HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

THE STRATEGY of the Helmholtz Association

Cutting-edge research for society, science, and business

“But knowledge alone is not the purpose of man on earth. […] Only action gives us a dignified existence; […] thus either the practical application of what has been learned or the increase of science itself must be the purpose.”

Hermann von Helmholtz (1821 – 1894)

Dear readers,

The Helmholtz Association has set itself the task of finding answers to some of the great questions facing our society.

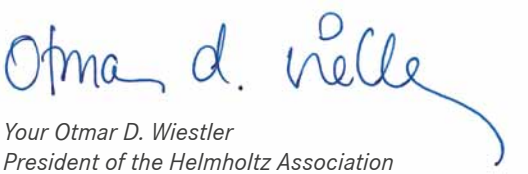
One of the greatest challenges of our time is undoubtedly the digital revolution. In this area, we are at the beginning of a development, the scope and conclusion of which we cannot yet foresee. But one thing is certain: The volumes of data we will be handling in science will continue to grow rapidly in the future. That is why we need a completely new approach to the information and data sciences and a new generation of data scientists, who enable data to give rise to knowledge.

Another major issue that we are poised to address is the energy transition. Helmholtz will make a decisive contribution to this transformation with its research. After all, the success of this major political project will be decisive for our country's prosperity.

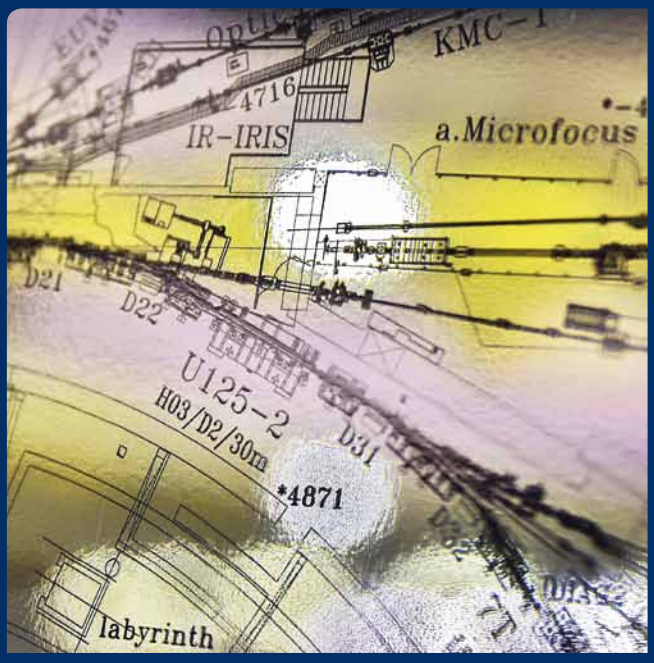
People in Germany will also be able to enjoy well-being that lasts for increasingly extended periods in the future due to rapid progress in medicine. This will make the life of each individual better. We desire to, and we must, continue to advance this development. One of the greatest challenges is still successfully treating or preventing major widespread diseases such as diabetes, cancer, and cardiovascular diseases.

Helmholtz will make a decisive contribution to meeting these and other challenges of our time. To ensure that this advance continues to be successful, we are investing in our research infrastructures and our outstanding staff – our greatest asset. We are creating the best possible research conditions for them so that they can develop their full potential beyond discipline boundaries. Sustained support from the federal government and the federal states is one of the factors that makes this possible.

On the following pages, we will inform you about the focal points of our research and our vision for the future. I wish you a stimulating read.



Your Otmar D. Wiestler
President of the Helmholtz Association










AT A GLANCE

The Helmholtz Association is active in the German and international scientific systems, making an indispensable contribution. With more than 39,000 employees at 18 research centers and an annual budget of about 4,5 billion euros, Helmholtz has the critical mass to use cutting-edge research to address the great questions of our time in a unique manner.

Helmholtz is a registered association with legally independent centers as members. These centers, with their enormous interdisciplinary expertise, are the scientific driving force behind the Association. At its head is a full-time President who moderates the implementation of program-oriented funding. Together with the Helmholtz Centers, he develops the Association's overall strategy and animates it both internally and externally.

