresponding to EUR 52 million. After the completion of both observatories the annual operational and maintenance costs will amount to approximately EUR 15 to 20 million.

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.1.

1.2.b Evaluation of CTA

Summary

Scientific Potential. Due to its uniqueness, the scientific significance of CTA is outstanding. The significantly increased detector sensitivity and higher accessible photon energies will improve the understanding of the high-energy processes in the universe. These investigations in an energy range formerly inaccessible with such quality will have an impact on a broad range of current astro- and high-energy physics. CTA crucially complements large-scale telescopes in other spectral ranges currently under construction.

Utilization. The world-wide community in this specialised field of physics is participating in CTA. It will be the major world observatory in this energy range to study astro- and high-energy physics questions. Operating CTA as an open observatory is a significant improvement over previous practice in ground-based gamma-ray astronomy, presenting significant organizational challenges.

Feasibility. The scientific expertise of the hosting institutions in Germany is of the highest rank allowing them to carry out this project successfully. The CTA consortium has extensive experience in ground-based gamma-ray astrophysics. The already on-going project CTA is based on well-understood and mature technologies and is ready for implementation after the finalization of the site selection process.

Relevance to Germany as a location of science and research. German institutes played a leading role in forerunner projects. Their scientific expertise is globally appreciated and as a result, they are highly attractive sites for the training of the next generation of young scientists. CTA will thus definitely maintain and enhance the attractiveness and visibility of Germany as a location of scientific and technological developments. A timely implementation will secure German leadership in this field.

Scientific potential

Scientifically, the relevance of CTA is outstanding due to its uniqueness. It will push the sensitivity by at least one order of magnitude allowing for an improved understanding of the most energetic processes in the universe, such as found in black holes, exploding stars, and colliding galaxies. The observations may also shed light on the dark matter puzzle.

The science being addressed will have impact on a broad range of current astrophysics and high-energy physics. This projection is justified by the present high citation factors for publications based on H.E.S.S. and MAGIC. CTA will be one of a handful of major world observatories operated as user facilities in different spectral ranges like ALMA (Atacama Large Millimetre Array), ELT (Extremely Large Telescope), JWST (James Webb Space Telescope), SKA (Square Kilometre Array), LOFAR (Low Frequency Array) |²⁰, and future space-based X-ray missions. Operating CTA in the mode proposed and providing an appropriate user-friendly data pre-processing will increase its complementarity by enabling its use by a broad community. Therefore, CTA will develop synergies with the broad spectrum of astrophysics.

Since astrophysical research is based on observations over the whole electromagnetic spectrum and on particle detections, telescopes and detectors applied to particular spectral ranges work per se complementarily, as e.g. the present-day panchromatic composition of target observations demonstrates. With re-

|²⁰ For further details on the observatories and further complementary research infrastructures, cf. Appendix 2.1.

spect to competing infrastructures in the high-energy gamma range, the internationality of the CTA consortium and the very much improved sensitivity will guarantee for its uniqueness for at least the upcoming decade.

CTA will be primarily dedicated to high-energy gamma-ray astronomy. The development of new and innovative use of the infrastructure is likely during the lifetime of the project. As an example, the current generation of Cherenkov arrays, while dedicated to the same field, have also been used to make measurements of the primary cosmic-ray electron and heavy nuclei flux, and to search for fast optical transients. In that sense, it will be multi-purpose.

CTA has been recognized in recent European strategic plans for astronomy (ASTRONET |²¹, ASPERA |²²) as one of the top research infrastructures and is listed in the ESFRI roadmap |²³. Also national strategic plans (e.g. the “*Denkschrift*” of the DFG from 2003) mention the potential of high-energy astrophysics projects but without specification of the CTA project because this “*Denkschrift*” was issued before the CTA project has been initiated.

Although the CTA design will be based largely on existing technology, a lifetime of 10 to 20 years will mean that design improvements and instrument upgrades will certainly be proposed and implemented during its operation. There is a potential for innovative technologies and thus, the infrastructure is also expected to be a technological test-bed for advances in electronics, optics, mechanical sensing and stability, atmospheric monitoring, and data handling and analysis. It may particularly further impact the development of photodetectors.

Utilization

CTA will be mainly used by the groups involved, but also by other astronomy groups throughout the world. There is no doubt that the user group is of sufficient size and scientific stature to make full and utmost use of the instrument. There is sufficient commitment of highly-skilled groups from within the German community. Operating CTA as an open observatory is a significant improvement. This will present significant organizational challenges and will require dedicated operational funding. Staff scientists operating CTA and providing user support, in particular post-docs, have to be scientifically reward-

|²¹ ASTRONET: The ASTRONET Infrastructure Roadmap: A Strategic Plan for European Astronomy, 2008, pp. 28-30.

|²² ASPERA: Astroparticle Physics. the European strategy, 2008, p. 35 and ASPERA: European Roadmap for Astroparticle Physics. Edition 2011, pp. 19-22.

|²³ Cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 68.

ed. Therefore, the issue of accumulating publication credit or guaranteed observation time needs careful consideration.

Although the concept of how the access to data will be regulated is not yet finalized, the usage of data is supposed to be facilitated for various other groups, including astronomers working with X-ray and lower-energy gamma instruments. Furthermore, the consortium plans to provide extensive data processing capabilities as well as the analysis packages and tools necessary for non-expert users, through the headquarters site which will be situated in Germany. There is the intention to provide the scientific end user with a standard astronomy product. To achieve that, a substantial data analysis team will be needed. The services provided by the consortium in terms of the inclusive serving of scientists from many backgrounds and the provision of public data products have to be clarified.

The work at such research infrastructures has proved to be attractive and an exceptionally good training ground for students. The field gives them a broad range of skills including design, construction and operation of detectors, photo-sensors and related signal processing electronics on the one and data-handling, modelling and simulation tools on the other hand. There are many niches for project work at the cutting edge of science which can suit students from high school level through senior graduates. This increases the often existing intrinsic interest in astrophysics.

Feasibility

The scientific standing of the hosting institutions in Germany is of the highest rank allowing them to carry out this project successfully. The centres of the Max Planck Society in Heidelberg and Munich have been the lead German institutions on the very successful H.E.S.S. and MAGIC projects; DESY's scientists have extensive experience in the field of ground-based gamma-ray astrophysics; DESY itself has a long history of collaborative international projects. All of the participating non-university research institutes as well as the universities have strong technical expertise.

The CTA consortium as a whole has extensive experience in ground-based gamma-ray astrophysics; its members have helped develop, construct, and operate the current generation of Cherenkov arrays. The project has been under development for several years and detailed design studies have been performed. The consortium is well advanced with respect to preparation and prototype construction. CTA has chosen a technologically conservative approach, with all major subsystems (optics, mechanics, light sensors, electronics, triggering) based on well-understood, mature technologies. The technique is also proven and the collaborating institutes have the expertise to carry out this project successfully.

Nevertheless, as this project is larger than its precursors, it will require significant work in software and data management.

Furthermore, as university groups are crucial for student training and outreach, funding models must be developed and cast into funding programs to ensure their strong participation.

The governance of CTA is still being developed. Therefore, the timeline of CTA is very ambitious given that also site selection, data access policies, and financial responsibilities are not yet finalized. Those important decisions have to be taken timely, but are scheduled for the end of the three-year European funding period in 2013.

Relevance to Germany as a location of science and research

CTA builds on the success of the projects H.E.S.S. and MAGIC and German scientists are playing a leading role. The scientific expertise of the German institutes is globally appreciated, and they have been leading contributors to the scientific output and to the training of a generation of young scientists in the field. Therefore, CTA will maintain and enhance the attractiveness and visibility of Germany as a location of scientific and technological developments and also its expertise in leading global scientific projects. A successful CTA as proposed would be seen as a Germany-based observatory even with a contribution of only 20 % of the personnel which would have a major international presence and whose results would be in line for international recognition and prizes.

The international aspect of the project should not be underestimated. Doing science in a large international collaboration gives students invaluable experience in project management and is therefore very attractive.

Overall evaluation

The CTA project is of outstanding scientific significance. It is a curiosity-driven fundamental science project with a potential for new insights as it moves into an energy range never accessible before with such high instrument resolution. The technology is mature, because it builds on basic experience in the past with Cherenkov gamma-ray telescopes under German leadership. The project has progressed through simulations, design studies, concept documents, and on to actual design and construction of prototypes. It is ready for implementation after the finalization of the site selection process and now needs support to move seriously into the next project phase.

This project unifies the world-wide scientific community in the field of high-energy gamma-ray astronomy including all major groups. As such, it is unique. CTA will crucially complement large-scale telescopes in other spectral ranges currently under construction as well as other existing observatories. CTA will be

available for a broad user community beyond gamma-ray astronomy. The advanced involvement of more applied science institutions and engineering has to be encouraged as enhanced cooperation would bring additional synergy.

Delaying CTA considerably would mean the loss of temporary overlap with currently operated ground-based and space-based telescopes, loss of momentum in the field, and loss of Germany's leading role. If the infrastructure is not supported by Germany, it would likely signal the end of the project.

1.3 Scientific landscape for research infrastructures in materials research

Materials research deals with the structure, synthesis, processing, and properties of matter. More specifically, it addresses primarily materials that are meant to serve current or future diverse applications such as metallic alloys, polymers, ceramics, composites, natural materials, photonic materials, or semiconductors. The field is highly multidisciplinary and encompasses all science disciplines, i.e. physics, chemistry, and biology, as well as engineering. Traditionally, the main goals of materials research are the characterisation and the manufacturing of complex, mostly artificial materials. Modern basic materials research aims at a better understanding of structure-property relationships at the quantum and atomic level as well as at a better understanding of the passage from quantum mechanics describing the elementary building blocks of matter to material defects up to the macroscopic properties and materials failure. The experimental and theoretical approaches address these scales from the quantum and atomic level (e.g. quantum design of LEDs) up to macroscopic dimension (e.g. materials for industrial equipment or consumer products).

The characteristics of a material include mechanical, magnetic, electronic, chemical, and optical properties. They play an important role for structural, functional, and biological materials. Current examples of applications and products, where materials science progress is crucial, are micro- and nano-electronics (e.g. mobile communication), energy conversion (e.g. turbines), mobility (e.g. light-weight structures), health (e.g. implants), safety (e.g. power plants), magnetic materials (e.g. information storage or electrical power conversion), and photonic materials (e.g. solid state lighting) to name but a few. Materials science is related closely to the development and testing of new products.

Research infrastructures in materials science are of enormous diversity and include atomic-scale resolving electron microscopes, atom probe tomographs, magnetic field laboratories, free electron lasers, synchrotron radiation facilities, neutron sources, or large parallel computer infrastructures. The research infrastructure **European Magnetic Field Laboratory (EMFL)** allows for the investigation of the properties of materials in high magnetic fields. The specific project at the Dresden High Magnetic Field Laboratory aims at the development of an entirely superconducting steady-field magnet. Concerning the research in high

magnetic fields that is of special interest here, networks of laboratories and facilities for either pulsed or steady fields are complementary and competing research infrastructures, respectively. The forerunner project EuroMag-Net, the major competing infrastructure at the Magnet Lab at Florida State University in Tallahassee as well as the different complementary infrastructures in this field are listed in Appendix 2.2.

1.4 European Magnetic Field Laboratory (EMFL)

1.4.a Short description of EMFL

Magnetic fields provide an essential thermodynamic state variable in addition to pressure and temperature, for example. They support the investigation of a range of electromagnetic properties and characteristics of materials. Thus, they serve research in materials sciences, physics, engineering, as well as in biology or chemistry, but also industrial applications. A number of electromagnetic phenomena in materials are not well understood including high-temperature superconductivity and electronic-property phase transitions.

The research infrastructure project, referred to as EMFL here and in the project proposal, is more specifically an infrastructure project at the Dresden High Magnetic Field Laboratory (Hochfeld-Magnetlabor Dresden – HLD). The project should not be confused with the larger EMFL network infrastructure project aiming at an association of four major European magnetic field laboratories. |²⁴ The EMFL infrastructure as a whole aims to address a few of the fundamental open questions in materials science. Furthermore, it is supposed to contribute to the development, testing, and characterization of novel materials and to develop expertise in the construction of all-superconductive magnets.

The EMFL infrastructure project at HLD, which is under consideration in the roadmap process, plans to build and operate two fully superconducting magnets which are able to reach steady state magnetic fields beyond 30 tesla, the so-called 30+ tesla magnets. The current limit for commercially available static magnets is at around 22 tesla. Certain laboratories using special constructions achieve up to 45 tesla in steady fields. With pulsed magnetic fields, nearly

|²⁴ The distributed research infrastructure EMFL comprises four sites: These are the German HLD, up to now only used for experiments in high pulsed magnetic fields, the French “*Laboratoire National des Champs Magnétique Intenses – Toulouse*” also for experiments in pulsed magnetic fields, the French “*Laboratoire National des Champs Magnétique Intenses – Grenoble*”, for experiments in static magnetic fields, and the Dutch “High Field Magnet Laboratory” in Nijmegen also specialized in static magnetic fields. For further details concerning the overall project EMFL, cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 71.

100 tesla can be reached. The goal of the EMFL project at HLD is to develop magnets which consume less energy due to their superconducting properties and which enable more homogeneous high magnetic fields. Building these two new 30+ tesla magnets is supposed to strengthen the European EMFL network.

The construction costs for the prototype 30+ tesla magnet systems at HLD are estimated to EUR 19 million (for the years 2013-2015). Operating cost for five years will be of the order of EUR 16 million (2016-2020).

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.2.

1.4.b Evaluation of EMFL

Summary

Scientific Potential. Better understanding of electromagnetically relevant material properties pursued by the project of the HLD as part of EMFL could contribute to technological progress in different fields of application. The use of the new magnets in combination with free-electron-lasers and other beam facilities holds potential for new discoveries in the long term. This project could create an internationally outstanding infrastructure to catch up with a rapidly evolving and highly competitive environment.

Utilization. The infrastructure is mainly focussed on an important special field of basic research, namely, materials science and materials physics. In this specific context it offers a platform for novel experiments for a variety of disciplines. The planned rules of access are appropriate.

Feasibility. The technically difficult and ambitious project is at an early stage. Important technical issues as well as the integration into the European consortium EMFL remain to be fully worked out. Based on the good track record of HLD in building pulsed field magnets, the extension to very high steady fields is expected to succeed. Adequate staffing is also critical for success.

Relevance to Germany as a location of science and research. The new facility will primarily enhance the capabilities of HLD and hence strengthen its role in the European consortium. The project has the potential to increase the attractiveness of Germany as a location of research in magnetic fields and to initiate possible new technological developments.

Scientific potential

The HLD as part of the EMFL network is well positioned for research in basic materials science. The infrastructure is essential for exploring material properties as a magnetic field is a tuneable fundamental experimental parameter. The

technology of utilising high-temperature superconductors to provide a static magnetic field of (ultimately) 30+ tesla will offer fields of significantly higher homogeneity and stability compared to those obtained by resistive technology and hence contribute to higher quality experiments. The instrument will serve multiple purposes focusing on fundamental aspects of materials science pertaining to the electromagnetic properties. This facility has potential for unexpected discoveries in superconductivity, superconductivity at interfaces, quantum spin systems, topological insulators, and other aspects of fundamental materials science. Ideally, these findings should in the longer run contribute to new developments in functional materials. The combination of the proposed high direct-current magnetic field with the available free-electron-lasers and other beam facilities (such as neutron or synchrotron X-ray sources) holds potential for new discoveries in the long term. The relevance of the scientific questions to be addressed within the materials, physics, and chemistry communities should have been worked out more convincingly in the proposal.

The whole field of high-current and high-field sources and managed power supplies could benefit from the design of magnets exploiting superconductivity. Furthermore, new concepts in magnet technology can be expected. The technological developments could offer the opportunity to possibly spin off commercial interest in high-field magnetic technologies. Successful realizations of magnets built with superconductive materials could ultimately lead to significant power savings in various demanding applications.

The new instrument at HLD will be a multi-purpose platform. Though the primary production of a magnetic field with high field strength is specific, the application will require a broad production of other extreme conditions in temperature, pressure, chemical composition etc. to realize the specific research goals. The infrastructure is designed to support varied applications. It is reasonable to anticipate that the scope of modes of operation and hence the usage modes will expand throughout its lifetime.

Nationally, the HLD is the only centre in high magnetic fields. It also has a leading role in pulsed high magnetic fields in Europe, which is, however, not directly related to the current EMFL project at HLD. World-wide, there are around a dozen high magnetic field laboratories providing steady or pulsed magnetic fields in the highest achievable region of magnetic field strength. Only one of those, the Magnet Lab at Florida State University in Tallahassee, which is part of the National High Magnetic Field Laboratory (NHMFL), is really competing with the planned EMFL infrastructure at HLD. |²⁵ Researchers at this laboratory are

|²⁵ For further information on competing and complementary projects, cf. Appendix 2.2.

currently further developing the hybrid technology, i.e. the combination of superconducting and resistive magnets, to achieve comparably high steady fields. Nevertheless, the current EMFL project proposed by HLD is a unique and complementary new research infrastructure. If it were not funded, the US will remain at the forefront of research on high-field magnets with high-temperature superconducting wires, and Asia might catch up in the future.

Utilization

World-wide, high magnetic field labs are oversubscribed by the current user base of physicists, chemists, and materials scientists. The HLD has already built up a user community which will eagerly transition to make use of the new infrastructure. So far, published papers very often have an author from HLD indicating large in-house cooperation and usage.

In addition to the usage from within Germany, the planned infrastructure will extend the capabilities of the European EMFL consortium. Users in other countries, including in particular Portugal, the UK, Austria, Poland, and Spain, will also experience and indirectly benefit of this extension. The extent of the potential user group is large and international, and extends beyond the mentioned countries. This is a demand-led project at a very timely point in the development of emerging superconducting and magnetic materials (such as the pnictides and the colossal magnetoresistance materials).

The HLD has established a successful user platform for high magnetic pulsed fields. The Dresden team has all the administrative and scientific processes established to support a large and diverse user group in running challenging experiments. Potential users will rely on local expertise for planning and assisting in performing experiments as it is done now for the pulsed field experiments. The planned rules of access are appropriate. However, the apparently existing “rapid access” procedure for time-critical experiments should be advertised and explained more clearly.

As any large-scale facility, HLD provides training opportunities for undergraduate and graduate students. The role is vital, and increasingly important given the global nature of large-scale research infrastructures. This project will require training in a range of interdisciplinary areas of research, which simply will not be possible without an effective research infrastructure.

Feasibility

The project is technically difficult, ambitious and at an early state. Many of the techniques currently used at lower fields need to be modified and expanded for use at ultra-high and pulsed magnetic fields; the in-house scientific staff at HLD are expected to be well positioned to successfully tackle the relevant tasks.

Based on the good track record of HLD in building pulsed-field magnets, it can be expected that the extension to very high steady fields can succeed, especially because of the continuous improvement strategy of the collaborators in the Dresden area. As the currently available expertise at the HLD is strongly focused on pulsed rather than on steady-state fields, the capability on designing and building high direct-current field magnets has to be newly developed in Dresden for this project. However, no one in the world has the capabilities yet which are necessary for magnets entirely based on high-temperature superconducting technology. The development strategy at HLD builds on an incremental improvement process to ramp up the performance of the instrument from 25 tesla to 30+ tesla, thus mitigating risk. They are supported by the collaboration with the Leibniz Institute for Solid State and Materials Research Dresden (IFW) who has excellent expertise in superconductive materials. One of the first steps in developing the magnet design should be the testing and evaluation of the different wire or sheet material designs which are relevant key technologies. Furthermore, the practical evaluation of coils, components, and systems must be conducted by the HLD soon. As the production and testing of the superconducting wires and sheets is mission critical, the availability of the required production processes should have been outlined in greater detail.

The foreseen three additional full-time equivalent appointments planned for the preparation and construction phase are not sufficient. The team has to be significantly extended by existing personnel as adequate staffing is also critical for success. In addition, resident scientists and technicians will have to be employed on at least medium-term contracts to ensure effective facility management and continuity. Some of these permanent operational and design issues need to be better outlined and included into the cost and personnel planning. Furthermore, even if there is a designated experienced senior scientist responsible for the operation of the facility, there is limited evidence of a professional project management at HLD, which will be mission critical for the success of the ambitious EMFL project.

There is little justification for the cost estimates and the timeline, both of which appear rather optimistic. These have to be made more transparent as the development of the 30+ tesla magnets is a project of high technological risk.

The new facility will primarily enhance the capabilities of HLD and will hence strengthen its role in the European EMFL consortium. The governance of the project at HLD is consistent with its scientific and technical aims. However, an efficient and detailed governance concept concerning, in particular, professional investment, project, and operations management at HLD but also on the European level of the EMFL network has not been sufficiently worked out. EU funding has been secured to establish the basic governance concepts by the end of 2013. An organizational framework beyond the current network structure

will be strongly required to keep the EMFL on a par with the National High Field Magnet Laboratory (NHMFL) in Florida and with emerging efforts in Asia. The EMFL partner institutions are strongly encouraged to closely coordinate the development of scientific infrastructure and experimental methods. In the future, collaborations have to be documented more carefully, in particular with the Leibniz Institute for Solid State and Materials Research Dresden (IFW) and the other EMFL partner laboratories, e.g. by letters of support, which were not provided so far.

Relevance to Germany as a location of science and research

The German track record in a number of related technical areas is outstanding and this will provide an excellent base for the medium- and long-term development of this national experimental facility. The project at HLD has the potential to increase the attractiveness of Germany as a location of research in magnetic fields with high field strength and to initiate possible technological developments. The achievement of the world record pulsed field of 91.4 tesla at HLD was noted world-wide and has spurred efforts at other labs.

The project at HLD is addressed at a better understanding of electromagnetically relevant material properties which is supposed to contribute to technological progress in different fields of application such as energy, mobility, and health care, for example.

Overall evaluation

High magnetic fields have become an important tool in research. The planned HLD infrastructure will extend the capabilities of the European EMFL consortium by ultimately providing a magnetic field of higher quality at reduced operational costs.

The project at HLD is at an early stage as is the constitution of the EMFL. The production of a 30+ tesla superconducting magnet is technically challenging and will require new engineering and production technologies. It is also likely to result in new materials for superconductivity applications. A few preliminary studies have been conducted, but no risk assessment has been done. Important technical issues remain to be fully worked out. Especially the capability of producing the necessary superconducting material seems to be mission critical.

Through this project, an internationally outstanding infrastructure could be created in order to catch up in a rapidly evolving and highly competitive environment. The major competitor, NHMFL, is the currently leading laboratory for high magnetic fields. Other high-capability centres are evolving in Asia.

Environmental sciences encompass a wide ranging spectrum of scientific disciplines such as physics, chemistry, biology, geology, geography, applied mathematics, computer science, and engineering in order to study environmental systems. The following chapter, after a general introduction, focuses on three specific fields of research of environmental sciences together with the corresponding research infrastructures of the roadmap process.

II.1 Scientific landscape for research infrastructures in environmental sciences

Research in environmental sciences provides knowledge on the Earth system on a wide range of spatial and temporal scales. An important field of research is the fundamental dynamics of and interaction between the subsystems of the environment including the climate system and its changes, ecosystem functions and services, or the hydrological cycle and its capacity to supply sufficient water for the natural and built environments.

Studies of environmental processes in individual domains or spheres increasingly are placed into the context of the complex and highly interconnected Earth System. The Earth System approach requires problem definition and results through a holistic approach that not only promotes research in traditionally defined fields within environmental sciences, but also the integration of this research into a larger framework of the Earth System including its socioeconomic and sociocultural domains and the needs of a broad stakeholder community.

Sustainable management of the natural and built environments including the socioeconomic and sociocultural systems with which they are intimately coupled requires a sound basic science foundation that can feed information into applied science, engineering and decision making on critical issues. These issues include climate change, ecosystem health and diversity, agricultural production, natural and anthropogenically induced hazards, and water resources to highlight just a few. To meet these needs, novel tools and technologies for understanding environmental processes as well as for monitoring, prevention, mitigation of and adaptation to environmental risks and impacts of human activities have to be developed. |²⁶

Due to the inherent system-oriented approach, environmental sciences tend to bridge the boundaries between many disciplines in the natural sciences, life sci-

|²⁶ Cf. amongst others: ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 28 and HGF: Helmholtz-Roadmap for research infrastructures. As of 2011, Bonn 2011, p. 17.

ences, medical sciences, engineering sciences, social sciences, and the humanities. Therefore, environmental sciences increasingly are applying transdisciplinary approaches to research and problem solving.

Climate change as one of the main global challenges is one of many examples to illustrate the need for transdisciplinary cooperation. Atmospheric properties and components, including water vapour, clouds, trace gases, and aerosols play a key role in the Earth's energy budget which is the main driver of climate. At the same time, the climate system strongly interacts with the ocean, cryosphere, biosphere, and anthroposphere and the combination of these complex, highly coupled interconnections feed back onto the atmosphere on many temporal and spatial scales.

Furthering the insight into the complex Earth system, its dynamics and interactions, and its reaction to natural and anthropogenic perturbations, requires increasingly complex, large research infrastructures. These include ground-based infrastructures (for example seismometer arrays, remote sensing laboratories, or stations that measure biotic parameters), satellites, airborne infrastructures (e.g. long-term aircraft observations or specific airborne research facilities, which are deployed during dedicated field experiments), research vessels, automated marine observing platforms, as well as localized observing stations in lakes or the ocean. Furthermore, for a comprehensive system-oriented approach, observing systems integrating various devices, instruments, and entire infrastructures are invaluable. Also, networks and integrating programmes dedicated to the investigation or the understanding of specific parts of the Earth system can serve as important research infrastructures.

The data needed in quest of understanding the Earth System and its future states are becoming more and more complex. The numerical simulations and models require larger computational capacities and qualified model and data handling. Therefore, e-infrastructures are also vital parts of the research infrastructure landscape in the environmental sciences. A non-exhaustive list of complementary research infrastructures in the environmental sciences is given in the Appendices 2.3, 2.4, and 2.5.

In order to embed the evaluated research infrastructures, the following classification of environmental sciences is used along the key components of the Earth system.

Atmosphere

Atmospheric research studies the composition of the atmosphere, the evolution of atmospheric motions and weather systems, the interaction of the atmosphere with other Earth system components, as well as the human impact on these aspects of the atmosphere. This encompasses a broad range of physical, chemical,

and biological processes reaching from the Earth's surface and the planetary boundary layer (lowest about 1 km) to the troposphere (from 0 to 10 km altitude) and the stratosphere (from 10 to 50 km altitude). Prominent examples of current research fields are related to global and regional climate change, the future of the stratospheric ozone layer, the prediction of extreme events, and the fundamental understanding of aerosol-cloud-precipitation interactions. Research in atmospheric sciences requires high-quality, long-term observations with remote instruments but also in-situ measurements, and a strong collaboration between observational, theoretical, and numerical modelling activities.

One of the four environmental research infrastructures under consideration is the **In-service Aircraft for a Global Observing System (IAGOS)** aboard airliners. Its primary goal is to understand long-term changes of the atmospheric composition in the region of the upper troposphere and lower stratosphere (i.e. in the altitude range from about 8 to 12 km). Monitoring, understanding and modelling these potential changes is essential for addressing important issues related to air quality, climate feedbacks and climate change.

Hydrosphere

Oceans and seas are an important, but still partially unexplored or not well known part of the Earth covering over two thirds of its surface. Parts of the global ocean, its physics, biogeochemistry, ecology, etc. are still in exploratory states. The oceans are deposits for several precious resources whose distribution and possible environment-friendly exploitation have so far only been explored insufficiently. Additionally, the coastal regime, i.e. the transition zone between continental (fresh) waters and oceanic (salt) waters requires substantial research as it is a zone of high anthropogenic impact and related change, which strongly influences its basic function and usability.

The research infrastructure **Cabled Ocean Observing System Frontiers in Arctic Marine Monitoring (Cabled OOS FRAM)** belongs to the class of local and regional observing systems, respectively. It will comprise a cabled underwater observatory to facilitate sustained year-round ocean observation in Fram Strait, a key region connecting the North Atlantic and the sea-ice covered Arctic.

Geosphere

Central fields in the study of the solid Earth research are geology, geophysics, and geochemistry. One of the most important aspects is the understanding of the Earth's lithosphere, the upper part of the solid Earth up to about 75 to 300 km in depth, and the fundamental geological processes and structures occurring in it. The lithosphere comprises the Earth's crust and the underlying mantle and consists of distinct plates moving on the plastic asthenosphere. Plate tectonics is a unique feature of planet Earth and is ultimately responsible

for the occurrence of earthquakes, volcanic eruptions and related hazards. Moreover, understanding the structure and dynamics of the lithosphere is an essential prerequisite for finding new natural resources, such as oil, gas, or metal deposits. Solid Earth research covers the study of Earth processes over a large spectrum of time and space scales. The research topics vary from the evolution of continents and oceans lasting millions of years to the sudden hazards such as rockfalls and earthquakes, which happen over periods of minutes or even seconds. The spatial scales, over which these events spread out, range from entire tectonic plates of thousands of kilometres to the nanometre-scale processes occurring on mineral surfaces.

There are two research infrastructure projects that primarily belong into the domain of solid Earth research. The German part of the **European Plate Observing System (EPOS)** aims at long-term measurements of plate movements and of seismic activity with high spatial resolution. It is primarily designed for hazard monitoring and mitigation. The aim of the **Global Earth Monitoring and Validation System (GEMIS)** is the observation of relevant geological and environmental processes with high resolution in space and time, as well as the measurement of critical abiotic and biotic parameters.

II.2 In-service Aircraft for a Global Observing System (IAGOS)

II.2.a Short description of IAGOS

High-quality and long-term observations of the atmospheric composition in the region of the troposphere and lower stratosphere (i.e. at altitudes up to 12 km) are vitally important for monitoring and understanding temporal variations and trends. Such trends strongly affect future climate and air quality, their early detection and understanding is critical for developing abatement or mitigation strategies. Most accurate observations of water vapour, trace gases, and aerosols can be obtained in this region of the atmosphere from in-situ aircraft measurements, which complement remote observations from the ground and by satellites. The project IAGOS builds upon and integrates two forerunner projects taking atmospheric measurements onboard commercial passenger aircraft. |²⁷

|²⁷ For further details concerning IAGOS, cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010. Luxembourg 2011, p. 35. For further details concerning the two forerunner projects, MOZAIC (Measurements of Ozone, water vapour, carbon monoxide and nitrogen by in-service Airbus aircraft) and CARIBIC (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container), cf. Appendix 2.3.

Up to 20 long-range aircraft will be involved in the project, each performing measurements world-wide during about 500 flights per year of important reactive gases and greenhouse gases (e.g. carbon dioxide and methane), as well as dust and cloud particles with fully automated instruments. In addition, one aircraft will be deployed once per month with a cargo container system, which allows measuring a large variety of atmospheric constituents using state-of-the-art measurement devices. This dual setup of IAGOS provides a cost-efficient approach due to the free transportation of the equipment offered by the airlines.

The project aims to contribute to several urgent and complex problems in environmental sciences, including for instance chemistry-climate interactions, the atmospheric carbon cycle, and stratospheric ozone recovery. The long-term perspective of IAGOS includes the identification of rapid unanticipated changes in the composition and/or dynamics of the atmospheric circulation, which will be essential for reacting in time to future environmental changes. The data from the project will be freely available via a centralized, already established, online data portal for the entire scientific community.

IAGOS is coordinated by the *Forschungszentrum Jülich* (FZJ), partners are research institutes and universities with an emphasis on atmospheric science in Germany, France, the UK, as well as weather services, specialized companies, and airlines. Germany has assumed the leading role within IAGOS already during the preparatory phase of this project and German institutes have developed the majority of the novel measurement systems for IAGOS.

It is foreseen that Germany will cover approximately 50 % of the total budget (investment and operational costs, 2012-2021), resulting in a German contribution of EUR 51 million.

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.3.

II.2.b Evaluation of IAGOS

Summary

Scientific Potential. IAGOS will foster the development of atmospheric science. The infrastructure is essential for the study of atmospheric chemistry and its changes and it will substantially improve the scientific understanding of some of the most important environmental problems. IAGOS will complement other programmes and fundamentally contribute to a global observational network by providing a unique instruments platform.

Utilization. IAGOS will be used by atmospheric and climate scientists in academia and by public stakeholders world-wide. Data can be accessed free of charge and will serve a broad range of purposes. There is already a large and well established network of users.

Feasibility. The scientific expertise of the hosting institution is of the highest international standard. IAGOS is well-planned and mature. As the project is an organic outgrowth of previous efforts, the technology is essentially all in place and the probability of success is high. It is a cost-effective and proven mechanism.

Relevance for Germany as a location of science and research. Germany is an attractive location for this kind of research. IAGOS will enhance Germany's visibility in terms of leadership – in Europe and globally – in this field. Through IAGOS, Germany will play a central role in both the generation and the interpretation of urgently required global atmospheric datasets.

Scientific potential

IAGOS will foster the development of atmospheric science. It is essential for the study of the atmosphere, how its composition affects climate, and how its properties are changing over time. The relevant fields include atmospheric chemistry, atmospheric physics, and the climate sciences. It will provide a platform for observations that is both unique and important for improving the understanding of atmospheric changes and how those changes influence climate, air quality, and the oxidizing or cleaning capacity of the atmosphere. The alternative roles the research infrastructure serves include the issue of improvement to global (and regional) climate/transport models, transboundary distribution of pollutants, the safety issues regarding volcanic emissions, and the potential identification of rapid unanticipated changes in the composition and/or dynamics of the atmospheric circulation.

This project has great significance in terms of providing infrastructure for scientific research that would be unachievable through dedicated research aircraft (e.g. HALO, HIAPER, Geophysica) which typically work for a few weeks on specific research questions. |²⁸ It builds on the predecessor programmes, MOZAIC and CARIBIC, and on an existing one in Japan that have utilized commercial aircraft on a smaller scale. IAGOS is poised to become an important and unique component of the global observing system required to understand how the cli-

|²⁸ For further information on the High Altitude Long range research aircraft (HALO), High-performance Instrumented Airborne Platform for Environmental Research (HIAPER), Geophysica, and further complementary projects, cf. Appendix 2.3.

mate and atmospheric environment is changing in response to human activities. It will substantially improve the scientific understanding of some of the most important environmental problems of the present day such as mentioned above. In terms of spatial and temporal coverage and the diversity of the measured parameters, this project will complement other programmes and existing ground- or space-based approaches by providing a unique instrumentation platform.

IAGOS is likely to deliver to a range of scientific research agendas and to operational needs. The data collected through this infrastructure will serve a broad range of purposes, from fundamental chemical, physical, and dynamical process understanding through to integrated model development, to forecasting and to the identification of hazard exposure for operation purposes. Although the sampling coverage provided by IAGOS (which is determined by the air traffic) is not optimal to address all scientific issues of interest, it does provide substantial improvements of the current capabilities at modest cost because of support from the participating airline companies. In the future, it is the strategy to consider improved and new measurement technologies as well as greater vertical and horizontal sampling. Once the infrastructure becomes more widely dispersed and utilised, additional applications should be taken into account to comply with evolving needs.

The long-term component to this project is important for understanding atmospheric changes that will likely occur over time, perhaps gradually, so detecting these changes requires an ongoing observational network in place before the changes occur. IAGOS will fundamentally contribute to such a global observational network, even more if considering including a larger number of aircraft and collaborating organisations in the future.

Utilization

The research infrastructure will be used by atmospheric and climate scientists in academia and by public stakeholders world-wide. The high level of interest in the precursor projects to IAGOS (MOZAIC and CARIBIC) provides a good measure of the interest expected from an enhanced research infrastructure that is IAGOS. The obtained results can potentially be used by governmental agencies as well as from a managerial perspective, serving both national and regional emissions inventories and aviation operations.

A large research community is supportive of and would benefit from funding this effort as demonstrated by the set of endorsements from the international research and operational community including letters of support.

The proposed central data base which users can access free of charge is seen as appropriate and will serve a broad range of purposes. It will be critical for ease

of use to allow query-based data requests, provide standard graphical products, and have a clear protocol for incorporation of revisions of pre-existing data including version control. These aspects will be handled by CNRS (*Centre national de la recherche scientifique*, France). A close partnership will be needed between the individuals gathering the data, the individuals designing the databases and access, and the individuals using the data. It is recommended to have workshops that are open to the data user community both for scientific stimulation and for engaging the user community in the discussion of improvements in instrument or data portal design.

IAGOS will provide excellent research opportunities for young scientists and continue to foster student involvement e.g. via projects for qualification. Many of the scientists expected to participate in IAGOS are intimately connected with educational and research institutions so that they are in an excellent position for recruiting and training students. Also a concerted effort for public outreach is desirable and should be delineated during the next steps of the project.

Feasibility

The scientific expertise of the hosting institution is of the highest international standard as demonstrated by a long history of quality research in this and related fields. IAGOS is well-planned and mature. As the project is an organic outgrowth of previous efforts, the technology is essentially all in place and the probability of success is high. It is a cost-effective and proven mechanism building on the predecessor programmes. Many if not most of the technical innovations are already in place and technical alternatives have been taken into account. The inclusion of a pilot phase seems appropriate for testing and implementing the new instrumentation.

The presence of a scientific advisory board which will assist in prioritizing research questions and payload decisions is appreciated. It will be particularly helpful for addressing whether the instrument package strikes an optimal balance between what is feasible and possible across different science fields (e.g. reactive chemistry, ozone, water, greenhouse gases, aerosols, and other tracers of interest).

There is the risk that the airlines' favourable facilitation of the project could change in the future. However, the involvement of multiple airlines, as done in MOZAIC, does minimize this risk. Although personnel requirements have been sufficient for the pre-IAGOS projects to succeed, it should be further specified how these needs will change if IAGOS moves forward in the future.

IAGOS could become Germany's most important contribution to a global atmospheric observing system. Thus, it will be both scientifically as well as politically significant and will even foster its role in design and use of global datasets. Through IAGOS, Germany will play a central role in both the generation and the interpretation of urgently required global datasets related to the atmospheric composition of the free troposphere. Already now, Germany is an attractive location for this kind of research. This infrastructure will enhance Germany's visibility in terms of leadership – in Europe and globally – in this field. The project would position Germany and German scientists at the centre of what would be a major scientific infrastructure.

Although Germany does not have extensive territories, it has the advantage (like Japan) of somewhat close working relationships between the science and industry, including the ability to develop contracts with airlines that allow projects like IAGOS to go forward, which have been more difficult elsewhere (e.g. the US).

The synergy effects of the required multi-disciplinarity (sub-disciplines of atmospheric sciences, engineering etc.) are anticipated to be very significant. Not funding the research infrastructure would prevent these advances, limit the role of German science in providing new insights and contributions to the understanding of Earth's climate system and climate change, diminish collaborative research within Germany, the EU, and abroad, and eliminate the advantage of Germany and German researchers in their past achievements in developing similar programmes of smaller scope.

Overall evaluation

The proposal for IAGOS is assessed as strong, mature, and timely. IAGOS will fill a very important gap that exists with regards to the understanding and monitoring of atmospheric composition associated with climatic change. It complements existing ground-based (baseline) observatories and satellite observations by providing observations in the upper troposphere and lower stratosphere of unique detail and accuracy. No comparable infrastructure exists worldwide, which underlines the importance of IAGOS.

IAGOS is a follow-up and integration of two successful projects developed during the last decade, MOZAIC and CARIBIC. This will lead to a complementary measurement strategy, which will allow obtaining a good global coverage of the most important reactive and greenhouse gases, and novel and technologically challenging measurements of additional trace gases. IAGOS will be able to provide these important measurements at low costs thanks to the long-term involvement and contributions of various airline companies.

The infrastructure will become a central pillar of atmospheric environmental science within Germany and the EU. Its influence will also be very significant for scientists worldwide, given the urgent need for data for monitoring environmental change and validating climate models. Funding IAGOS would provide a key infrastructure for long-term international collaborative research targeted at some of the most pressing environmental problems of today.

The FZJ as the leading institute is highly qualified and holds the required expertise and capacities. Thanks to the preparatory projects, IAGOS is ready for being implemented. The envisaged development of new detectors is reasonable and very likely to succeed. In the longer term, the potential of the project to contribute to a wider range of scientific questions as currently foreseen and to address emerging strategic demands should be considered.

II.3 Cabled Ocean Observing System Frontiers in Arctic Marine Monitoring (Cabled OOS FRAM)

II.3.a Short description of Cabled OOS FRAM

The project Cabled OOS FRAM is designed as a local cabled observing system situated in Fram Strait, a key region connecting the North Atlantic and the sea-ice covered Arctic. Cabled OOS FRAM consists of a deep-sea cable with nodes and junction boxes to connect and power modular sensor platforms, starting from Svalbard as riparian station up to Greenland. Connected to this cable are fixed-point and mobile sensor platforms to enable in-situ environmental observation and sampling, and an integrated e-infrastructure providing access to data and samples. The infrastructure is designed to monitor physical, chemical, and biological data for an analysis of water movement, matter transport, and transformation in the Fram Strait.

This cabled infrastructure is intimately connected with an autonomous observation system currently under development by the Helmholtz Association called FRAM (Frontiers in Arctic Marine Monitoring).^{|²⁹} This system provides two already existing observatories in the Fram Strait, HAUSGARTEN and HAFOS^{|³⁰}, with modern autonomous sensor networks.

The deep-sea cabled infrastructure FRAM – this is the only one the text refers to in the following – will allow a continuous measurement of water movement and matter transport as well as matter transformation between the water bod-

^{|²⁹} Cf. HGF: Helmholtz-Roadmap for research infrastructures. As of 2011, Bonn 2011, p. 21.

^{|³⁰} For further details concerning the projects HAUSGARTEN and HAFOS (Hybrid Arctic/Antarctic Float Observation System), cf. Appendix 2.4.

ies of the Arctic and the Atlantic Ocean. Continuous measurements during summer and winter will allow obtaining a complete picture of these processes, including physical and chemical data. Measuring devices for biological data are to follow later after sufficient technical development. Obtaining reliable, year-round measurements on these data is an essential prerequisite for a better understanding of heat and matter exchange in this delicate region which is most severely influenced by climate changes through the past decades. This cabled observing system addresses the overarching challenges of integrated Earth system observation in times of rapid environmental changes.

According to the present concept, the infrastructure FRAM will integrate a series of continuous measurement systems operating on the ocean ground as well as in the water column. Moreover, remotely operated vehicles (e.g. crawlers, gliders) and other equipment can be charged at the docking stations of this infrastructure and their activity be maintained over long times, including the winter period.

The institution in overall charge of this proposed national research infrastructure is the Alfred Wegener Institute (AWI), together with the German Marine Research Consortium (KDM). German scientists would have preferred access to this infrastructure, but it would as well be available to the international oceanographic community.

The costs for the construction of the infrastructure, which is assumed to take seven years, are estimated to EUR 140 million. The annual operational costs after completion of the infrastructure were calculated to about EUR 6.5 million.

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.4.

II.3.b Evaluation of Cabled OOS FRAM

Summary

Scientific Potential. At present, cabled infrastructures are the only practical way to reach climatically relevant ice-covered regions year-round and to acquire continuous coverage of critical physical, biogeochemical, and biological parameters. It seems convincing that cutting-edge and novel science will emerge from the outstanding FRAM initiative. The fast pace of present changes necessitates rapid implementation.

Utilization. FRAM is multi-purpose and flexible. The user community for the infrastructure exists on both a national and an international level and includes researchers, industry, and other stakeholders. The real-time access to high quality, multi-disciplinary data will be highly attractive for science, and also have educational value. It provides a foundation for predictive models, for

search and recovery of natural resources, and for adaptation strategies to environmental changes.

Feasibility. The AWI is an internationally leading institution in polar research with excellent scientific and technical expertise. Strategies for integration with other European partners should be finalized. The technical concept is solid.

Relevance for Germany as a location of science and research. Germany is a leader in polar and high-latitude marine sciences and has proven capacity for developing marine technology. FRAM extends this leadership with an infrastructure unique to Europe and the Arctic. The project will be a major flagship for studying Arctic climate changes.

Scientific potential

At present, cabled infrastructures are the only practical way to reach climatologically relevant remote ice-covered regions year-round to acquire continuous and unaltered temporal variability of critical physical, biogeochemical, and biological properties of the water column. The mobile assets are essential adjuncts to the cable to provide additional spatial context. The two methodologies complement each other extremely well, creating an integrated system that is much more useful than the sum of the parts if they were operated independently.

Compelling reasons for the need of a cabled observatory are as follows: (1) the need for power for new biogeochemical sensor types to study ecosystem processes and evolution; (2) the need for real-time data for event detection and sampling modification; (3) the need for power for vertical profilers to maintain year-round operation (otherwise impossible under battery power), thus acquiring critical vertical resolution (some ecosystems are dominated by intermittent activity in very thin – 0.2 to 2.0 m – layers); (4) the need for monitoring instrument performance to ensure uninterrupted time series, e.g. by tasking a glider to make measurements in case a mooring fails.

A concern is the extent to which the environment will be affected by the placement of such a structure and whether it will affect the very same parameters that are to be studied. Perhaps experience on this matter is emerging at existing benthic observatories and could be used.

It is widely recognized that benthic observatories are required to significantly advance marine science and this has triggered the development of more international marine observatories, each having a different research focus – none so far had a polar focus. To measure the effects of global change cannot be done by

a single cabled underwater observatory and therefore it is important that this infrastructure is coupled to a global observatory network as it is planned. |³¹

With FRAM, there will be a much better chance of understanding how the high-latitude ocean is changing and what the impact of that local, regional and global change will be in the near future. It fills an important gap, which will enable scientists to understand and further predict ongoing global changes with better measurements (e.g. year-round). It is a great advantage that ecosystem processes such as nutrient dynamics, biodiversity, and genomics and food-web interactions are included in this project. The development of sensors and automated sampling and fixation for these parameters are planned within the first phase of the project. Such measurements are globally in a highly developmental phase of technical innovations. In a future project draft, it must be clearly stated which additional parameters can be measured through the cabled observatory. Especially the concept on how the measurements of biological parameters will be achieved must be developed during the first project phase.

FRAM will yield exceptionally significant and novel contributions to Arctic Ocean research (in many if not all sub-disciplines of the marine sciences), commercial operations and educational opportunities. The planned infrastructure is multi-purpose and flexible. It seems convincing that absolute cutting-edge and novel science will emerge from the outstanding initiative. However, it will be a challenge to ensure sufficient flexibility to target emerging research questions while maintaining times series of key parameters. For this purpose, a policy has to be developed that describes what sets of observations need to be maintained for long periods of time in order to address the climate-relevant scientific goals. This means that some infrastructure (e.g. particular sensors, numbers of profiles per day obtained by the profilers) may be deemed essential for understanding long time-scale variability and therefore should not be available for re-tasking without strong justification.

Utilization

There exists a user community on a national as well as on an international level, including researchers, industry, and other stakeholders. Although there are already very many support letters and expressions of interest from leading research institutions and stakeholders, the appropriateness of the capacity needs to be evaluated in detail. Therefore, a capacity adjustment has to take place in the first project phase.

|³¹ For further details on global observatory networks and other complementary research infrastructures, cf. Appendix 2.4.

Three levels of access and hence users are outlined: users who may re-task particular existing Ocean Observing System (OOS) infrastructure and sensors, users who may deploy their own instruments on existing OOS infrastructure, and data users. This last group especially includes ocean and climate modellers. Access to the data is appropriately planned to be open and immediate. It is also foreseen that quality control and quality assessment will lie in the responsibility of the FRAM programme. It still needs to be specified whether or not this policy includes data from instruments provided by users (instead of instruments deployed by FRAM itself), since such inclusiveness could result in a large, unplanned work effort. It is also important to realise that there is a time lag required for different levels of quality control and assessment. The conditions for getting data access and the planned review process still need to be specified in more detail. Additionally, a detailed outline must be provided on how external users can obtain information about and access to the evolving data basis and the continuous data stream.

The kind of multi-disciplinary data collected and the quality and quantity of that data, along with the immediacy of access to the data, will be highly attractive to scientists, especially to young scientists tackling the most important problems in marine science that require interdisciplinary effort and/or application of technologies that presently cannot be deployed for more than a few weeks at a time due to battery limitations. The opportunities for engaging students and the public in general in ocean education will also be profound as the sights and sounds of the deep-sea are delivered in near real-time to any desktop computer around the globe. This will fascinate and motivate students at all levels and this feature can be integrated into teaching programmes with great benefit. The facility should develop an internet site for educational purposes with real-time measurements with advanced exercises for university students and attractive informative exercises for school children or for the general public.

Feasibility

The AWI is an internationally leading institution in polar research with excellent scientific and technical expertise. It is among the best in the world. The proposers are extremely experienced in organizing and running mega-projects and large-scale infrastructures. There is confidence that they will be able to establish an efficient and flexible management structure. However, the governance concept has to be further developed if the project is funded. Strategies for integration of other European partners should be finalized. As a lot of responsibility will rely on the technical advisory committee, its ultimately applied policies have to be developed with great care.

The detail of the plan is at an advanced level for this stage of the proposal compared to similar proposals seen over the past ten years (e.g. the US Ocean Observatories Initiative). The technical concept is solid. However, the specifics of the infrastructure that is planned were not elaborated on, e.g. how many moorings will be deployed, what sensors each of them will carry etc. It is necessary to work this out, especially with regard to the budget and the long-term perspective of such a research infrastructure whose potential will tap the full potential only if it is operated over several decades. As information technology and data transfer is constantly evolving, the optimal technical solutions and strategies have to be selected during the first project phase.

The additional manpower requirements for co-ordinating, deploying, and maintaining the unique infrastructure associated with the FRAM cabled observatory proposal are reasonable. The plans for recruiting and training of the new generation of academics are fully adequate at the present stage.

Relevance to Germany as a location of science and research

Germany has taken on a leading position in polar and high-latitude marine sciences and has proved capacity for developing marine technology. The FRAM cabled observatory extends this leadership with an infrastructure unique for Europe and the Arctic. It is very plausible that the infrastructure will attract talented young scientists and increase the awareness of Arctic research – and thereby further enhance the very strong national and international recruitment at German research institutions.

Obviously, changes in sea-level rise, changes in ocean currents and weather patterns will have large implications for the German and the European societies. However, Arctic climate changes also offer possibilities for exploitation of new natural resources, change in transportation routes, and affect political stability. With the proposed infrastructure, adaptation strategies can be founded on a more solid scientific basis. Furthermore, the technical innovations can have positive spin-offs for German industry.

An infrastructure of the proposed magnitude will represent a massive flagship in a national as well as European and international context. It is easy to imagine that on a national level it will dominate the research landscape of marine climate changes, both financially, logistically, politically, and in public awareness, and as such to some extent undermines the foundation for existing structures. This potential effect has to be realized by the proposers.

If FRAM was not realised, effects would include the lost opportunity for Germany (and Europe) to strengthen the dominant international lead in marine Arctic science. Other big players (amongst others US, Canada, Japan, Korea, China) are

massively investing in this research area for many reasons that go beyond science.

Overall evaluation

The proposed FRAM cabled ocean observing system is seen as an ambitious, relevant, and timely infrastructure. Its realization is planned as an appropriate two-step process with a preparatory and a construction phase. At the moment, it is only in a conceptual phase but will represent a major leap forward in the investigation of changes in the marine system. Placement in Fram strait is well rationalized. FRAM's geographical positioning is at a location which is critical for science and commercial operations cutting across numerous disciplines and applications. It clearly offers novel and groundbreaking opportunities and is unique in a European and Arctic context.

Within the area of marine and climate research, this project is outstanding. If realized, it will represent a major flagship for investigating, understanding, and monitoring Arctic changes. It provides a foundation for developing predictive models, for search and recovery of natural resources, and adaptation strategies to environmental changes that are urgently required by German, European as well as global societies. The facility will be central to maintain and even further strengthen the leading role of the Alfred Wegener Institute and German polar sciences in general in international polar and climate change sciences in the coming years.

The fast pace of present changes requires a rapid realization. There is a strong urgency for cutting-edge facilities and science assessing Arctic changes. It would even be desirable if FRAM could be deployed sooner, given that the changes occurring in the Arctic Ocean right now need to be understood. However, the plan should not be accelerated if this would harm its potential success.

II.4 European Plate Observing System (EPOS)

II.4.a Short description of EPOS

Understanding the structure of Earth's crust and upper mantle is important for assessing the risk of natural hazards, such as earthquakes and volcanic eruptions. Improvements of seismic imaging techniques allow now three-dimensional models of Earth's structure to be derived with a level of precision that was unachievable a few years ago. Also, major progress has been made in understanding earthquakes and volcanoes. Volcanic eruptions and their side effects (e.g. ash clouds) can usually be very well predicted. Earthquake predictions are not yet possible, but the general seismic risk in a given area can be assessed. Risk assessment and rapid warning, however, requires instantaneous ac-

cess to geophysical data from all of Europe and adjacent areas. Presently, this is not possible, as instruments are operated by different national institutions.

The project EPOS with its basic concept to build an infrastructure that integrates and expands existing seismic and geodetic stations and networks, would change the situation. EPOS is an integrated European system for the observation of the solid Earth (crust and mantle) below Europe and adjacent areas. It combines seismic and geodetic measurements with observations of the local magnetic field. Existing facilities in Europe will be integrated and complemented by additional instrumentation, such as mobile seismometer arrays or ocean-bottom seismometers. Open access to all data will be provided through a new electronic infrastructure portal.

There is an urgent need for such a network particularly in the Mediterranean region, where major seismic risks exist. The 1908 Messina earthquake, for example, killed more than 100,000 people directly or by the associated tsunami. Due to the increased population density, a similar event in the near future would have even more severe effects, unless accurate early warnings become possible.

For Germany, seismic and volcanic risks are more limited, but they do exist. A major problem with the exploitation of geothermal energy and the potential subsurface storage of carbon dioxide is, however, the possibility to induce seismic activity. Moreover, detailed images of the structure of Earth's crust in Germany could help in the search for new oil, gas, and ore deposits. Due to the increasing prices of fossil fuels and of metals, small deposits that were not economically attractive a few years ago can now be commercially exploited. Finding these deposits requires highly accurate mapping of the crustal structure.

The German contribution is supposed to pursue three basic objectives. The first is the integration of the existing geophysical and geodetic infrastructures and laboratory capacities in Germany into a single research infrastructure for geosciences with a common base of support. Secondly, the existing infrastructure should be complemented with additional components. Furthermore, a new e-infrastructure should be created with the aim of integrating the acquired data and making it readily available to the broad user community.

Within EPOS, Germany is in charge of the technical infrastructure work package being led by the GeoForschungsZentrum Potsdam (GFZ). More than 20 European countries are involved in EPOS as a whole.

The estimated total investment costs for the construction phase are EUR 500 million |³², and Germany is assumed to contribute around EUR 27 million (calculated for five years of construction). The German contribution of the annual operational costs lies at approximately EUR 0.9 million for the five years following completion.

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.5.

II.4.b Evaluation of EPOS

Summary

Scientific Potential. EPOS will extend the coverage of seismic observation in Europe and thus allow the geophysical community to see the structure of Earth's interior in greater detail. The project will help in the search for new natural resources and will provide unified, real-time access to seismic, geodetic, and magnetotelluric data from all of Europe.

Utilization. The instruments are highly adaptable and flexible. The e-infrastructure will allow comprehensive, harmonized, and more efficient access to and the integration of existing data. It will be used globally by a broad scientific community, with further interest expected from public stakeholders and industry. The open data access is assessed positively. EPOS will greatly enhance the ability to assess the risks of natural hazards. Implementation is urgent because of the seismic hazard in the Mediterranean.

Feasibility. The basic concept of EPOS is well conceived and convincing. The project is technically feasible; however many technical details require further elaboration. Particularly, an architecture for the e-infrastructure, appropriate for the planned utilization, needs to be developed. The GFZ Potsdam and partners are well qualified and hold all required expertise and capacities.

Relevance to Germany as a location of science and research. EPOS will enhance the visibility and attractiveness of Germany as an important and prominent geoscience location. It would place Germany in a leadership position among other European countries within seismology. The research infrastructure is unique to Europe and complements EarthScope in North America.

| ³² Cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 33.

The overall idea of developing a research infrastructure to integrate seismic and geodetic observation networks, being well linked into related European and international projects, is convincing. EPOS will extend the coverage of seismic observation in Europe and thus allow the geophysical community to see the structure of Earth's interior at a higher level of detail. It is therefore likely to provide new insights that may potentially be paradigm changing.

Societal benefit can especially be seen in forecasting and alerting about natural hazards. In this regard, the research infrastructure is very significant. It will also provide opportunities in the search for new natural resources, which includes the possibility of a future exploitation of the results through industry.

The e-infrastructure as an essential part of the proposed research infrastructure will allow for an open and integrated online access to Earth observations. The harmonized access towards all of these observations, allowing potentially for a comprehensive and more efficient access and usage of existing seismic sensor data (archives), is seen as an added value.

There is no infrastructure that directly competes with EPOS. The EarthScope project of the United States is in many aspects similar and complementary to EPOS. |³³

Utilization

The data will be used globally by a broad scientific community. In general, interest in the potentially provided harmonized observations and observation products can be foreseen and potential users range from Earth scientists to public stakeholders and industry.

As the instrument platform (e.g. portable seismometers) is highly adaptable to a diversity of applications and environments (land versus sea), the infrastructure platforms are multi-purpose and highly flexible. However, a higher degree of European integration in the use of instruments, e.g. the mobile seismometer arrays, would be desirable. Moreover, it needs to be ensured that mechanisms for competitive science-driven project assessment concerning the usage of the instruments are incorporated. To this end, an international advisory board should be installed.

The idea of open access to the acquired data is assessed positively as providing open data from seismic and geodetic observations would very much stimulate

| ³³ For further information on complementary projects, cf. Appendix 2.5.

international cooperation throughout different disciplines of Earth sciences. However, a complete and convincing concept, whether and how to deal with access restrictions, licenses, and fees is missing and has to be developed and communicated as soon as possible. The procedures still have to be put in place. The financial consequences of this open access have to be checked thoroughly as they will probably be more significant than anticipated and might need new funding concepts.

Furthermore, a concept about different “information products” (dedicated to different user groups) or specific “non-expert” services is lacking and should be provided. An architecture for the e-infrastructure appropriate for the planned utilization needs to be developed. Especially regarding the computing power and the portal and software interface, clarification is needed. It is necessary to plan a comprehensive user and usage study in order to design the e-infrastructure.

This infrastructure will be useful for the training of the next generation of academics and of students in Germany and throughout Europe. The e-infrastructure could serve as a data source for Earth science studies and could also be taken as a subject for research seminars and theses in geophysics and geoinformatics. As a database, the integration and access of data will be very useful for training students, e.g. by providing real-time data. It would stimulate research in geophysics and could become one of the most attractive resources in this field. However, it would be desirable to develop an in-depth concept related to the academic use of the infrastructure, recruitment and training of the new generation of academics.

Feasibility

As equipment and technology providers, the GFZ and partners are well qualified and certainly capable to manage and operate the infrastructure. The project is technically feasible and there are no fundamental technical innovations required as the similarly designed and complementary US project EarthScope shows. Though, it would be beneficial to see instrumental advances made to improve, for example, instrument efficiency, sensitivity, etc. However, the maturity of the proposed approaches (electronic platforms and architectures, sensors, computing power) cannot fully be judged at this stage as more technical details and further elaboration are required to do so.

One innovation challenge is in the data integration (mass data, diverse semantics, reference systems etc.). As the software and the computational hardware required are not yet well-defined, it cannot be fully assessed if the skills existing within the partners will be adequate. Clarification is needed here.

The governance scheme outlined is very preliminary. It will need to be further developed, e.g. concerning regulations on data access, licenses etc. Also, the plans for management, recruitment and training strategies, work and maintenance need to be elaborated in greater detail.

Relevance to Germany as a location of science and research

German Earth sciences have a prominent tradition. In the past, the mobile instruments available for land and ocean-bottom seismology and for magnetotelluric studies from Germany have served as models for other European countries. The GFZ as the hosting organisation of the proposed infrastructure is internationally well respected and for example led the development of the German Indonesian Tsunami Early Warning System (GITEWS). The proposed new infrastructure will be a highly visible scientific activity. It will enhance the visibility and attractiveness of Germany as an important and prominent geoscience location. It would place Germany in a leadership position among other European countries within seismology. It will raise already existing facilities within Germany to the European stage via the integration of existing and planned partial infrastructures. The infrastructure could potentially produce excellent science return to the global community. In addition, it provides direct societal benefits by enabling a better assessment of natural hazards and by helping in the search for natural resources.

The German role, being in charge of the technical infrastructure work package, seems appropriate and quite realistic. However, it has to be ensured that German capacities on sensor and geoinformation technologies are mobilized to the best extent possible, by involving not only one research institute but a number of research and industrial institutions holding the required capacity for such an infrastructure.

Overall evaluation

The basic concept of EPOS is well conceived and convincing. EPOS will provide a unified, real-time access to seismic, geodetic, and magnetotelluric data from all of Europe. It will greatly enhance the ability to assess the risks of natural hazards. The infrastructure will also help in the search of new natural resources and could potentially produce major advances in Earth sciences. The realization of the project is urgent due to the hazard aspects particularly in the Mediterranean. The research infrastructure is unique to Europe and complements the EarthScope in North America.

GFZ as the leading institution and its partners are well-qualified and hold all required expertise and capacities. In summary, the concept of EPOS is sound. However, many aspects of the project cannot yet be fully assessed as many details including technical details require further elaboration.

II.5.a Short description of GEMIS

On the one hand, GEMIS aims to observe relevant geological and environmental processes with high resolution in space and time, and on the other hand, it tends to measure critical abiotic and biotic parameters. This geosciences research infrastructure is in a very early stage of development. |³⁴

The main focus of GEMIS is to identify and study natural hazards and to observe impacts of global change including climate change, limited supply of fresh water, increasing human perturbation of the environment, and the growing need to use subterranean space for extraction and storage of energy and materials. In addition, the data collected by GEMIS are envisioned to be used for initialization and calibration of models that project future states of the Earth system. The latter includes transfer of Earth science knowledge into decision making on questions concerning sustainable development of the whole planet. Finally, GEMIS aims to develop the sensor systems needed to verify that human use of geological structures is safe.

The concept for GEMIS envisions an observing system with three components including (1) land-based multi-parameter observatories for measurement of physical, chemical and biotic state variables, fluxes, and parameters, (2) a system of mini-satellites for global high precision and near real-time observations, and (3) a centre for infrastructure operations and for capacity development. GEMIS is designed as a multi-purpose platform, which, after establishing the basic infrastructure facilities, will allow users to integrate additional sensors and measuring devices. It will also deliver new data and scientific findings for all Earth science disciplines including geophysics, geodesy, remote sensing, geology, or climate research. Shared operation of GEMIS offers a base for capacity development in both developing and emerging countries.

The leading and so far only participating institution is the GeoForschungsZentrum Potsdam.

The total costs will sum up to EUR 416 million. Included in the total costs are ten years of operation with annual costs of EUR 7 million. For the preparatory phase, EUR 3.5 million are needed.

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.6.

|³⁴ Cf. HGF: Helmholtz-Roadmap for research infrastructures. As of 2011, Bonn 2011, p. 19.

Summary

Scientific Potential. The vision and idea of GEMIS are not clear. The project lacks a comprehensive scientific theme. Many questions and concerns arise from the present version of the draft. These include, for example, the justification of co-location of sensors for studying and observing geological hazards and global change simultaneously as well as the justification of launching a large number of new satellites.

Feasibility. The principal investigators have experience in designing and implementing long-term observation sites and arrays. However, it is not clear how the research infrastructure can be developed from the present proposal to a fully functioning system without fundamental rethinking of the goal, the components of the observational system, and the implementation and operation strategies for sustained data collection. GEMIS is in a very early stage of development and many details are missing. Resources for a preparatory phase do not seem to be sufficient to move the project forward. It seems to be necessary for the responsible scientists to go through a new conceptualization phase with strong community input.

Scientific potential

This project of a combined network of ground-based and satellite observations is in a very early stage of development and its vision and idea as well as its justification are not clear. Many details are missing from this proposal and it remains on a very superficial level. Problematic issues could not be clarified and therefore, the proposal can be evaluated only in a very general fashion.

The research infrastructure lacks in a comprehensive scientific theme and thus it is impossible to assess if and how it could make significant contributions to grand challenges in Earth and environmental sciences. Questions and concerns that arise from the present version of the draft for the research infrastructure include first of all the justification of co-location of sensors for studying and observing geological hazards and global change simultaneously. Secondly, no proper justification of launching a large number of new satellites is given. And lastly, there is a lack of observing system design on the basis of a set of scientific questions derived from the overarching goal, a lack of discussion of results from existing observing stations in developing countries, and a lack of explanation of the process for identifying new partners with a firm commitment to open data access.

The principal investigators have experience in designing and implementing long-term observation sites and arrays, i.e. the problem with the proposed research infrastructure is not on the technical and operational side. Rather, the concern is that the concept for the research infrastructure seems to have been developed from an institutional perspective instead of resulting from a scientific need.

It is not clear how the proposed research infrastructure can be developed from the present proposal to a fully functioning system without fundamental rethinking of the goal, observing system components, and implementation and operation strategies for sustained data collection.

Overall evaluation

In view of the lack of (1) concrete scientific questions and challenges for the proposed observing system, (2) observing system design, and (3) a concept for implementation and operation, resources for a preparatory phase do not seem to be sufficient to move the project forward. It seems to be necessary for the responsible scientists to work out a new formulation of a scientific concept with strong input from the international community.

B.III BIOLOGICAL AND MEDICAL SCIENCES

Biological and medical sciences encompass a multitude of scientific disciplines that deal with life processes, living organisms and their organization, and relationships between organisms and the environment. The focus of the following section will be on the three fields of research that can be related to the research infrastructures of interest here.

III.1 Scientific landscape for research infrastructures in biological and medical sciences

Research objectives in biological and medical sciences include the elucidation of the structural and functional basis of biological phenomena, knowledge transfer between basic science and clinical application, the principles of health maintenance, and the prevention and treatment of disease. The rapid development of new technologies in biomedical research (such as genome sequencing, personalized medicine, high-throughput microarray and imaging technologies) makes it increasingly possible to study issues of complex systems. Biological and medical sciences have developed from data-poor into data-rich disciplines with increasing use of sophisticated bioinformatics tools and databases. This is changing the character of biomedical research towards large-scale, technology-

driven studies that critically rely on the availability of appropriate research infrastructures. So far, the new “omics” technologies have not been fully exploited for translation into health science, pharmacology and medicine. For example, sequencing the genome has not resulted in a significant increase of validated therapeutic targets. One key challenge of the next twenty years will be to bridge the gap between basic science and applications in health sciences, pharmacology, and medicine.

The focus of the research infrastructures of this roadmap process is on chemical biology for the identification of novel chemical and physical tools (EU-OPENSCREEN), on biomedical imaging for the non-invasive visualization of biological processes (GEBI), and on structural biology for the analysis of the biomolecular structures and functions with the highest possible resolution (INSTRUCT).

These fields are situated at the forefront of interdisciplinary biomedical research, and can be expected to advance biological and medical sciences towards a deeper understanding of biological processes. Fundamental to studies in modern biology and medicine are chemically defined bioactive molecules which can act as probes for biological processes which form the basis for the development of highly specific medicines. In chemical biology, targeted discovery of bioactive small molecules is largely driven by systematic large-scale and high-throughput screenings of compound libraries using specific bioassays to detect defined cellular responses. This approach requires technically and logistically demanding screening facilities that provide appropriate cutting-edge methods and databases. Such chemical probes can be used with modern imaging technologies, e.g. advanced light microscopy, magnetic resonance imaging (MRI) and positron emission tomography (PET), to study biological functions in contexts of physiological and pathological conditions all the way up from single molecules and single cells to whole-body imaging of animals and humans. Due to rapid advancement of imaging methods, the development of new technologies and the increasingly higher requirements on scientific expertise to use imaging tools, access to bioimaging facilities are nowadays essential in biomedical sciences. Structural biology allows mapping in atomic detail three-dimensional structures of biological macromolecules to study biological functions and to provide the basis for structure-guided pharmaceutical design. Structural biology uses complex technical approaches and equipment – for example X-ray crystallography, nuclear magnetic resonance (NMR) and electron microscopy – whose construction and maintenance are cost-intensive.

In view of the steadily increasing demands for the use of these technologies by biomedical sciences, there is a need for centralized infrastructures to provide access to high-end instrumentation and to maximally leverage infrastructure investments. Appropriate e-infrastructures for handling and storing vast

amounts of data are an essential part of research infrastructures in biomedical sciences. A list of important research infrastructures competing with and complementary to the research infrastructures related to the three fields of research that are in the focus of this roadmap process is included in the Appendices 2.6, 2.7, and 2.8.

Chemical biology

Chemical biology is an overarching term that pulls together a wide range of research methods and sub-areas, in particular at the interface of chemistry, biology, and medicine. The uniting features are that the methods used require a significant level of chemical and physical expertise and that the output has an effect on scientists' understanding how a biological system works. Chemical biology provides the fundamental tools for applications in many industries related to health and personal care, biotechnology, agriculture, food, materials, security, energy, and environment. |³⁵ A recent attempt to classify chemical biology led to the identification of several core subgroups of chemical biology. |³⁶ However, this is a fast developing research field and areas of rapid growth and newly emerging areas were also identified.

A key challenge that remains in chemical biology is the discovery and optimisation of novel chemical tools. There are many approaches to this, but the use of high-throughput screening techniques is very important as it enables researchers to probe understudied areas of biology hunting for new tools to dissect complex processes. Accordingly, chemical entities that are introduced into biological systems can serve as suitable tools in biological research. In addition to this impact on the fundamental understanding of biological processes and pathophysiological conditions, investments in high-throughput screenings provide a key instrument to integrate the academic and industrial sectors and help to translate the great advances that have been made in the molecular sciences to applications in agriculture, health and medicine. For example, validation of drug targets through the use of chemical tools de-risks and helps to prioritise drug discovery programmes. Drug discovery is in a period of considerable turmoil and one potential way forward recognised by many pharma companies is through improved academic-industry collaborations. Examples of areas of drug

| ³⁵ Altmann, K.-H. et al.: The state of the art of chemical biology, in: *ChemBioChem*, 10 2009 (1), pp. 16-29 and Bunnage, M. E. (Ed.): *New Frontiers in Chemical Biology. Enabling Drug Discovery*, Cambridge 2010.

| ³⁶ Pirrie, L.; Westwood, N. J.: *Chemical Biology: What is Its Role in Drug Discovery?*, in: Kapetanovic, I. M. (Eds.): *Drug Discovery and Development, Present and Future*, Rijeka 2011, pp. 193-230.

discovery that require novel approaches are the ESKAPE pathogens |³⁷ and neurological disorders.

The **European Infrastructure of Open Screening Platforms for Chemical Biology (EU-OPENSREEN)** will contribute to the development of bioactive small molecules in order to identify, characterize, and optimize chemicals for different purposes including the important areas of drug development, improvement of food production, and creation of diagnostic assays.

Biomedical imaging

Biological and molecular imaging methods enable the non-invasive visualization of biological processes and the molecular basis of human disease in their specific contexts in living cells in real-time and at high resolution. Bioimaging encompasses an increasing complexity ranging all the way up from single cells, tissues and organs to whole-body imaging of animals and humans. Innovative biomedical imaging technologies represent indispensable tools in life sciences to gain insights into the function of living systems at the molecular and organismal levels in biological model systems as well as in patients. Compared to so-called “omics” technologies like genomics, proteomics and metabolomics that cannot entirely reflect the dynamics, interactions and status of a particular molecule in its natural environment over time, imaging technologies provide this functional context. Therefore, they can contribute to the identification and validation of biomarkers and also provide high content assays for drug development. The interdisciplinary collaboration of basic, translational and clinical researchers using a common imaging infrastructure in research and healthcare affords prompt translation of basic biological discoveries in cells into animal models of human disease and clinical application.

The **German Research Infrastructure for Imaging Technologies in Biology and Medical Sciences (German Euro-BioImaging – GEBI)** seeks to visualize the molecular processes at work inside intact living cells at nanometre resolution and will provide access to state-of-the-art imaging technologies from basic biological imaging in cells via molecular imaging in animal models *in vivo* to medical imaging in humans.

Structural biology

Structural biology aims at resolving the three-dimensional structure of biological macromolecules such as proteins or nucleic acids at the highest possible

|³⁷ ESKAPE pathogens comprise *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* species.

resolution down to the atomic level. Structural biology constitutes an integral part of the life sciences, since basic information on the structural composition of molecular building blocks provides the ground for a better understanding of biological functions. For example, access to structural information on ligand-target interaction forms the crucial basis for structure-based drug design. Therefore, development and achievements in structural biology have constantly propelled biological research and pharmaceutical development, over the recent decades. Essential and complementary structural biology tools comprise X-ray crystallography, nuclear magnetic resonance and electron microscopy. Bridging and combining the different resolution ranges of these complementary technologies is one of the essential steps in this field of research. The goal thereby is to combine the different scopes of resolution so that the analysis on the level of single molecules can be extended to the system level of cells and organisms. Such a multi-scale approach with a continuous flow in resolution – from single molecules to molecular complexes to cellular organelles – will then make it possible to describe entire cells with all of their basic components at a pseudo-atomic resolution and to assign detailed structures to functions. The combination of structural biology with cell biology and systems biology can make a novel and integrative understanding of the basic components of biological systems possible.

The **Integrated Structural Biology Infrastructure (INSTRUCT)** aims at providing access to infrastructure in structural biology for individual laboratories at the national and European level to obtain structural information on cellular processes in a multi-scale approach. The instrumentation ranges from facilities for sample preparation to high-end instrumentation for NMR spectroscopy, X-ray crystallography, and cryo-electron microscopic analysis.

III.2 European Infrastructure of Open Screening Platforms for Chemical Biology (EU-OPENSREEN)

III.2.a Short description of EU-OPENSREEN

The research field of chemical biology emerged from classical pharmacological and cell biology disciplines studying the effects of exogenously applied substances to living species. Chemical biology today studies biological processes using a variety of sophisticated chemical techniques and tools. EU-OPENSREEN aims to deliver new bioactive compounds for all fields of the life sciences. |³⁸ These compounds will be used by scientists as tools to investigate the molecular

|³⁸ For further details concerning the European project EU-OPENSREEN, cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 57.

mechanisms of biological processes. Results shall yield deep insights into how these compounds act and, thus, inspire the design of new drugs and many other marketable products.

The use of novel chemical tools to study cellular function can pave the way for exploitations by industry – most obviously in the health-related science but also in agriculture, biotechnology, energy, and veterinary sciences. The discovery of chemical tools would be achieved by a “consortium approach” linking chemists, who will design and synthesise novel compound libraries, with cell biologists who will develop and apply high-throughput screening techniques. Such an approach has already been proved at a national (German) stage and the current project is to expand the programme to the European level led by German scientists.

The present project is characterized by a concept that envisages to provide open access to chemists and biologists and to commit itself to making results publicly available. This is in contrast to commercial screening facilities which charge user fees and/or keep results confidential. It would be expected that the great need for chemical tools and their application in cell biology can only be successfully met by such a publicly funded “open” approach.

Eighteen partners from twelve European countries have already joined the EU-OPENSREEN consortium. The European Molecular Biology Laboratory-European Bioinformatics Institute (EMBL-EBI), an international organisation based in United Kingdom, participates with its unique expertise in the field of bioinformatics. It will host the European Chemical Biology Database (ECBD) with data bridges to many other life sciences databases. Each of the scientific partners represents its national chemical biology community. In Germany, the *Leibniz-Institut für Molekulare Pharmakologie* (FMP), Berlin, the Max Delbrück Center for Molecular Medicine (MDC), Berlin-Buch, and the Helmholtz Centre for Infection Research (HZI), Braunschweig, are the institutions in overall charge.

The total costs for realisation of the project are estimated to EUR 54 million (investment costs about EUR 20 million and operating costs about EUR 34 million for the years 2014-2018).

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.7.

III.2.b Evaluation of EU-OPENSREEN

Summary

Scientific Potential. EU-OPENSREEN is crucial for the identification of novel molecules within the life and medical sciences and for the understanding of their effects. The discovery and use of new chemical tools are an indispensable

prerequisite for the understanding of biological processes including human diseases.

Utilization. This research infrastructure will be primarily beneficial to a broad academic community of life scientists. Industry will benefit from new lead compounds and the standardization of assays. The proposed access procedure has a solid base and the quality management is a key strength of this proposal.

Feasibility. EU-OPENSSCREEN is a very mature effort which is supposed to integrate the German research infrastructure into the existing European infrastructure landscape. The German partners have gained a lot of experience in this area and will take on the leading role in EU-OPENSSCREEN on the European level.

Relevance to Germany as a location of science and research. EU-OPENSSCREEN will be among the leading open screening facilities in the world and is essential for chemical biology in Germany. It will allow Germany to keep pace internationally in this very important area.

Scientific potential

Rather than being focussed on a narrow scientific question, EU-OPENSSCREEN is addressing a broader problem in science. The central question is: How do cells work? Whilst there are many ways to gain insights into this question, this draft convincingly argues that the use of chemical tools to study cellular function has considerable advantages. The discovery and use of new chemical tools are an indispensable prerequisite for the understanding of biological processes including human diseases. This is a very powerful argument as it potentially provides the often missing link between what can be done in an open, academic environment and what can be exploited by industry – in other words, the science that this infrastructure will enable will have a considerable impact on the health agenda.

This research infrastructure will be the place to go for the development of tool compounds to better understand disease biology before initiating a drug discovery programme. Very important applications in the areas of infectious diseases (ESKAPE pathogens which might have implications to national security), neurological diseases (including schizophrenia, Alzheimer's, autism etc.), psychiatric diseases (such as depression, dementia, and neuropathies), metabolic disorders (obesity and diabetes), and cancer can be seen. These research areas have been

abandoned by large pharmaceutical companies en masse. |³⁹ This argues that the synthesis and screening of new chemical entities are required. In neurological diseases, there are simply no new validated targets. This infrastructure project is the first step towards developing novel chemical tools to overcome key bottlenecks in the drug discovery process.

EU-OPENSREEN is necessary to allow the comparison of data across multiple projects and will enable common standards for compound purity, assay development and high-throughput screening. Only with this infrastructure in place, screening data that is generated Europe-wide will be integrated and made useful to the scientific community. Furthermore, there is a strong commitment of informatics in this infrastructure and so this will drive forward the development of new and integration of existing databases. In addition to the screening technology, it is also essential that suitable chemical collections are put in place. This is an area where change can take place over time although not too much as a key goal is to produce information across a lot of screens for a fixed set of compounds.