The Association's central bodies are the internally staffed Assembly of Members and the externally staffed Senate. The Assembly of Members is made up of members of the boards of directors of the affiliated Helmholtz Centers; the Senate is made up of representatives from the federal and federal state governments, science, business, and other research organizations. The Senate arranges evaluation of the research programs by independent, internationally respected experts and receives the results. On the basis of these evaluations, it makes recommendations to the funding bodies – that is, the federal and federal state governments – regarding the amount of funding for the individual research programs.

Research within the Helmholtz Association is divided into six research fields: Energy; Earth and Environment; Health; Matter; Information (formerly Key Technologies) and Aeronautics, Space and Transport.

THE MISSION

- "We contribute to solving great and pressing social, scientific, and economic issues through strategic, programmatic, cutting-edge research in the fields of Energy, Earth and Environment, Health, Matter, Information (formerly Key Technologies) and Aeronautics, Space and Transport."
- "Together with national and international partners, we research systems of great complexity using large-scale facilities and scientific infrastructures."
- "We contribute to shaping our future by combining research and technological development with innovative application and prevention perspectives."
- "We attract and develop the best talent, providing them with a unique scientific environment and sustainable support at all stages of their development."

LOCATION OF THE HELMHOLTZ RESEARCH CENTERS

1 BERLIN
HELMHOLTZ-ZENTRUM BERLIN FÜR MATERIALIEN UND ENERGIE (HZB)
www.helmholtz-berlin.de

2 BERLIN-BUCH
MAX DELBRÜCK CENTER FOR MOLECULAR MEDICINE IN THE HELMHOLTZ ASSOCIATION (MDC)
www.mdc-berlin.de

3 BRUNSWICK
HELMHOLTZ CENTRE FOR INFECTION RESEARCH (HZI)
www.helmholtz-hzi.de

4 BREMERHAVEN
HELMHOLTZ CENTRE FOR POLAR AND MARINE RESEARCH (AWI)
www.awi.de

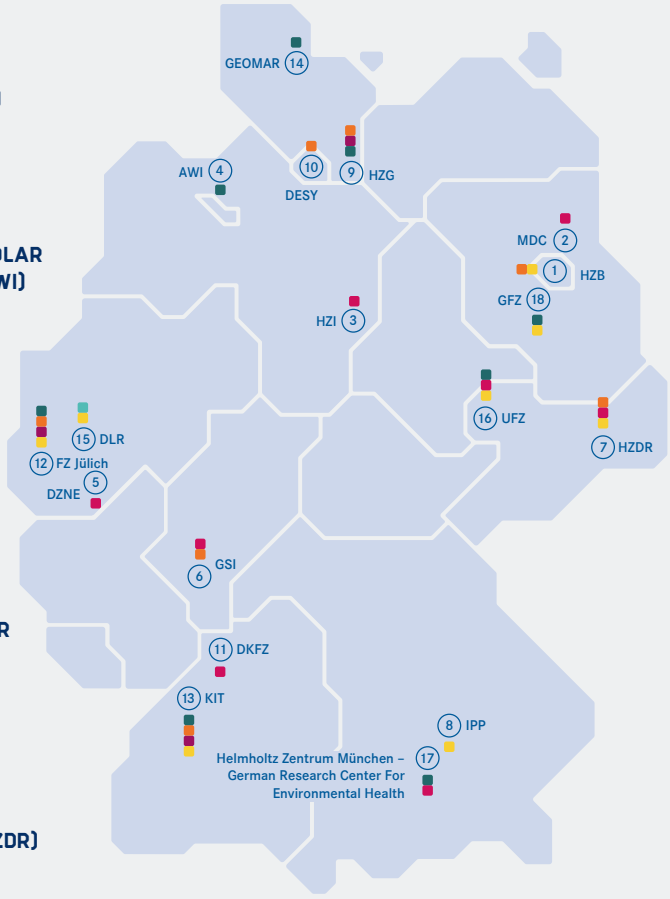
5 BONN
GERMAN CENTER FOR NEURODEGENERATIVE DISEASES (DZNE)
www.dzne.de