There are a lot of synergies and there seems to be very few direct overlaps with one exception – the planned IMI European Lead Factory. |⁴⁰ At first sight, this appears to be a direct competitor of EU-OPENSREEN and an argument may be made that both are not needed. However, the IMI-funded project will be at a single site in the EU and will serve the pharmaceutical industry. This may well be an excellent idea but none of the data will be available to the scientific community at large. This is a problem for chemical biology in the EU. If the academic and industrial communities are to be integrated successfully, then the academic community needs to be enabled. Academic labs will be able to use the facility to drive forward “out of the box projects” and the results will be made publicly accessible for the whole community to use.

Utilization

This research infrastructure will be primarily beneficial to a broad academic community of life scientists. Many current biology labs have reservations about the use of high-throughput screening approaches for their science. If the process of running a screen is made easier or achievable in the first place, then, given the inherent drivers for interdisciplinary, team working, and link to

|³⁹ In infectious diseases, large companies have screened all of their in-house libraries (over one million compounds) and failed to find any progressable compound (Livermore, D. M.: Discovery research: the scientific challenge of finding new antibiotics, in: *Journal of Antimicrobial Chemotherapy*, 66 (2011) 9, pp. 1941-1944).

|⁴⁰ For further information on complementary projects, cf. Appendix 2.6.

health applications prevalent now, it could be expected that a lot more scientists will start to use this approach in academia. It is very important that as much of the data generated by EU-OPENSSCREEN is put into the public domain as quickly as possible – it is this deliverable that makes this research infrastructure different from the planned IMI facility. This is a very important part of this infrastructure and this section could be expanded upon in future plans. Industry will benefit from new lead compounds and the assay standardization.

The early phases of drug discovery that EU-OPENSSCREEN will support need to be highly regulated and professionally run to ensure the desired results. The outputs of its work will be the starting point for the next steps in the value creation process and that is where the current infrastructure will produce its greatest value. Overall, the proposed access procedure has a solid base and the quality management is a key strength of this proposal.

The proposed budget is appropriate. If the goal is to open up screening to the academic community at large, it is important that this research infrastructure is driven by scientific quality not totally by funds. Good administrative skills are required all-round, but the expertise required for utilization is already available. In-house training for screening will be essential.

Feasibility

EU-OPENSSCREEN is a very mature effort which shall integrate the German research infrastructure into the existing European infrastructure landscape. The German partners have gained a lot of experience in this area and will take on the leading role in EU-OPENSSCREEN on the European level. A clear timeline for the process is given. The proposed research infrastructure is focused on enhancing, standardising, and uniting the existing infrastructures to create an EU-wide screening facility. Thereby, it is achieving an adequate level of EU-wide integration that is critical for its success. There are many relatively minor technical innovations required to bring this project together, but this is a low risk project, with a high gain in research output. EU-OPENSSCREEN is more of an implementation and socialization exercise. Everything appears to be in place on a smaller scale so the step to the full infrastructure is relatively at low risk.

Also essential for the successful implementation is a transparent and quality-oriented procedure for the selection of those projects which could make use of this research infrastructure. Precisely the questions on how the assay development selection would work, and also how projects would be prioritised for the “chemical optimisation of hits” section, what would be involved and how this would be resourced need to be clarified. Furthermore, it has to be worked out, how the IP (Intellectual Property) would be managed effectively so as to ensure that as much data from the screens is in the public domain as fast as possible.

The scientists of the hosting institutions are very capable of leading this effort, and staffing is accordingly suitable for this investment. They have the necessary expertise to deliver on this project when combined with the other excellent facilities identified throughout Europe. The research groups involved have more than enough experience to create the required e-infrastructure. This is a real strength of this project. The EMBL-EBI is a world-class centre for data-base creation and maintenance.

The structure of governance seems to be appropriate. A strong scientific advisory board and an external review panel will be important.

Relevance to Germany as a location of science and research

An investment in a European chemical biology infrastructure is a clear need. With respect to international standing, it is very likely that European consortia will lose ground, especially following the Molecular Libraries Program (MLP) initiative in the US. EU-OPENSREEN will complement the MLP with new developments and possible breakthroughs and could position itself as a leading open screening facility in the world. It will allow Germany to internationally keep pace in the important area of chemical biology.

In addition, the idea of integrating Europe, in terms of the scientific large-scale facilities available is a good one and if Germany were to lead a successful bid in the area of screening – and drive it in the future – then this would be very positive for German science as a whole. The projects are too complex for any one discipline to make a major impact alone. Therefore, academics need to modify the way they perform their science. It is critical that the next generation of German academics are not left behind in the new model of academic research and that, too, is something that really ought to have been taken into account.

There is considerable uncertainty and change in the world-wide pharmaceutical industry. One way forward may be increased collaboration between industry (including small- and medium-sized enterprises) and academic institutions. If this does materialise, then research infrastructures such as EU-OPENSREEN may well be the reason as this infrastructure will facilitate academic research in the biosciences. Whilst it will not deliver the next drug, it may deliver the next validated drug target that can then be taken up by industry to deliver the next drug.

Overall evaluation

EU-OPENSREEN is crucial for the identification of novel molecules within the life and medical sciences and the understanding of their effects. The discovery and use of new chemical tools are an indispensable prerequisite for the under-

standing of biological processes including human diseases. It is the foundation of the next generation of drug discovery.

Screening is a very important tool in the life and medical sciences. By establishing this infrastructure, it is clear that many more screening projects will be completed in Germany and across the EU than would otherwise be the case – this will lead to the discovery of more useful chemical tools. Leading this research infrastructure is a real opportunity for Germany and the involved German centres are excellent.

It is important to note that the screening tools developed here can be used in a wide range of applications: in the life health sciences, but also in research on renewable energy, plant sciences, agriculture or veterinary sciences. Screening will be an important tool in all aspects of biotechnology. It should be considered if a focus is necessary for the sake of achieving the goals of the concept or if a strong argument can be made for keeping the breadths of applications.

The most compelling argument in terms of societal impact is that the discovery and use of novel chemical tools can pave the way for the understanding of biological processes including human diseases. The better understanding of biological processes will result in a clear definition and better validation of targets that will then translate into novel and effective medicines. This potentially provides added value to what can be done in an open, academic environment and what can be exploited by industry. In other words, this infrastructure will have a considerable impact on the health agenda, in particular very prevalent diseases with imminent medical needs. Very important applications in the areas of infectious diseases, neurological and psychiatric diseases, metabolic disorders, and cancer can be seen. These research areas have been abandoned by large pharmaceutical companies en masse. This emphasises the continued need for the synthesis and screening of new chemical entities as bacteria are not going away. The academic screening effort will now provide a step change by introducing novel exciting chemistry that has previously not been available.

III.3 European Research Infrastructure of Imaging Technologies in Biological and Medical Sciences (German Euro-Biolmaging – GEBI)

III.3.a Short description of German Euro-Biolmaging

Imaging has evolved into a central technology of the life sciences that links basic and preclinical research with medical applications and clinical trials. Recent breakthroughs in nanometre resolution opened up new perspectives for the visualization of physiological processes in real time and of the molecular basis of human diseases in cells and tissues. The application of these cutting-edge imaging technologies to address biological and medical questions will enable many discoveries with the aim to be the driving force for new generations of

even more advanced biomedical imaging technologies. The transfer of imaging techniques from cells to mice to humans offers novel possibilities for biomarker development, drug discovery and new molecular treatment concepts. A challenge will be to achieve high temporal resolution also for clinical imaging of diseases.

The German imaging infrastructure, GEBI for short, shall contribute to the corresponding European research infrastructure Euro-BioImaging, the infrastructure for imaging technologies in life sciences on the European roadmap ES-FRI. |⁴¹ Key objectives of GEBI are (1) to establish an openly accessible research infrastructure for biological and medical imaging technologies within Germany ranging from basic biological to molecular and medical imaging, (2) to establish strong imaging technology nodes to prepare Germany's contribution to Euro-BioImaging, and (3) to establish a strong coordinating hub in Germany that represents both medical and biological imaging and successfully integrates the national and European level of the research infrastructure. This shall be achieved by (1) major upgrades of the five leading advanced light microscopy facilities, by (2) establishing strong European open access technology nodes for the two biological imaging technologies where Germany plays a leading role worldwide, i.e. super-resolution microscopy and high-throughput microscopy, and by (3) providing open access at distributed research nodes to high-end molecular and medical imaging technologies.

Similar national imaging infrastructures are currently formed in many European member states, driven by the pan-European research infrastructure project Euro-BioImaging. Nodes that receive national funding in the framework of national infrastructures will be in a very competitive position to apply as European nodes. 50 % of the newly created capacity will be openly accessible to external users.

The European Molecular Biology Laboratory (EMBL), Heidelberg, will serve as the coordinating institution of GEBI and the medical and biological imaging communities are represented by their national coordinating persons through the Institute for Medical Technology (IMT, medical imaging), Mannheim (part of the University of Heidelberg and the University of Applied Sciences Mannheim), and the University of Konstanz (biological imaging).

The total investments for realisation of the infrastructure are estimated to EUR 188 million (investment costs about EUR 94 million and operating costs about EUR 94 million for five years).

|⁴¹ Cf. ES-FRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 58.

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.8.

III.3.b Evaluation of German Euro-Biolmaging

Summary

Scientific Potential. GEBI addresses an important need in the life sciences and is unique in Europe. The distributed research infrastructure for molecular imaging, including up-to-date technologies, is crucial for elucidating a broad range of processes of diseases such as cancer, heart disease, Alzheimer's, and diabetes.

Utilization. The infrastructure is a multi-purpose platform which opens up new scientific fields to the life sciences and is available for an enhanced user community of scientists, medical doctors, and industries. The access procedure is fair, transparent and quality-assured. The training programme is very convincing and has a high educational value.

Feasibility. The scientific and technical expertise of the involved institutions is excellent. The project can be immediately implemented. The governance structure with clearly delineated powers and responsibilities is convincing. The chosen hub-and-node-structure can become a model for these types of research infrastructures.

Relevance for Germany as a location of science and research. The project has exceptional potential and is of the highest relevance for Germany. It will further enhance Germany's world-leading position in optical technologies and biomedical imaging. The implementation of GEBI is of great urgency.

Scientific potential

Biomedical imaging technologies play an increasingly important role in biology and medicine. The non-invasive assessment of biological and medical samples, from the molecular level all the way up to the organ and systems level, has become an essential tool in studying a large range of biological processes and medical questions. Biologists have now turned to understanding not just the molecular structures and chemical reactions but also the functional context or the process in which the molecules act in synergies to execute biological or pathological functions. Germany has contributed in a leading way for some aspects of the visualization of the molecular basis of human diseases in cells and in tissues, still there is a major gap of clinical imaging of diseases in this scale. Even though the magnetic resonance imaging resolution has reached the scale of biological imaging, this is not achieved at high temporal resolution. There are many other bridging technologies at the mesoscale that have been more devel-

oped in the rest of the world. Many of these new technologies are very expensive and require an extremely high level of expertise. Therefore, it appears prudent to develop research infrastructures that provide wide ranging access to these technologies and methods.

The proposed German imaging infrastructure GEBI addresses an important need in the life and medical sciences. In addition, it can become the driving force for new generations of even more advanced biomedical imaging technologies. GEBI proposes to address the integration of biological information into medical solutions via imaging. It is an accepted grand societal challenge that poses to the whole world since the vast amount of biological information accumulated over the past few decades has unsatisfactory impact on healthcare practices and this is poised to change through understanding of biological and pathological functional processes via imaging. These processes are driven and governed by molecular interactions, cellular mechanisms, and organ and systems interactions. Modern imaging technologies allow monitoring all of these aspects from the nanometre scale up to the entire body. As such, the infrastructure has the potential to lead to novel diagnostic tools and treatment modalities that will influence a very wide range of medical problems. The distributed research infrastructure for molecular imaging is crucial for elucidating a broad range of processes of diseases such as cancer, heart diseases, Alzheimer's, and diabetes.

GEBI is unique in Europe. Complementary research infrastructures include the European imaging facility ALMF (Advanced Light Microscopy Facility), the Australian facility AMMRF (Australian Microscopy & Microanalysis Research Facility) as well as the two American facilities ICMICs (In vivo Cellular and Molecular Imaging Centers, NIH) and SAIRP (Small Animal Imaging Resource Programs, NIH). |⁴²

There already exist collaborations of German institutes with other facilities elsewhere; it is envisioned that such synergy will be strengthened between the involved institutions and others. There already exist infrastructures on a smaller scale, e.g. the German BioImaging network at the University of Konstanz. The proposed infrastructure will subsume all these centres and will provide a single point of entry for the end user from the life sciences.

Utilization

GEBI will increase the access to advanced imaging facilities to many scientists at institutions without large core facilities. Users are expected to come from all fields of the biological and medical sciences as well as from neighbouring disci-

|⁴² For further details, cf. Appendix 2.7.

plines, from all major German research institutions, from all levels of scientific career development, from international research institutes, and from industry.

The infrastructure is a multi-purpose platform which opens up new scientific fields to the life and medical sciences and is available for an enhanced user community of scientists, medical doctors, and industries. The participating institutions expect that more than 75 % of all life sciences research groups would apply imaging technologies regularly if they had sufficient access to instruments and expertise. With the information at hand, it is however impossible to assess if the calculated capacity is appropriate.

Leading companies in the field have expressed their strong interest to further extending existing collaborations with all applicants of the proposal and to support the proposal by providing equipment, supporting training activities, and developing selected nodes into technology test sites. An average use of about 10 % of the GEBI nodes by industrial users is expected.

The application of advanced medical imaging technologies to the laboratory or clinic may face some problems if the imaging technology is at specific national sites, since the strengths of imaging often relate to repeated and serial measurements in living (small) animals or humans. To address this issue the incorporation of additional partners into the network to increase the accessibility to molecular and medical imaging sites should be taken into consideration.

GEBI aims to train users as well as facility managers and technical staff and establish a coordinated forum to expand the use of the existing infrastructure or individual facilities from pure internal users to external users. This coordination will certainly help to synergize the training needs of each facility.

The access procedure is fair, transparent, and quality-assured based on scientific merits and technical feasibility of the projects to be conducted at the research infrastructure.

The research infrastructure will either provide imaging service or will train users to do the experiments themselves. Training of staff and users in the imaging technologies is a key component of the proposed research infrastructure. A plan for training which ensures adequate expertise to use the facilities is in place. In summary, the training programme is convincing and has a high educational value.

Feasibility

The individual centres that make up the hub and the nodes of this research infrastructure project are very mature. Most of them have worked in the area of biomedical imaging for years and have provided imaging services to local user

groups. The integration of all these groups into an umbrella organization is a novel idea and has not yet been implemented.

State-of-the-art imaging technology is already in place and no new technical innovations are required to realize this research infrastructure in Germany in the first place. The existing technologies are sufficient to drive novel research in the life sciences. An additional important aspect of the proposed infrastructure is to ensure that the novel technologies will be identified in a timely manner and that technology innovation takes place. The project highlights a strategy to link academia and industry for a new innovation cycle model.

Preliminary studies in the context of Euro-BioImaging to test the operational feasibility are sound and well supported. As the underlying imaging technologies have already been developed, used, and verified, preliminary studies for clarifying the technical feasibility or the technical implementation are not necessary.

Appropriate e-infrastructures for data compression, storage, transfer, and analysis have become critical issues for supporting imaging technologies in the life sciences. The required e-infrastructure including methods and tools of bioinformatics including locally required infrastructures at the nodes and centrally supplied computing and data repository services at the German hub-hosting institutions are integral parts of the infrastructure to optimally support future users for their data storage and analysis. These IT infrastructures are linked to ongoing efforts on the European level. For example, the German hub will collaborate closely with ELIXIR, the European life-science infrastructure for biological information, and profit from synergies. |⁴³ A strong integration of all of these e-resources and the inclusion of new cloud-computing technologies will be crucial for the success of GEBI.

The participating institutes that provide the biomedical imaging services and related support for external users are all well-established centres. Therefore, the relevant support structures for the instruments' operation exist – not only with respect to facilities but also with respect to administration and scientific expertise of staff. There is a substantial interest by the participating entities to become part of the German research infrastructure as expressed in their letters of support and the details provided throughout the proposal.

While the proposed project in itself is an infrastructure model, this infrastructure relies on the availability of state-of-the-art technology at the nodes, where

|⁴³ For further information on ELIXIR (European life-science infrastructure for biological information), cf. Appendix 2.7.

biomedical-imaging services will be provided. Indeed, the proposal requests large sums for facility and instrumentation upgrades. The question of sustainability after the initial round of funding needs to be addressed.

Given that the proposed research infrastructure involves a large group of independent universities and research centres, the success of this network relies heavily on an appropriate management structure and concept of governance. The right governance structure will ensure that the sum is truly larger than its parts (here the individual organizations that make up the hub and the nodes). Given the philosophy of this hybrid model, the mode of governance is very appropriate. It does involve the node heads and retain the operating autonomy of the hub through the executive committee.

The participating hub and node institutions are headed by leading scientists and engineers in their respective fields. The scientific and technical expertise of the involved institutions is excellent. The project can directly be implemented.

Relevance to Germany as a location of science and research

The proposal focuses on areas of strength within the German research environment: various optical (microscopic) techniques, high-field MR- and MR-PET-imaging (positron emission tomography) and translational nuclear medicine. A major investment in upgrading, expanding, and in making it available to researchers in life science and medical research from Germany and elsewhere will be critical for the competitiveness of Germany and “brain gain”. Strengthening imaging science in areas that Germany has a long tradition in and is already leading in the world will help to maintain and increase the visibility of Germany as a location of science and research. GEBI is well suited to become the conduit through which Germany maintains and increases its lead in biomedical optics and imaging technologies.

The infrastructure project serves as a tool to overcome the fragmentation of the existing infrastructure, which consists of single independent institutions that provide services in an uncoordinated way. There is currently no competing infrastructure in Germany but other countries in Europe have started to build such infrastructures with the goal to integrate them into the pan-European Euro-BioImaging structure. The proposed infrastructure will enable Germany to play a significant role in the pan-European and world-wide imaging efforts. By focusing on optical and MRI technologies, two areas of traditional strengths in German research, GEBI clearly sets realistic and appropriate goals. A realization of state-of-the-art imaging infrastructures in Europe cannot be realized without Germany’s input in these crucial areas. Lack of support will put Germany at a strategic disadvantage in Europe to maintain its leading position in development and application as well as commercialization of imaging technologies. In addition, it will result in a substantial “brain drain” of scientists to those coun-

tries that are already putting major new imaging infrastructure in place. If GEBI is not supported, there is a danger that Germany will lose its competitive edge in life sciences.

Training is one key contribution of the project in order to generate a new generation of academics in Germany, through high quality training programmes for staff and users. Access to cutting-edge imaging technologies will not only be granted for those interested in imaging but also in biological and medical research as well. The utilization of the facilities is also necessary for the training of students, who are involved in many imaging studies. This new generation of scientists and engineers will have a clear understanding of what are important questions in the life and health sciences. They will drive the technological advances.

Overall evaluation

Biological and medical imaging has a great tradition in Germany, and German universities and research institutes are internationally renowned for their expertise in these areas. This is particularly true for sub-disciplines of biomedical optics and imaging, where German researchers have made major scientific advances and are leading in science and technological innovations. These advances will enable studies of biological systems in a completely new and exciting way that undoubtedly will lead to new major discoveries; which, in turn, will lead to a better understanding of the molecular and cellular basis of many diseases.

This proposal builds upon the existing and unparalleled expertise of the participating academic centres of excellence. The proposal plays to the strengths of existing state-of-the-art biological and medical imaging platforms with the intention of sharing, training, and enhancing these resources as well as strategically developing new capabilities and increasing network activities.

GEBI is a multipurpose platform that caters to numerous biological and medical applications and services a broad range of users. The access procedure is transparent, fair and quality-assured.

This is a mature project and the proposers have already begun to work together in a cohesive and strategic manner. No new technical innovations are required to realize GEBI. The establishment of an appropriate e-infrastructure is a central challenge of the proposed infrastructure. The governance structure with clearly delineated powers and responsibilities is convincing. The chosen hub-and-node-structure can become a model for these types of research infrastructures. There is substantial commitment of the participating institutions as documented by letters of support.

The project has exceptional potential and is of highest relevance for Germany. It will further enhance Germany's leading position in optical technologies and bi-

omedical imaging. The implementation of GEBI as an important part of Euro-BioImaging is of great urgency for Germany. The infrastructure is expected to promote many new discoveries and the development of novel imaging technologies that directly impact important societal issues related to health care. In addition, it has significant potential to strengthen the health care industry and related technological industries such as bio-optics. This may entail significant economic benefits for Germany.

III.4 Integrated Structural Biology Infrastructure (INSTRUCT)

III.4.a Short description of INSTRUCT

A major future challenge in structural biology is to achieve a more integrative understanding of biological systems that goes beyond the level of atomic structures of molecules and organelles. The INSTRUCT project aims at bridging the gap between classical high-resolution structural biology methods, cell biology, and the emerging field of systems biology. |⁴⁴ INSTRUCT will optimize the utilization of Europe's best existing research infrastructures in the area of structural research in order to stay at the forefront of progress. Institutions of the most important European research facilities have joined to ensure access for the structural biology community in Europe to high-end equipment. This endeavour is considered a central element in integrating regional strengths into the overall European research potential.

Every INSTRUCT centre will guarantee external users at least 20 % of the total infrastructure capacity, and it is open to users from countries participating in INSTRUCT, upon payment of an annual fee amounting to EUR 50,000 for the first two years. Access to the infrastructure will be regulated via an application process. An online system for submission of research proposals has been installed, preliminary studies have been completed, and feasibility studies were carried out during INSTRUCT's three-year preparatory phase (2008-2011). A business plan and a finance concept have been installed, and since April 2011 INSTRUCT is in the so-called construction phase, which is followed by the operational phase. The German partners have jointly signed a "Memorandum of Understanding" for enabling participation in INSTRUCT from 2012 onwards, and the partners have agreed to pay the subscription fee covering the period up to March 2013, in order to ensure continuity of operation of INSTRUCT.

|⁴⁴ For further details concerning the European project INSTRUCT, cf. ESFRI: Strategy Report on Research Infrastructures. Roadmap 2010, Luxembourg 2011, p. 60.

Germany is strongly represented in INSTRUMENT, namely through three of the total seven core centres, and two associated centres. These core centres are the Max Planck Institute (MPI) of Biochemistry in Martinsried, the MPI of Biophysics in Frankfurt/Main, the Goethe University Frankfurt, the European Molecular Biology Laboratory (EMBL) in Heidelberg and in Hamburg, the Helmholtz Centre for Infection Research in Braunschweig, and the Leibniz Institute of Molecular Pharmacology in Berlin.

The estimated investment for realisation of the infrastructure is at approximately EUR 79 million (investment costs about EUR 37 million and operating costs about EUR 42 million for the years 2013-2017).

A detailed description of the project along the dimensions of evaluation is provided in Appendix 1.9.

III.4.b Evaluation of INSTRUMENT

Summary

Scientific Potential. INSTRUMENT pursues an advanced multi-dimensional approach to structural biology in Europe. INSTRUMENT will enable a new dimension of understanding in biology and medical sciences. For instance, it will provide a feasible basis for a new level of tailored drug design.

Utilization. INSTRUMENT will provide access to and optimise utilization of high-end infrastructures by life scientists. Affordable access to this research infrastructure needs to be guaranteed to a broad user community in Germany.

Feasibility. The participating institutions are world-leading in their field, and they contribute all the scientific and technical prerequisites necessary for a successful implementation of the project. The integration of the existing experience from the European level into the project and the incorporation of the individual activities under the joint roof of INSTRUMENT will be critical for success.

Relevance for Germany as a location of science and research. Structural biology is an area of science where Germany has traditionally contributed to setting the pace and is internationally at the forefront. National and international user facilities for structural biology, providing broad access, must be funded, as they are essential tools in the life sciences. Therefore, the proposed research infrastructure is timely.

Scientific potential

The central scientific question of structural biology is clearly defined in the INSTRUMENT project, namely to obtain three-dimensional structural information on

cellular processes in a multi-scale approach: ranging from atomic resolution (X-ray, NMR) to the molecular scale (electron microscopy) and up to the cellular level (light microscopy, electron tomography), preferentially even in a time-dependent manner. The main challenge will be to bridge the different size scales and to correlate the bits of information that have been obtained with the various methods, in particular if those methods have been applied at different scales in a cell or organism. The INSTRUMENT initiative aims at such a combination of state-of-the-art techniques and a link of different scales of analyses, through establishing an ideally suited (inter-)national infrastructure.

Results derived from studies at INSTRUMENT have the potential to significantly enhance our knowledge of essential components of the cell and organism, which provides a basis for causal understanding of human health and disease. The INSTRUMENT approach is highly specific, is based on excellent expertise within the field of structural biology, and is geared towards deciphering biologically important targets at various resolution. The methods used in this approach cover an enormous range of resolution. While this is needed to understand the analyzed processes and to place them in the context of higher order structures like the cell, it is not always clear how the different approaches will converge, both in technical and conceptual terms. It is recommended to include molecular dynamics for bridging the different size scales.

This INSTRUMENT research infrastructure is essential for structural biology and in a wider sense for virtually every aspect of life sciences, because identification and analyses of molecular structures is one important pre-requisite to understand molecular and cellular functions, to manipulate these processes in a rational way, and to derive strategies for controlled intervention during pathological alterations. Furthermore, the research infrastructure is essential for biochemistry – developments in the area of protein expression and cell-free biosynthesis will allow the analysis of targets that were not available so far. Drug development is an additional strong aspect: as soon as new structures through the use of this infrastructure are available, they can be targeted for structure based drug design approaches.

Structural biology has played an important role in Germany for many years. INSTRUMENT represents a convincing continuation of these structural biology efforts, though on a higher level and with increases in access by external users. The INSTRUMENT research infrastructure is not unique if each participating institution is analyzed individually. However, through the combination of the different centres with the different techniques, a unique level of synergy can be generated. In comparison to existing infrastructures, INSTRUMENT would help to eliminate bottlenecks in the access to instrumentation by researchers without their own equipment. To address future challenges, the pipeline from protein production to NMR/X-ray and to in-situ analysis within Germany should be

strengthened further. In an extended version of the proposal it is therefore essential to elaborate on strategies of convergence of the various approaches and distributed expertise in order to maximize synergies generated among the different participating institutions.

In Europe, there exist a handful of similar initiatives. Only two of them, the pan-European Bio Nuclear Magnetic Resonance (Bio-NMR) and the French *Centre de Résonance Magnétique Nucléaire À Très Hauts Champs* (CRMN) are really competing with the proposed INSTRUMENT research infrastructure, especially on the subject of NMR. |⁴⁵

Utilization

INSTRUMENT is beneficial by providing access to expensive state-of-the-art facilities. It will allow external users to carry out research projects that would otherwise not be possible, for instance due to the high cost of the instrumentation, and hence potentially trigger important advances in this field.

Structures of macromolecular complexes and membrane proteins are the most sought-after, high-impact targets of structural biology. Analysis of entire cells by cryo-tomography is just at the beginning, but has enormous potential. The community both from academia and industry is at a size that is more than adequate to make full use of INSTRUMENT.

Making these resources available to the large structural biology community (following the example of synchrotron beamlines) will be highly beneficial also to the infrastructure providers, in that the additional research input will largely contribute to their scientific profile. The research infrastructure will, again similar to existing synchrotron beamlines, take on a leading national role. However, this can be achieved only if access is straight-forward and cost-effective also for individual, smaller groups. Within the overall integrative concept, it is essential that access to the infrastructure is provided to a broad spectrum of users with complementary scientific topics.

The use of the research infrastructure seems overall feasible as proposed in the concept. However, some concern relates to the access procedure, which should be governed by an overriding principle within the infrastructure, generating timely and coordinated decisions. Special attention should be given to clear and transparent access procedures that should be handled in the shortest possible amount of time with constructive feedback to the potential users. The federally funded research infrastructure should be made accessible to the broad user

|⁴⁵ For further information, cf. Appendix 2.8.

community to 100 %, although the host institutions should be able to request time for its own projects equivalent to outside users.

Overall, the concept of governance seems adequate. However, the instruments should be set up and used as shared facilities. In fact, most users will need to rely heavily on their own small-scale instruments (NMR, microscopes, X-ray sources) to prepare and optimize the samples to be measured at the large-scale facility. Therefore, it is crucial to ensure appropriate funding also of the local groups and initiatives. For the same reason, it is evident that a large-scale infrastructure cannot substitute for or replace the need for local activities. In fact, central infrastructures and local activities are complementary and mutually reinforcing.

INSTRUCT will provide access to and optimise utilization of high-end infrastructures by life scientists. It cannot be expected that users will have the expertise to utilize the infrastructure without assistance. This is even more so, as the approach covers a range of techniques, each of which requires in-depth knowledge and experience of usage. Extensive training and supervision to operate the instruments will be necessary. In any case, feasibility and required expertise will have to be evaluated separately on a project-to-project basis for each instrument and infrastructure. It is therefore essential to provide personnel with the necessary expertise at the various institutions, and to establish training programmes on a regular basis. The centres have described appropriate plans to provide local expertise to meaningfully collect and analyse data. Synchrotron beamlines, again, may serve as examples on how to appropriately set up such shared facilities.

Overall, the role of this research infrastructure is twofold: (1) Training will be offered in addition to other courses that are already in place, thereby ensuring that new generations of scientists will enter the field of structural biology, and (2) equipment that is cost-intensive, both in terms of purchase and maintenance, will be accessible to smaller groups or junior research groups, allowing them to pursue projects that would otherwise be impossible. This requires that the infrastructure is open to a wide range of users and that courses are well organized. Research and training will be highly beneficial for the new generation of academics, who already have an excellent background in structural biology due to their exposure to numerous small-scale laboratories in Germany.

Feasibility

INSTRUCT is a rather mature endeavour. The hosting institutions have the best possible expertise to ensure research at the cutting edge. The visualization equipment will be installed at existing excellent centres with long-standing experience, and there are no major concerns about the realization. However, certain aspects of the proposal are in need of more detailed consideration, such as

the actual implementation of the “multi-scale” approach amongst the German participants and the training syllabus on a national level. If the premise is to provide an infrastructure for “seamless integration of techniques that provide information at different levels of resolution”, sample preparation and characterization should be an integrated part of this infrastructure project as well. A stronger effort to help researches to generate and test multi-protein complexes for structural characterization is desirable. It is a significant strength of the European INSTRUCT initiative that mass spectrometry facilities in Oxford and Utrecht are available to the users.

The operation of the platforms should be guaranteed by dedicated, experienced staff scientists. Personnel requirements will be very high due to training efforts and for the maintenance of the equipment. Each of the local host institutions requests an entire research group (three to six additional people), which is equivalent to a typical university chair with staff. If the service character of the facilities is to be emphasized, one would probably need fewer scientists but more designated (and highly trained) technical staff and engineers, plus one long-term scientific operator for each facility. Furthermore, the organization of such an integrated approach as well as processing of the applications and allocation of user time will be time intensive. Personnel should be hired to ensure that the large user community can use the facilities. Funding of adequate positions is thus mandatory for a successful and sustained operation of these infrastructures.

The requirements for e-infrastructures are very high. All projects will require handling of vast amounts of data. Furthermore, it should be noted that the centres are located at different places thus hindering easy interactions. Therefore, a robust and well-maintained electronic platform will be essential.

Teaching is certainly an important component of such an infrastructure and should be an integral part of such a proposal. Courses and teaching programmes will also have the added benefit of bringing together scientists from very different research areas and thus provide a platform for future collaboration.

Relevance to Germany as a location of science and research

Structural biology is traditionally very strong in Germany. For instance, approaches to decipher the structures of membrane proteins have been pioneered in Germany. The intended leading role of Germany in this research infrastructure is very appropriate and important to keep the nation at the forefront in this field of science. INSTRUCT pursues an advanced multi-dimensional approach to structural biology in Europe. However, with the exception of correlative microscopy it is not clear how this multi-dimensional approach will be achieved by the different German institutions under the joint roof of INSTRUCT.

It is essential to clarify more specifically what the contribution of each participating group will be, and how these contributions will be integrated in order to promote and pursue multi-level projects on molecular complexes and cellular processes of interest.

Altogether, this approach certainly has the potential to further strengthen the leading role of Germany in the field of structural biology. One of the distinct and obvious advantages of Germany as a location for science is the existence of excellent equipment and core funding in many of the internationally competitive centres, providing an appropriate infrastructural basis. Another plus is the availability of highly trained technical specialists to run and maintain sophisticated equipment. This edge should be maintained in the medium- and long-term run, and the INSTRUCT concept can clearly be part of such an effort. INSTRUCT should be fully integrated into other European infrastructure projects and it should be made clear that overlap is avoided. Especially in the USA there are efforts to set up similar structures.

Overall, the proposed infrastructure of INSTRUCT is unique in its attempt to combine different centres with complementary techniques. If INSTRUCT is successfully implemented, it could take on a world-leading role.

Overall evaluation

Structural biology is an area of science where Germany has traditionally contributed to setting the pace and is internationally at the forefront. The participating institutions are world-leading in their field, and they bring along all scientific and technical prerequisites necessary for a successful implementation of the project. It is also clear that the technical development in this field is rapid and requires large-scale infrastructural investments in order to maintain this leading role and integration into the EU infrastructural landscape. National and international user facilities for structural biology, providing broad access, must be funded, as they are essential tools in the life sciences. Therefore, the proposed research infrastructure is timely.

INSTRUCT pursues an advanced multi-dimensional approach to structural biology in Europe. Integration of the German structural biology community is both an essential and necessary step. Synergies between the individual methodologies and institutes can be generated through this multi-level infrastructure approach, which can be assumed to move the field of structural biology significantly ahead.

The integration of the existing experience from the European level into the project and the incorporation of the individual excellent centres under the joint roof of INSTRUCT will be critical for success. One prerequisite for sustained and

professional operation of the facilities and instruments is long-term staff, for which adequate funding should be guaranteed.

Furthermore, the overriding governance is not fully transparent. Specifically, the principles for coordinated access to the infrastructure, and the criteria allowing dynamic development of the integrative network (inclusion/exclusion of new/non-performing groups) requires further explanation. In order to facilitate greater accessibility and particularly to encourage also a broader range of research groups, a “hub-and-node-model” should be envisaged. The inclusion of additional partners should be considered, decisions at the European level should be in accordance with German national interests, and the underlying principles should be clarified.

Overall, INSTRUCT emphasizes the focus of infrastructural development on a few centres of excellence in Germany. While this is justified on scientific and technical grounds, it is essential that affordable access to this research infrastructure is guaranteed to a broad user community in Germany. The combination of bottom-up research activities and broad access to large-scale infrastructure will promise the continued and synergistic success of structural biology. This integrated approach offers new gateways to pursue research projects that would not be possible if such large-scale infrastructure networks were absent. This is particularly critical now, as there is a current development to integrate single molecule structures into their cellular and organismal context. This approach will enable a new dimension of understanding in biology and medical sciences, and thus provides a feasible basis for a new level of tailored drug design. Therefore, it is essential that this research infrastructure is adequately funded.

B.IV COMPARATIVE EVALUATION OF RESEARCH INFRASTRUCTURE PROPOSALS

Based on the individual evaluations, all projects underwent a comparative evaluation in the four dimensions. One requirement for being included in the comparison was that sufficient scientific potential had to be discernible. In the case of the Global Earth Monitoring and Validation System (GEMIS), the scientific approach was unconvincing, with the result that GEMIS was not included in the comparative evaluation.

To enable the projects to be compared on the most solid basis possible, a set of guidelines |⁴⁶ was prepared in advance, which asked the hosting institutions to answer questions about each of the dimensions with their different aspects, and in so doing to elaborate their concept from these four perspectives. The individual evaluations of the research infrastructure projects are also based on these four evaluation dimensions. But because it is particularly important to consider all aspects of these dimensions for the comparative evaluation, they are explained here again in more detail.

Scientific potential exists when a central question in the respective field of research or in the fields of research involved can be addressed using the research infrastructure. Entire fields of research can be opened up and completely new knowledge generated, or existing fields can be developed further. In evaluating the potential, consideration is also given to the consequences for the expected generation of knowledge, the assumed development of innovations, and the expected new partnerships, should the research infrastructure not receive funding. The scientific potential also includes the question as to the width of applications of a research infrastructure over the course of its life. Research infrastructures can be designed very specifically with regard to a research question. But it can also be possible to respond flexibly to unforeseen scientific developments, for example. By placing the research infrastructure proposal in the landscape of existing and planned competing and also complementary projects, it is possible to estimate the added value attached to the project and whether it will be unique in Germany, Europe, or the world.

The dimension of the **utilisation** of a research infrastructure comprises the size and internationality of the user group(s) and the level of interest, also from industry, in the new research infrastructure. Access, meaning questions of access criteria and the access procedure, as well as the structure of possible usage fees, also play a role. A crucial factor is that a transparent and quality-based access procedure should be developed. Moreover, the hosting institutions must ensure that users have or can acquire the necessary expertise to implement their projects with the aid of the research infrastructure.

The third dimension, **feasibility**, involves technical, institutional, and staffing requirements. Technical requirements include, for example, the maturity of the technologies being used, a feasibility analysis and risk assessment as part of preliminary studies, the availability of e-infrastructures for long-term data management, and the multi-dimensional evaluation of the measured data. Institu-

|⁴⁶ Cf. Wissenschaftsrat: Appendix to the Concept for a Science-driven Evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilot Phase) (Drs. 1766-11), Cologne December 2011, pp. 25 ff.

tional requirements include scientific and administrative expertise, as well as fundamental support from the hosting institutions. Also important here are governance structures, which are key to the successful operation of the infrastructure facility. As far as staffing is concerned, feasibility means strategies for recruiting technical and technical-scientific personnel and also for attracting new generations of researchers.

The fourth dimension, **relevance to Germany as a location of science and research**, looks beyond the scientific quality of the project and focuses on the interests of Germany as a location of science and research. The position that Germany occupies in European or international projects is considered, as well as the question whether and how the performance, attractiveness, and visibility of Germany as a location of science and research can be enhanced for renowned scientists, for young researchers, and for scientific-technical personnel. This dimension can only be evaluated from a national perspective.

In contrast, the socio-political significance of the project does not form part of the science-driven evaluation. Hence a good evaluation result in the science-driven evaluation process does not constitute sufficient grounds for a financing decision. This aspect plays a key role in the political sphere.

Not all aspects of a dimension are relevant for each of the research infrastructure proposals, since they are so diverse. For some projects, for example, interest on the part of industry can certainly be expected, but for others this is rather unlikely as they are purely knowledge-oriented.

Furthermore, certain aspects of a dimension should be weighted differently according to the area of science or field of research. In view of this, the differentiated evaluation of the respective dimension relies on the judgement of peers in order for it to be properly contextualised in the scientific area or research field.

A scale of one to five stars was used for the comparative evaluation, which can be expressed as sufficient, satisfactory, good, very good, and outstanding. The comparative, exclusively dimension-based evaluation yielded the results presented in Table 1.

Table 1: Results of the dimension-based comparative evaluation

Vorhaben	Scientific Potential	Utilisation	Feasibility	Relevance for Germany as a location of science and research
CTA	*****	***	****	*****
EMFL	***	**	*	***
IAGOS	****	****	*****	*****
FRAM	*****	****	****	*****
EPOS	***	****	***	****
EU-OPENSREEN	****	****	****	****
GEBI	****	*****	*****	*****
INSTRUCT	****	***	****	****

Lower scores generally mean that individual dimensions, such as e.g. the feasibility of the project, still require development at the present time. Thus, a project's standing could improve if more work was done on its governance structures, for example. Notes on this development potential can be found in the detailed individual evaluations. In addition to this aspect, they also contain recommendations intended to help improve the concepts.

There are two key methodological points to bear in mind for a proper understanding of the summary table. Firstly, in each dimension the ranking is ordinal, i.e. a project with four stars received a better evaluation than a project with three stars, although the magnitude of the difference is not quantifiable. Secondly, the evaluation is performed independently in each dimension. Hence it is not methodologically sound to rank projects based on total scores or an average of the dimensions which were evaluated separately. Instead, the differentiated view together with the assessment of the maturity and urgency of the project forms the basis for the political prioritisation.

C. Conclusion

In the following, the aim is to draw a conclusion based on the experiences from the successfully completed science-driven evaluation process. First of all, challenges are identified which emerged particularly during the science-driven evaluation process as being specific to large-scale research infrastructures. The goal here is to bring together the insights gained from the process beyond the individual assessments. The committee sees an urgent need for analysis and action in this regard.

Addressing these overarching issues is urgent for two reasons:

- _ The identified challenges directly influence the success of the individual research infrastructures. How they are dealt with impacts on the entire scientific system. For example, the question of how the use of research infrastructures with limited access is regulated is decisive for the realisation of the scientific potential associated with the research infrastructure, for its ties with the respective scientific communities, and also for the performance of the scientific system in Germany as a whole.
- _ At the level of the roadmap process, recommendations for addressing these challenges help to make the evaluation clearer for the reviewers and more transparent for the scientists responsible for the proposals. This results in quality assurance and hence improvement of the roadmap process in the future.

Therefore, the German Council of Science and Humanities reserves the right to address these topics in more detail in the future.

The most important challenges specific to research infrastructures relate to aspects such as financing (C.III), data management (C.IV), and governance (C.V). In view of the progressive Europeanisation and internationalisation of research infrastructures, these challenges must always be analysed in a context that goes beyond national and disciplinary boundaries.

Providing the background to this analysis is the fact that the field of research infrastructures has become more differentiated (cf. C.I). The full width of this field must therefore be considered. In addition, research infrastructures should

be considered across their entire life-cycle, since they go through different phases (cf. C.II). The roadmap process follows only one of these phases, namely the preparation phase through to the start of the implementation of a research infrastructure. To begin with, the widening of the field is examined in more detail below.

C.I TYPES OF RESEARCH INFRASTRUCTURES

As mentioned earlier, the roadmap process is based on a specific definition of research infrastructure. Accordingly, research infrastructures are large-scale instruments, resources or service facilities of national strategic importance, having a long lifespan, significant investment and/or operating costs, and quality-controlled access regulation (cf. A.I).

In current science policy debate, a wider definition is often used, which is due not least to the development of new types of research infrastructures. Whereas, at first, only large-scale facilities such as accelerators or research vessels were regarded as research infrastructure, today the term includes not only distributed research infrastructures but also, in particular, such things as collections, databases, e-infrastructures and social research infrastructures. The following typology illustrates the full spectrum of research infrastructures.

1 – Instruments – single-sited and distributed research infrastructures

These instruments include, first of all, “classic” large-scale facilities such as particle accelerators, telescopes and research vessels. They fit into the roadmap process provided an investment amount of EUR 15 million is exceeded and access is open. For a smaller investment amount, other funding instruments are usually available in the German scientific system. |⁴⁷

|⁴⁷ (1) Large-scale equipment with investment costs of more than EUR 200,000 (universities) or EUR 100,000 (universities of applied sciences) up to a maximum of EUR 5 million financed either by the *Land* (state major instrumentation programme (*Großgeräte der Länder* - LAGG) in accordance with art. 143c of the German Basic Law) or respectively half each by the *Land* and the DFG (scientific equipment as part of the major research instrumentation programme (FUGG) in accordance with art. 91b of the German Basic Law). The DFG is responsible for assessing the large-scale equipment. (2) In the case of funding large-scale equipment in the context of research buildings requiring an investment of less than EUR 5 million, the German federal government and the *Land* each provide half of the funding in accordance with art. 91b of the German Basic Law. The Council is responsible for the assessment. (3) Large-scale equipment with investment costs in excess of EUR 5 million is treated in the same way as research buildings and is initially assessed by the Council and the DFG. Generally this equipment does not exceed the threshold of EUR 15 million; however in isolated cases the investment costs may exceed the limit of EUR 15 million, such as in the case of a nuclear magnetic resonance centre. In the vast majority of cases, these are re-

In recent years, alongside classical large-scale facilities at a single site, research infrastructure concepts have been developed which involve a large number of instruments at different locations. These are known as distributed research infrastructures. Particularly in the biological and medical sciences, existing laboratories have joined forces to form a common research infrastructure within which research questions in a defined field are investigated. In addition, a standardised governance structure is developed and use of the infrastructure is centrally regulated. In this respect, distributed research infrastructures go beyond networks or partnerships.

2 – Resources – information infrastructures

Resources are those information infrastructure facilities which collect and maintain data, information, and knowledge relevant to research and teaching in a systematic way and make it accessible for scientific use. In particular, this includes scientific data collections and databases, but also archives, libraries, and object-based collections, whether these are natural objects as in herbaria or cultural objects such as books, films and audio recordings – including their digital copies.

Unlike research infrastructures consisting of large-scale facilities and distributed large-scale equipment pools, access to information infrastructures is usually not limited, which means there is no need to prioritise its use according to the quality of the scientific projects. Professional use is required nonetheless.

3 – Service facilities – IT infrastructures

Support in the form of centralised information technology infrastructures – e-infrastructures – is becoming increasingly important for research. These are high-performance and supercomputers, and high-performance communication networks, and computer grids, including the necessary storage systems, network connections, and software that are used for example in grid computing or in collecting and processing large data volumes (big data). Locally used personal computers or smaller, local data centres do not belong to this class for the simple reason that access to them is restricted.

Investments in high-performance and supercomputers in Germany are currently not decided within the roadmap process. High-performance computers are funded via a dedicated funding line as part of the programme for re-

search infrastructures which do not provide open access, with the result that they cannot be said to be of national importance.

search buildings (in accordance with art. 91b of the German Basic Law). |⁴⁸
There is a separate administrative agreement for supercomputers. |⁴⁹

4 – Social research infrastructures

The German Council of Science and Humanities has defined a social research infrastructure as being a type of research infrastructure which is relevant in particular, but not exclusively, to the humanities and social sciences. These are meeting centres and research centres which are created for the purpose of discussing or developing new research questions. |⁵⁰ Examples include Institutes for Advanced Study or the *Mathematisches Forschungsinstitut Oberwolfach*.

The distinctions between research infrastructures made here are of course idealised. In many cases, research infrastructures cannot be clearly assigned to one class or the other. For example, centres associated with large-scale equipment such as accelerators can function as social research infrastructures, and service facilities can be designed as distributed infrastructures. Nevertheless, the focus of the research infrastructure proposals can be assigned to one of the four characteristic types.

While the proposals in the roadmap process can primarily be assigned to the first type, i.e. instruments having a single-sited or distributed arrangement, on other occasions the Council has also dealt with information infrastructures and IT infrastructures. |⁵¹ The interfaces between the individual processes should be analysed more closely in the future and coordinated with each other. |⁵² With regard to the evaluation procedure within the roadmap process, it should also be examined whether the guidelines for producing and evaluating proposals should be differentiated with respect to the typology of research infrastructures described above.

|⁴⁸ Cf. Wissenschaftsrat: *Empfehlungen zur Einrichtung einer programmatisch-strukturellen Linie „Hochleistungsrechner“ im Rahmen der Förderung von Forschungsbauten an Hochschulen einschließlich Großgeräten nach Art. 91b Abs. 1 Nr. 3 GG* (Drs. 8619-08), Berlin 2008.

|⁴⁹ For more on this point, cf. Wissenschaftsrat: *Strategische Weiterentwicklung des Hoch- und Höchstleistungsrechnens in Deutschland. Positionspapier* (Drs. 1838-12), Berlin January 2012, pp. 14 ff.

|⁵⁰ Cf. Wissenschaftsrat: *Recommendations on Research Infrastructures in Humanities and Social Sciences* (Drs. 10465-11), Berlin January 2011, pp. 17-21.

|⁵¹ Cf. also Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012.

|⁵² For example, the Alliance of Science Organisations in Germany is currently developing a national hosting strategy. Requirements are examined for a suitable “safety net” ensuring the permanent accessibility of digital publications at scientific institutions via suitable infrastructure (cf. http://www.allianzinitiative.de/de/start/handlungsfelder/nationale_hosting_strategie/ of 4 March 2013).

Research infrastructures are characterised both by a long period of development until their implementation and by a long lifespan. The latter is usually at least ten years, and often longer. The roadmap process is focused on a key phase in the life-cycle of a research infrastructure, namely the preparation phase. This comprises the transition from an initial draft or outline of a research infrastructure project as “sketch” through to a more fully developed “concept” that in principle is ready for implementation. This section in the overall lifespan of a research infrastructure is preceded by the requirements development phase; the preparation phase is followed by the implementation and operation phase, through to the decommissioning of the research infrastructure. Each phase is briefly characterised below:

1 – Requirements development phase

Before a research infrastructure reaches concept maturity, a project first goes through a requirements development phase. This serves to identify needs within the scientific communities, discuss an initial idea for a research infrastructure, and develop it to the point that a sketch is produced in the sense of an early concept. The committee considers this phase to be extremely important. Development of such requirements may be driven from the bottom up, or it may be assisted from the top down – for example via a themed call for proposals. Discursive consultation in the participating communities may take different forms. Workshops and other events provide the opportunity to develop an idea further and compare alternative approaches. But this also includes strategy papers, white papers, thematic roadmaps etc., in which the scientific communities agree on research challenges – in some cases also considering the necessary research infrastructures – for the future of the corresponding scientific field.

Via these self-understanding processes, the basic idea for a research infrastructure is examined in respect of its scientific potential and its support in the communities – including in other countries. Only once there is a clear scientific profile and corresponding support in the relevant scientific communities, an idea for a research infrastructure does have enough substance to be developed into a sketch.

2 – Preparation phase

If the idea for a research infrastructure stands up in its communities and the need for a particular project has been established, the scientists involved can develop the idea further. This phase in the preparation of a research infrastructure is generally relatively long and can take several years. The result at the end is a detailed concept for a research infrastructure that can be implemented.

It has proven useful in the pilot phase for research infrastructure projects to go through the science-driven evaluation process both at the beginning of the preparation phase as a sketch at an early stage, and at the end of that phase as a mature concept, in order to be included in the roadmap. Inclusion in the national roadmap in Germany indicates a willingness in principle on the part of the BMBF to provide funding. This funding may be used for the further elaboration of a sketch through to a concept ready for implementation, or for the implementation of the research infrastructure.

If the project is at the beginning of the preparation phase and the initial aim is to finance preliminary studies, such a sketch should undergo a comparative assessment again. A well-founded political decision concerning the implementation of a project can only be taken on the basis of a developed concept, the results from any preliminary studies, and a further science-driven and economic evaluation.

Upgrades, if the costs exceed EUR 15 million, should also go through the roadmap process including the science-driven and economic assessment. In this case, it should also be considered whether a ground-breaking alternative has been developed in the meantime, with the result that the existing research infrastructure should be replaced with a new one.

3 – Implementation phase

The start of the implementation phase can be determined more or less exactly depending on the type of research infrastructure. With distributed research infrastructures, for example, this point in time cannot be clearly defined since existing large-scale equipment at individual sites is included and therefore research is carried out continuously. In other cases, the implementation of a single piece of large-scale equipment can be precisely defined from the moment the first shovel of earth is turned to its commissioning, and hence the implementation phase is clear-cut.

The roadmap process does not accompany the implementation phase. In other countries, as for example in the case of the Department of Energy (DOE) in the United States, this phase is also supported by an accompanying process, known as “Lehman Reviews”.^{|53} These aim at ensuring that the various different scientific, technical, organisational, financial, and scheduling requirements are brought into line over the entire implementation phase for the research infrastructure.

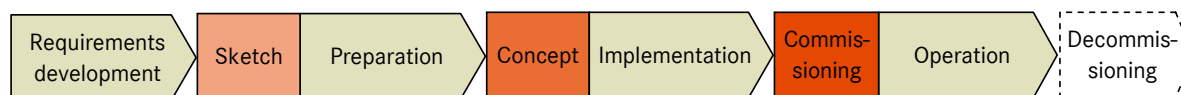
4 – Operation phase

Research infrastructures are generally monitored by scientific advisory boards or similar bodies during their years of operation. In Germany, however, they are not currently subject to systematic and regular higher-level external evaluations. In view of the importance of research infrastructures for the scientific system and their lasting high level of resource usage, it is worth considering whether to carry out regular evaluations to increase the quality and efficiency of research infrastructures and also to initiate a higher-level learning process – for example in respect of governance issues. Structural evaluations for specific subject areas could also help to identify gaps or a surplus relating to research infrastructures in particular fields of science.

Efforts are being made at the European level to develop indicators for evaluations and corresponding evaluation processes.^{|54} The first results are expected in 2013.

The following overview shows all the phases in the life of a research infrastructure (see Figure 3). The descriptions of the phases are idealised: in reality they cannot always be distinguished so clearly.

Figure 3: Phases in the life of a research infrastructure



International experience shows how important it is to monitor all phases in the life-cycle of a research infrastructure.

^{|53} Cf. http://science.energy.gov/~media/opa/pdf/processes-and-procedures/1201_Review_Process.pdf of 17 December 2012.

^{|54} In 2012, ESFRI set up an ad-hoc Expert Group on Indicators for the Evaluation of Research Infrastructures. This was based on and a response to the Evaluation Report 2011 published by ESFRI, which explains the need for such an evaluation (cf. http://ec.europa.eu/research/infrastructures/pdf/esfri_evaluation_report_2011.pdf of 17 December 2012).

Research infrastructures are financed in different ways in different phases of their lives. Moreover, financing is not organised in the same way for all types of research infrastructure or for all implemented research infrastructure projects. This is the case not only at the European or global level, but differences are also evident at the national level.

1 – Preparation costs

For many researchers, raising funds to finance the preparation of research infrastructures is a challenge that can be overcome in view of the comparatively low sums involved. Nevertheless, scientists at universities in particular are generally obliged to apply for external funding to enable them to develop a sketch to concept maturity.

Some costs for the preparation of research infrastructures can be covered by the European Union's research budget, while investment and operating costs generally cannot. |⁵⁵ The Seventh Framework Research Programme (2007-2013) provides a total of EUR 1.7 billion |⁵⁶ for research infrastructures as part of the Capacities programme. In addition to financing the preparation phase for new research infrastructures, this programme aims to support the optimisation of existing research infrastructures and the development of e-infrastructures. |⁵⁷ The preparation of most of the research infrastructure projects evaluated here was supported via the Seventh Framework Research Programme. |⁵⁸ The funding amounts vary between about EUR 3 million for IAGOS European Research Infrastructure and over EUR 5 million for Euro-BioImaging and for CTA Preparatory Phase. |⁵⁹ Even if the funding total is increased in the next framework programme (Horizon 2020) to around EUR 2.7 billion – including funding for e-infrastructure projects |⁶⁰ – this does not imply any fundamental change in the funding strat-

|⁵⁵ Some countries in Europe can also access European funding beyond the preparation phase. This funding generally comes from European structural funds, particularly the European Regional Development Fund (ERDF). This funding instrument of European regional policy is aimed at reducing development gaps between European regions or Member States, respectively.

|⁵⁶ Cf. BMBF: *Bundesbericht Forschung und Innovation 2012*, Bonn, Berlin 2012, pp. 355-356.

|⁵⁷ Cf. <http://www.forschungsrahmenprogramm.de/forschungsinfrastrukturen.htm> of 19 December 2012.

|⁵⁸ IAGOS already received funding of EUR 2.6 million in the Sixth Framework Programme.

|⁵⁹ European Commission, CORDIS (Community Research and Development Information Service), http://cordis.europa.eu/fp7/home_en.html of 19 July 2012.

|⁶⁰ Cf. European Commission: COM (2011) 811 final of 30 November 2011.

egy. Preparation for research infrastructures can also be funded at national level, e.g. via BMBF funding.

The real challenge, however, lies in financing the total investment costs on the one hand, and, on the other, in financing the operating costs incurred over the lifetime, which include maintenance and modernisation costs.

2 – Investment costs

Investment costs are currently covered primarily by the national actors. In Germany, expenditures by the federal and *Länder* governments on funding research infrastructures are not systematically recorded. This is also due in part to the development of new research infrastructure types and expansion of the term as described above (cf. C.I).

As far as the German portion of a European or international project is concerned, investment in research infrastructures is generally funded predominantly by the BMBF or other federal ministries. In some cases, the hosting institutions or the *Länder* take on a share of the investment costs.

With some projects, in the course of implementation, an enormous increase in investment costs compared to the original estimate can be observed. This development can be seen around the world and is not restricted either to Germany or to research infrastructures. This creates huge problems both for the German federal government as the main source of investment funding as well as for the *Länder* and hosting institutions. The committee therefore welcomes in principle the efforts by the BMBF aimed at achieving greater planning certainty by carrying out an economic assessment while the project is still in the preparation phase. Any such cost estimate – as is usual when planning large-scale industrial facilities, for instance – should be updated at defined intervals to increase its predictive accuracy as planning progresses. Supporting processes of this kind have been successfully developed in the international context.

With regard to different sources of financing which could play a role in implementation at national level either now or in the future, particularly for networked research infrastructures, it is necessary to clarify the interfaces and as far as possible coordinate the various forms and lines of funding. |⁶¹

|⁶¹ For example, the DFG set up a new funding line for “core facilities” in 2011. It aims at opening up existing facilities at universities and provides exemplary support for suitable centres or networks of national or international importance. Rather than equipment, it finances the development of a management system that meets the needs of science, and extensive user support. The funding volume of EUR 150,000 annually, initially for a period of three years, serves as start-up funding.

It is particularly important to coordinate the different funding measures with the investment plans of the major scientific organisations.

3 – Operating costs

The ongoing operating costs after implementation are also funded primarily at national level, but unlike operating costs incurred during the investment phase, they are not funded to any great extent by the BMBF. |⁶² They are covered by various sources. In many cases, however, operation is not fully funded, as can also be seen in some of the proposals considered here. This is due not only to an absolute increase in costs, but also to a change in the relationship between operating and investment costs. There are various reasons for this:

- *Different types of research infrastructures.* Whereas the rule of thumb for classical large-scale facilities (cf. centralised instruments in section C.I) is to calculate around 10 % of investment costs annually for operation, for most other types of research infrastructures this percentage is significantly higher. Among the proposals evaluated here, this applies not only but above all to the biomedical projects. As an example, let us compare the CTA telescope as a classical research infrastructure and INSTRUMENT, a distributed (biomedical) research infrastructure. For CTA, the annual operating costs are put at 8 to 11 % of investment costs, whereas for INSTRUMENT the stated figure is 23 %. |⁶³ In the case of distributed infrastructures, this stems partly from higher costs for consultation, coordination and management – tasks which also require suitably qualified personnel. With research infrastructures in the humanities and social sciences, and also social infrastructures, usually the operating costs are the most significant costs. |⁶⁴
- *Staff requirements.* In many cases, providing personnel for the use and operation of research infrastructures has become more difficult owing to their complexity. There is an increasing need for trained scientific-technical (service) personnel who can help external users to utilise the research infrastructure or carry out tests on their behalf. The provision of processed data or development of analysis software also requires trained staff. Insti-

|⁶² Operating costs can be financed indirectly with federal and *Länder* resources via the budgets of scientific organisations.

|⁶³ These figures are based on the submitted research infrastructure proposals and were not validated via the cost assessments.

|⁶⁴ Cf. Wissenschaftsrat: Recommendations on Research Infrastructures in Humanities and Social Sciences (Drs. 10465-11), Berlin January 2011, pp. 23 f.

tutions within the large scientific organisations are usually in a better position than universities when it comes to guaranteeing the necessary personnel resources and structures over a long period of time. This is due in part to the financing situation at universities. It is much more difficult for them to make long-term commitments because limited basic funding means they have to rely to a large extent on project funding, which is awarded on a competitive basis for a limited period of time. |⁶⁵

- _ *Modernisation and energy costs.* Energy costs are constantly rising, and because the performance requirements involved are generally at the outer limit of what is technologically feasible, it is not possible simply to compensate for these increased costs by using suitably energy-saving equipment. This cost factor makes a particular difference to energy-intensive research infrastructures, especially information technology research infrastructures and research infrastructures that need to develop appropriate capacities for data management. The costs of some materials such as copper, steel, and rare earths, which are used in replacement equipment, are subject to considerable fluctuations and therefore represent a factor that is difficult to calculate in view of the long lifespan. In addition, because of rapidly advancing technology, modernisation and improvement cycles are becoming shorter both for instruments and equipment and for data analysis tools. Nevertheless, the best possible estimate of the costs incurred, with realistic risk margins, should be used during the concept development stage, even if these figures may change during the lifetime of a research infrastructure.

Both the increase in investment costs and the structural changes in the operation of a research infrastructure affect the entire scientific system. In the selection of nine research infrastructure proposals presented here, eleven institutions of the HGF are involved as hosting institutions, six of them in a leading role. The MPG is represented by ten institutions, three of them in a leading role. In addition to three institutes in the Leibniz Association, one of them in a leading role, universities are cooperation partners in numerous cases (23). In three

|⁶⁵ The background to this is that the “*Anteil der Drittmittel an den Hochschulen [...] bis 2008 auf fast 20 % des Gesamtbudgets angewachsen [ist], während er 1995 noch bei 11 % lag. [...] Auf einen Euro Drittmittel entfielen im Jahr 1995 knapp zwei Euro Grundmittel für die Forschung, im Jahr 2008 nur noch 85 Cent.*” [The proportion of third-party funding at universities had grown to nearly 20 % of the total budget by 2008, whereas in 1995 it stood at just 11 %. For every euro of third-party funding, in 1995 there was almost two euros of basic funding for research; in 2008 this had fallen to just 85 cents.] (*Bericht des Vorsitzenden des Wissenschaftsrates zu aktuellen Tendenzen im Wissenschaftssystem (2011): Neuere Entwicklungen der Hochschulfinanzierung in Deutschland*, http://www.wissenschaftsrat.de/download/archiv/VS_Bericht_Juli_2011.pdf of 12 September 2012).

projects, a total of four universities have taken the lead in developing the research infrastructure proposals.

The costs for the utilisation of research infrastructures comprise the costs of the research project being conducted as well as a portion of the operating costs of the research infrastructure being used. In some cases, the research infrastructure hosting institutions cover the costs of use by external parties, or usage fees are charged which cover the operating costs on a pro-rata basis. In individual cases, the hosting organisations are also refinanced from other sources to cover part of the operating costs of a research infrastructure. Especially for investigations in physics, funding initiatives such as the collaborative research (*Verbundforschung*) funded by the BMBF support cooperative projects between research groups at national and international research centres and infrastructures. However, the funding programmes seem not to be sufficient. In individual cases, a critical financing situation has even resulted in successful university research groups having to abandon their plans.

Hence, the real challenge is to achieve sustained financing for the lifetime costs and for the utilisation of research infrastructures. In view of the complexity and lack of clarity regarding the financing situation, the committee sees a need for analysis here. Two aspects in particular should be considered:

- _ *Financing the entire lifetime.* When making a decision, it is important to consider the entire lifetime of a research infrastructure, which may also involve several equipment life-cycles. For example, in the environmental sciences, many research infrastructures only develop their full scientific potential if they can be operated over many decades and long-term data series can be recorded. This requires planning and consideration of replacement equipment purchases and possible reinvestments beyond the first ten years. With some research infrastructures, provisions should be made for considerable decommissioning costs – as is the case with research nuclear reactors, for example.
- _ *Path dependencies.* The expected long-term commitment of resources over multiple life-cycles results in path dependencies which should be considered systematically since they limit future decision-making freedom. This applies both to funding within individual areas of science and to the resources that are available in the system as a whole for research infrastructures, their operation, and their use.

C.IV DATA MANAGEMENT

Data aggregation and analysis form an integral part of research infrastructures. The associated data management systems have reached very different levels of advancement in the research fields. Various aspects are involved, such as

(1) data collection and archiving, (2) data access, and (3) data processing, as well as the necessary technical requirements. Individual research fields such as astrophysics and Earth system research serve as a role model in this regard, as in these fields concrete decision criteria for long-term data archiving already exist. |⁶⁶ The publication of research data in the form of independent publications is beginning to develop; the committee welcomes this trend. |⁶⁷ In many areas, however, the challenges associated with data management and its technical requirements are systematically underestimated. This was also seen during the evaluation process for the infrastructure proposals presented here. These challenges are therefore described briefly below.

1 – Data collection and archiving

For data collection and long-term archiving, researchers always have to manage the challenge of, on the one hand, justifying the need for data by concrete research questions, whereas on the other hand, trying to collect data as comprehensively as possible. Comprehensive collection and non-application specific archiving of all data promotes interdisciplinary research questions, which may still be largely undecided at the time of data collection, and allows trends to become visible through long-term data series. In addition, data is preserved for subsequent generations and their research questions, which cannot be foreseen today. Finding a solution to this conflict is the first major challenge; a concept has to be developed individually for each research infrastructure project.

It is necessary to implement and adhere to standards already at the time of data acquisition, pooling, and archiving in order to generate high-quality data sets and ensure their usability, comparability, and suitability for long-term archiving. |⁶⁸ This requires both the systematic recording and storage of all necessary meta data, and an appropriate software environment. The standards and conditions of data acquisition – for example the equipment and settings that were used when measurements were recorded and what error distribution can be expected in the data – should be entered in the

|⁶⁶ Cf. Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, p. 59.

|⁶⁷ Cf. *Ibid.*, pp. 39 and 54.

|⁶⁸ This is becoming particularly clear in the environmental sciences, where comprehensively calibrated data series covering long periods of time are practically a prerequisite for the success of the scientific discovery process, especially when all the recorded data is to be merged into a single database to enable the study of a system. Efforts are currently being made to do this for the system Earth, with a single global database being created. Cf. goals and strategies of GEOSS (Global Earth Observation System of Systems), see Appendix 2.3.

meta data and also archived. An important requirement here is that there should be a broad consensus concerning the data model. Later additions are almost impossible, and harmonising existing data is extremely time-consuming. |⁶⁹ Recording meta data is necessary but not sufficient for successful long-term archiving. In order to be able to read the data and interpret it correctly decades from now, suitable system software is required which must be compatible with the more advanced hardware in the future.

Therefore, in the course of developing a research infrastructure project, with regard to data collection and archiving, a higher-level concept should be developed which reflects the differing demands of specific research questions and non-specific data collection. This concept should also provide for systematic and as far as possible uniform recording of meta data in accordance with a standardised data model that is accepted by the scientific community, with explicitly defined semantics. |⁷⁰ Finally, it should also contain provisions relating to the suitable software environment.

2 – Data access

So that data, once collected, can be used as profitably as possible for the society, research data – at least from publicly funded projects – should be made widely accessible and usable. On this point there is widespread agreement between scientific communities, governments, funding organisations, and other organisations connected with research. Open access to research data (open data) is therefore increasingly becoming standard. |⁷¹

Despite all the advantages of open data access and the legitimate interest of the communities in it, |⁷² the preservation of intellectual property rights to

|⁶⁹ Cf. Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, pp. 53-58.

|⁷⁰ If these standards do not yet exist, efforts should be made by the entire community.

|⁷¹ Cf. e.g. OECD: *OECD Principles and Guidelines for Access to Research Data from Public Funding*, 2007, <http://www.oecd.org/science/scienceandtechnology-policy/38500813.pdf> of 29 August 2012; Swan, A.: *Policy Guidelines for the Development and Promotion of Open Access*, UNESCO 2012, <http://unesdoc.unesco.org/images/0021/002158/215863e.pdf> of 29 August 2012; Open Access working group in the Alliance of German Science Organisations: *Open Access. Positionen. Prozesse. Perspektiven*, October 2009, <http://www.allianzinitiative.de/fileadmin/openaccess.pdf> of 26 October 2012; Alliance of German Science Organisations: *Grundsätze zum Umgang mit Forschungsdaten* [Principles for the Handling of Research Data], June 2010, <http://www.allianzinitiative.de/de/handlungsfelder/forschungsdaten/grundsätze/> of 8 February 2012.

|⁷² The requirement for open data is often rigorously implemented in order to provide public access to a large portion of the collected data as quickly as possible. Scientists in the Human Genome Project set an example here when they agreed on the Bermuda Principles back in 1996. All the identified genetic sequences had to be made public within 24 hours in the database provided for this purpose, cf.

the data and above all the recognition of priority rights should be assured in a suitable way. Some solution approaches to this have been developed, as illustrated below:

- _ *Persistent identification of data sets.* The introduction of what are known as persistent identifiers both for data sets (keyword: digital object identifier, DOI) |⁷³ and for researchers |⁷⁴ can enable attribution to the author and at the same time ensure rapid use. Researchers gain in reputation by simply publishing data. This serves as an incentive for swift publication, but also for publishing truly complete and well-documented data sets, thus ensuring their subsequent usability. Without secure identification of the data and its attribution to the respective authors, if the data were published immediately without a certain embargo period, other research groups could evaluate the data more quickly and publish results first.
- _ *Contractual arrangements.* In the preparation of planned studies, an attempt should be made to address the requirement for an open data concept, while also preserving priority rights and intellectual property rights through appropriate contractual arrangements. This is particularly important in the biological and medical sciences, for example in the development of pharmacological target compounds, and in some cases this is already implemented.
- _ *Data for the further development of the research infrastructure.* For all research infrastructures, the question arises of how to deal with findings that are directly related to the research infrastructure, that is, to its further development, technical equipment, etc. Here the interests of the infrastructure should be put before those of its users, by ensuring that the rights to use such findings are retained by the infrastructure. |⁷⁵
- _ *Data protection.* The question of data protection predominantly but not exclusively concerns research infrastructures in the fields of biomedical and

<http://www.genome.gov/25520385> of 31 July 2012. This openness, which is often understood at the same time to mean that the data is largely free of charge, has other advantages too: it increases the legitimacy and visibility of the research, promotes interdisciplinary projects, and enables replicate analysis, which is valued both for the self-regulation of science and for educational purposes.

|⁷³ Cf. Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, p. 57.

|⁷⁴ Cf. for example the ORCID project, <http://about.orcid.org/> of 22 August 2012.

|⁷⁵ For example, the US Department of Energy (DOE) introduced a rule stating that scientists who are external users at national laboratories can exploit and publish scientific findings. However, the rights to findings that are relevant to the research infrastructure are retained by the research infrastructure itself. Cf. <http://techtransfer.energy.gov/docs/NonProprietaryUserAgreementClassWaiver.pdf> of 22 August 2012.

social science. The data in these cases is personal information relating to patients and test persons. In order to make this data available to another user group or to the public – in keeping with the open data concept – it must be anonymised, in some cases at considerable cost and time. |⁷⁶

It has become clear that the requirement for the implementation of open data strategies creates entirely new challenges for research infrastructures. The associated legal and ethical implications, along with the necessary security standards, should be included in the concept for a research infrastructure.

3 – Data processing

The use of research data generally includes developing and testing models based on the data and carrying out simulations. |⁷⁷ Simulations, for example, can be used with the aim of generating the most accurate possible projection of future climate changes, or of economic developments; they can also enable a more efficient design for costly experiments, or completely replace some such experiments. Model-based evaluation software for research data, which often entails a lot of programming work, is in some cases developed, maintained and made available by the hosting institutions themselves. Making such software and evaluation methods available, which can be essential to understanding the results produced at a research infrastructure, should be taken into account when research infrastructure concepts are developed. Personnel and technical resources need to be provided for this.

A key finding from the roadmap process is that the challenges of data processing are for the most part underestimated. This also applies to the associated essential technical and IT requirements such as computing, storage, and communication resources. Examples show that these information technology infrastructures are playing an increasingly important role in research and for research infrastructures. |⁷⁸ Added to this is the rapid development of these technologies, of model-assisted evaluation of research data,

|⁷⁶ Cf. Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, pp. 53-58.

|⁷⁷ Simulation sciences are regarded as one of several possible forms of research. Cf. Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, pp. 36 f.

|⁷⁸ Cf. for example the BioMedBridges project, which is intended to provide a shared e-infrastructure for ten biomedical projects on the ESFRI roadmap, <http://www.biomedbridges.eu/> of 31 October 2012.

and of the results that are obtained in this way, particularly in the context of simulations.

In future, therefore, in the planning and implementation of research infrastructure concepts, systematic consideration should be given to how and for what purpose data is to be processed, and what the IT requirements for this are.

C.V GOVERNANCE OF RESEARCH INFRASTRUCTURES

The governance of research infrastructures is a wide field that includes all kinds of rules and regulations which determine the organisational structure and decision-making competences in the planning, construction, operation, and use of a research infrastructure. For example, access procedures for series of experiments and observations must be defined. Governance further includes administrative structures such as the scientific advisory body, the governing body, and management across all phases of life. In addition, the legal form and mission of the research infrastructure and its integration into supra-national consortia can also be regarded as aspects of governance. |⁷⁹

One of the main points of criticism with nearly all the research infrastructure projects that were considered in the roadmap process is an insufficiently developed governance concept. Although good governance makes a decisive contribution to the (long-term) success of a project, it is often in the shadow of the research question. Even if initial general recommendations for governance structures are in place, |⁸⁰ it has become evident that there is need for further analysis on this point. Particular aspects of governance that were discussed during the evaluation process concern access to research infrastructures, their personnel structure, the significance of management, and recording the impact of a research infrastructure. Specifically these aspects are described in more detail below. They represent only one part of the governance of research infrastructures.

|⁷⁹ Cf. <http://www.ictresearchinfrastructures.eu/research-infrastructures/future-ict-research-infrastructures/#governance> of 7 August 2012.

|⁸⁰ The forum of the European Intergovernmental Research Organisations (EIROforum) examined governance aspects and produced a report in 2010, cf. http://www.eiroforum.org/downloads/201003_policy_paper.pdf of 7 August 2012. The OECD Global Science Forum (GSF) also published a report on this topic in 2010, cf. <http://www.oecd.org/sti/sci-tech/47027330.pdf> of 12 March 2013.

Access to a research infrastructure here means the opportunity to use a research infrastructure in three senses, namely in the sense of using the equipment available there (for example a magnetic resonance tomograph, in which a sample is to be measured), in the sense of submitting samples to be investigated, |⁸¹ and in the sense of modifying the equipment embedded in the research infrastructure (for example the integration of a new buoy into ocean observation systems). There is consensus that “(a)ccess to the research infrastructures should be controlled via scientific quality”. |⁸² However, numerous details are as yet unresolved, and are touched on briefly below:

- _ *Amount of external use.* The research infrastructure should in principle be open to the entire community. It is not possible to make a generalised recommendation as to what proportion of existing capacity should be available for external use. However, it is essential that sufficient amounts of usage time and usage opportunities are available to external parties.
- _ *Structuring of access.* A decision should be taken concerning the assignment of usage times and opportunities as part of a science-driven access procedure. Clear rules for this should be developed and written down in a set of rules for users. |⁸³ The specification of time contingents, i.e. reserved usage times, for the hosting institution, for users who make their own financial contributions, |⁸⁴ for financiers, or for industry must be structured appropriately so that open access is still guaranteed for all potential user groups, especially those from universities. |⁸⁵
- _ *External review committee.* Responsibility for the access procedure should be adopted by an independently operating external review committee. While both the composition of such a body and its exact function will vary greatly, it is nevertheless important that it should make transparent deci-

|⁸¹ This is necessary particularly when specially trained, experienced scientific-technical personnel are required in order to use the equipment of a research infrastructure.

|⁸² Wissenschaftsrat: Concept for a Science-driven Evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilot Phase) (Drs. 1766-11), Cologne December 2011, p. 8.

|⁸³ The DFG, for example, in its requirements for usage rules for core facilities, also only specifies rough guidelines, cf. http://www.dfg.de/download/pdf/foerderung/programme/wgi/nutzungsordnungen_geraetezentren.pdf of 31 July 2012.

|⁸⁴ This type of own financial participation is widespread for instruments in astronomy, for example.

|⁸⁵ Particularly in oceanography, bartering among research infrastructure operators for usage times has become established at the European level. Cf. Wissenschaftsrat: *Empfehlungen zur zukünftigen Entwicklung der deutschen marinen Forschungsflotte* (Drs. 10330-10), Lübeck November 2010, pp. 54-57.

sions according to the agreed rules and scientific quality independently of the institutional affiliation of potential users.

- _ *Collection of user charges.* The conflict between wanting to guarantee free access on the one hand and assuring the financing of operation on the other is recognised by the hosting organisations of research infrastructures, yet there is still no universally satisfactory solution. This is particularly significant for the inclusion of universities, small research groups, and groups from less developed countries as fees could deter them from using research infrastructures.
- _ *Training and advice services.* To open up access to research infrastructures that are well equipped to the latest technological and scientific methodological standards for a broad scientific community, it is absolutely essential to offer training and advice services. Again, smaller research groups at universities and in industry and researchers from less developed countries are particularly reliant on suitably specialised training offerings and methodological advice and support in order to carry out their scientific investigations, especially if they have been unable to gain much previous experience with research infrastructures.

2 – Personnel for research infrastructures

It takes highly qualified technical and scientific-technical personnel to run and maintain state-of-the-art research infrastructures.

- _ *Technical personnel.* The high quality of technical personnel at facilities in Germany is emphasised internationally. This high standard is due both to the very well developed and highly differentiated academic and dual vocational education system in all technical fields, and to the ability of non-university institutions to retain these personnel at their facilities in the long term. It is essential to keep the relevant personnel up to date and to enable their professional development and further training.
- _ *Scientific-technical personnel.* The scientific system in Germany offers uncertain career prospects for talented young researchers. Particularly for scientists coming from various scientific fields who decide to specialise in the interface between science and technology in the area of research infrastructures, the career paths are not always clearly marked out. In certain areas, for example for beamline scientists, there is an attractive job market. But in other areas, corresponding career options are lacking. Yet building up this expertise and retaining personnel in the long term are essential for the successful operation of a research infrastructure. Primarily but not only in the biological and medical sciences, so far there seems to be a lack of suitable career development prospects that would make this field attractive for top scientific staff in the long term. A personnel devel-

opment concept that takes the specific requirements of a large-scale research infrastructure into account, thereby ensuring a continuously high standard of service and operation, is therefore also important in the design and implementation of large-scale research infrastructures.

The challenges associated with the specific personnel requirements ultimately go beyond the design of the individual research infrastructure as they affect the entire scientific system. Nevertheless, with regard to their performance, it matters for the success of research infrastructures whether sufficient incentives and career prospects can be created for the various categories of personnel, especially for scientific-technical personnel. |⁸⁶

3 – Management of research infrastructures

A new job description is developing for research infrastructures – that of the infrastructure manager. These managers do not necessarily come from within the discipline itself, and they require special skills to coordinate complex projects. Particularly in European or international research infrastructures, and for the distributed infrastructure type, competent infrastructure management is absolutely necessary and critical to success. Proposals have been put forward for ways of professionalising training in infrastructure management. |⁸⁷ At the same time, it is an open question as to what role the manager's expertise relating to the technical focus of the research infrastructure plays, and to what extent management should be in the hands of expert scientists. |⁸⁸ The question of management goes well beyond the personnel issue. Here lies a challenge which is often underestimated and which can merely be mentioned at this point.