6 DARMSTADT
GSI HELMHOLTZ CENTRE FOR HEAVY ION RESEARCH
www.gsi.de

7 DRESDEN
HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF (HZDR)
www.hzdr.de

8 GARCHING
MAX PLANCK INSTITUTE FOR PLASMA PHYSICS (IPP, ASSOCIATE MEMBER)
www.ipp.mpg.de

9 GEESTHACHT
HELMHOLTZ-ZENTRUM GEESTHACHT CENTRE FOR MATERIALS AND COASTAL RESEARCH (HZG)
www.hzg.de



RESEARCH FIELDS

- Energy
- Earth and Environment
- Health
- Aeronautics, Space and Transport
- Matter
- Information (formerly Key Technologies)

10 HAMBURG
DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY
www.desy.de

11 HEIDELBERG
GERMAN CANCER RESEARCH CENTER (DKFZ)
www.dkfz.de

12 JÜLICH
FORSCHUNGSZENTRUM JÜLICH
www.fz-juelich.de

13 KARLSRUHE
KARLSRUHER INSTITUTE FOR TECHNOLOGYIE (KIT)
www.kit.edu

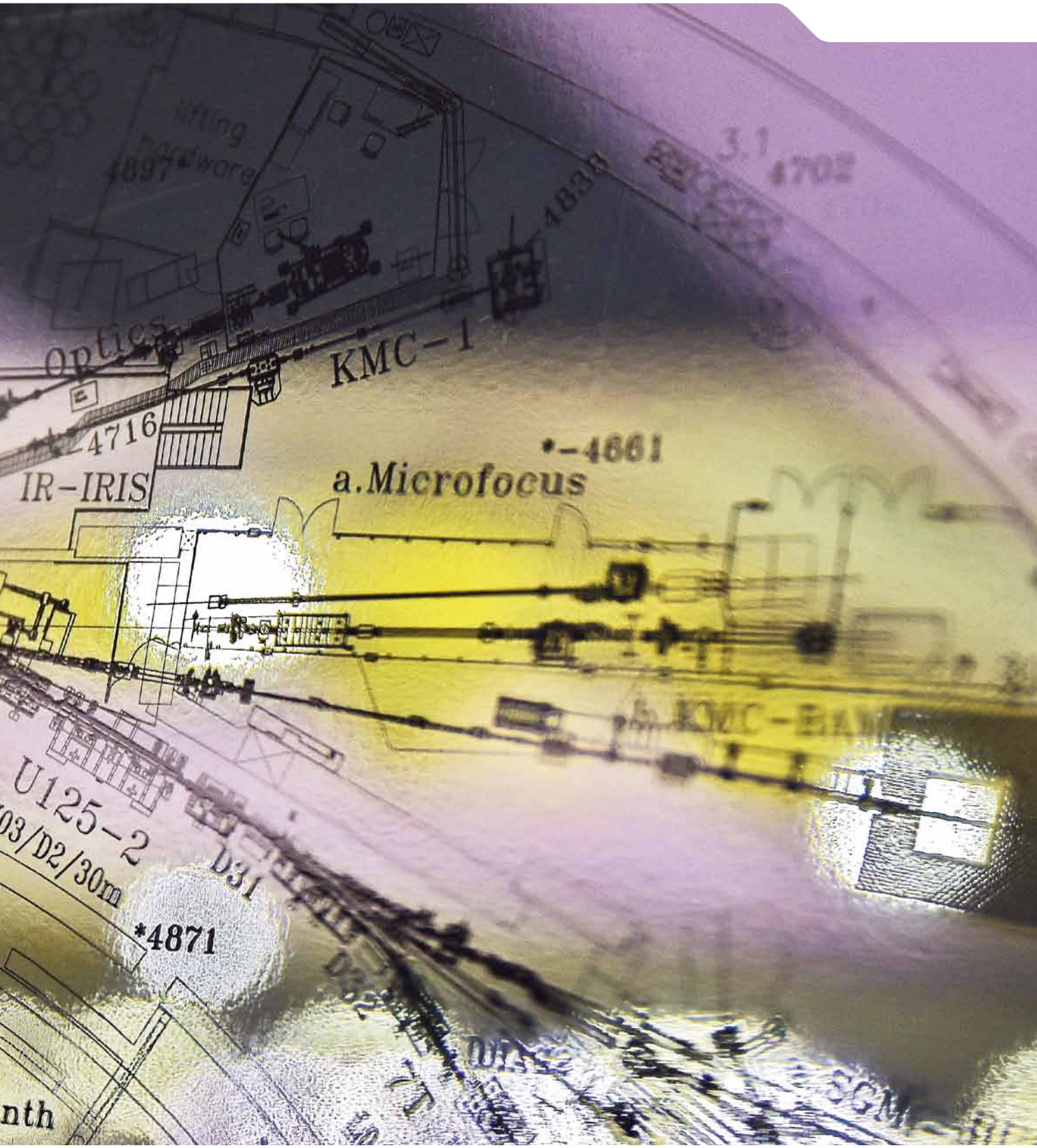
14 KIEL
GEOMAR HELMHOLTZ CENTRE FOR OCEAN RESEARCH KIEL
www.geomar.de