4 – Evaluation of research infrastructures – impact

Research infrastructures have an impact not only on the scientific communities but also on the environment in which they are located. The Science and Technology Facilities Council (STFC) in the United Kingdom conducted a case study on the impact of the Daresbury Synchrotron Radiation Source,

|⁸⁶ On this point, cf. also Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, pp. 69-72.

|⁸⁷ The Realising and Managing International Research Infrastructures (RAMIRI) project is dedicated to training in this profession, particularly in respect of governance issues. Cf. <http://www.ramiri.eu/> of 29 August 2012.

|⁸⁸ On this point, cf. also Wissenschaftsrat: *Empfehlungen zur Weiterentwicklung der wissenschaftlichen Informationsinfrastrukturen in Deutschland bis 2020* (Drs. 2359-12), Berlin July 2012, p. 68.

following its closure in 2008 after nearly 30 years of operation. |⁸⁹ It illustrates the extent to which unforeseen effects occurred, such as the establishment of spin-offs. However, such comprehensive, methodologically demanding studies are still rare, highly time-consuming and because of the long time horizon are of limited use in decision-making processes.

It is currently unclear how the challenges of anticipatory collection of data relevant to the impact can be addressed, or on what basis success or failure should be ascribed. Firstly, however, the amount of work for the researchers themselves and the research infrastructure hosting institutions should be kept to a minimum. Hence there have been efforts to measure the impact using data which is already available or which can be collected automatically, such as CVs, employment relationships, completed doctorates, etc. |⁹⁰ Secondly, each project should develop its own success indicators for itself. If the basic data relevant to these metrics of success is continuously collected once operation begins, the hosting institutions will also be able to prepare regular evaluations without great expense.

Another task of a research infrastructure is to communicate its results to a wider public with the aim of creating an impact on social developments and being able to perform advisory tasks in political decision-making processes. One example in the environmental sciences is the Intergovernmental Panel on Climate Change (IPCC), |⁹¹ an organisation of scientists which through its research and findings aims at contributing to an understanding of climate change and find the best possible way of addressing the challenges it poses. The involvement of science is also indispensable for the solution of other Grand Challenges such as the problems of an ageing society. Research infrastructures should therefore develop a concept for transferring their results into the political public sphere and to a wider public, and ensure that this transfer actually takes place.

|⁸⁹ STFC: New Light on Science – The Social and Economic Impact of the Daresbury Synchrotron Radiation Source, (1981-2008), <http://www.stfc.ac.uk/resources/PDF/SRSImpact.pdf> of 13 August 2012.

|⁹⁰ Cf. Lane, J.: STAR METRICS and the Science of Science Policy, in: Review of Political Research, 29 (2012) 3, pp. 431-438, and Lane, J.; Bertuzzi, S.: Measuring the Results of Science Investments, in: Science, 331 (2011) 6018, pp. 678-680.

|⁹¹ „The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts” (<http://www.ipcc.ch/organization/organization.shtml> of 3 June 2012).

The relevance of research infrastructures to the productivity of science and research is growing – from the **scientific** perspective since today all disciplines rely on the use of research infrastructures, from the **organisational** perspective because research infrastructures are becoming ever more complex, and from the **financial** perspective because of the ever-increasing use of resources. Seen against this background, a roadmap process based on a science-driven evaluation is aimed at minimising bad investments, optimising the use of resources from a scientific perspective with a view to supporting a highly effective scientific system, and establishing Germany’s position in the international arena.

Various scientific organisations in Germany have made attempts to systematically assess the need for research infrastructures. The Helmholtz Association published its first roadmap of research infrastructures in September 2011. |⁹² The Leibniz Association is also planning its own roadmap. |⁹³ At the European level, the ESFRI roadmap plays a central role. All research infrastructure projects from the pilot phase are already listed on the ESFRI or Helmholtz roadmap.

The roadmaps have the character of “wish lists” in so far as they do not lead to direct funding of the implementation of research infrastructures. The committee expressly welcomes the goal of the BMBF, with the process tested here, of going beyond the concept of a needs assessment that does not include any financial support commitment (“wish list”).

Germany is among the few countries in Europe which have not yet produced a roadmap. Outside Europe also, numerous countries including the United States, China, Japan, Australia and New Zealand have developed their own roadmap for research infrastructures – in each case with specific approaches.

By producing a national roadmap for research infrastructures, Germany will strengthen its position in the European and international context. A roadmap of this kind publicises for the first time Germany’s investment priorities in the years ahead. This could reinforce Germany’s role as one of the leading science countries.

|⁹² The Helmholtz-Roadmap provides a basis for negotiations with the funding agencies and is also aimed at the research infrastructure user communities as well as members of the Helmholtz Association for ongoing internal discussion. Cf. HGF: Helmholtz-Roadmap for Research Infrastructures. As of 2011, Bonn 2011, p. 5.

|⁹³ Cf. Leibniz Association: *Zukunft durch Forschung. Positionspapier der Leibniz-Gemeinschaft*, 2012, p. 14.

In addition, common challenges facing research infrastructures were identified during the evaluation process. Not all of the challenges referred to can be tackled at the same time. However, they urgently need to be addressed in view of the large number of research infrastructure projects with German involvement which are pending implementation. Many scientific communities can benefit from the recommendations, especially those which – unlike astrophysics, for example – cannot yet look back on a long history and wealth of experience in developing and operating research infrastructures.

Producing and publishing a roadmap for research infrastructures therefore contributes at different levels to enhancing the effectiveness of the German scientific system and improving Germany's position in the European and global context.

AISBL	<i>Association Internationale Sans But Lucratif</i>
ASPERA	ASTroParticle ERAnet
AWI	<i>Alfred Wegener Institut für Polar und Meeresforschung</i> The Alfred Wegener Institute for Polar and Marine Research
BMBF	<i>Bundesministerium für Bildung und Forschung</i> Federal Ministry of Education and Research
CARIBIC	Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container
CTA	Cherenkov Telescope Array
DESY	<i>Deutsches Elektronen-Synchrotron</i> German Electron Synchrotron
DFG	<i>Deutsche Forschungsgemeinschaft</i> German Research Foundation
ECBD	European Chemical Biology Database
ECBL	European Chemical Biology Library
EIROforum	European Intergovernmental Research Organizations – Members: <i>Organisation européenne pour la recherche nucléaire</i> (CERN), European Fusion Development Agreement – Joint European Torus (EFDA-JET), European Molecular Biology Laboratory (EMBL), European Space Agency (ESA), European Southern Observatory (ESO), European Synchrotron Radiation Facility (ESRF), European X-Ray Free-Electron Laser (European XFEL) and <i>Institut Laue-Langevin</i> (ILL).
ELIXIR	European life-science infrastructure for biological information
EMBL	European Molecular Biology Laboratory
EMBL-EBI	European Molecular Biology Laboratory – European Bioinformatics Institute
EMFL	European Magnetic Field Laboratory
EMSO	European Multidisciplinary Seafloor Observatory

112	EPOS	European Plate Observing System
	ERIC	European Research Infrastructure Consortium
	ESA	European Space Agency
	ESFRI	European Strategy Forum on Research Infrastructures
	ESKAPE	<i>Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species</i>
	ESO	European Southern Observatory
	EU	European Union
	EU-OPENSREEN	European Infrastructure of Open Screening Platforms for Chemical Biology
	Euro-BioImaging	European Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences
	FhG	<i>Fraunhofer-Gesellschaft e. V.</i>
	FMP	<i>Leibniz-Institut für Molekulare Pharmakologie</i>
	FRAM	Frontiers in Arctic Marine Monitoring
	FZJ	<i>Forschungszentrum Jülich</i>
	GEBI	German Euro-BioImaging
	GEMIS	Global Earth Monitoring and Validation System
	GEO	Group on Earth Observations
	GEOSS	Global Earth Observing System of Systems
	GFZ	<i>GeoForschungsZentrum Potsdam</i> German Research Centre for Geosciences
	GMES	Global Monitoring for Environment and Security
	GPS	Global Positioning System
	HALO	High Altitude and Long range research aircraft
	H.E.S.S.	High Energy Stereoscopic System
	HLD	<i>Hochfeld-Magnetlabor Dresden</i> Dresden High Magnetic Field Laboratory
	HGF	<i>Helmholtz-Gemeinschaft Deutscher Forschungszentren e. V.</i> Helmholtz Association

HZI	<i>Helmholtz-Zentrum für Infektionsforschung</i> Helmholtz Centre for Infection Research
IAGOS	In-service Aircraft for a Global Observing System
IAGOS-DS	In-service Aircraft for a Global Observing System – Design Study
IAGOS-ERI	In-service Aircraft for a Global Observing System – European Research Infrastructure
IFW	<i>Leibniz Institut für Festkörper- und Werkstoffforschung Dresden</i> Leibniz Institute for Solid State and Materials Research Dresden
IMI	Innovative Medicines Initiative
IMT	Institute for Medical Technology
INSTRUCT	Integrated Structural Biology Infrastructure
KDM	<i>Konsortium Deutsche Meeresforschung</i> German Marine Research Consortium
LED	Light emitting diode
MAGIC	Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes
MDC	Max Delbrück Center for Molecular Medicine
MERIL	Mapping of the European Research Infrastructure Landscape
MLP	Molecular Libraries Program
MOZAIC	Measurements of Ozone, water vapour, carbon monoxide and nitrogen oxides by in-service Airbus aircraft
MPG	<i>Max-Planck-Gesellschaft</i> Max Planck Society
MPI	Max Planck Institute
MR / MRI	Magnetic resonance / magnetic resonance imaging
MR-PET	Magnetic Resonance – Positron Emission Tomography
NHMFL	National High Magnetic Field Lab
NIH	National Institutes of Health
NMR	Nuclear magnetic resonance

OOS	Ocean Observing System
SIOS	Svalbard Integrated Arctic Earth Observing System
VDI/VDE-IT	<i>VDI/VDE Innovation und Technologie GmbH</i>
WGL	<i>Wissenschaftsgemeinschaft Wilhelm Gottfried Leibniz e. V.</i> Leibniz Association
WR	<i>Wissenschaftsrat</i> German Council of Science and Humanities

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This Appendix includes the detailed project descriptions of the nine research infrastructure projects. They were compiled on the basis of the submitted drafts and the English version was agreed upon with the responsible hosting institutions.

Appendix 1.1: Detailed project description of CTA

Scientific potential according to the proposal

High-energy gamma-ray astronomy studies the origin and interaction of the highest energetic photons in the universe. Cosmic high-energy gamma radiation is a highly energetic form of electromagnetic radiation that occurs for example in supernovae or black holes. The typical energy range spans from a few tens of gigaelectron volts (GeV) up to hundreds of teraelectron volts (TeV).

These gamma rays are absorbed in the Earth's atmosphere. When a gamma ray hits an atom in the air, the interaction creates a cascade of charged particles that themselves can interact with further atoms. The particles in the cascade are faster than the speed of light in the atmosphere and emit a cone of bluish light, so-called Cherenkov radiation. This process is analogue to the supersonic boom known from jets moving faster than the speed of sound. Observing such Cherenkov radiation with several telescopes allows for an exact reconstruction of the particle cascade and hence of the original gamma-ray photon energy and direction.

The gamma-ray observatory CTA features a sensitivity that is one order of magnitude better than existing instruments. The leading scientists stress that CTA will be the most important facility for high-energy astrophysics for a period of 10 to 20 years. The expected results will not only, as they state, increase the understanding of high-energy particles in the universe and their acceleration mechanisms. They will also address important questions of fundamental physics, e.g. the search for the particles of the dark matter, the nature of the fundamental interactions as well as a potential modification of the space-time structure by quantum gravity effects. Gamma-ray astronomy will play a central role in the study of high-energy phenomena.

Utilization according to the proposal

The CTA observatory will be used primarily by astronomers and physicists that work in the fields of high-energy astrophysics and astroparticle physics, and are currently active in the fields of X-ray astronomy, satellite- and ground-based gamma-ray astronomy. Moreover, the community of users will include the neighbouring fields of cosmology, plasma physics, physics of the fundamental

interactions, and theoretical astrophysics. In addition, scientists from the fields of atmospheric physics will also be interested in using CTA measurements.

The responsible scientists in Germany state that more than 860 scientists from over 120 institutes in 25 countries are currently active in the CTA project. This comprises a significant portion of the world-wide user community of more than 1,000 scientists active in high-energy gamma-ray astronomy. In addition to European countries, the US, Argentina, Brazil, South Africa, Namibia, India, and Japan are involved. It is stressed that for the first time, all research groups active in this field concentrate their efforts in one project.

Despite a predominant European composition of the participating teams, CTA is a global research infrastructure. As with other open observatories, access to the CTA arrays will primarily be based on scientifically founded observation proposals. The observation applications will be evaluated and approved by independent experts. Successful applicants will be given an exclusive right of access to the measurement results for a limited period of time. On expiry of the time limit, a larger community of users will be given access to the archived data for scientific analysis. While direct use, i.e. data analysis, of existing high-energy gamma-ray instruments is restricted to a relatively small group of experts, the simple and transparent analysis tools available for CTA will allow a much wider group of active users to work with CTA data, as the project scientists stress. The planned analysis tools are modelled on tools in X-ray astronomy and allow researchers from this field to “switch” with ease.

Scientific use will most likely be reserved to those research groups whose responsible ministries or sponsoring institutions finance the construction and operation of CTA. The exact terms of access and possible quotas will have to be decided in cooperation with the funding bodies.

Feasibility according to the proposal

Until now, this kind of gamma-ray astronomy has been conducted with instruments like the H.E.S.S. (Namibia) and the MAGIC telescopes (Canary Island La Palma) operated by mainly European groups as well as with the telescopes of VERITAS (Very Energetic Radiation Imaging Telescope Array System), a predominantly US-collaboration in Arizona. In 2006, representatives from the H.E.S.S. and MAGIC collaboration started to work on the conceptual design of CTA at various institutes. The CTA consortium was formed and performed a design study from 2008 to 2010. Since then, a three-year ESFRI preparatory-phase project for the Cherenkov Telescope Array has been started. Meanwhile the concept of the CTA telescope system demonstrated its capability through field-proven simulation calculations. Current work is focusing on the preparation of the efficient and cost-effective production of telescope components, the site selection as well as the governance concept for CTA.

The current preparatory phase will be followed by a five-year construction phase of the CTA arrays on the northern and southern hemisphere. Partial science operation can start two to three years after the start of construction. Full operation is planned to last a decade and after an appropriate upgrade, another ten years of operation are foreseen.

For the future, the current concept envisages an independent legal entity – the CTA Observatory – as institution responsible for the construction of the infrastructure, the activities at different sites, the scientific operation of the facilities, and the administration of the overall project. European experiences with the successful ESO-like governance and operation will serve as example. In April 2011, a CTA resource board was formed to prepare the legally binding commitments for the construction of CTA. In Germany, the Federal Ministry of Education and Research, the Helmholtz Association, and the Max Planck Society (MPG) participate in this board.

Relevance to Germany as a location of science and research according to the proposal

According to the institutions in charge, German teams are leading in the young field of gamma-ray astronomy at very high energies. CTA as a globally unique research infrastructure will enable astronomers, astroparticle physicists, particle physicists, and cosmologists from Germany, Europe, and the whole world to gain new scientific understanding of the universe.

In Germany, eleven institutions (DESY, MPG, and nine universities) are already participating in the CTA initiative and have formed a research consortium. The spokesperson of the CTA Consortium is scientific member of the Max Planck Society and a director of the MPI for Nuclear Physics. The international project office is set up at the Landessternwarte, University of Heidelberg. The institutions in charge assume that Germany's role in the construction and the use of the facility will primarily depend on the financial contribution of German institutions, the type of organisation of CTA, and the size of the German user community.

Appendix 1.2: Detailed project description of EMFL

Scientific potential according to the proposal

A magnetic field is an important external parameter in physics, such as temperature or pressure, for probing the state of matter. Consequently, magnetic fields serve as an experimental tool to gain deeper insight into matter in very diverse research areas. These are mainly physics, materials science, chemistry, and with increasing importance also life sciences and medicine. The leading project scientists claim that research in high magnetic fields has often resulted in path-breaking discoveries of fundamental importance. Some of these observations helped advance the current knowledge in materials sciences and have opened the doors for new technological applications and branches.

According to the project scientists, the scientific and economic performance of Germany strongly depends on the introduction of new and innovative products and production methods. These products and processes often require functional materials such as high-performance specialized semiconductors, battery-storage devices, thin-film and nanostructured materials, superconductors, or suitable alternatives for ferromagnetic rare-earth compounds. In some of these material design tasks high magnetic field experiments could play a pivotal role. Novel materials are characterized at the EMFL partner labs in order to access their fundamental properties as a foundation for tailoring them to specific magnetic or information-technology applications. In particular, electronic and magnetic properties are investigated in detail. The in-house research programme and the external use of the HLD aim at such investigations to promote the development of such materials. As well, the HLD is engaged in the development of methods and technological innovations in relation to high-power applications and high-field magnets.

The aim of this proposed part of the overall research infrastructure EMFL is to make fully superconducting static magnetic fields beyond 30 tesla available for users and in-house research. Providing magnetic fields beyond 30 tesla is aimed to be realized by developing a new generation of entirely superconducting coils. According to the project scientists, this scientifically and technologically very challenging goal has evident potential application consequences. The technology developed in the course of the project will not only be useable for novel high-field research magnets, but also e.g. for medical applications, including magnetic resonance imaging and ion-beam therapy. In the long term, it is highly desirable to replace, where applicable, the cost-intensive resistive magnets for static fields by superconducting ones. A later commercialization with interested companies is a realistic option.

Utilization according to the proposal

Currently, the HLD as a pulsed field facility is intensively frequented by external users. About 75 % of the measurement time is authorized to external user groups. Among these, approximately 65 % come from abroad. Similar numbers fit to the other EMFL partner laboratories. At present, the call and selection is administrated via the European project EuroMag-NET II. All user access to EMFL partner sites is coordinated by an international committee. This committee evaluates twice a year all proposals only according to their scientific quality. The demand for magnet time is so strong that the committee can only approve reduced magnet time in many cases. For this reason, the EMFL partners aspire to extend their lab sites. All in all, the current user database of the EMFL laboratories comprises more than 1,500 scientists around the globe. In most cases, the users are physicists and materials scientists (85 %), as well as chemists or engineers with a focus on novel functional materials. They come from universities and non-university research institutions. In particular, in the work areas of superconductivity, magnetism, and semiconductor physics, fields above 20 tesla are utilized. The HLD staff supports external users and discusses methodical questions as well as results.

The attention of potential new user groups is and will be attracted by their perspectives at the infrastructures through well-targeted measures (at conferences, by workshops, flyers, on websites, and press releases). According to the leading scientists, the possibilities offered by high-field research have already initiated a number of interdisciplinary collaborations and will continuously attract new user groups.

At present, there is no documented interest of companies to use the facilities. However, a few collaborations exist in joint technological developments. For example, the HLD has developed pulsed-power technology for electromagnetic metal forming, joining, and welding. The prospective research activity on developing a superconducting 30+ tesla magnet has found attention of companies and a commercialization of superconducting magnets beyond the current limit seems to be realistic.

Feasibility according to the proposal

In the years 2003-2006, the first part of the HLD was built. The responsible scientists stress that since then, it has reached a leading position as a pulsed field facility in the international arena of research institutions active in the field of solid-state physics. The laboratory is in the process of being extended to roughly double its size during 2011-2013 while its research programme remains undisturbed. The integration of the HLD into the structure of the EMFL is planned in an ESFRI preparatory-phase project (2011-2013) and is developed actively by the head of the HLD and the board of directors of the hosting institution.

The proposed research infrastructure part consists of the installation of two 30+ tesla magnet systems at the HLD within the next three years. The realization plan for these systems comprises besides the two magnet systems a helium liquefier, an annex building, the necessary infrastructure, and the experimental equipment.

This infrastructure should be able to operate for at least 20 years. Through continuous improvement of the magnet technology and measurement infrastructure, operation for a much longer period will be possible and is desired.

The HLD as well as its EMFL partners have governance structures according to their head organizations, which are the *Centre National de la Recherche Scientifique* in France, the Radboud University and the *Stichting voor Fundamenteel Onderzoek der Materie* in the Netherlands, and the Helmholtz Association in Germany. According to its affiliation with the *Helmholtz-Zentrum Dresden-Rossendorf*, the HLD has the organizational form of an institute.

A joint governance structure of the EMFL is at this point not existent. However, it is claimed to be currently under intense discussion. At the moment, the creation of a foundation according to Belgian law, an AISBL (*Association Internationale Sans But Lucratif*), residing in Belgium, is favored. The EMFL shall be governed by the board of directors, consisting of the directors of the three participating head organizations. One of the three directors shall be appointed president of this board for a fixed period (probably two years). The board will be supervised by a council consisting of representatives of the head organizations. The council will be the highest authority, deciding on all financial issues. It will appoint a scientific advisory committee. Further details still have to be discussed and agreed.

Relevance to Germany as a location of science and research according to the proposal

The German user community is large. The aim of the HLD, which is unique in Germany, and its ambition to provide the highest pulsed magnetic fields up to the current feasibility limit of about 100 tesla, makes this facility attractive and visible as is certified by its intensive international utilization.

The Dresden area is well suited for realizing the 30+ tesla magnet project. Research both on fundamental aspects as well as applied superconductivity is visible at high international level. Through the scientific concentration in the fields of materials sciences and solid-state physics, a corresponding high demand in research at the highest possible magnetic fields is claimed to exist.

Appendix 1.3: Detailed project description of IAGOS

Scientific potential according to the proposal

The project scientists state that IAGOS will provide long-term, frequent, regular, accurate, and spatially resolved in-situ observations of atmospheric composition in the upper troposphere and lower stratosphere, where information is very sparse compared to the surface. IAGOS combines two complementary approaches, IAGOS-CORE and IAGOS-CARIBIC. The CORE component comprises the implementation and operation of autonomous instruments installed on up to 20 long-range aircraft of international airlines for continuous measurements of important reactive gases and greenhouse gases (e.g. carbon dioxide, methane and water vapour), as well as aerosol and cloud particles. The fully automated instruments are designed for operation aboard the aircraft in unattended mode for several weeks and the data are transmitted automatically. The complementary CARIBIC component consists of the monthly deployment of a cargo container equipped with instrumentation for a larger suite of components. It includes instruments that cannot yet be implemented in full routine operation for measuring e.g. organic compounds or water vapour isotopes. The installation combines instrumentation for in-situ measurements, remote sensing, and collection of samples for post-flight analysis in the laboratory. This dual setup of IAGOS aims at providing global coverage of key observables on a day-to-day basis with a more complex set of observations with reduced coverage.

The assessment of climate change and the development of abatement or mitigation strategies are addressed by numerical models operating on various scales (from urban to global). Model products include validation of emissions of trace gases and particles, their impact on air quality and climate, as well as air quality forecasts, climate predictions or cost-benefit analyses of mitigation options. The quality of the model products and the accuracy of the predictions depend on the ability of the models to simulate the relevant atmospheric processes. In order to reduce uncertainties, the models require input from measurements. The German scientists state that routine aircraft observations represent the only way to collect detailed and representative information in the altitude range where the natural and anthropogenic greenhouse effect is largely generated and where the dynamical complexity and physical limitations (e.g. for satellite or remote-sensing instruments) hamper representative monitoring by any other platform existing today. Passenger aircraft are also regarded as the only means for collecting in-situ measurements of vertical profiles of many trace gases and aerosol throughout the troposphere in a representative manner. As in numerical weather forecasting, these profiles are essential for the validation of numerical models and satellite data products. Real-time transmission of IAGOS multi-component data sets will enable weather services and airlines to exploit the da-

ta for improved (chemical) weather forecast and potentially for enhanced crisis management during volcanic eruptions.

Using research aircraft – instead of commercial airlines - is no alternative because of much higher operational costs, which limits the usage of research aircraft to short campaigns of typically a few weeks with specific objectives. Furthermore, only around ten of the existing world-wide fleet of research aircraft are capable of reaching the tropopause. Clearly, the IAGOS approach of using commercial aircraft is the only one suited for obtaining continuous, long-term, and almost global measurements in the tropopause region.

Utilization according to the proposal

The IAGOS infrastructure will generally be used by scientists engaged in atmospheric and climate research. There are more than 100 research groups involved in the analysis and scientific exploitation of data from MOZAIC and CARIBIC, which are precursory projects. This group of direct users comprises about 500 persons world-wide. Furthermore, interest in participation in the new research infrastructure also exists in terms of proposals for new technical developments and by researchers in the USA and Taiwan to fully join the operation of IAGOS. There is also a strong interest of the aviation sector from airlines who agreed to provide free transportation of the equipment. Reasons are their intention to contribute to a better understanding of climate change with particular emphasis on the impact of aviation and the scientific basis for emission trading.

IAGOS is planned to be an open infrastructure in two aspects. The data measured onboard the aircraft will be transferred to a central data base and interested users can access the data base free of charge after having signed a data protocol. Access to real-time data will also be free of charge and is foreseen to be achieved in the framework of Global Monitoring for Environment and Security (GMES) via the European meteorological network. The access will be regulated by contracts with the European Environment Agency which is designated to handle the provision of in-situ data for GMES. The provision of the more complex and not fully automated CARIBIC measurement data from air samples that have to be analyzed in laboratories might take a few months. Concerning experimental participation or partnership, the IAGOS General Assembly will decide on the approval of proposals for new instrument developments and on the admission of new partners to the consortium. Assessments made by the scientific advisory board in advance will be used as a basis for decisions.

Feasibility according to the proposal

According to the leading scientists, the research infrastructure builds on 15 years of experience in the projects MOZAIC and CARIBIC. Besides, extensive preparatory work was conducted since 2005 in two three-year European pro-

jects, IAGOS-DS and IAGOS-ERI. The main objectives of the ESFRI project IAGOS-ERI were the completion of the certification of the scientific instrumentation and of the scientific data base. Furthermore, the legal and organizational preconditions for the new research infrastructure were prepared, the needs for funding investigated and the legal preconditions for installation, operation and maintenance of the new instrumentation aboard passenger aircraft in compliance with aeronautic regulations were established. Therefore, IAGOS is ready for implementation with the end of the preparatory phase.

It is planned to complete the installation of 20 aircraft within the first six years. Operation of the 3 remaining MOZAIC aircraft is foreseen to be continued during this phase as part of IAGOS as long as the aircraft are maintained in service by Lufthansa and Air Namibia. Operation of the CARIBIC container is also ongoing. Within the next five years, some of the older instruments are planned to be replaced by more powerful devices. A changeover of the installation to a newer aircraft is planned for 2016/2017. It is foreseen to operate and further develop the new research infrastructure over at least 20 years with regular scientific reviews and with adaptation to new scientific issues and technological developments. IAGOS-CORE equipment will be operated during ca. 500 flights per aircraft and year and deployment of the CARIBIC container is foreseen for ca. 50 flights per year.

IAGOS has considered the requirements for an e-infrastructure from the beginning. Two data portals are in preparation under the lead of French partners and the World Meteorological Organization. This includes the implementation of a specific data portal for scientific users and the use of the existing e-infrastructure of the meteorological services for real-time data. The adaptation of these existing structures has a large advantage for the users, as they can utilize their usual data pathways.

It was agreed between the IAGOS-ERI partners to initially manage IAGOS as an international not for profit association under Belgian law (AISBL) and to investigate the option for founding a European Research Infrastructure Consortium (ERIC) after the initial construction phase. The project office will be located at the Forschungszentrum Jülich. Draft statutes are currently being circulated among the partners.

Relevance to Germany as a location of science and research according to the proposal

The new research infrastructure will join the activities of major German research institutions, namely from the Helmholtz Association, Max Planck Society, Leibniz Association, and Universities, engaged in the field of atmospheric research. According to the leading scientists, the funding of IAGOS is essential to secure the German and European capacities for high quality in-situ observations of atmospheric composition.

128 Germany has assumed the leading role within IAGOS already during the preparatory phase project. German institutes have developed the majority of the novel measurement systems for IAGOS. The German project coordinators expect that with a majority of German institutes involved in the research infrastructure, the funding of IAGOS will ensure the leading role of Germany in this scientifically important area and will increase both the visibility in the global atmospheric community and the attractiveness of Germany for young researchers and students from other countries.

Appendix 1.4: Detailed project description of Cabled OOS FRAM

Scientific potential according to the proposal

This proposed infrastructure represents a novel approach to ocean observation in polar regions, as the project scientists state. It is expected to support a multitude of innovations in the fields of international marine and polar science, in development and operation of maritime technology, as well as in e-infrastructures for Earth observation. Furthermore, according to the institutions in charge, it represents the only technological solution for long-term, year-round ocean observations. It can overcome the obstacles of monitoring polar change – namely access to continuous, multi-disciplinary, synchronous observations of ice-covered oceans, with provision of near real-time data in open-access mode and with bidirectional data communication. Therefore, consequences and feedback mechanisms of rapid climate, ocean and ecosystem change at the gateway between the Atlantic and Arctic Ocean could be investigated by this observatory.

Combining fixed point and mobile instrument platforms, the planned infrastructure complements expedition-based and remote sensing data by persistent measurements from the ocean surface to the deep sea including year-round ice-covered regions. The change and interdependencies of physical, chemical, biological and geological features can be investigated. Among the main scientific cases to which the FRAM cabled OOS is supposed to allow a new access are:

- _ Freshening of the Arctic Ocean outflow and its influence on the global overturning circulation,
- _ Volume, heat, and salt exchanges between the North Atlantic and the Arctic,
- _ Carbon cycling, export and sequestration in the ocean,
- _ Mesoscale water mass and particle transport for the full depth range of the water column,
- _ Annual and interannual variations in biodiversity and function of plankton and benthos,
- _ Geological dynamics of the region, including interaction with gas hydrate deposits,
- _ Pollution by increasing ship traffic and other types of human impact.

The implementation and long-term operation of the FRAM cabled OOS is supposed to be a contribution to integrative observation of the Earth system. It should objectively determine natural dynamics, as well as the effects of global change on different spatial and temporal scales. The planned integrated network of all cabled observatories will play an important role in ocean observation for the next 25 to 50 years. According to the leading institutions, the FRAM cabled OOS would be unique in addressing the ecosystem change in the Arctic

region by continuous multi-disciplinary observation and would thereby contribute to a number of scientific programmes, including FONA (BMBF) |⁹⁴, EMSO and SIOS (EU) as well as international programmes of the Arctic Council. Furthermore, the success of the international initiative Group on Earth Observations (GEO) depends on the implementation and support of such national observation infrastructures in hot spot areas of change.

Utilization according to the proposal

For the entire field of marine and polar research in Germany, in total approximately 2,200 scientists are represented by the German Marine Research Consortium (KDM), including 15 institutions and universities in the field of marine, coastal and polar sciences. Their research is embedded in national, European and international scientific networks, many of which could profit directly (via cruise participation) or indirectly (e-infrastructure) from the proposed observation system, as evidenced by several brochures and white papers for the future of Arctic monitoring and Earth observation.

From the national and international polar and marine scientific communities two types of user groups will engage in the cabled observatory. The direct users of the infrastructure will add instruments to the cabled observatory network and/or will be carrying out contextual sampling and measurements in the network area for comprehensive studies. As specific users for the proposed infrastructure, the following groups are expected: Scientists working in operational oceanography, climate monitoring and modelling, marine environmental monitoring and modelling, satellite remote sensing, underwater technology and deep-sea exploration, gas hydrate stability and geohazards, education and outreach, and Arctic fisheries. Thus, the potential user community would exceed that of previous shipborne campaigns by far. Indirect users can register through the FRAM web portal and profit from data provision through the e-infrastructure component of the cabled observatory for scientific analyses, modelling, or for training, teaching, and public outreach purposes.

According to the draft, the integrated and generally open-access mode of operation would be based on the existing planning of large scale ocean and Earth observatory infrastructures carried out within European and international projects, and would be state of the art for Earth system observation. This mode involves the creation of a virtual, interlinked research environment, from desktop interaction with sensing capacities, to the provision of data streams, assimi-

|⁹⁴ FONA stands for "Forschung für nachhaltige Entwicklungen" (Research for Sustainable Development) and is the Framework Programme of the Federal Ministry of Education and Research (BMBF).

lation, synthesis and visualization tools, and connected sample and product archives. It will be designed according to the principles of the Global Earth Observation System of Systems (GEOSS) promoting common standards and a networked e-infrastructure so that data from thousands of different instruments can be combined into coherent multi-disciplinary data sets. The main partners of FRAM OOS in Germany are involved in the European ESFRI projects European Multidisciplinary Seafloor Observatory (EMSO) and The Svalbard Integrated Arctic Earth Observing System (SIOS) where the basic foundation of such common standards and interoperability were laid.

Feasibility according to the proposal

The proposed infrastructure builds on existing time-series observatories operated since 1997 by AWI and its national and international partners. In 2011, a proposal to establish an integrated autonomous OOS was submitted to the Helmholtz strategic infrastructure programme (“FRAM Autonomous Ocean Observing System”). Its main purpose is to integrate and upgrade the already existing sensor and instrument networks for next-generation ocean observation in physical and biological oceanography. Since 2006 KDM plans a larger, multi-disciplinary ocean observing system including solutions for instruments and platforms requiring a continuous supply with energy and data transfer in the framework of the EU project EMSO. This resulted in an initiative towards the installation of a cabled OOS FRAM as a new sustained infrastructure for polar and marine research, in consultation with Norwegian partners of related projects. It would provide the link from shore to the deep sea and from West Svalbard to East Greenland. It would utilize and integrate existing and novel sensor systems and instrument platforms, provide sufficient energy even for demanding sampling systems, transmit large data streams and allow interactive control of the system. First types of submarine cable systems were established in the past five years in the US, Canada, Japan and Taiwan. The Cabled OOS FRAM will represent the only cabled observatory in an open ocean ice-covered region of the Earth.

For the specific planning of the proposed FRAM cabled OOS, the following four phases are proposed by the leading scientists. The first phase of three years duration includes a feasibility study providing the thorough assessment of scientific requirements, environmental impact assessment, long-term viability, costs, and logistical frameworks as well as funding opportunities, and ends by internal and external evaluations of the detailed plans for realization. Depending on the outcome, a four-year long phase covers the development and the implementation of the shallow and deep-water nodes and instruments. After seven years, the FRAM cabled OOS will be fully operational and should provide data and research opportunities to national and international users for 10-20 years lifetime typical for cabled ocean infrastructure.

The FRAM cabled OOS is led by the observatory steering committee as the highest decision-making body; it is made up of representatives of the KDM including the director of the AWI. There will be a coordination office hosted at AWI preparing the annual budget and science reports, and facilitating the work of the managing director and the governing bodies. An international scientific advisory board and a technical advisory board will include international experts and advise the steering committee.

Relevance to Germany as a location of science and research according to the proposal

The leading project scientists stress that the proposal answers to numerous strategic plans of the national and international marine and polar science communities, in full agreement with national and European research priorities. They state that it will have a high scientific, strategic and societal impact in ocean sciences, enabling Germany to meet current political and ecological key challenges of national and international importance, including climate change, environmental monitoring, sustainable marine resource management and geo-hazard warning. It is also supposed to set impulses for maritime technology development and as such will have economical relevance for German industry. In the longer run, it could contribute to the sustainable management of marine resources, however, fundamental research is the main driver of the project. Marine and polar research in Germany is described as internationally highly recognized, especially with regard to its strength in open ocean research and polar science.

The KDM was involved in the development of the draft of the cabled observatory and will continue to define the joint research interests across all of Germany's marine research institutions. Numerous letters of support by the international marine science communities are available, as well as letters of interest from the German maritime technology community. According to the scientists, the proposed cabled observatory is a consequent advancement of the already existing strength into a new era of ocean observation. Seamless integration of the research data into the international Earth observation network GEO is planned for the cabled observatory and will attract even wider interest from other fields of science and public outreach.

Appendix 1.5: Detailed project description of EPOS

Scientific potential according to the proposal

The study of the system Earth requires the linking of a large number of diverse instruments and the integration of the obtained data. The various components that make up the research infrastructure EPOS are:

- _ The instrument systems component, which includes a number of different sensor systems, multi-scale three-component three-dimension arrays, mobile seismic arrays, ocean-bottom seismometers, geodesy and GPS, and magnetic field measurement stations.
- _ The modelling and simulation component, which uses complex software to evaluate, visualise and further process the data.
- _ The integration portal, which provides access to data from each of the sensor systems via a defined interface, supplies high-quality products (also in real time) derived from standardised data analysis techniques, and administers the metadata of the infrastructure.

The project scientists expect that the complete and systematic accumulation of observation and monitoring data from each of the geoscience disciplines in the European framework will open up new technological prospects for the development of methods, instruments, innovative observation and monitoring strategies, and model-based data analysis and interpretation. Bringing together the various geoscience communities for the purpose of cooperation will generate new fields of research, modelling approaches and applications. Another important point is that the research infrastructure is foreseen to have the ability to record homogenous data series of consistent quality around the globe.

The planned integrated, coordinated, and distributed e-infrastructure as an essential constituent of EPOS will ensure long-term data availability and optimum data analysis conditions for a large user group that includes both geoscientists and players from the public and private sectors. Such an e-infrastructure will also allow data mining at the European level and communication with the environmental scientists in general and satellite data providers.

For the responsible project scientists, it is not yet possible to state with accuracy how much this research infrastructure will impact upon the scientific understanding of the system Earth but they are certain that EPOS will exert a major influence in fields such as disaster prevention, natural hazards mitigation and the search for new natural resources.

Utilization according to the proposal

The potential user group is defined by the approach of the already existing European EPOS project, in which 26 countries and organisations actively participate together with their geoscience communities. These partners have officially committed themselves to contributing their national research infrastructures and to ensuring the exchange of data and information required for the operation of an integrated research infrastructure. The high visibility of an integrated project that is active throughout Europe is expected to attract new user groups to the infrastructure.

Requests to use the infrastructure or certain infrastructure components such as the mobile seismometer arrays can be submitted by the community in the form of project applications. These applications, which must describe the scientific objectives of the project, the scope of infrastructure components to be used, and the duration of use, will be appraised once or twice a year by a steering committee that includes external members. This should ensure that usage time is distributed objectively based on scientific justification. Concerning the e-infrastructure, open access is envisioned.

Feasibility according to the proposal

The four-year preparation phase for the ESFRI project EPOS was launched in November 2010. This phase serves to prepare for the so-called construction phase which is planned for the subsequent five years. The following operation phase should last at least ten years. Across Europe, a structure has been established consisting of clearly defined work packages (management, technical preparation, control, legal, finances, strategy) and technical working groups (seismology, volcanology, geology, geodesy, rock physics and laboratories, information technology, satellite data). The following activities are pursued in the current preparation phase:

- _ Identify the research infrastructures that currently exist in Europe and neighbouring areas and compile a “research infrastructure register” (completed in 2011).
- _ Catalogue the specific characteristics of the existing research infrastructures, set data policies, and identify the data exchange formats.
- _ Develop and implement an architecture model for the integration of existing research infrastructures into a European e-infrastructure.
- _ Establish an initial prototype of an e-infrastructure.

Organisation and management of the research infrastructure will be done using a structure commonly practised at the GeoForschungsZentrum Potsdam for the management of such distributed infrastructures. The central body will be the board of directors, which includes representatives from all of the institutions

involved in project design, setup, and operation. This board will make the decisions on the operation and utilisation of the infrastructure. It may also request the opinion of the above mentioned steering committee concerning the expansion of the research infrastructure or other measures under consideration. The participating institutions will also subject themselves to this procedure with regard to their own projects. Based on the recommendations of the steering committee, a time and usage plan is drafted for approval by the board of directors ensuring that all institutions involved in the setup and operation of the integrated infrastructure have a fair say. In addition, EPOS is involved in global initiatives such as the Group on Earth Observation (GEO) and the Global Earth Observation System of Systems (GEOSS).

Relevance to Germany as a location of science and research according to the proposal

For the geosciences, the EPOS infrastructure is expected to satisfy the EU's need for a long-term scientific integration plan and the social benefits and added value that this would bring. The German project scientists state that geoscience observation and monitoring are activities that have a very long tradition in Germany and that are very highly developed. Examples of their capabilities include the installation of early warning systems in Indonesia or the operation of a global earthquake monitoring system. The whole scientific community in Germany is said to see enormous potential in the EPOS infrastructure, as such integration will bring additional value to existing research structures and thus help pave the way to solving international problems of great social importance. Cooperating German partners of EPOS are the German Federal Institute for Geosciences and Natural Resources, the Helmholtz Association, and six universities.

According to the leading institutions, no comparable geosciences infrastructure exists anywhere in the world that pursues such an approach. However, the US EarthScope project managed by the National Science Foundation represents a similar and complementary entity with which a cooperation is also foreseen.

Appendix 1.6: Detailed project description of GEMIS

Scientific potential according to the proposal

The aim of a global integrated multi-parameter Earth observation system lies in the spatial and temporal high-resolution documentation of relevant geological and environmental variables, the monitoring of state and trends in the system Earth, the measurement of key abiotic and biotic parameters, as well as long time recording of global and regional changes. These should allow scientists to gain better understanding of the processes taking place in the system Earth. Of particular importance, according to the project leaders, is the gathering of homogenous data series of consistent quality around the globe in order to minimise uncertainties of variables used in model calibration and projection of scenarios, and thereby, to improve model-based forecasts and the decision making basis. In addition, the land-based part of the infrastructure is supposed to serve as the urgently needed scientific ground segment for all types of Earth observing satellites for validation and calibration of satellite data.

Global change including climate change, limited supply of fresh water, increasing human intervention in the environment and the growing need to use the subterranean space for extraction, accumulation and short- and long-term storage of energy and materials represent challenges to which the environmental sciences can make a decisive contribution. An integrated multi-sensor/multi-parameter research infrastructure is seen to be the basis for providing the quality-assured input parameters and time series required for model simulations and projections. It will further permit the development of the sensor systems needed to verify that the human use of geological structures is safe.

Utilization according to the proposal

The research infrastructure is designed as a multi-purpose platform, which, after establishing the basic infrastructure facilities, will allow users to integrate additional sensors and measuring devices. It will also deliver new data and scientific findings for all Earth science disciplines including geophysics, geodesy, remote sensing, geology, or climate. Although a prognosis of the user community cannot be established yet, it is assumed that by providing multi-parameter data that have a clear regional context, as well as compatibility on a global scale, international recognition of the initiative will be strong, and all relevant scientific groups will use the infrastructure.

The planned simplified access to data will lower the barriers for data exploitation. According to the lead scientists, unlike today, no special knowledge will be required to obtain access to data. A competent analysis of raw data will still require specialists, but the provision of data products will greatly simplify holistic

analysis and facilitate research that goes beyond traditional disciplinary boundaries. The leading project scientists are confident that the provision of integrated data products simplifies the transfer of geoscience expertise to the private sector and to policy makers.

The question of how the access to the infrastructure will be regulated is still open.

Feasibility according to the proposal

During a preparatory phase of two years, it is planned to develop an elaborated concept. This should include a requirement analysis together with the potential users, a feasibility study and details of the mini satellite mission, the definition of the basic configuration, the equipment and the location of the multi-parameter integrated observatories, an IT and communications concept, a governance structure, a financial plan, and a time schedule. The following four-year construction phase will be used for construction and launch of the satellites as well as the installation of the ground components, especially the multi-parameter observatories.

The operation phase of the satellites and the operations centre is expected to last for a decade whereas it is planned to hand over the multi-parameter observatories to the respective host countries where they can be used subsequently. Already starting with the construction phase of the observatories, a capacity development programme shall be conducted to ensure the necessary professional competence for this operation in the host countries.

E-infrastructures are the essential constituents of this proposed research infrastructure, and there are existing e-infrastructures that would probably be used. For example, the GeoForschungsZentrum is involved in a leading role in the project European Plate Observing System (EPOS), with a main objective of establishing an e-infrastructure. GEMIS shall be involved in global initiatives such as the Group on Earth Observations (GEO) and the Global Earth Observation System of Systems (GEOSS). In addition, it is a Helmholtz infrastructure.

Relevance to Germany as a location of science and research according to the proposal

According to the project leaders, multi-parameter observatories are very attractive for international partners in the various host countries, but also for the globally networked environmental community. A well-equipped global base network has never been planned or foreseen either in national activities or at the European or international level, but rather represents a previously lacking and important building block in constructing an international or global monitoring system. This would give Germany a unique and outstanding position on the international stage.

138 Shared operation of this type of research infrastructure continues to offer an outstanding base for capacity development in both developing and emerging countries and for coupling them to international developments (science diplomacy).

Appendix 1.7: Detailed project description of EU-OPENSSCREEN

Scientific potential according to the proposal

The research field of chemical biology emerged from classical pharmacological and cell biology disciplines studying the effects of exogenously applied substances to living species. Chemical biology today investigates biological processes using a variety of sophisticated chemical techniques and tools. The biologist applies a bioactive compound to (1) visualise the target cellular structure through e.g. a covalently conjugated dye by fluorescence imaging or whole body tomography (*seeing*), (2) isolate the target from treated samples through a covalently conjugated tag (*grabbing*) and (3) modulate the function of the target, e.g. enzyme activity or interaction with other cellular components (*interfering*). Chemicals act instantly when hitting their targets in a cell or model organism. This enables researchers to interfere with complex processes such as cell division, transport, movement, or signalling in a time-resolved manner; the transporting and dynamic distribution of targets in cells and model organisms can be studied by sophisticated imaging technologies using the compounds as visualising/diagnostic tools. Many fundamental questions about the molecular mechanisms that underlie biological processes can be addressed advantageously – and sometimes exclusively – by using chemical probes.

The major route for the targeted discovery of bioactive substances is systematic empirical screening of large compound collections with dedicated bioassays designed to show a robust signal to an anticipated biological response. The screening provides hit compounds as entry points for further modification towards valuable tools and potential products. The screening collection of EU-OPENSSCREEN (European Chemical Biology Library, ECBL) is planned to be built on the expert knowledge of European chemists and will help with exploring the chemical space by profiling the compounds against hundreds of assays per year conducted by the network of screening centres. The ECBL shall be designed to serve the needs of the scientific community and society. It will cover a global, diversity-based selection of 100,000 to 200,000 compounds from commercial sources, some 100,000 approved drugs and environmental chemicals, about 100,000 proprietary compounds donated from academic chemistry labs or small- and medium-sized enterprises; furthermore, a significant part of it will be composed of natural products which are currently neglected by industry.

Common standards are defined by EU-OPENSSCREEN for all its operations and are applied at all participating research groups. These standards will allow, for the first time, screening results (e.g. screening data, assay protocols, as well as chemical information about the substances and their biological activity properties) of different European platforms to be collected and compared as part of a shared database (European Chemical Biology Database, ECBDB). Currently, such

data generated by expensive research projects are published only in a limited and restricted manner (e.g. only positive data). ECBD will make all data fully available to the scientific community.

The long-term goal of EU-OPENSREEN is to establish the routine use of methods for the biochemical (pharmacological) modulation of biological processes at a very early stage in basic biological and medical research. According to the proposal this will advance the pharmacological and (bio)chemical knowledge significantly.

Utilization according to the proposal

According to the institutions in charge the majority of users are:

- _ Biologists and medical scientists aiming to identify molecules with a specified biological activity (e.g. inhibition of their enzyme or receptor of interest) for use as molecular probes in basic research to study biological processes, and which may be further developed into candidates for potential drugs or other products;
- _ Synthetic chemists donating their chemical compounds for bioprofiling and screening in a multitude of biological assays to learn about the bioactivity potential of their compounds;
- _ Computational chemists and bio-informaticians working on theoretical predictive models, based on the data available in the ECBD, and aiming to validate their hypotheses through experimental screening;
- _ Engineers designing novel assay technologies, instrumentation, or robotics (e.g. liquid handling, compound storage) and seeking to test them in a wet-lab situation.

In disciplines where scientists have not yet tapped the full potential of chemical biology, such as plant science, EU-OPENSREEN seeks to attract new user groups to provide them with novel tools for scientific progress in their fields. Furthermore, the screening of chemical compounds in many different biological assays generates a deep knowledge about the biological activity (both beneficial and potentially adverse) of chemicals. This also represents a valuable source of information for regulatory authorities to (1) evaluate the risk of chemicals (e.g. REACH |⁹⁵) and (2) develop *in vitro* assays that might replace animal studies, among other things.

|⁹⁵ REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals in the European Union.

In order to estimate the appropriate size of the future EU-OPENSSCREEN research infrastructure, Germany's site at FMP, which has been open to external users for more than eight years, is taken as a representative example. Based on the experience at the FMP screening unit and within the German ChemBioNet (see below), the leading institutions anticipate 20 additional projects per year for the German platform; with the 25 expected national projects (internal, collaborative and ChemBioNet) this adds up to approximately 45 projects per year for the German platform. With a conservatively envisaged network of ten EU-OPENSSCREEN screening sites of similar capacity, about 200 projects will be conducted per year Europe-wide.

Feasibility according to the proposal

EU-OPENSSCREEN's concept is based on the German network for support of academic research in chemical biology, the ChemBioNet. This initiative was founded in a bottom-up process in 2003 as the result of a meeting of scientists from involved disciplines and currently consists of ten committed German laboratories. ChemBioNet operates a core open access screening platform located at FMP and HZI which has already conducted about 150 screening projects for the community and created a compound library which is shared with nine other screening sites in Europe.

In 2004, ChemBioNet submitted a proposal for a European-type ChemBioNet under the name of EU-OPENSSCREEN. Since then, ChemBioNet has served as a model for national networks in other European countries. EU-OPENSSCREEN builds on these existing networks and facilities. With its transnational and integrating concept, EU-OPENSSCREEN will synergise Europe's expertise in the field and allow Europe to speak with one voice and to a global audience for promoting a broader and more general use of chemical biology.

The individual partner sites of EU-OPENSSCREEN have already set up operational infrastructures for supporting academic screening projects and are already offering services both domestically and, increasingly, abroad. During the preparatory phase of this ESFRI research infrastructure, the criteria that a screening centre must fulfil in order to be chosen as a partner site in the future infrastructure will be defined. Therefore, no technical innovations are prerequisite for starting operation of EU-OPENSSCREEN. However, a harmonisation of standards (data and screening formats for data transfer into ECBD or inter-screen analysis, European standards for operating protocols, quality standards) is essential for synergistic interactions amongst platforms. Respective work on defining these standards is part of the preparatory phase and experts from the partner EMBL-EBI will deliver these before the operational phase commences. Provision and maintenance of the infrastructure facilities shall be covered by the partner institutes. The running costs of EU-OPENSSCREEN projects (including

costs for salaries, consumables and the maintenance of the compound collection) shall be co-financed, e.g. by user fees.

Relevance to Germany as a location of science and research according to the proposal

EU-OPENSREEN has been conceived and initiated by the three institutions in overall charge, FMP, MDC and HZI. All participate in the current preparatory phase, which is coordinated by the FMP. According to the participating institutions, it would be desirable for Germany to continue to play a driving role beyond the preparatory phase and become the statutory seat of the European Research Infrastructure Consortium (ERIC). Although the governance structure has not yet been finally agreed upon in detail, the EU-OPENSREEN consortium has decided to pursue an ERIC as its legal form. An ERIC has as its principal task the establishment and operation of a research infrastructure on a non-economic basis and must devote most of its resources to this task. It is an entity that has been designed and regulated with the aim of providing a valuable tool to the EU for the organisation and creation of supranational research-focused infrastructures. The ERIC is the only legal form which is specifically designed for the operation of pan-European research infrastructures. FMP, MDC and HZI will together form the initial German EU-OPENSREEN site and dedicate a fixed part of their capacity to EU-OPENSREEN. The ChemBioNet partners will be involved as special expert cooperation sites during the pre- and post-screening phases. Additional German screening sites can be included in the future.

With its integrative approach, EU-OPENSREEN shall link the most prominent screening centres in Europe with the central hub located in Germany. The participating institutions expect that the limited capabilities of individual centres will be overcome by this coordinated networking, from which Germany will likewise profit and benefit from many new opportunities. For instance, Germany has excellent research groups in all areas of chemistry (in particular natural products), which are a source of new chemical diversity. At the same time the number of available bioactive compounds for biochemical research remains very limited. Therefore research groups that possess new molecules and identify new targets have a significant competitive advantage. EU-OPENSREEN is supposed to enable a broad transnational interaction between chemical and biological research groups and thereby open up many opportunities for attracting outstanding projects to Germany. EU-OPENSREEN wants to support Germany, and Europe, in regaining its leading role in the field of health and nutrition research and strengthen the competitiveness of its domestic chemical and pharmaceutical sectors.

Appendix 1.8: Detailed project description of GEBI

Scientific potential according to the proposal

Imaging is a central technology platform of the life sciences for both biological and medical research. Molecular and medical imaging has evolved into pivotal disciplines that link basic research and preclinical research with clinical trials and applications which ultimately alter patient management. New imaging technologies can make entire new research fields accessible for scientists. The responsible institutions give examples for illustration: The ability to observe molecules with nanometre resolution by light microscopy is currently leading to a new discipline that could be called nanobiology, that combines structural and cell biology with molecular specificity and resolution. Scientists will be able to see directly how molecular machines carry out the basic functions of life and disease.

By integrating biological and molecular imaging modalities, scientists can for the first time visualize the molecular basis of human disease, including tumorigenesis or Alzheimer's disease, in living cells and tissues in real time. The collaboration of biologists and medical researchers using a common imaging infrastructure allows direct translation of basic biological discoveries in cells into animal models of human disease. This translational concept within the proposed German imaging research infrastructure allows for seamless transfer of imaging techniques literally from cells to mice to humans and the development of new molecular treatment concepts. So, imaging technologies will make a major contribution for both biomarker and drug discovery. The data explosion in genomics, proteomics, and metabolomics over the last decade has built an essential knowledge base, but the outcome in terms of diagnostic and therapeutic tools was rather meagre. Imaging technologies hold the key to turn "omics" information into successful leads for the pharmaceutical industry by visualizing the molecular machines at work inside intact living cells at nanometre resolution. While "omics" technologies simply cannot reflect the dynamics, interactions, and status of a particular molecule in its natural environment over time, imaging technologies can provide this functional context and therefore identify and validate biomarkers and provide high content assays for drug development. To successfully translate preclinical data GEBI provides a seamless coverage of medical imaging techniques that span from molecular imaging in rodents over large animal imaging to state-of-the-art imaging in humans (7 tesla MRI, MR-PET, and other techniques), which will be supported by dedicated tracers supplied by the national radiotracer network.

The proposed national imaging research infrastructure for Germany is closely aligned with the Euro-BioImaging concept and is based on a hub-and-node model. The nodes will become part of the distributed infrastructure via long-term agreements with the hub without losing their own legal independence. GEBI is aligned with the long-term strategy of the coordinating institution EMBL, the hub-hosting institutions EMBL, University of Konstanz, and the IMT as part of the University of Heidelberg, and all node-hosting institutions. According to the institutions in overall charge, users for the nodes will come from all fields of the biological and medical sciences, as well as from neighbouring disciplines including (bio)physics, chemical biology, radiochemistry, biomedical engineering, and veterinary medicine. In addition to academic users, a significant number of users from industry is foreseen.

The existing biological and medical imaging facilities in Germany use almost all of their capacity for internal users. As a consequence, the many scientists at institutions without large core facilities have only very limited access to the imaging technologies and expertise they need. The open access to the national infrastructure shall fill this gap between the demonstrated user need and the existing imaging technology platforms. Due to the rapidly growing role of imaging technologies in life science research also already existing core facilities are expected to receive higher user numbers in the future. The project scientists expect that more than 75 % of all life sciences research groups would apply imaging technologies regularly if they had sufficient access to instruments and expertise.

The hub of GEBI shall provide coordination and support for all existing national imaging facilities in Germany by several key measures. First, this hub will be the central point of user access to the German infrastructure nodes. The German infrastructure will base its user access on the Euro-BioImaging Proof-of-Concept Studies, which have successfully tested a model for transnational and national user access to different facilities in Europe. The hub will present a single, transparent web entry point for users (hosted by EMBL), where they will find detailed information about all German infrastructure nodes in different imaging technologies including contact details for specific technical questions to plan their application. The community specific access modalities of biological and medical imaging technologies will then be hosted by the IMT, Mannheim (Medicine), and the University of Konstanz (Biology). Second, it will formulate new training curricula for biomedical imaging scientists from basic to advanced level together with participating academic institutions and offer regular and regionally rotating training courses for imaging infrastructure users, which will increase the expertise in these technologies and their use in the life science community. Beyond user training, training curricula for facility managers and

technical staff will be established to guarantee the highest level of expertise and service, which will be open for all German imaging facilities. Third, the German hub will coordinate a national network of all existing biological imaging facilities and medical imaging facilities to increase their visibility nationally and internationally, exchange best practice on facility management and user access, exchange new technical developments in the field, establish sustainable career options for facility managers, and provide a forum for common grant applications and research policy discussions especially regarding user access funding together with funders including the German Research Foundation (DFG). Fourth, the hub will provide a common imaging data resource. Fifth, the hub will ensure compliance of European-leading German imaging technology nodes with the pan-European Euro-BioImaging infrastructure for their future integration, which will provide transnational access of German scientist to Euro-BioImaging nodes outside of Germany and bring transnational users to German nodes.

Feasibility according to the proposal

The nodes of the German infrastructure for integrated access to biological and medical imaging will be upgraded to offer state-of-the-art, yet commercially available imaging technologies. The nodes for super-resolution, high throughput microscopy and innovative medical imaging will offer also non-commercial technology that is however academically developed to a sufficient level of robustness to offer access to external users. Therefore, realization of the infrastructure will not depend on and will not be delayed by the need to accomplish technical innovations. All German nodes will be regularly evaluated for their user access performance and quality of user service based on their quality criteria for facility management and coordinated by the German hub. For keeping the imaging facilities at the cutting edge, the German nodes are closely associated to centres of excellent imaging-based research and will closely collaborate with academic instrument developers and the biooptics and medical imaging technology industry.

Preparatory studies to plan distributed research infrastructure in the biological and medical sciences have been undertaken in the context of ESFRI since 2004. Euro-BioImaging is on the ESFRI roadmap since 2008 and has started its preparatory phase in 2009. The principles along which the GEBI proposal is drafted rely on the results of the Euro-BioImaging preparatory phase studies. In 2011, Euro-BioImaging conducted a European-wide survey on the existing imaging research infrastructure landscape in Europe receiving 660 complete data sets from survey participants representing biological and medical infrastructure users, providers, industry, and funders. In the first half of 2012, Euro-BioImaging demonstrated operability by conducting over 100 proof-of-concept user projects at imaging facilities across Europe. According to the leading institutions, the

results from the survey and the proof-of-concept studies clearly demonstrated an enormous unmet need for access to innovative imaging technologies by German and European life scientists. Through its common coordination with Euro-BioImaging, the German imaging infrastructure will continue to profit from the preparation and implementation work and experiences derived thereof in Euro-BioImaging.

In addition to the proposed German nodes, the German consortium applies for additional 30 % dedicated flexible budget for the future integration of new infrastructure nodes. This flexible budget is crucial to respond to changing user needs and update the national research infrastructure according to the developments of new cutting-edge imaging technologies for open user access.

Relevance to Germany as a location of science and research according to the proposal

The national imaging research infrastructures in the different member states will be integrated at the European level within the pan-European infrastructure Euro-BioImaging, which will start to identify nodes from competitive applications in an open call in 2012/2013. According to the responsible institutions, it is already becoming clear that nodes that receive national funding in the framework of national infrastructures (such as for example in France and the Netherlands) will be in a very competitive position to apply to become European nodes. To put also the German nodes in a strong position to apply for European node status within Euro-BioImaging, and to put Germany in a strong position to make a bid to host the hub of the future pan-European infrastructure, the participating institutions have organized the German hub and nodes along the Euro-BioImaging principles with a clear view towards future European integration. As in Euro-BioImaging, EMBL will serve as the coordinating institution, while the community specific coordinating activities will be hosted by the IMT (for medical imaging) and by the University of Konstanz (for biological imaging).

GEBI is expected to afford added values for Germany particularly with regard to a better return on investment in imaging infrastructure by sharing complementary technologies with European countries. Furthermore, Germany's imaging infrastructure will be of higher quality by applying the Euro-BioImaging standards, best practice and operational models and Germany will profit from the brain gain of European researchers that access the Euro-BioImaging nodes in Germany.

Appendix 1.9: Detailed project description of INSTRUMENT

Scientific potential according to the proposal

According to the participating institutions, it is essential to bridge the gap between classical high-resolution structural biology methods, cell biology, and the emerging field of systems biology in order to address future challenges in structural biology, which aim at an integrative understanding of biological systems. Therefore, methods allowing for bridging this gap, specifically involving electron/light microscopy and their correlative use with high-resolution analyses of macromolecules, will be central to future state-of-the-art structural biology. Through the seamless integration of structural data derived from different technologies and on different length and time scales in vitro and in vivo, research will identify the principles that allow proteins, protein complexes, or whole cells, or pathogens to dynamically interact with their environment.

The field of structural biology is currently experiencing a revolution, in that research is increasingly aiming at an integrative view that links molecular data derived mostly from in vitro experiments with functional observations obtained at the cellular and organism level. Such an integrative approach in structural biology, often termed “cellular structural biology”, enables a detailed, structural biological, mechanical description of cellular processes. Cellular functions rely on the concerted interactions of a wide range of “functional modules”. At one end of the scale, stable interactions exist that are robust enough to withstand purification processes (molecular complexes). They can be studied using the established methods of structural biology. At the other end of the scale, interactions occur more fleetingly, allowing dynamic interactions within and between functional modules. One of the challenges of structural biology is to develop methods for studying such transient complexes or interaction networks. Through these methods and the correlation of molecular and cellular data, new fundamental insights can be expected into physiological and pathophysiological principles, which are critical to many aspects in biology and medicine.

Utilization according to the proposal

The research infrastructure provided by INSTRUMENT will primarily be made available to European users. While structural biologists with an interest in the analysis of macromolecules in cellular processes are likely to make up the majority of the INSTRUMENT user community, additional users are expected from cell biological and biomedical groups, aiming at an identification of molecular mechanisms or the characterisation of therapeutic target molecules. Furthermore, users from industry, especially instrument manufacturers, have expressed a strong interest in INSTRUMENT in the hope of advances in methods developments through collaborations with the INSTRUMENT centres.

Every INSTRUMENT centre will guarantee external users at least 20 % of the total infrastructure capacity. This limit was set to allow the centres sufficient internal utilization as well as utilization from cooperation partners and international guests. Extended external usage can be expected if additional resources become available through national funding. In any case, INSTRUMENT is open only to users from countries participating in INSTRUMENT, and upon payment of an annual fee amounting to EUR 50,000 for the first two years. Currently, the fee has been paid by the participating German institutions and EMBL (details below) ensuring that Germany remains a partner in this effort at least until 2013.

Access to the infrastructure will be regulated via an application process. An online system for submission of research proposals has been installed on the INSTRUMENT website, which is currently in the test run. Every applicant is allocated a moderator, who puts together an independent peer review committee, which will review the individual proposal based on scientific relevance and quality as well as technical suitability and feasibility. INSTRUMENT generally prefers proposals that require an integrative approach of several technological platforms. The committee evaluates and rates the proposal, and it recommends changes as necessary. The applicant can modify and refine the proposal, before a final decision is made by the committee.

Feasibility according to the proposal

Necessary preliminary studies have already been completed. Feasibility studies were carried out during INSTRUMENT's three-year preparatory phase (04/2008 – 04/2011). Furthermore, a business plan and finance concept have been put together for every INSTRUMENT partner. Since April 2011 INSTRUMENT is in the so-called construction phase, to be followed by the operational phase.

The German INSTRUMENT partners (including EMBL) have jointly signed a "Memorandum of Understanding" (MoU) at the end of 2011 to join INSTRUMENT and to grant all German users the participation in INSTRUMENT (including access to infrastructure, participation in training courses etc.) from 2012 onwards. The partners have agreed to pay the subscription fee to equal amounts for 2012 and 2013, in order to ensure continuity of operation of INSTRUMENT.

Relevance to Germany as a location of science and research according to the proposal

According to the participating institutions, Germany is traditionally very strong in structural biology research and it has been emphasized that almost all important methods of structural biology have their origin in Germany. While the leading German centres are very well equipped, they are also highly specialized with respect to methodologies. The INSTRUMENT consortium is thus considered to take full advantage of Germany's strength in the area of structural biology, and to provide an integrating umbrella for the various highly specialized centres.

The INSTRUMENT centres in Germany have been selected based on scientific excellence and track record in establishing cutting-edge infrastructures in the field of structural biology. It is in the interest of Germany that these centres further strengthen and extend their leading role. According to the participating institutions, it is extremely important to maintain an optimal link to scientific and technological developments, particularly within the European framework. Equally important is the commitment of INSTRUMENT to provide talented young scientists access to excellent research infrastructure and to support their research.

INSTRUMENT aims at optimizing the utilization of Europe's best existing research infrastructures in the area of structural research and to push forward their development to stay at the forefront of progress. To this end, institutions of the most important European research facilities have come together to ensure access for the structural biology community in Europe to high-end equipment with optimal maintenance and specialist know-how and expertise. This endeavour is considered a central element in the integration of regional strengths into the overall development of the European research potential. In view of increased global competition in knowledge, innovation, markets, and workforce, it is becoming increasingly important to make efficient use of the regional potential of Europe, to improve the transfer of knowledge and technologies, and to integrate the regionally distributed regional research strengths within Europe. INSTRUMENT is an example on how these distributed entities are integrated in a common research infrastructure.

Appendix 2 Complementary and competing research infrastructures

Appendix 2.1 Complementary research infrastructures of CTA

The following chart contains the major complementary infrastructures of CTA. The list is not exhaustive and the listed complementary research infrastructures have mainly been provided by the responsible scientists. For CTA, there is no competing research infrastructure.

The complementary projects are sorted in the categories “Forerunners”, “Existing research infrastructures” and “Planned research infrastructures/under construction”. Within each category, the projects are classified into the following sub-categories:

- _ Ground-based gamma-ray astronomy
- _ Satellite-based gamma-ray astronomy
- _ Air shower arrays
- _ Ground-based multi-spectral astronomy
- _ Satellite-based multi-spectral astronomy
- _ E-infrastructure

Within these categories, the most recent project is mentioned first.

Table 1: Complementary research infrastructures of CTA

CTA			
Name	Brief description and Internet link	Time frame	Location, involved countries
Forerunners			
<i>Ground-based gamma-ray astronomy</i>			
VERITAS - Very Energetic Radiation Imaging Telescope Array System	VERITAS is a ground-based gamma-ray instrument operating at the Fred Lawrence Whipple Observatory in southern Arizona, USA. It is an array of four 12 m optical reflectors for gamma-ray astronomy in the GeV - TeV energy range. These imaging Cherenkov telescopes are deployed such that they have the highest sensitivity in the very high energy (VHE) band (50 GeV - 50 TeV), with maximum sensitivity from 100 GeV to 10 TeV. This VHE observatory effectively complements the NASA Fermi mission. http://veritas.sao.arizona.edu/ of 10 May 2012.	Prototype: 2003; Four-telescope array: 2007; Dislocation of telescope 1: 2009	Arizona, US CA, IE, UK, US
H.E.S.S. - High Energy Stereoscopic System (name also as homage to	H.E.S.S. is a system of imaging atmospheric Cherenkov telescopes that investigates cosmic gamma rays in the 100 GeV to 100 TeV energy range. The initial four H.E.S.S. telescopes (phase I) are arranged in form of a square with 120 m side length, to provide multiple stereoscopic views of air showers. In phase II of the project,	First telescope: 2002; Four H.E.S.S.	Khomas Highland, NA AM, CZ, DE

Victor Hess, who received the Nobel Prize in 1936 for the discovery of cosmic radiation)	a single huge dish with about 600 m ² mirror area will be added at the centre of the array, increasing the energy coverage, sensitivity and angular resolution of the instrument. http://www.mpi-hd.mpg.de/hfm/HESS/ of 10 May 2012.	1 telescopes: 2003; H.E.S.S. II expected: 2012	(leader), FR, IE, NA, PL, UK, ZA
MAGIC - Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes	The MAGIC Collaboration has built in 2001-2003 a first large atmospheric imaging Cherenkov telescope, MAGIC-I, with a mirror surface of 236 m ² and equipped with photomultiplier tubes of optimal efficiency. In 2009, a second telescope of essentially the same characteristics was added; MAGIC-II was installed at a distance of 85 m from MAGIC-I. With the accent of these instruments on large mirror surface and best light collection, cosmic gamma-rays at an energy threshold lower than any existing or planned terrestrial gamma-ray telescope have become accessible. A threshold of 25 GeV has been achieved so far. http://magic.mppmu.mpg.de/index.en.html of 10 May 2012.	MAGIC I: 2001-2003; MAGIC II: 2009	La Palma, Canary Island, ES BG, CH, DE (leader), ES, FI, HR, IT, JP, PL
Existing research infrastructures			
<i>Satellite-based gamma-ray astronomy</i>			
AMS - Alpha Magnetic Spectrometer	The Johnson Space Center is home to the Alpha Magnetic Spectrometer Project Office. The AMS-02 experiment is a state-of-the-art particle physics detector being constructed, tested and operated by an international team composed of 60 institutes from 16 countries and organized under United States Department of Energy sponsorship. The AMS flew in space in June of 1998 aboard the Space Shuttle Discovery, and it is being integrated and tested to fly on the International Space Station (ISS). The AMS-02 was transported in the cargo bay of the Space Shuttle for installation on the ISS. Once on the ISS S3 Upper Inboard Payload Attach Site, the AMS will remain active for the duration of ISS. http://ams.nasa.gov/ of 10 May 2012. http://ams-02project.jsc.nasa.gov/ of 10 May 2012.	Launch of AMS-02: 2011	US
Fermi - in honour of E. Fermi; Former name: GLAST - Gamma-ray large area telescope	The Fermi Gamma-ray Space Telescope is an international and multi-agency space mission that studies the cosmos in the energy range 10 keV - 300 GeV. The main instrument, the Large Area Telescope (LAT), has superior area, angular resolution, field of view, and deadtime that together will provide a factor of 30 or more advance in sensitivity, as well as provide capability for study of transient phenomena. The Gamma-ray Burst Monitor has a field of view several times larger than the LAT and provides spectral coverage of gamma-ray bursts that extends from the lower limit of the LAT down to 10 keV. http://fermi.gsfc.nasa.gov/ of 10 May 2012.	Launch: 2008; Primary mission planned: for 5 years	AT, DE, ES, FR, IS, IT, JP, SE, US
Swift Gamma-Ray Burst Mission	The Swift Gamma Ray Burst Explorer carries three instruments to enable the most detailed observations of gamma ray bursts to date: the X-ray Telescope (XRT), the UV/Optical Telescope (UVOT) and the Burst Alert Telescope (BAT). The XRT and UVOT are X-ray and a UV/optical focusing telescopes respectively which produce sub-arcsecond positions and multiwavelength lightcurves for gamma ray burst (GRB) afterglows. Broad band afterglow spectroscopy produces redshifts for the majority of GRBs. BAT is a wide Field-Of-View coded-aperture gamma ray imager that produces arcminute GRB positions onboard within 10 s. http://www.swift.psu.edu/ of 10 May 2012.	Launch: 2004	IT, UK, US

INTEGRAL - INTErnational Gamma-Ray Astrophysics Laboratory	ESA's INTErnational Gamma-Ray Astrophysics Laboratory is detecting some of the most energetic radiation that comes from space. It is the most sensitive gamma-ray observatory ever launched. INTEGRAL is an ESA mission in cooperation with Russia and the United States. Integral is the first space observatory that can simultaneously observe objects in gamma rays, X-rays and visible light. Its principal targets are violent explosions known as gamma-ray bursts, powerful phenomena such as supernova explosions, and regions in the Universe thought to contain black holes. http://sci.esa.int/science-e/www/area/index.cfm?fareaid=21 of 16 May 2012. http://www.esa.int/esaMI/Integral/ of 16 May 2012.	Launch: 2002; Mission end planned: 2014	CH, DE, DK, ES, ESA (lead- er), FR, IT, NL, RU, US
<i>Air shower arrays</i>			
ARGO-YBJ - Astrophysical Radiation with Ground- based Obser- vatory at YangBajing	The aim of the ARGO-YBJ experiment is to study cosmic rays, mainly cosmic gamma-radiation, at an energy threshold of ~ 100 GeV, by means of the detection of small size air showers. The detector consists of a single layer of RCPs (Resistive Plate Counters) covering an area of ~6700 m ² and providing a detailed space-time picture of the shower front. ARGO-YBJ is devoted to a wide range of fundamental issues in Cosmic Rays and Astroparticle Physics, including in particular Gamma-Ray Astronomy and Gamma-Ray Bursts Physics. http://argo.na.infn.it/ of 10 May 2012.	Stable data taking: since 2007	Yang- bajing, Tibet CN, IT
Tibet-Array	The Tibet air-shower array is designed not only for observation of air showers of nuclear-component origin but also for that of high energy celestial gamma rays. Because of such multiple purposes, the detector is constructed to cover a wide dynamic range for particle density covering 0.1 to 5000 and a good angular resolution for the arrival direction of air showers with energy in excess of a few TeV being better than 1 degree. http://www.icrr.u-tokyo.ac.jp/em/ of 10 May 2012. http://jp.arxiv.org/PS_cache/arxiv/pdf/0801/0801.1803v2.pdf of 10 May 2012.	Tibet-I: 1990; Tibet-II: 1994; Tibet-III: 1999	Yang- bajing, Tibet CN, JP
<i>Ground-based multi-spectral astronomy</i>			
ALMA - Atacama Large Milli- meter/ sub- millimeter Array	The Atacama Large Millimeter/submillimeter Array (ALMA), an international partnership of Europe, North America and East Asia in cooperation with the Republic of Chile, is the largest astronomical project in existence. ALMA will be a single telescope of revolutionary design, composed initially of 66 high precision antennas located on the Chajnantor plateau, 5000 m altitude in northern Chile. http://www.almaobservatory.org/ of 25 October 2012.	First opera- tions: 2011; Com- pletion plan- ned: 2013	Atacama desert, CL Europe (ESO), North America, East Asia, CL
LOFAR - Low Frequen- cy Array	LOFAR started as a new and innovative effort to force a breakthrough in sensitivity for astronomical observations at radio-frequencies below 250 MHz. LOFAR is the first telescope of this new sort, using an array of simple omni-directional antennas instead of mechanical signal processing with a dish antenna. The electronic signals from the antennas are digitised, transported to a central digital processor, and combined in software to emulate a conventional antenna. The cost is dominated by the cost of electronics and will follow Moore's law, becoming cheaper with time and allowing increasingly large telescopes to be built. So LOFAR is an IT-telescope. The antennas are simple enough but there are a lot of them - about 7000 in the full LOFAR design. To make radio pictures of the sky with ade-	First test- facility: 2004; Cycle 0: 2012	DE, FR, NL, SE, UK

	<p>quate sharpness, these antennas are to be arranged in clusters that are spread out over an area of 100 km in diameter within the Netherlands and over 1500 km throughout Europe.</p> <p>http://www.lofar.org/ of 25 October 2012.</p>		
VLT - Very Large Telescope array	<p>The Very Large Telescope array (VLT) is the flagship facility for European ground-based astronomy at the beginning of the third Millennium. It is the world's most advanced optical instrument, consisting of four Unit Telescopes with main mirrors of 8.2 m diameter and four movable 1.8 m diameter Auxiliary Telescopes. The telescopes can work together, to form a giant "interferometer", the ESO Very Large Telescope Interferometer (VLTI), allowing astronomers to see details up to 25 times finer than with the individual telescopes. The light beams are combined in the VLTI using a complex system of mirrors in underground tunnels where the light paths must be kept equal to distances less than 1/1000 mm over a hundred metres. With this kind of precision the VLTI can reconstruct images with an angular resolution of milliarcseconds, equivalent to distinguishing the two headlights of a car at the distance of the Moon.</p> <p>The VLT instrumentation programme is the most ambitious programme ever conceived for a single observatory. It includes large-field imagers, adaptive optics corrected cameras and spectrographs, as well as high-resolution and multi-object spectrographs and covers a broad spectral region, from deep ultraviolet (300 nm) to mid-infrared (24 μm) wavelengths.</p> <p>http://www.eso.org/public/teles-instr/vlt.html of 21 January 2013.</p>	First Unit Telescope: 1999; All four Unit Telescopes: since 2000	Atacama desert, CL Europe (ESO), CL
Planned research infrastructures/under construction			
<i>Ground-based gamma-ray astronomy</i>			
MACE - Major Atmospheric Cherenkov Experiment	<p>In view of the present developments in the field of GeV/TeV astronomy, the Division proposes to set up a 21 m diameter imaging telescope at the high altitude (4200 m) observatory site at Hanle in the Ladakh region of northern India. Operating at an energy threshold of ~ 20 GeV this telescope is expected to detect a large number of sources in the GeV sky.</p> <p>http://www.geocities.ws/goalsnrl/mace.html of 19 November 2012.</p>	Planned	Tibetan plateau, IN
LHAASO - Large High Altitude Air Shower Observatory	<p>The LHAASO detector is planned to be established in two phases, consisting of three parts: the 1 km² complex array (LHAASO-KM2A), including 5100 scintillation detectors and 40 km² distributed detectors, 24 air fluorescence/Cherenkov detectors (LHAASO-WFCTA) and 100 m² burst detectors array (LHAASO-SCDA), and 90 km² water Cherenkov detector (LHAASO-WCDA). In the second phase, advanced detection technology will be introduced through international cooperation, such as full coverage track detection technology, and two MAGIC (Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes) -like telescopes, etc., so that they can improve the spatial resolution and lower the threshold energy. The first stage is expected to close within 5 years, with construction cost about 850 million RMB. The second stage would be completed in 6 to 7 years, or an even shorter period, depending on the international cooperation progress, and about 200 million RMB worth foreign investment is planned to be introduced.</p> <p>The measurement of cosmic rays energy spectra will cover the widest energy ranges, from 20 TeV to a few EeV.</p>	Planned	Yangbajing, Tibet CN, FR, IT, RU

	http://english.ihep.cas.cn/ic/ip/LHAASO/ of 15 May 2012.		
HAWC - The High-Altitude Water Cherenkov Observatory	The High-Altitude Water Cherenkov Observatory is a facility designed to observe TeV gamma rays and cosmic rays with an instantaneous aperture that covers more than 15 % of the sky. With this large field of view, the detector will be exposed to half of the sky during a 24-hour period. HAWC is currently under construction on the flanks of the Sierra Negra volcano near Puebla, Mexico. Located at an altitude of 4100 m, HAWC will be used to perform a high-sensitivity synoptic survey of the sky at wavelengths between 100 GeV and 100 TeV. http://hawc.umd.edu/index.php of 15 May 2012.	Under construction	Puebla, MX MX, US
<i>Ground-based multi-spectral astronomy</i>			
E-ELT - European Extremely Large Telescope	Since the end of 2005 ESO has been working together with its user community of European astronomers and astrophysicists to define the new giant telescope needed by the middle of the next decade. More than 100 astronomers from all European countries have been involved throughout 2006, helping the ESO Project Offices to produce a novel concept, in which performance, cost, schedule and risk were carefully evaluated. Dubbed E-ELT for European Extremely Large Telescope, this revolutionary new ground-based telescope concept will have a 39 m main mirror and will be the largest optical/near-infrared telescope in the world: “the world’s biggest eye on the sky”. With the start of operations planned for early in the next decade, the E-ELT will tackle the biggest scientific challenges of our time, and aim for a number of notable firsts, including tracking down Earth-like planets around other stars in the “habitable zones” where life could exist – one of the Holy Grails of modern observational astronomy. It will also perform “stellar archaeology” in nearby galaxies, as well as make fundamental contributions to cosmology by measuring the properties of the first stars and galaxies and probing the nature of dark matter and dark energy. On top of this astronomers are also planning for the unexpected – new and unforeseeable questions will surely arise from the new discoveries made with the E-ELT. The ability to observe over a wide range of wavelengths from the optical to mid-infrared will allow scientists to exploit the telescope’s size to the fullest extent. http://www.eso.org/public/teles-instr/e-elt.html of 25 October 2012.	Under construction; Start of operations planned: early in the next decade	Atacama desert, CL Europe (ESO)
SKA - Square Kilometre Array	The Square Kilometre Array, or SKA, is a next-generation radio telescope currently planned by institutions from over 20 countries. The SKA will be the largest and most capable radio telescope ever constructed. During its 50+ year lifetime, it will expand our understanding of the universe and drive technological development worldwide. Dishes will form a substantial part of the SKA; around 3000 dishes, each 15 m in diameter, are currently planned. http://www.skatelescope.org/ of October 29 2012. http://www.ska.ac.za/ of October 25 2012. http://www.ska.gov.au/Pages/default.aspx of 25 October 2012.	Construction of phase 1 planned: 2016-2020	AU, NZ Consortium of institutions from over 20 countries
<i>Satellite-based multi-spectral astronomy</i>			
JWST - James Webb Space Telescope	The James Webb Space Telescope (sometimes called JWST) is a large, infrared-optimized space telescope. The project is working to a 2018 launch date. Webb will find the first galaxies that formed in the early Universe, connecting the Big	Start planned: 2018	CA (CSA), ESA, US (NASA)

<p>named after the NASA Administrator who crafted the Apollo programme, and who was a staunch supporter of space science</p>	<p>Bang to our own Milky Way Galaxy. Webb will peer through dusty clouds to see stars forming planetary systems, connecting the Milky Way to our own Solar System. Webb's instruments will be designed to work primarily in the infra-red range of the electromagnetic spectrum, with some capability in the visible range.</p> <p>Webb will have a large mirror, 6.5 m (21.3 feet) in diameter and a sunshield the size of a tennis court. Both the mirror and sunshade won't fit onto a rocket fully open, so both will fold up and open once Webb is in outer space. Webb will reside in an orbit about 1.5 million km (1 million miles) from the Earth.</p> <p>http://www.jwst.nasa.gov/ of 25 October 2012.</p>		
<i>E-infrastructures</i>			
<p>CTA's e-infra-structure</p>	<p>The development and implementation of the CTA observatory research ICT-based infrastructures for efficient and high performance data management and data archiving will be based on modern European e-infrastructures such as EGEE/EGI (Enabling Grids for E-science/European Grid Infrastructure), GÉANT (pan-European communication infrastructure) and International Virtual Observatory Alliance (IVOA).</p> <p>A science user gateway including user-configured tools for access to shared computing resources, tools for data access, data processing, and data analysis will be developed, as well as the implementation plans for the offline CTA e-infrastructure.</p> <p>http://www.cta-observatory.org/?q=node/178 of 15 May 2012.</p>	<p>Planned</p>	

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as "About us"). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Appendix 2.2 Competing and complementary research infrastructures of EMFL

The following charts contain the major competing and complementary infrastructures of EMFL. The lists are not exhaustive and the listed competing and complementary research infrastructures have mainly been provided by the responsible scientists.