15 COLOGNE
GERMAN AEROSPACE CENTER (DLR)
www.dlr.de

16 LEIPZIG
HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ
www.ufz.de

17 MUNICH
HELMHOLTZ ZENTRUM MÜNCHEN – GERMAN RESEARCH CENTER FOR ENVIRONMENTAL HEALTH
www.helmholtz-muenchen.de

18 POTSDAM
HELMHOLTZ CENTRE POTSDAM – GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES
www.gfz-potsdam.de


Optics
KMC-1
4716
IR-IRIS
a.Microfocus
U125-2
D31
*4871

ANSWERS TO THE GREAT QUESTIONS

Bertolt Brecht said, ***"Change the world, it needs it."*** In many respects, this could also describe the mission of the Helmholtz Association, which was founded in 1995 to contribute to answering the great and pressing questions of society, business, and science with cutting-edge research. These questions can only be answered by changing the world step by step, and the answers themselves in turn also change the world. Work at Helmholtz, more than that at any other German research institution, focuses on people and their environment.

What exactly causes cancer? How does climate change affect our lives? What modes of transport will we use in the future? Researchers at Helmholtz are part of the solution to the great challenges of our time and of the future. In answering these questions, scientists can rely on a strong organization that provides a platform for the best minds and supports them in their work. After all, the expertise, creativity, and innovative strength of researchers are the Association's greatest asset. Only through them can Helmholtz fulfill its role as a driving force in answering the great questions. This is an aspiration that Helmholtz, the largest German research institution, has for itself.

Founded more than 20 years ago from a loose network of varied research institutions, Helmholtz now engages in research that connects people across geographical, disciplinary, and thematic boundaries. The six research fields to which the Association research programs belong are closely linked. There is a lively exchange both within the Centers and between the areas. Helmholtz demands and promotes this kind of networking. It is a key to long-term success.

But it is not only the employees and the close networking within the Association that make Helmholtz successful. The Association is also unique due to its large, complex research infrastructures. Helmholtz has the task of creating, operating, and refining such infrastructures. This is made possible by the very highest levels of research management.

Helmholtz uses these infrastructures to enable national and international scientists to conduct research at the highest international level, making it the epicenter of new cooperation efforts and networks. Networking and active exchange between research institutes and individual research groups and researchers contribute greatly to scientific success. The borders between nations and federal states play no role. Science at Helmholtz is free and open to the world. The Association relies on an international network because today's complex issues are often global and can only be solved jointly.

Research at Helmholtz covers the entire spectrum, from basic to application-oriented research. Excellent basic research is the foundation. Without its insights, there can be no further development. However, taking up the results and transferring them, step by step, to application is as important as bringing results obtained in the application back into the laboratory. All elements of this cycle can be found at Helmholtz. It is an important prerequisite for fulfilling the mission.

Improving understanding of the world and contributing to long-term preservation of human livelihoods requires not only outstanding employees, interactive networks, and unique infrastructures, but also the courage to develop and pursue new ideas. The Helmholtz Association will always leave plenty of room for such creative ideas, because one thing is necessary to find answers to the great questions: breaking new ground.

ENERGY

In the field of energy research, Helmholtz scientists are working to develop economically, ecologically, and socially sustainable solutions for the energy supply of tomorrow.

The challenges

If global warming is to be counteracted, greenhouse gas emissions must be reduced significantly. Moreover, the transition to a climate-friendly society must be designed in a way that involves all partners from science, politics, business, and society. In the field of energy research, the focus in the coming years will therefore be on the energy transition. Helmholtz's aspiration is to be a scientific architect of that transformation.