The competing and complementary projects are sorted in the categories “Forerunners”, “Existing research infrastructures” and “Planned research infrastructures/under construction”. Within each category, the projects are classified into the following sub-categories:

- _ Steady fields and pulsed fields
- _ Steady fields
- _ Pulsed fields
- _ Networks

Within these categories, the most recent project is mentioned first.

Table 2: Competing research infrastructures of EMFL

EMFL			
Name	Brief description and Internet link	Time frame	Location, involved countries
Existing research infrastructures			
<i>Steady fields and pulsed fields</i>			
The Magnet Lab at Florida State University Part of NHMFL (National High Magnetic Field Laboratory)	The Tallahassee site is home to four of the lab’s seven user programmes and more than a dozen high-field magnets, spectrometers and other instruments, e.g.: _ The 45 T, world-record hybrid magnet, which produces the highest field of any continuous field magnet in the world, _ Two 36 T, world-record resistive magnets, _ 25 T, wide-bore magnet for magnetic resonance research _ 14.5 T, shielded superconducting magnet for ion cyclotron resonance. Other key resources include: _ A world-renowned Magnet Science and Technology group, which includes materials development and characterization facilities and the Large Magnet Component Test Laboratory, _ The Applied Superconductivity Center, which relocated to the Magnet Lab from the University of Wisconsin in 2006, _ A state-of-the-art image furnace capable of growing crystals such as magnetic oxides and high-temperature superconductors, _ The Center for Integrating Research and Learning, offering programmes and resources to teachers and students at all levels, _ An impressive utility infrastructure that features a 56 megawatt power supply and a 4.2 million gallon chilled-water plant.	Since 1990s	Tallahassee, US

	http://www.magnet.fsu.edu/about/tallahassee.html of 15 May 2012.		
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Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as “About us”). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Table 3: Complementary research infrastructures of EMFL

EMFL			
Name	Brief description and Internet link	Time frame	Location, involved countries
Forerunners			
<i>Networks</i>			
EuroMagNET II - Research Infrastructures for High Magnetic Field in Europe	A coordinated approach to access, experimental development and scientific exploitation of all European large infrastructures for high magnetic fields. For the EU’s Seventh Framework Programme for Research, the principal actors of Europe’s high magnetic field research, the Grenoble High Magnetic Field Laboratory (GHMFL), the High field magnet laboratory (HFML), the Dresden High Magnetic Field Laboratory (HLD) and the <i>Laboratoire National des Champs Magnétiques Pulsés</i> (LNCMP) propose to unite all their transnational access, together with joint research activities and networking activities into one I3 (Integrated Infrastructures Initiative), called “EuroMagNET II”. This I3 is considered as a very important step towards full collaboration between Europe’s high field facilities, and as a necessary intermediate step towards the creation of a multi-site European Magnetic Field Laboratory (EMFL). http://www.euromagnet2.eu/spip.php?rubrique1 of 15 May 2012.	Since 2009	DE, FR, NL
Existing research infrastructures			
<i>Steady fields and pulsed fields</i>			
LNCMI - Laboratoire National des Champs Magnétiques Intenses Part of EMFL	The <i>Laboratoire National des Champs Magnétiques Intenses</i> is the French large scale facility enabling researchers to perform experiments in the highest possible magnetic field. Continuous fields are available at the Grenoble site (LNCMI-G) and pulsed fields at Toulouse (LNCMI-T). The LNCMI is open to European and other visitors for their high field projects, which can be submitted through the EuroMagNET website. http://lncmi.cnrs.fr/ of 15 May 2012.	Since 2009	FR
LNCMI-G - Laboratoire National des Champs Magnétiques Intenses Grenoble	The LNCMI-G gives access to researchers to static high magnetic fields up to 35 T in a 34 mm bore. Former Name: GHMFL - Grenoble High Magnetic Field Laboratory http://ghmfl.grenoble.cnrs.fr/?lang=en of 15 May 2012.	Since 1990s	Grenoble, FR
LNCMI-T - Laboratoire National des Champs Magnétiques Intenses Toulouse	The <i>Laboratoire National des Champs Magnétiques Intenses de Toulouse</i> (LNCMI-T, for High Magnetic Field National Laboratory of Toulouse) is a host laboratory for experiments in pulsed magnetic fields. http://www.toulouse.lncmi.cnrs.fr/?lang=en of 15 May 2012.	Since 1970	Toulouse, FR

<p>High field magnet facility, University of Oxford + Nicholas Kurti Magnetic Field Laboratory (NKMFL)</p>	<p>The high field magnet facility enables the Department of Physics to continue its strong track record in high-field, low-temperature experiments on new and novel materials. World-class superconducting magnets provide steady fields up to 21 T, while liquid helium cryogenic systems allow access to temperatures in the mK range. In addition, the Nicholas Kurti Magnetic Field Laboratory supplies the UK's highest available magnet fields by the use of pulsed magnet technology. Experimental techniques possible in their magnet systems include magnetometry, electronic transport and optical measurements.</p> <ul style="list-style-type: none"> _ Mobile superconducting magnet systems up to 21 T _ Custom-built superconductive magnets dedicated to individual experiments _ A pulsed field facility <p>http://www2.physics.ox.ac.uk/enterprise/high-field-magnet-facility of 15 May 2012. http://www.physics.ox.ac.uk/magnet/ of 15 May 2012.</p>	<p>Currently operating</p>	<p>Oxford, UK</p>
<p>NHMFL - National High Magnetic Field Laboratory</p>	<p>This large and high-powered magnet laboratory consists of three institutions. http://www.magnet.fsu.edu/ of 15 May 2012.</p>	<p>Since 1990s</p>	<p>US</p>
<p>The Magnet Lab at Los Alamos National Laboratory Part of NHMFL</p>	<p>The Pulsed Field Facility houses both semi-destructive and non-destructive magnets. This collection includes the most powerful non-destructive magnet in the world, a 100 T multi-shot magnet jointly developed by the Department of Energy and the National Science Foundation. Among the facility's magnets are: 50 T mid pulse (300 ms pulse), 50 T short pulse (35 ms pulse), 65 T short pulse (35 ms pulse), 60 T short pulse (35 ms pulse), 60 T short pulse (35 ms pulse), 300 T single turn magnet system (6 μs pulse) (in this type of system, the magnet is destroyed by explosives during operation, but the sample is preserved), 100 T multi-shot (15 ms pulse), 60 T long pulse (2 s controlled waveform pulse). http://www.magnet.fsu.edu/about/losalamos.html of 15 May 2012.</p>	<p>Since 1990s</p>	<p>Los Alamos, US</p>
<p>The Magnet Lab at the University of Florida Part of NHMFL</p>	<p>The University of Florida is home to two Magnet Lab user programmes, the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) and High B/T (the "B" stands for high magnetic fields, the "T" refers to the extremely low temperatures) user programs.</p> <p>AMRIS:</p> <ul style="list-style-type: none"> _ A powerful 11.7 T magnetic resonance imaging (MRI) system, _ A 17.5 T, 750 MHz wide bore nuclear magnetic resonance (NMR)/MRI magnet system, _ A 3 T human system, _ An on-site radio frequency coil lab. <p>High B/T Facility:</p> <ul style="list-style-type: none"> _ Bay 3 of the μK Laboratory: a 16 T magnet system with a 10 T demagnetization stage, _ Bay 2 of the μK Laboratory: a 10 T magnet system with an 8 T demagnetization system, _ Williamson Hall Annex: a 10 T magnet system, _ An ultra-quiet environment that insulates experiments from outside interference due to vibrations and electromagnetic fields. <p>http://www.magnet.fsu.edu/about/gainesville.html of 15 May 2012.</p>	<p>Since 1990s</p>	<p>Gainesville, US</p>

<i>Steady fields</i>			
HFML – High Field Magnet Labor- atory Part of EMFL	<p>The HFML is a Large European Research Infrastructure and a Dutch national research facility.</p> <p>The HFML is committed to generate the highest available continuous magnetic fields. 33 T magnets are available, a 38 T resistive magnet and a 45 T hybrid magnet are under development. They perform research with these fields and make them available to qualified external users.</p> <p>Local research interests are (1) magnet technology, (2) soft condensed matter and molecular material, (3) strongly correlated electron systems and (4) semiconductors and nano-systems.</p> <p>http://www.ru.nl/hfml/ of 15 May 2012.</p>	Since 2003	Nijmegen, NL
TML – Tsukuba Mag- net Laboratory	<p>Tsukuba Magnet Laboratory is one of the largest high mag- netic field facilities in the world. TML is capable of generat- ing highest steady magnetic field and is engaged in the de- velopment of technology utilizing magnetic fields:</p> <ul style="list-style-type: none"> _ Hybrid magnet inserted with a superconducting magnet creates a high magnetic field at room temperature; 32 T in 52 mm bore or 35 T in 30 mm bore, _ Water-Cooled Magnet 25 T in 32 mm bore, _ Superconducting Magnets for General Purpose, _ Superconducting Magnet for Solid-State Physics, _ Nuclear magnetic resonance (NMR) Magnet, _ Water-Cooled Pulsed Magnet 30 T in 30 mm bore, _ N₂-Cooled Pulsed Magnet 50 T in 16 mm bore. <p>http://www.nims.go.jp/TML/english/ of 19 November 2012.</p>	Since 1993	Tsukuba, JP
High Field Laboratory for Super- conducting Materials	<p>The high field laboratory consists of several magnets:</p> <ul style="list-style-type: none"> _ Hybrid magnet which generates steady high magnetic fields up to 31 T (consists of a superconducting outer coil and a water-cooled inner coil), _ Many cryogenfree superconducting magnets which have been developed by their laboratory are installed. The cryo- genfree superconducting magnet makes great progress. Recently, they succeeded in developing the world's first cryogenfree hybrid magnet, and achieved a static field gen- eration of 27.5 T using the newly developed magnet. <p>The laboratory also provides instruments for measuring var- ious physical properties. These facilities are open to scien- tists and engineers on superconductors and other materials research. Cooperative research programmes are under way in a nation-wide scale.</p> <p>http://www.hflsm.imr.tohoku.ac.jp/cgi-bin/index-e.cgi of 15 May 2012.</p> <p>http://www.imr.tohoku.ac.jp/en/org/facility/03.html of 15 May 2012.</p>	First estab- lished: 1981; Labora- tory restart: 2001	Sendai, JP
<i>Pulsed fields</i>			
IMGSL – International MegaGauss Science Labor- atory Part of the In- stitute for Solid State Physics, University of Tokyo	<p>The aim of this laboratory is to study the physical properties of matters under ultra-high magnetic field conditions. Such a high magnetic field is also used for realizing the new mate- rial phase and functions. Their pulse magnets can generate up to 80 T by non-destructive way (the world record), and from 100 up to 730 T (the world strongest as an indoor rec- ord) by destructive (the single turn coil and the electro- magnetic flux compression) methods. The former offers physical precision measurements (the electro-conductance, the optics, and the magnetization). The multiple extreme physical conditions combined with ultra-low temperature and ultra-high pressure are also available, and are open for domestic and international scientists. The magnet technolo- gies are intensively devoted to the quasi-steady long pulse</p>	Cur- rently operat- ing	Kashiwa, JP

	<p>magnet (an order of 1-10 s) energized by the world largest DC (direct current) generator (51.3 MW, 210 MJ), and also to a 100 T non-destructive magnet. Consists of four laboratories: Takeyama Lab, Kindo Lab, Tokunaga Lab, Matsuda Lab.</p> <p>http://www.issp.u-tokyo.ac.jp/labs/mgsl/indexe.html of 15 May 2012.</p>		
<p>Wuhan National High Magnetic Field Center at HUST - Huazhong University of Science & Technology</p>	<p>The main task of the centre is the development of a pulsed high magnetic field facility (two measuring stations). The prototype 1 MJ/25 kV/30 kA capacitor bank, 50-70 T magnets and helium cryostats together with a measuring and control system are available for a variety of scientific research.</p> <p>A 12 MJ capacitor bank and a 100 MJ/100 MVA pulse generator power supply will be developed and built in order to generate pulsed magnetic fields in the range from 50 T to 80 T with pulse duration from 15 ms to 1000 ms.</p> <p>http://www.whmfc.cn/ of 15 May 2012 (in Chinese only). http://english.hust.edu.cn/Optoelectronics.html?id=6 of 15 May 2012.</p>	<p>Established: 2005; Opening of the new facility planned: 2012</p>	Wuhan, CN
Planned research infrastructures/under construction			
<i>Steady fields and pulsed fields</i>			
<p>HMFL - High Magnetic Field Laboratory, Chinese Academy of Sciences</p>	<p>Infrastructure for the generation of high static magnetic fields.</p> <p>HMFL was founded to provide first class steady high magnetic field facilities to researchers and to better develop high magnetic field science:</p> <ul style="list-style-type: none"> _ Hybrid magnet: 40 T, 32 mm, _ Resistive magnets: 33 T, 32 mm; 25 T, 50 mm; 19,5 T, 200 mm; 26 T, 32 mm, _ Superconducting magnet: 10 T, 100 mm; 18 T, 52 mm; 18,8 T, 54 mm; 94 T, 310 mm. <p>The facility is planned to be open for external users in 2011 with the implementation of various experimental techniques in pulsed magnetic fields up to 80 T. Pulse durations are in the range from 15 to 1000 ms with the magnet bore sizes from 12 to 34 mm. The pulsed power supplies are a 12 MJ, 25 kV capacitor bank and a 100 MVA/100 MJ flywheel pulse generator.</p> <p>http://english.hfcas.ac.cn/High_Magnetic_Field_Science_and_Technology.htm of 15 May 2012. http://www.chinatechgadget.com/the-pulsed-high-magnetic-field-laboratory-in-china.html of 15 May 2012.</p>	<p>Founded: 2008; Completion planned: 2012</p>	Hefei, CN
<i>Steady fields</i>			
<p>High-field magnet for neutron scattering investigation, Helmholtz-Zentrum Berlin</p>	<p>Possible candidate for EMFL membership</p> <p>At the Helmholtz Centre Berlin for materials and energy a new high field magnet is under construction: internationally unique and with a magnetic field strength of 25 to 30 T.</p> <p>http://www.helmholtz-berlin.de/zentrum/perspektiven/hfm/index_en.html of 15 May 2012.</p>	<p>Under construction</p>	Berlin, DE

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as "About us"). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Appendix 2.3 Complementary research infrastructures of IAGOS

The following chart contains the major complementary infrastructures of IAGOS. The list is not exhaustive and the listed complementary research infrastructures have mainly been provided by the responsible scientists. For IAGOS, there is no competing research infrastructure.

The complementary projects are sorted in the categories “Forerunners”, “Existing research infrastructures” and “Planned research infrastructures/under construction”. Within each category, the projects are classified into the following sub-categories:

- _ Airborne
- _ Observation Systems
- _ E-infrastructures
- _ Programmes, networks, missions and organizations (these mostly are beneficiaries of research infrastructures)

Within these categories, the most recent project is mentioned first.

Table 4: Complementary research infrastructures of IAGOS

IAGOS			
Name	Brief description and Internet link	Time frame	Involved countries
Forerunners			
<i>Airborne</i>			
CARIBIC – Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container	CARIBIC is an innovative scientific project to study and monitor important chemical and physical processes in the Earth’s atmosphere. Detailed and extensive measurements are made during long distance flights. They deploy an airfreight container with automated scientific apparatus which are connected to an air and particle (aerosol) inlet underneath the aircraft. The CARIBIC project is integrated in IAGOS. http://caribic.de/ of 10 May 2012.	Since 2004	BE, CH, DE, FR, NL, SE, UK
MOZAIC – Measurements of OZone, water vapour, carbon monoxide and nitrogen oxides by in-service Airbus air-Craft	MOZAIC consists of automatic and regular measurements of reactive gases by five long range passenger airliners. The research project MOZAIC evolves towards the European Research Infrastructure IAGOS. Its goal is to collect experimental data on atmospheric composition and its changes under the influence of human activity, with particular interest in the effects of aircraft. In MOZAIC, regular measurements of ozone (O ₃), water vapour (H ₂ O), carbon monoxide (CO) and nitrogen oxides (NO _y) are made by autonomous instruments deployed aboard five long range passenger airliners of the type AIRBUS A340-300. http://www.iagos.fr/web/rubrique2.html of 10 May 2012.	Initiated: 1993; 1st phase: 1994-1996; 2nd: 1997-2000; 3rd: 2001-2004	DE, FR, UK

Existing research infrastructures			
<i>Airborne</i>			
Geophysica	<p>The Geophysica is currently the only aircraft in Europe capable of carrying instruments to the altitude range of 15-20 km, which plays an important role in the climate system. The topics of planned projects include the climate forcing of the tropics (e.g. Asian monsoon) as well as of aerosols and clouds, interactions between ozone and climate in the stratosphere and the demonstration of future satellite instruments [e.g. see below PREMIER (Process exploration through measurements of infrared and millimetre-wave emitted radiation), ATMOSAT (Adjustment of atmospheric correction methods for local studies)]. In atmospheric research with Geophysica, successful long-standing cooperations exist between IEK-7 (Institute for Energy and Climate Research Stratosphere), KIT (Karlsruhe Institute of Technology), DLR (German Aerospace Centre), five German universities and a large number of international institutions. HALOX (Halogenoxide monitor) is placed in the wingpod under the left wing of the M-55 Geophysica. http://www.fz-juelich.de/iek/iek-7/EN/Forschung/Projekte/Geophysica/geophysica_node.html of 10 May 2012.</p>	Plan of use in 2010: 5-8 years of operation	DE, RU
HALO – High Altitude and Long range research aircraft	<p>IEK-7 (Institute for Energy and Climate Research Stratosphere) will make a significant contribution to the instrumentation of the new German research aircraft HALO by developing an ice-water package (Lyman-α hygrometer, tunable diode laser for water vapour, particle measurements) and the novel remote sensing instrument GLORIA-AB (up to 40 trace gases, aerosols, clouds). The German Research Foundation (DFG) has also earmarked funds from the priority programme Atmospheric and Earth System Research with HALO for IEK-7 to develop and operate two instruments for measuring water and particles, respectively, HAI (Hygrometer for Atmospheric Investigations) and NIXE-CAPS (New Ice eXperiment – Cloud and Aerosol Particle Spectrometer). Within the scope of the DFG project Lagrangian Support of Stratospheric Operations of HALO (LASSO), scientists from IEK-7 will also support the HALO measurement campaigns with model predictions for flight planning in order to optimize the flight patterns. http://www.halo.dlr.de/ of 10 May 2012. http://www.fz-juelich.de/iek/iek-7/EN/Forschung/Projekte/HALO/halo_node.html of 10 May 2012.</p>	Since 2009	DE
HIAPER – High-performance Instrumented Airborne Platform for Environmental Research	<p>The research jet, known as the HIAPER, has a range of about 7,000 miles (11,000 km), which allows scientists to traverse large regions of the Pacific Ocean without refueling, gathering air samples along the way. Researchers will take the jet from an altitude of 1,000 feet (300 m) above Earth's surface up to as high as 47,000 feet (14,000 m), into the lower stratosphere. The project, HIAPER Pole-to-Pole Observations (HIPPO), brings together scientists from organizations across the nation, including National Center for Atmospheric Research (NCAR), Harvard University, the National Oceanic and Atmospheric Administration (NOAA), the Scripps Institution of Oceanography, the University of Miami, and Princeton University. National Science Foundation (NSF) and NOAA are funding the project. Many of the instruments aboard HIAPER have been designed especially for the HIPPO project. They will enable scientists to measure CO₂ and other gases across the planet in real time, in-</p>	Five missions: 2009-2011	US (NSF, NOAA)

	<p>stead of collecting a limited number of samples in flasks and bringing them back to the lab for later analysis.</p> <p>https://www2.ucar.edu/atmosnews/news/881/pole-pole-flights-provide-first-global-picture-greenhouse-gases of 10 May 2012.</p> <p>http://www.hiaper.ucar.edu/ of 10 May 2012.</p>		
PGGM – Pacific Greenhouse Gases Measurement	<p>The PGGM programme was started in 2008 by Taiwanese scientist, aircraft manufacturers and airlines. Its goal is to establish a highly horizontal resolution observation about greenhouse gases such as ozone (O₃), water vapour (H₂O), carbon dioxide (CO₂) etc. through the autonomous instruments deployed aboard the China-airline's passenger airliners of the type AIRBUS A340, A300, the EVERGREEN MARINE CORP international vessels, and the CPC Corporation international oil tankers. By the measurements of greenhouse gases they can assist the research about the global warming and climate change.</p> <p>http://140.115.35.249/h/PGGM-new/Index-1.htm of 10 May 2012.</p> <p>http://www.iagos.org/Related_Projects of 10 May 2012.</p>	Since 2008	TW
CONTRAIL – Comprehensive Observation Network for TRace gases by Air-Liner	<p>CONTRAIL is the second phase of a project initiated 1993 in Japan to monitor greenhouse gases from passenger aircraft operated by JAL (Japanese Airlines). Therefore a new Automatic air Sampling Equipment (ASE) for flask sampling and a new Continuous CO₂ Measuring Equipment (CME) for in-situ CO₂ measurements were installed on Boeing 747-400 and Boeing 777-200ER aircraft. In all, one or both of these instruments have been installed on several Boeing aircraft operated by JAL with regular flights from Japan to Australia, Europe, East, South and Southeast Asia, Hawaii, and North America, providing significant spatial coverage, particularly in the Northern Hemisphere.</p> <p>http://www.jal-foundation.or.jp/shintaikikansoku/Contrail_index.htm (in Japanese only) of 10 May 2012.</p> <p>http://www.iagos.org/Related_Projects of 10 May 2012.</p> <p>http://www.cger.nies.go.jp/contrail/index.html of 10 May 2012.</p>	Since 2005	JP
<i>Observation Systems</i>			
ICOS – Integrated Carbon Observation System	<p>ICOS is a new European Research Infrastructure for quantifying and understanding the greenhouse balance of the European continent and of adjacent regions. ICOS aims to build a network of standardized, long-term, high precision integrated monitoring of:</p> <ul style="list-style-type: none"> _ atmospheric greenhouse gas concentrations of CO₂, CH₄, CO and radiocarbon-CO₂ to quantify the fossil fuel component _ ecosystem fluxes of CO₂, H₂O, and heat together with ecosystem variables. <p>The ICOS infrastructure will integrate terrestrial and atmospheric observations at various sites into a single, coherent, highly precise dataset. These data will allow a unique regional top-down assessment of fluxes from atmospheric data, and a bottom-up assessment from ecosystem measurements and fossil fuel inventories. Target is a daily mapping of sources and sinks at scales down to about 10 km, as a basis for understanding the exchange processes between the atmosphere, the terrestrial surface and the ocean.</p> <p>http://icos-infrastructure.eu/ of 10 May 2012.</p>	Preparation: 2008-2011; Operation: 2012-2031	BE, CH, CZ, DE, DK, ES, FI, FR, IE, IT, NL, NO, PL, PT, SE, UK

ESRL/GMD - Earth System Research Laboratory/ Global Monitoring Division	ESRL's Global Monitoring Division (formerly CMDL, Climate Monitoring Diagnostics Laboratory) of the National Oceanic and Atmospheric Administration (NOAA), conducts sustained observations and research related to source and sink strengths, trends and global distributions of atmospheric constituents that are capable of forcing change in the climate of Earth through modification of the atmospheric radiative environment, those that may cause depletion of the global ozone layer, and those that affect baseline air quality. http://www.esrl.noaa.gov/gmd/ of 10 May 2012.	Since 2005	US (NOAA)
IGACO - Integrated Global Atmospheric Chemistry Observations	IGACO is a strategy for bringing together ground-based, aircraft and satellite observations of 13 chemical species in the atmosphere. IGACO will be implemented as a strategic element of the Global Atmospheric Watch (GAW) programme of the World Meteorological Organization (WMO). The implementation will be organised in four focus areas: Ozone, Aerosols, Greenhouse gases and Air Quality / Long-range transport. IGACO is a theme in the International Global Observing Strategy (IGOS). http://www.igaco-o3.fi/en/index.html of 10 May 2012.	Implementation: since 2005	FI
<i>E-infrastructures</i>			
WIS - WMO (World Meteorological Organisation) Information System	The WMO Information system (WIS) is the single coordinated global infrastructure responsible for the telecommunications and data management functions. It is the pillar of the WMO strategy for managing and moving weather, climate and water information in the 21st century. WIS provides an integrated approach suitable for all WMO Programmes to meet the requirements for routine collection and automated dissemination of observed data and products, as well as data discovery, access and retrieval services for all weather, climate, water and related data produced by centres and Member countries in the framework of any WMO Programme. http://www.wmo.int/pages/prog/www/WIS/ of 10 May 2012.	Implementation: since 2012	WMO has 189 member states and territories
Planned research infrastructures/under construction			
<i>Observation Systems</i>			
GEOSS - Global Earth Observation System of Systems	This "system of systems" will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets. The "GEOPortal" offers a single Internet access point for users seeking data, imagery and analytical software packages relevant to all parts of the globe. http://www.earthobservations.org/geoss.shtml of 10 May 2012.	Currently in preparation: 10-year implementation plan 2005-2015	75 involved nations

<i>Programmes, networks and organizations</i>			
GMES – Global Monitoring for Environment and Security	GMES is the European Programme for the establishment of a European capacity for Earth Observation. In practice, GMES consists in a complex set of systems which collects data from multiple sources (earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors), processes these data and provides users with reliable and up-to-date information through the services. Over the last 10 years, numerous research and development projects have contributed to the development of the GMES infrastructure and services. http://gmes.info/ of 10 May 2012.	Since 1998; Full operation: 2014	ESA, EU

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as “About us”). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Appendix 2.4 Complementary research infrastructures of Cabled OOS FRAM

The following chart contains the major complementary infrastructures of FRAM. The list is not exhaustive and the listed complementary research infrastructures have mainly been provided by the responsible scientists. For FRAM, there is no competing research infrastructure.

The complementary projects are sorted in the categories “Existing research infrastructures” and “Planned research infrastructures/under construction”. Within each category, the projects are classified into the following sub-categories:

- _ Observation Systems
- _ Research Vessels (RV), Remotely Operated Vehicles (ROV)
- _ E-infrastructures
- _ Programmes, networks and organizations (these mostly are beneficiaries of research infrastructures)

Within these categories, the most recent project is mentioned first.

Table 5: Complementary research infrastructures of FRAM

FRAM			
Name	Brief description and Internet link	Time frame	Involved countries
Existing research infrastructures			
<i>Observation Systems</i>			
COSYNA - Coastal Observation System for Northern and Arctic Seas	COSYNA aims to develop and to test analysis systems for the operational synoptic description of the environmental status of the North Sea and of Arctic coastal waters. Following an open data policy, COSYNA provides real-time or near real-time data and forecasts via Internet to the public. The main characteristic of the COSYNA system is the integrated approach that combines observations and numerical modelling. http://www.cosyna.de of 11 May 2012.	Start of measurements: 2009	DE
MACHO - Marine Cable Hosted Observatory	The purpose of MACHO project has several folds. Firstly, the extension of seismic stations on land to offshore area can increase the resolution of earthquake relocating. Secondly, the extension of seismic stations may obtain tens of second before the destructing seismic waves arrive on land or tens of minute before the arrival of giant tsunami, which is helpful for earthquake or tsunami warning. Thirdly, the seafloor scientific station can monitor the active volcanoes in the Okinawa Trough, which is directly adjacent to the Ilan plain in northeastern Taiwan. Fourthly, the seafloor observatory can be used to continuously study the Kurosho current, off eastern Taiwan. http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4231138&tag=1 of 11 May 2012.	Expected to be fulfilled: 2009	TW

NEPTUNE Canada	<p>The NEPTUNE Canada regional cabled ocean network, located in the Northeast Pacific, is part of the Ocean Networks Canada (ONC) Observatory. The network extends the internet from the rocky coast to the deep abyss. It gathers live data and video from instruments on the seafloor, making them freely available to the world, 24/7. NEPTUNE Canada is the world's first regional-scale underwater ocean observatory network that plugs directly into the Internet.</p> <p>People everywhere can "surf the seafloor", while ocean scientists run deep-water experiments from labs and universities anywhere around the world. NEPTUNE Canada is located off the west coast of Vancouver Island, British Columbia. The network, which extends across the Juan de Fuca plate, gathers live data from a rich constellation of instruments deployed in a broad spectrum of undersea environments. Data are transmitted via high-speed fibre optic communications from the seafloor to an innovative data archival system at the University of Victoria. This system provides free Internet access to an immense wealth of data, both live and archived throughout the life of the planned 25-year project. http://www.neptunecanada.ca of 11 May 2012.</p>	Since 2009	CA
ICOS – Integrated Carbon Observation System	<p>ICOS is a new European Research Infrastructure for quantifying and understanding the greenhouse balance of the European continent and of adjacent regions. ICOS aims to build a network of standardized, long-term, high precision integrated monitoring of:</p> <ul style="list-style-type: none"> _ atmospheric greenhouse gas concentrations of CO₂, CH₄, CO and radiocarbon-CO₂ to quantify the fossil fuel component _ ecosystem fluxes of CO₂, H₂O, and heat together with ecosystem variables. <p>The ICOS infrastructure will integrate terrestrial and atmospheric observations at various sites into a single, coherent, highly precise dataset. These data will allow a unique regional top-down assessment of fluxes from atmospheric data, and a bottom-up assessment from ecosystem measurements and fossil fuel inventories. Target is a daily mapping of sources and sinks at scales down to about 10 km, as a basis for understanding the exchange processes between the atmosphere, the terrestrial surface and the ocean. http://icos-infrastructure.eu/ of 11 May 2012.</p>	Preparation: 2008-2011; Operation: 2012-2031	BE, CH, CZ, DE, DK, ES, FI, FR, IE, IT, NL, NO, PL, PT, SE, UK
HAFOS – Hybrid Arctic/ Antarctic Float Observation System	<p>HAFOS provides oceanic data under the sea ice cover. To measure the variations of the watermass properties of the warm deep water with sufficient spatial and temporal resolution to be able to conclude on the origin and the effect of the changes a float system is established in the HAFOS project, which is providing comparable data as the Argo project (see below) in the open ocean. http://www.awi.de/en/research/research_divisions/climate_science/observational_oceanography/projects/ of 11 May 2012. http://www.whoi.edu/science/po/arcticgroup/projects/ipworkshoppresentations/ipworkshop_awi.pdf of 11 May 2012.</p>	Prototype expected: 2007/2008	DE
DONET – Dense Ocean-floor Network System for Earthquakes and Tsunamis	<p>DONET is a unique development programme of submarine cabled real-time seafloor observatory network. This programme has aimed to establish the technology of large scale real-time seafloor research and surveillance infrastructure for earthquake, geodetic and tsunami observation and analysis. The first phase of this programme has been carried out since 2006 to settle on To-Nankai region in Nankai trough as the target of observation. The initial plan sched-</p>	1st phase: since 2006; 2nd: since 2010	JP

	<p>uled to install twenty sets of complex cabled monitoring observatories to cover the active seismogenic zone of To-Nankai earthquakes.</p> <p>http://www.jamstec.go.jp/jamstec-e/maritec/donet/ of 11 May 2012.</p>		
MARS - Monterey Accelerated Research System	<p>Providing electrical power and data connections for new research instruments in the deep-sea. That's the vision behind the MARS. The system consists of a 52 km (32 mile) undersea cable that carries data and power to a "science node" 891 m (2,923 feet) below the surface of Monterey Bay. More than eight different science experiments can be attached to this main hub with eight nodes. Additional experiments can be daisy-chained to each node. The undersea cable was installed in 2007.</p> <p>http://www.mbari.org/mars/ of 11 May 2012.</p>	Initiation: 2002; Operation: since 2008	US
HAUSGARTEN - Deep-sea long-term observatory	<p>Enabling the detection of expected changes in abiotic and biotic parameters in a transition zone between the northern North Atlantic and the central Arctic Ocean, the Alfred Wegener Institute for Polar and Marine Research established the deep-sea long-term observatory HAUSGARTEN in the eastern Fram Strait. HAUSGARTEN comprises 16 permanent stations covering a depth range of 1.000 to 5.500 m water depth. Repeated sampling and the deployment of moorings and different free-falling systems, which act as observation platforms, has taken place since the beginning of the studies in summer 1999. At regular intervals, a Remotely Operated Vehicle (ROV) is used for targeted sampling, the positioning and servicing of autonomous measuring instruments and the performance of <i>in situ</i> experiments. A 3.000 m depth-rated Autonomous Underwater Vehicle (AUV) will further extend the sensing and sampling programmes. HAUSGARTEN represents a key site of the European Network of Excellence ESONET (European Seas Observatory Network) and is a member of the German Long Term Ecological Research - Network (LTER-D).</p> <p>http://www.awi.de/en/research/deep_sea/deep_sea_ecology/deep_sea_long_term_observatory_hausgarten/ of 11 May 2012.</p>	Repeated samplings: since 1999	DE
<i>Research Vessels (RV), Remotely Operated Vehicles (ROV)</i>			
RV Maria S. Merian	<p>The 95 m multipurpose Research Vessel is for use in the Atlantic Ocean to the edge of the ice, for the North and Baltic Sea, but also suitable for trips to the equator.</p> <p>http://www.io-warnemuende.de/tl_files/forschung/schiffe/datenblatt_merian.pdf of 11 May 2012.</p> <p>http://www.io-warnemuende.de/fs-maria-s-merian.html (only in German) of 11 May 2012.</p>	Since 2006	DE
ROV QUEST	<p>The ROV QUEST, based at Marum, is dedicated to scientific work and research operations in water depths down to 4000 m.</p> <p>http://www.marum.de/QUEST_4000_m.html of 11 May 2012.</p>	Since 2003	DE
RV Polarstern	<p>Since the ship was first commissioned on December 9th 1982 Polarstern has completed a total of more than fifty expeditions to the Arctic and Antarctic. It was specially designed for working in the polar seas and is currently one of the most sophisticated polar research vessels in the world. The Polarstern spends almost 310 days a year at sea. Between November and March it usually sails to and around the waters of the Antarctic, while the northern summer months are spent in Arctic waters.</p> <p>http://www.awi.de/en/infrastructure/ships/polarstern/ of 11 May 2012</p>	Since 1982	DE

<i>Programmes, networks and organizations</i>			
EuroSITES	Successor project is FixO3 (Fixed point open ocean observatory network). EuroSITES forms an integrated European network of nine deep-ocean observatories sited in waters off the continental shelf and of greater than 1000 m depth, measuring variables from sea surface to sea floor. EuroSITES will integrate and enhance the existing European open-ocean observational capacity to encompass the ocean interior, seafloor and subseafloor. http://www.eurosites.info/ of 11 May 2012.	Launch: 2008	UK (coordination), 13 partners across Europe, Cape Verde Islands
Arctic-ROOS – Arctic Regional Ocean Observing System	Arctic ROOS aims to foster and develop Arctic ocean observing and forecasting systems. Objectives: (1) Build a circumpolar Arctic GOOS Regional Alliance as a contribution to the Global Ocean Observing System (GOOS) (2) Develop operational oceanography in the Arctic and sub-Arctic seas by: _ In situ observing systems (ice buoys, ships, moorings, floats, drifters, etc.) _ Satellite remote sensing using active and passive microwave, optical and infrared data from polar orbiting satellites _ Modelling, data assimilation, now casting, short-term forecasting, seasonal forecasting, hind casting and validation _ Dissemination of information products to users. www.arctic-roos.org of 11 May 2012. http://www.damocles-eu.org/artman2/uploads/1/poster_Sopot_task_7.1.pdf of 11 May 2012.	Since 2007	DE, DK, FI, FR, NO, PL, RU, SE, UK
NOON – Norwegian Ocean Observing Network	The Vision of NOON is to actively engage Norway in research based mapping of the sea bed and understanding of the natural processes and phenomena and processes created by human interventions. The main objective is the long term monitoring of environmental processes related to the interaction between hydrosphere, geosphere and biosphere during global warming. The data enable the understanding of the dynamics related to change, the robustness and the effect of influence from ocean current systems, fisheries, sediment transport processes, installations and pollution. The sub objectives are: _ Establish a cable-based test ocean observatory at an O&G (oil and gas) installation together with NCE (Norwegian Centres of Expertise) Subsea, where EMSO (European Multidisciplinary Seafloor Observatory)/ESONET (European Seafloor Observatory Network) is invited to participate, _ Establish a fjord laboratory (a cable-based test ocean observatory in a fjord), _ Establish a larger cable-based observatory off the Norwegian continental shelf. NOON has submitted a proposal on research infrastructure (Cabled Observatories for Monitoring of the Ocean System - COSMOS) to the Research Council of Norway: The vision of the COSMOS project is to establish a next-generation infrastructure for a permanent and interactive presence in the ocean, enabling sustainable monitoring and management of the marine environment. This includes understanding ecosystems, marine resources, bio-geological processes, and challenges from global climate and environmental change. The observatory will contribute to operational forecasting of natural environmental disasters, climate change and its effects. http://oceanobservatory.com/ of 11 May 2012.	Since 2007	NO

ISAC – International Study of Arctic Change	ISAC is a programme that provides a scientific and organizational framework focused around its key science questions for pan-Arctic research including long-term planning and priority setting. ISAC establishes new and enhances existing synergies among scientists and stakeholders engaged in arctic environmental research and governance. ISAC promotes observations, synthesis, and modelling activities to provide an integrated understanding of the past, present and future arctic environment needed for responding to change. ISAC fosters links between arctic environmental change initiatives and relevant global programmes. http://www.arcticchange.org/ of 11 May 2012.	Since 2003	SE (office location)
ASOF – Arctic/ Sub-arctic Ocean Fluxes	ASOF is an international programme on the oceanography of the Arctic and Subarctic seas and their role in climate. ASOF focuses on ocean fluxes of mass, heat, freshwater, and ice in the Arctic and Subarctic oceans. The first ASOF phase had the overall goal to: measure and model the variability of fluxes between the Arctic Ocean and the Atlantic Ocean with the view to implementing a longer-term system of critical measurements needed to understand the high-latitude ocean's steering role in decadal climate variability. http://asof.npolar.no/ of 11 May 2012.	1st phase: 2000–2008; 2nd: since 2008	Sponsored by 16 agencies and institutes in 7 countries
GMES – Global Monitoring for Environment and Security	GMES is the European Programme for the establishment of a European capacity for Earth Observation. In practice, GMES consists in a complex set of systems which collects data from multiple sources (earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors), processes these data and provides users with reliable and up-to-date information through the services. Over the last 10 years, numerous research and development projects have contributed to the development of the GMES infrastructure and services. http://gmes.info/ of 11 May 2012.	Since 1998; Full operation: 2014	ESA, EU
CLIVAR – Climate Variability and Predictability	CLIVAR is an international research programme dealing with climate variability and predictability on time-scales from months to centuries. CLIVAR is the World Climate Research Programme (WCRP) project that addresses climate variability and predictability, with a particular focus on the role of ocean-atmosphere interactions in climate. It works closely with its companion WCRP projects on issues such as the role of the land surface, snow and ice and the role of stratospheric processes in climate. CLIVAR is one of the four core projects of the WCRP. WCRP was established in 1980 under the joint sponsorship of the International Council for Science (ICSU) and the World Meteorological Organisation (WMO), and since 1992 has also been sponsored by the Intergovernmental Oceanographic Commission (IOC) of UNESCO (United Nations Educational, Scientific and Cultural Organization). http://www.clivar.org/ of 25 June 2012.	Established: 1995	International, UK and US (coordination)
Planned research infrastructures/under construction			
<i>Observation Systems</i>			
FRAM – Frontiers in Arctic marine Monitoring Observatory	The planned FRAM integrated marine observation system will be installed in Fram Strait, the key region for exchange between the North Atlantic and Arctic Ocean. It will combine existing observatories of the Alfred Wegener Institute (AWI) into a multidisciplinary Earth-monitoring system. FRAM provides new, innovative sensor modules and interfaces, which facilitate the study of complex interactions between physical, chemical, biological and geological components of the Arctic Ocean. FRAM contributes to improved monitoring of seasonal, inter-annual and long-term environ-	Construction: 2013–2016	DE (coordination), FR, NO, PL, UK

	<p>mental changes in this climate-sensitive region – from the coast and ocean surface, to the deep sea. Monitoring of local variations will be linked with information about the global climate system.</p> <p>http://www.helmholtz.de/fileadmin/user_upload/publikationen/pdf/11_Helmholtz_Roadmap_EN_WEB.pdf of 10 September 2012.</p>		
SIOS – Svalbard Integrated Observation System	<p>SIOS is the central node in the global monitoring of the High Arctic. The goal of SIOS is to understand ongoing and future environmental and climate related changes which requires an integrated - Earth System - approach, in particular in the polar regions. While Earth System Models already have reached far in the integration process, observation systems have not been developed with the same systematic approach so far. SIOS envisages to fill this gap at a regional scale by:</p> <ul style="list-style-type: none"> _ Establishing an Arctic Earth observing system in and around Svalbard that integrates and complements existing research and monitoring platforms for geophysical, biological and chemical studies with the aim to match integrated models; _ Utilizing satellite remote sensing data that are available via the Svalbard receiving stations and the space agencies using this station; _ Building up close cooperation with other ESFRI (European Strategy Forum on Research Infrastructures) projects that plan activities in the European Arctic, existing regional research networks in the European Arctic and to pan-Arctic initiatives such as the Sustained Arctic Observing Network (SAON). <p>http://www.sios-svalbard.org/ of 11 May 2012.</p>	Preparation: until 2013	CN, DE, DK, FI, FR, IT, JP, KR, NL, NO (leader), PL, RU, SE, UK
EMSO – European Multi-disciplinary Seafloor Observatory	<p>EMSO is the European infrastructure composed by seafloor observatories for long-term monitoring of environmental processes related to ecosystems, climate change and geohazards. EMSO nodes are placed in specific marine sites of the European Continental Margin from the Arctic to the Black Sea through the Mediterranean Basin. EMSO will constitute the sub-sea segment of GMES (Global Monitoring for Environment and Security) and GEOSS (Global Earth Observation System of Systems).</p> <p>http://www.emso-eu.org/management/images/documents/EMSOposter_VISO.pdf of 11 May 2012.</p>	Preparation: 2008-2012	DE, ES, FR, GR, IE, IT (leader), NL, NO, PT, SE, TR, UK
<i>E-infrastructures</i>			
OOI CI – Ocean Observatories Initiative Cyberinfrastructure	<p>OOI Cyberinfrastructure manages and integrates data from many different sources, including OOI sensors, select ocean community models, and external observatories. Data from three external observatories are integrated: the Integrated Ocean Observing System (IOOS), the World Meteorological Organization (WMO), and NEPTUNE Canada. The integration project schedules are staggered; they have started working on IOOS integration already, with NEPTUNE.</p> <p>http://ci.oceanobservatories.org/ of 11 May 2012.</p>	Start of five-year construction period: 2009	US
<i>Programmes, networks and organizations</i>			
OOI – Ocean Observatories Initiative	<p>The OOI, a project funded by the National Science Foundation, is planned as a networked infrastructure of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean and seafloor. The OOI will be one fully integrated system collecting data on coastal, regional and global scales.</p> <p>http://www.oceanobservatories.org of 11 May 2012.</p>	1st data expected: 2012; Going online: late 2014	US

GEOSS – Global Earth Observation System of Systems	This “system of systems” will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets. The “GEOPortal” offers a single Internet access point for users seeking data, imagery and analytical software packages relevant to all parts of the globe. http://www.earthobservations.org/geoss.shtml of 11 May 2012.	Plan for ten-year imple- menta- tion: 2005- 2015	75 coun- tries in- volved
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Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as “About us”). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Appendix 2.5 Complementary research infrastructures of EPOS

The following chart contains the major complementary infrastructures of EPOS. The list is not exhaustive and the listed complementary research infrastructures have mainly been provided by the responsible scientists. For EPOS, there is no competing research infrastructure.

The complementary projects are sorted in the categories “Existing research infrastructures”, “Planned research infrastructures/under construction” and “Expired research infrastructures”. Within each category, the projects are classified into the following sub-categories:

- _ Observation Systems
 - _ Ground-based
 - _ Satellites
 - _ E-infrastructures
 - _ Programmes, networks and organizations (these mostly are beneficiaries of research infrastructures)

Within these categories, the most recent project is mentioned first.

Table 6: Complementary research infrastructures of EPOS

EPOS			
Name	Brief description and Internet link	Time frame	Involved countries
Existing research infrastructures			
<i>Observation Systems</i>			
GITEWS – German-Indonesian Tsunami Early Warning System	Different Components of the Tsunami Early Warning System: seismometer, global positioning system (GPS) station, risk maps and education of the population, buoy, inauguration of the early warning centre, simulation, satellite-hub, warning centre, tide gauge. GEOFON was appointed to design and implement the land based seismic component of GITEWS. Transfer of ownership to Indonesia in 2011. http://www.gitews.org/index.php?id=23&L=1 of 11 May 2012.	Development launch: 2005	DE, ID
<i>Ground-based</i>			
USArray Part of EarthScope	USArray is a 15-year programme to place a dense network of permanent and portable seismographs across the continental US. The seismographs record local, regional, and distant (teleseismic) earthquakes. The USArray consists of four important observatories. Key USArray facilities include the Transportable Array, which is being deployed progressively across the 48 contiguous states and Alaska, and the pool of portable seismometers in the Flexible Array. They directly permit acquisition of the requisite seismic data for imaging subsurface structure at multiple scales and for studying earthquakes in many environments. USArray also consists of permanent broadband seismic stations—	Since 2003	US

	Reference Network—that provide a large-aperture, fixed grid of observing sites essential for tying together the 70-km-spaced grid of sequential Transportable Array deployments. Data acquired by USArray’s Magnetotelluric Facility supplement the seismic data by providing images of crustal and lithospheric conductivity structure. Transportable Array and Reference Network station distribution together provide unprecedented spatial coverage and uniformity of seismic wavefield sampling, enabling well-established and new seismological analyses to reveal deep Earth structure and to characterize earthquake sources throughout the continent. The scientific community is able to conduct a host of research projects with Transportable Array data and with separately funded field deployments of Flexible Array sensors. Data collected from these EarthScope facilities are openly available to the scientific and educational communities. http://www.usarray.org/ of 11 May 2012.		
GERESS Array - GERman Experimental Seismic System	The GERESS Array in the Bavarian Forest (<i>Bayerischer Wald</i>) consists of 24 shortperiod stations and a three-component broadband station in four concentric rings with a maximum diameter of about 4 km. http://www.bgr.bund.de/EN/Themen/Seismologie/___Content_alt/Seismo_Stationen_en_alt/seismo_stationen_node_en.html of 11 May 2012. http://www.bgr.bund.de/DE/Themen/Erdbeben-Gefaehrdungsanaly-sen/Seismologie/Kernwaffenteststopp/Ueberwachungsnetz/Deutsche-IMS-Stationen/GERES/geres_inhalt.html (in German only) of 11 May 2012.	Construction: 1989–1991	DE
GRF - Gräfenberg Array	Thirteen broadband stations in the Franconian mountain region (<i>Fränkische Alb</i>) form the Gräfenberg Array (GRF). It extends about 100 km north-south and about 40 km in east-west direction. http://www.bgr.bund.de/EN/Themen/Seismologie/___Content_alt/Seismo_Stationen_en_alt/seismo_stationen_node_en.html of 11 May 2012.	Since 1976; Full operation: since 1980	DE
<i>Satellites</i>			
ESA Swarm mission	The objective of the Swarm mission is to provide the best ever survey of the geomagnetic field and its temporal evolution, and gain new insights into improving our knowledge of the Earth’s interior and climate. The Swarm concept consists of a constellation of three satellites in three different polar orbits between 400 and 550 km altitude. High-precision and high-resolution measurements of the strength and direction of the magnetic field will be provided by each satellite. In combination, they will provide the necessary observations that are required to model various sources of the geomagnetic field. Global positioning system (GPS) receivers, an accelerometer and an electric field instrument will provide supplementary information for studying the interaction of the magnetic field with other physical quantities describing the Earth system – for example, Swarm could provide independent data on ocean circulation. http://www.esa.int/esaLP/ESA3QZJE43D_LPswarm_0.html of 11 May 2012. http://en.wikipedia.org/wiki/Swarm_%28spacecraft%29 of 11 May 2012.	Launch planned: before mid-2012	ESA
<i>E-infrastructures</i>			
VERCE - Virtual Earthquake and	The strategy of VERCE, driven by the needs of data-intensive applications in data mining and modelling, aims to provide a comprehensive architecture and framework adapted to the	Start: 2011	DE, FR, IT, NL, UK

seismology Research Community e- science envi- ronment in Europe	scale and the diversity of these applications, and integrating the community Data infrastructure with Grid and High Performance Computing (HPC) infrastructures. http://www.verce.eu/ of 11 May 2012.		
NERA – Network of European Research Infrastruc- tures for Earthquake Risk Assess- ment and Mitigation	NERA (2010-2014) is an infrastructure project that integrates key research infrastructures in Europe for monitoring earthquakes and assessing their hazard and risk. NERA integrates and facilitates the use of these infrastructures and access to data for research, provides services and access to earthquake data and parameters, and hazard and risk products and tools. NERA activities are coordinated with other relevant European-Commission-projects and European initiatives, and contribute to the ESFRI (European Strategy Forum on Research Infrastructures) EPOS infrastructure and the OECD GEM (Global Earthquake Model) programme. http://www.nera-eu.org/ of 11 May 2012.	2010- 2014	AT, BE, CH, DE, ES, FR, GR, IS, IT, NL, NO, PT, RO, TR, UK
TRIDEC – Collaborative, Complex and Critical Deci- sion Support in Evolving Crises	TRIDEC focuses on new technologies for real-time intelligent information management in collaborative, complex critical decision processes in earth management. Key challenge is the construction of a communication infrastructure of interoperable services through which intelligent management of dynamically increasing volumes and dimensionality of information and data is efficiently supported; where groups of decision makers collaborate and respond quickly in a decision-support environment. The research and development objectives include the design and implementation of a robust and scalable service infrastructure supporting the integration and utilisation of existing resources with accelerated generation of large volume of data. These include sensor systems, geo-information repositories, simulation- and data-fusion-tools. http://www.tridec-online.eu/ of 11 May 2012.	Since 2010	AT, DE, IT, PT, TR, UK
<i>Programmes, networks and organizations</i>			
GEOFON	GEOFON seeks to facilitate cooperation in seismological research and earthquake and tsunami hazard mitigation by providing rapid transnational access to seismological data and source parameters of large earthquakes, and keeping these data accessible in the long term. Rapid global earthquake information is a major task of the GEOFON Programme of GFZ (German Research Centre for Geosciences) Potsdam. As a key node of the European Mediterranean Seismological Centre (EMSC) GFZ has the responsibility for rapid global earthquake notifications. GFZ has also become a driving force in earthquake monitoring for tsunami warning in the Mediterranean and the North-East Atlantic as well as for the Indian Ocean. Most of the acquired European networks are members of the Virtual European Broadband Seismic Network (VEBSN). The GFZ Seismological Data Archive (GIDA) is a major node in the European Integrated Data Archive (EIDA). GEOFON is part of the Modular Earth Science Infrastructure (MESI) housed at the GFZ providing services within the “Permanent networks”, “Data Distribution and Archiving” and “Communications” groups of MESI. http://geofon.gfz-potsdam.de/ of 11 May 2012.	-	DE
EarthScope	The EarthScope scientific community conducts multidisciplinary research across the Earth sciences utilizing freely available data from instruments that measure motions of the Earth’s surface, record seismic waves, and recover rock samples from depths at which earthquakes originate. EarthScope deploys thousands of seismic, global positioning	Since 2004	US (NSF)

	<p>system (GPS), and other geophysical instruments to study the structure and evolution of the North American continent and the processes the cause earthquakes and volcanic eruptions. The Plate Boundary Observatory (PBO) is the geodetic component of EarthScope, operated by UNAVCO (University Navstar Consortium). The PBO consists of several major observatory components: a network of 1100 permanent, continuously operating GPS stations many of which provide data at high-rate and in real-time, 78 borehole seismometers, 74 borehole strainmeters, 28 shallow borehole tiltmeters, and six long baseline laser strainmeters. These instruments are complemented by InSAR (interferometric synthetic aperture radar) and LiDAR (light detection and ranging) imagery and geochronology acquired as part of the GeoEarthScope initiative. Further observatories in addition to PBO are USArray and San Andreas Fault Observatory at Depth (SAFOD). UNAVCO is a consortium of research institutions that supports and promotes a better understanding of Earth by using high-precision techniques to measure crustal deformation.</p> <p>http://earthscope.org/ of 11 May 2012.</p>		
ECGN – European Combined Geodetic Network	<p>Objectives of the ECGN as an integrated European Reference System for Spatial Reference and Gravity are:</p> <ul style="list-style-type: none"> _ Maintenance of a long time stability of the terrestrial reference system with an accuracy of 10⁻⁹ for Europe especially in the height component _ In-situ combination of global positioning system (GPS) with physical height and other Earth gravity parameters in 1 cm accuracy level _ Modelling of influences of time-dependent parameters of the solid Earth of the Earth gravity field, the atmosphere, the oceans, the hydrosphere for different applications of positioning. <p>Among the further aims rank</p> <ul style="list-style-type: none"> _ contribution to the European gravity field modelling _ the modelling of gravity field components to validate the satellite gravity missions CHAMP (CHALLENGING Minisatellite Payload), GRACE (Gravity Recovery and Climate Experiment) and GOCE (Gravity field and steady-state Ocean Circulation Explorer) _ and to be a platform for further geo-components [Global Monitoring for Environment and Security (GMES), Global Earth Observation System of Systems (GEOSS), Global Geodetic Observation System (GGOS)]. <p>The ECGN is considered as a European contribution to the International Association of Geodesy (IAG) project GGOS. The primary concern of the project consists in connecting the height component with the gravity determination while allowing for measuring data that are acquired in the European coastal regions and above adjacent seas.</p> <p>http://www.bkg.bund.de/geodIS/ECGN/EN/Home/homepage__node.html__nnn=true of 11 May 2012.</p>	1st call for participation: 2003; 2nd call planned	BE, CZ, DE, FI, FR, HU, LU, MC, UK
Hi-net – High sensitivity seismograph network	<p>Hi-net consists of 696 stations. At most of Hi-net stations strong-motion seismographs are also equipped both at depth and the ground surface. The National Research Institute for Earth Science and Disaster Prevention (NIED) Hi-net, uniformly covers the Japanese Islands with a spacing of 20-30 km. NIED Hi-net borehole stations are equipped with a three-component short-period velocity seismometer, three-component strong motion accelerometer and horizontal-component high-sensitivity accelerometer. The high-sensitivity accelerometer covers a wide response range</p>	Since 2003	JP

	<p>from ground tilting to long-period seismic waves. There are four advantages of Hi-net; high sensitivity, high signal-to-noise ratio, broadband property of sensors and high density of stations. As a result, detection capability for micro earthquakes has been dramatically improved and some new geophysical phenomena have been discovered.</p> <p>http://www.terrapub.co.jp/journals/EPS/pdf/2004/5608/5608xv.pdf of 11 May 2012.</p> <p>http://adsabs.harvard.edu/abs/2008AGUFM.G21B0696O of 11 May 2012.</p> <p>http://rsi.aip.org/resource/1/rsinak/v76/i2/p021301_s1?isAuthorized=no of 11 May 2012.</p> <p>http://www.hinet.bosai.go.jp/ (in Japanese only) of 11 May 2012.</p>		
Planned research infrastructures/under construction			
<i>Observation Systems</i>			
EMSO – European Multidisciplinary Seafloor Observatory	<p>EMSO is the European infrastructure composed by seafloor observatories for long-term monitoring of environmental processes related to ecosystems, climate change and geohazards. EMSO nodes are placed in specific marine sites of the European Continental Margin from the Arctic to the Black Sea through the Mediterranean Basin. EMSO will constitute the sub-sea segment of GMES (Global Monitoring for Environment and Security) and GEOSS (Global Earth Observation System of Systems).</p> <p>http://www.emso-eu.org/management/images/documents/EMSOposter_VISO.pdf of 11 May 2012.</p>	Preparation: 2008-2012	FR, DE, ES, GR, IE, IT (leader), NL, NO, PT, SE, TR, UK
<i>E-infrastructures</i>			
EUDAT	<p>EUDAT project aims to contribute to the production of a Collaborative Data Infrastructure (CDI). The project's target is to provide a pan-European solution to the challenge of data proliferation in Europe's scientific and research communities.</p> <p>http://www.eudat.eu/ of 11 May 2012.</p>	Pilot service: 2012; Full operation: 2014	13 countries; FI (coordination)
Expired research infrastructures			
<i>Satellites</i>			
CHAMP – CHALLENGING Minisatellite Payload	<p>CHAMP is a German small satellite mission for geoscientific and atmospheric research and applications, managed by GFZ (German Research Centre for Geosciences). With its highly precise, multifunctional and complementary payload elements [magnetometer, accelerometer, star sensor, global positioning system (GPS) receiver, laser retro reflector, ion drift meter] and its orbit characteristics (near polar, low altitude, long duration) CHAMP will generate for the first time simultaneously highly precise gravity and magnetic field measurements over a 5 year period. In addition with the radio occultation measurements onboard the spacecraft and the infrastructure developed on ground, CHAMP will become a pilot mission for the pre-operational use of spaceborne GPS observations for atmospheric and ionospheric research and applications in weather prediction and space weather monitoring. Follow up mission is GRACE (Gravity Recovery and Climate Experiment).</p> <p>http://op.gfz-potsdam.de/champ/ of 11 May 2012.</p>	End: 2010	DE

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as "About us"). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

The following chart contains the major complementary infrastructures of EU-OPENSREEN. The list is not exhaustive and the listed complementary research infrastructures have mainly been provided by the responsible scientists. For EU-OPENSREEN, there is no competing research infrastructure.

The complementary projects are sorted in the categories “Forerunners” and “Existing research infrastructures”. All projects can be classified as “Screening facilities”.

The most recent project is mentioned first.

Table 7: Complementary research infrastructures of EU-OPENSREEN

EU-OPENSREEN			
Name	Brief description and Internet link	Time frame	Involved countries
Forerunners			
<i>Screening facilities</i>			
ChemBioNet - Network Supporting Academic Chemical Biology Research	The ChemBioNet was initiated by biologists and chemists from academia who realized the need for interdisciplinary open access platforms to support research projects for systematic usage of small molecules to explore biological systems. This initiative wants to provide chemists with bioprofiles for their unique synthetic molecules and biologists developing unique assay systems, with access to high throughput technologies to identify compounds useful for dosage dependent, temporally or locally controlled interference with biological functions. In summary a novel discipline termed Chemical Biology. http://www.chembionet.info/index.php?id=6 of 11 May 2012.	Since 2009	DE (leader) (five partner institutes and joint Chemical Biology Division)
Existing research infrastructures			
<i>Screening facilities</i>			
Broad Institute – Chemical Biology Platform	The Chemical Biology Platform empowers researchers in the broad community to discover small-molecule probes (used to understand cell circuitry and disease biology) and small-molecule therapeutics (used to treat disease). A central goal of chemical biology is to harness the power of synthetic organic chemistry to discover and to elucidate molecular pathways fundamental in cellular, developmental and disease biology. The creation and use of small molecules to probe the genome is a fertile area of research that facilitates the translation of biological insights into powerful new medicines. The Chemical Biology Platform comprises scientists from a wide range of disciplines (chemistry, biology, computational science, software and automation engineering), innovating and working cooperatively towards these goals. The platform team works in an extraordinary research environment that has high-throughput research capabilities in organic synthesis and small-molecule screening. Informatics and computational analysis teams integrate these capabilities to enable collaborating researchers to design new experiments and members of the global re-	Since 2004	US

	<p>search community to benefit from the resulting discoveries. http://www.broadinstitute.org/scientific-community/science/platforms/chemical-biology of 18 May 2012.</p>		
ESP – European Screening Port	<p>European ScreeningPort is a public private partnership which offers fee-for-service small molecule screening to academic institutions.</p> <p>The goal is to transform the exciting new science, taking place at the benchtops of Europe’s academic laboratories, into chemical tools and high quality assets of explicit value to potential major partners in the pharmaceutical industry and - ultimately to patients. http://www.screeningport.com/ of 14 May 2012.</p>	Since 2007	BE, DE, UK, Scandinavia
IMI – The Innovative Medicines Initiative	<p>IMI is Europe’s largest public-private partnership aiming to improve the drug development process by supporting a more efficient discovery and development of better and safer medicines for patients. With a 2 billion euro budget, IMI supports collaborative research projects and builds networks of industrial and academic experts in Europe that will boost innovation in healthcare. Acting as a neutral third party in creating innovative partnerships, IMI aims to build a more collaborative ecosystem for pharmaceutical research and development (R&D). IMI will provide socio-economic benefits to European citizens, increase Europe’s competitiveness globally and establish Europe as the most attractive place for pharmaceutical R&D. IMI supports research projects in the areas of safety and efficacy, knowledge management and education and training. Projects are selected through open calls for proposals.</p> <p>The research consortia participating in IMI projects consist of: (1) large biopharmaceutical companies that are members of European Federation of Pharmaceutical Industries and Associations (EFPIA), (2) and a variety of other partners, such as: small- and medium-sized enterprises, (3) patients’ organisations, (4) universities and other research organisations, (5) hospitals, (6) regulatory agencies, (7) any other industrial partners.</p> <p>IMI is a Joint Undertaking between the European Union and the EFPIA. http://www.imi.europa.eu/ of 14 May 2012.</p>	FP7 2007-2013	Industry, EU
LDC – Lead Discovery Center GmbH	<p>LDC was established in 2008 by the technology transfer organization Max Planck Innovation (MI), as a novel approach to capitalize on the potential of excellent basic research for the discovery of new therapies for diseases with high medical need. The LDC seeks to advance promising research projects into the development of novel medicines in a professional manner. There is a great fundamental need for novel drugs. In order to respond to this need, the pharmaceutical industry is increasingly interested in innovative compounds that can become the basis for new drugs. With a world-class team of interdisciplinary scientists, drug discovery experts, pharmacologists and seasoned project managers, the LDC offers the full scope of drug discovery support – from target to lead – according to the highest industry standards. As an independent company with an entrepreneurial outlook, the LDC closely collaborates with research institutions, universities and industry. Our aim is to transform promising early-stage projects into innovative pharmaceutical leads that reach initial proof-of-concept in animals. http://www.lead-discovery.de/english/home.htm of 11 May 2012.</p>	Since 2008	DE (research organizations, universities and companies)

<p>MLP – Molecular Library Program of the National Institutes of Health (NIH)</p>	<p>The flagship of the MLP is the Molecular Libraries Probe Production Centers, a network of national laboratories, whose aim is generate novel small molecule probes by performing HTS (High-Throughput-Screening), secondary screens and medicinal chemistry. The assays for these probes are sourced from the scientific community. Small molecules, often with molecular weights of 500 or below, have proven to be extremely important to researchers to explore function at the molecular, cellular, and in vivo level. Such molecules have also been proven to be valuable for treating diseases, and most medicines marketed today are from this class. A key challenge is to identify small molecules effective at modulating a given biological process or disease state.</p> <p>The Molecular Libraries Roadmap, through one of its components, the Molecular Libraries Probe Production Centers Network (MLPCN), offers biomedical researchers access to the large-scale screening capacity, along with medicinal chemistry and informatics necessary to identify chemical probes to study the functions of genes, cells, and biochemical pathways. This will lead to new ways to explore the functions of genes and signalling pathways in health and disease.</p> <p>NIH anticipates that these projects will also facilitate the development of new drugs, by providing early stage chemical compounds that will enable researchers in the public and private sectors to validate new drug targets, which could then move into the drug-development pipeline. This is particularly true for rare diseases, which may not be attractive for development by the private sector.</p> <p>http://mli.nih.gov/mli/ of 18 May 2012.</p>	<p>Since 2005; MLSCN (Molecular Libraries Screening Centers Network) Pilot phase end: 2008; MLPCN Production phase: since 2008</p>	<p>US</p>
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Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as “About us”). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

The following list contains the major complementary infrastructures of GEBI. The list is not exhaustive and the listed complementary research infrastructures have mainly been provided by the responsible scientists. For GEBI, there is no competing research infrastructure.

All complementary projects belong to the category “Existing research infrastructures”. Within this category, the projects are classified into the following sub-categories:

_ Imaging facilities

_ E-infrastructures

Within these categories, the most recent project is mentioned first.

Table 8: Complementary research infrastructures of GEBI

GEBI			
Name	Brief description and Internet link	Time frame	Involved countries
Existing research infrastructures			
<i>Imaging facilities</i>			
ALMF - Advanced Light Microscopy Facility	Biological imaging facilities are at the laboratory for Advanced Light Microscopy Facility at EMBL (European Molecular Biology Laboratory) Heidelberg (open access for external scientists). The Advanced Light Microscopy Facility at EMBL in Heidelberg offers a collection of state-of-the-art light microscopy equipment including high-content screening and accessory services. The ALMF was set up as a cooperation between the EMBL and Industry to improve communication between users and producers of high end microscopy technology. To support in-house scientists and visitors in the use of all kinds of microscopy methods for their research. http://www.embl.de/almf/almf_services/about_us/index.html of 18 May 2012.	Since 2010	DE, FR, IT, SE, UK (all leaders)
AMMRF - Australian Microscopy & Microanalysis Research Facility	Established in July 2007 under the Commonwealth Government’s National Collaborative Research Infrastructure Strategy (NCRIS), the AMMRF is a joint venture between Australian university-based microscopy and microanalysis centres. The AMMRF is a national grid of equipment, instrumentation and expertise in microscopy, microanalysis, electron and x-ray diffraction and spectroscopy providing nanostructural characterisation capability and services to all areas of nanotechnology and biotechnology research. The Euro-Biolmaging consortium will sign a collaboration framework with the Australian Microscopy and Microanalysis Research Facility (The AMMRF is a national grid of leading edge expertise and instrumentation in microscopy and microanalysis.) In the collaboration framework, Euro-Biolmaging and AMMRF will collaborate on defining best practice and benchmark performance in the areas of user access and experience; training; operation, facility management; stakeholder reporting; areas of research supported, publication output, research outcomes etc. Furthermore, they envision	Since 2007	AU

	developing joint research programmes in the areas of biological and medical sciences, advanced light microscopy and imaging techniques and instrumentation. http://sydney.edu.au/acmm/about/ammrf.shtml of 18 May 2012.		
ICMICs - In vivo Cellular and Molecular Imaging Centers	The NIH (National Institutes of Health) has recently set up a nation-wide funding programme named “In vivo Cellular and Molecular Imaging Centers (ICMICs)” that supports seven major scientific sites among them five of the above already mentioned MGH (Massachusetts General Hospital), MSKCC (Center for Multidisciplinary In Vivo Molecular Imaging in Cancer), Stanford, UCLA (University of California Los Angeles – Center for In vivo Imaging in Cancer Biology) and the Johns Hopkins University. http://icmic.rad.jhmi.edu/ of 18 May 2012.	Since 2003	US
SAIRP – Small Animal Imaging Resource Programs	Small Animal Imaging Resource Program grants support shared imaging research resources to be used by cancer investigators and support research related to small animal imaging technology. SAIRs will enhance capabilities for conducting basic, clinical, and translational cancer research relevant to the mission of the NCI (National Cancer Institute). Major goals of these resources are to increase efficiency, synergy, and innovation of such research and to foster research interactions that cross disciplines, approaches, and levels of analysis. Building and strengthening such links holds great potential for better understanding cancer, and ultimately, for better treatment and prevention. http://imaging.cancer.gov/programs&resources/specializedinitiatives/sairp of 16 July 2012.	Since 2000	US
<i>E-infrastructures</i>			
ELIXIR - European life-science infrastructure for biological information	The mission of ELIXIR is to construct and operate a sustainable infrastructure for biological information in Europe to support life science research and its translation to medicine and the environment, the bio-industries and society. http://www.elixir-europe.org/ of 14 May 2012. http://ec.europa.eu/research/infrastructures/pdf/esfri-strategy_report_and_roadmap.pdf of 14 May 2012.	Preparation: 2007-2011; Construction: 2011	DE (leader) 14 participating countries

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as “About us”). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Appendix 2.8 Competing and complementary research infrastructures of INSTRUMENT

The following charts contain the major competing and complementary infrastructures of INSTRUMENT. The lists are not exhaustive and the listed competing and complementary research infrastructures have mainly been provided by the responsible scientists.

All complementary projects belong to the category “Existing research infrastructures”. Within this category, the projects are classified into the following sub-categories:

- _ NMR
- _ Sample screening/sample analysis
- _ Sample preparation
- _ Imaging/Microscopy
- _ E-infrastructures

Within these categories, the most recent project is mentioned first.

Table 9: Competing research infrastructures of INSTRUMENT

INSTRUMENT			
Name	Brief description and Internet link	Time frame	Involved countries
Existing research infrastructures			
<i>NMR</i>			
Bio-NMR - Bio-Nuclear Magnetic Resonance	Bio-NMR is a project that aims to further the structuring of the Biological NMR infrastructures, their user community and biological NMR research in Europe into a coherent research community prepared to tackle scientific and biomedical challenges of increasing complexity at the forefront of research worldwide. Bio-NMR involves a comprehensive group of top NMR research infrastructures providing access in Europe and related stakeholders. Bio-NMR completely subsidizes access by European scientists of the instrumentation and expertise available at the partner infrastructures. http://www.bio-nmr.net/ of 21 May 2012.	FP 7: 2007-2013	14 participating countries
CRMN - Centre de Résonance Magnétique Nucléaire À Très Hauts Champs	The Centre for High Field NMR (Nuclear Magnetic Resonance) in Lyon, France, is the home to multidisciplinary research groups actively involved in developing NMR spectroscopy in chemistry, physics and biology included medicine. The Centre is a European large scale NMR facility and hosts the first commercial 1 GHz spectrometer worldwide since August 2009. Partnership for Structural Biology (PSB) with ESRF (European Synchrotron Radiation Facility), ILL (<i>Institut Laue-Langevin</i>) and the Grenoble Outstation of the EMBL (European Molecular Biology Laboratory). http://www.ens-lyon.fr/crmn/crmn/index.html of 6 August 2012.	Since 1998; PSB: since 2002	FR

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as “About us”). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.

Table 10: Complementary research infrastructures of INSTRUMENT

INSTRUMENT			
Name	Brief description and Internet link	Time frame	Involved countries
Existing research infrastructures			
<i>Sample screening/sample analysis</i>			
EU-OPEN-SCREEN - European Infrastructure of Open Screening Platforms for Chemical Biology	EU-OPENSREEN integrates high-throughput screening platforms, chemical libraries, chemical resources for hit discovery and optimisation, bio- and cheminformatics support, and a database containing screening results, assay protocols, and chemical information. http://www.eu-openscreen.de/ of 21 May 2012.	Preparation: 2010-2013; Construction: 2014	DE (leader), 12 participating countries
<i>Sample preparation</i>			
P4EU - EMBL - Protein Production and Purification Partnership	The INSTRUMENT centres [HZI (Helmholtz Centre for Infection Research), EMBL (European Molecular Biology Laboratory) Heidelberg, Grenoble, MPI (Max Planck Institute) und Goethe University Frankfurt] are building-up a social E-network in the area of protein production. This “Protein Production and Purification Partnership” in Europe (P4EU) was founded in 2010. The aim of the partnership is to assemble as many partners from academic research and industry as possible that are involved in the production of recombinant proteins. Together, the exchange of knowledge, new methods and efficient further training in new technologies will be made available for the partners. A new interactive website will provide modern communication possibilities for an efficient exchange of information. http://www.embl.de/pepcore/pepcore_services/P4EU_network/ of 14 May 2012.	Since 2010	DE (leader)
<i>Imaging/Microscopy</i>			
Euro-Biolmaging - European Biomedical Imaging Infrastructure	Euro-Biolmaging will be a European Research Infrastructure for biomedical imaging stretching from basic biological imaging up to medical imaging of humans and populations. It will consist of a number of distributed and strongly coordinated biomedical imaging infrastructures (“nodes”), which will serve European scientists by providing access to, and training in, advanced imaging technologies across the full scale of biological and medical applications. At the same time, the infrastructure will provide the possibility for many existing imaging research institutions or laboratories to contribute to technology development and training. Euro-Biolmaging will also serve as a platform delivering knowledge and expertise, allowing exchange of methodologies and the joint use of acquired data. http://www.eurobioimaging.eu/ of 14 May 2012. http://ec.europa.eu/research/infrastructures/pdf/esfri-strategy_report_and_roadmap.pdf of 14 May 2012.	Preparation: 2010-2013; Construction: 2013-2017; Operation: 2013	DE (leader), 17 participating countries
<i>E-infrastructures</i>			
ELIXIR - European life-science infrastructure for	The mission of ELIXIR is to construct and operate a sustainable Infrastructure for biological information in Europe to support life science research and its translation to medicine and the environment, the bio-industries and society.	Preparation: 2007-2011;	DE (leader), 14 participating countries

biological information	http://www.elixir-europe.org/ of 14 May 2012. http://ec.europa.eu/research/infrastructures/pdf/esfri-strategy_report_and_roadmap.pdf of 14 May 2012.	Construction: 2011	tries
theBiotech-Knows	This platform resembles a social network, but is currently developed into a specialized facility for the analysis of collaborative projects and in particular for protected data exchange. In the long run, it will serve the joint analysis of projects and will offer a simple platform for data exchange. theBiotechKnows is a scientific networking and consulting platform developed by the EPISODE (Exploiting the Potential of Structural Biology through NMR and Associated Technologies) project, with the aim of: <ul style="list-style-type: none"> _ profiling the involved actors (people, companies, institutes...) and their resources _ stimulating the free exchange of information _ facilitating navigation to the points where expertise, equipment or products are available http://thebiotechknows.com/ of 21 May 2012.	-	-

Source: The brief descriptions of the projects have literally been taken from the main project homepages (with all the further leading pages such as "About us"). Generally, only the main project homepages are listed as source of information. If the information on the homepage was not sufficient, further information from scientific publications is used. Those links are listed in the table as well.