A major challenge is the decentralization of the energy system. One answer lies in the development of system solutions – that is, solutions in which the focus is not on a single technology, but on the systemic interaction of multiple technologies, such as solar power generation and storage technology. Central to this effort is the coupling of the electricity, heat, and transport sectors; the development of technologies that allow cost-effective provision of energy generated from renewable sources; and the implementation of novel storage and conversion concepts.

The strategy

Systemic and cross-sectoral research and development approaches are necessary if the energy transition is to be successful. It is important to incorporate all relevant energy chains and to develop innovative technological options for a safe, affordable, sustainable energy supply. Its system expertise makes the Helmholtz Association an obvious candidate for playing a pioneering role in transforming the energy system.

The core elements of the research strategy in the next few years will be the development of smart energy systems and research into key technologies for energy supply, conversion, and storage. Research into nuclear fusion as a potential future primary energy source, safe nuclear decommissioning, and interim and final disposal are further central tasks and focal points of the research area.

These priority topics are being pursued in close networking of the eight Centers involved in the research field and in cooperation with partners from business along the entire innovation chain. If the energy transition is to be successful, socio-economic considerations and questions of social participation must also be incorporated from the outset. This can only be achieved if partners from industry, politics, civil society, and research work on the problem together.

Measures

Energy System Integration

The energy transition requires, among other things, intelligent networking of the various components of energy systems. Cross-sector interaction between energy system components has so far been given little attention. The Energy System Integration project therefore concentrates on technological and economic interactions between these components. The objective is to design an environmentally compatible, resource-efficient, flexible, stable energy system. A special feature: Processes in the metalworking, cement processing, and petrochemical industries will be integrated.

Energy Lab 2.0 and Living Lab Energy Campus

The optimization of the energy system requires a holistic understanding of it. Two complementary and closely networked platforms are being developed for this purpose. Energy Lab 2.0 offers an infrastructure that can be used to research the interaction of the components of future energy systems and to realistically test new approaches to stabilizing energy grids. A system network links electrical, thermal, and chemical energy flows and information and communication technologies. This network is closely interwoven with the "Living Lab Energy Campus", a blueprint for a smart distributed energy system which offers an infrastructure for real-time analysis and system optimization.

EARTH AND ENVIRONMENT

Geo-, marine, and environmental research investigates the functions of the earth system and the interactions between nature and society. It creates a solid knowledge base that allows the foundations of human life to be secured in the long term.

The challenges

Life on earth is undergoing a profound change: The number of people is constantly increasing, as are their needs for food, energy, raw materials, and a healthy environment. At the same time, accelerating climate change is accompanied by global warming.

Preserving and sustainably developing the natural foundations of life on our planet is a constantly growing challenge for politics, business, and society. The integrated exploration of the earth, encompassing its land areas, seas, oceans, and polar regions, is of crucial importance. It is the prerequisite for being able to derive courses of action for political and social decisions.

The strategy

The Centers within the earth and environment research field are well equipped to meet the challenge of a global, integrated approach to data collection, modelling, synthesis, and application in earth system research. In part, this is due to structural and content innovations that sharpen the work focus on socially relevant topics, such as bioeconomics. The sustainable production of organic raw materials plays a particularly important role here.

Research field activities focus on investigating the causes and effects of global change, development in the direction of sustainable use of resources, and investigating the causes of and risks associated with natural hazards and changes in various ecosystems. Their increased commitment to the areas of knowledge and technology transfer will allow the participating Helmholtz Centers to make an even greater contribution to decision-making processes in the field of earth and environment. All in all, the aim is to sharpen forecasting capacity, which creates an important foundation for evidence-based political and social decisions.

In the future, the research field, enhanced by joint strategy development, will contribute to the Helmholtz mission in an even more targeted manner and position itself internationally as an outstanding competence platform for earth system research. The upcoming tasks can be completed successfully only in close cooperation with research institutions of other sponsors, universities, and associated business partners. The refinement of the research field will be aligned with existing national and international initiatives in order to complement them.

Measures (selection)

Modular Observation Solutions for Earth Systems (MOSES)

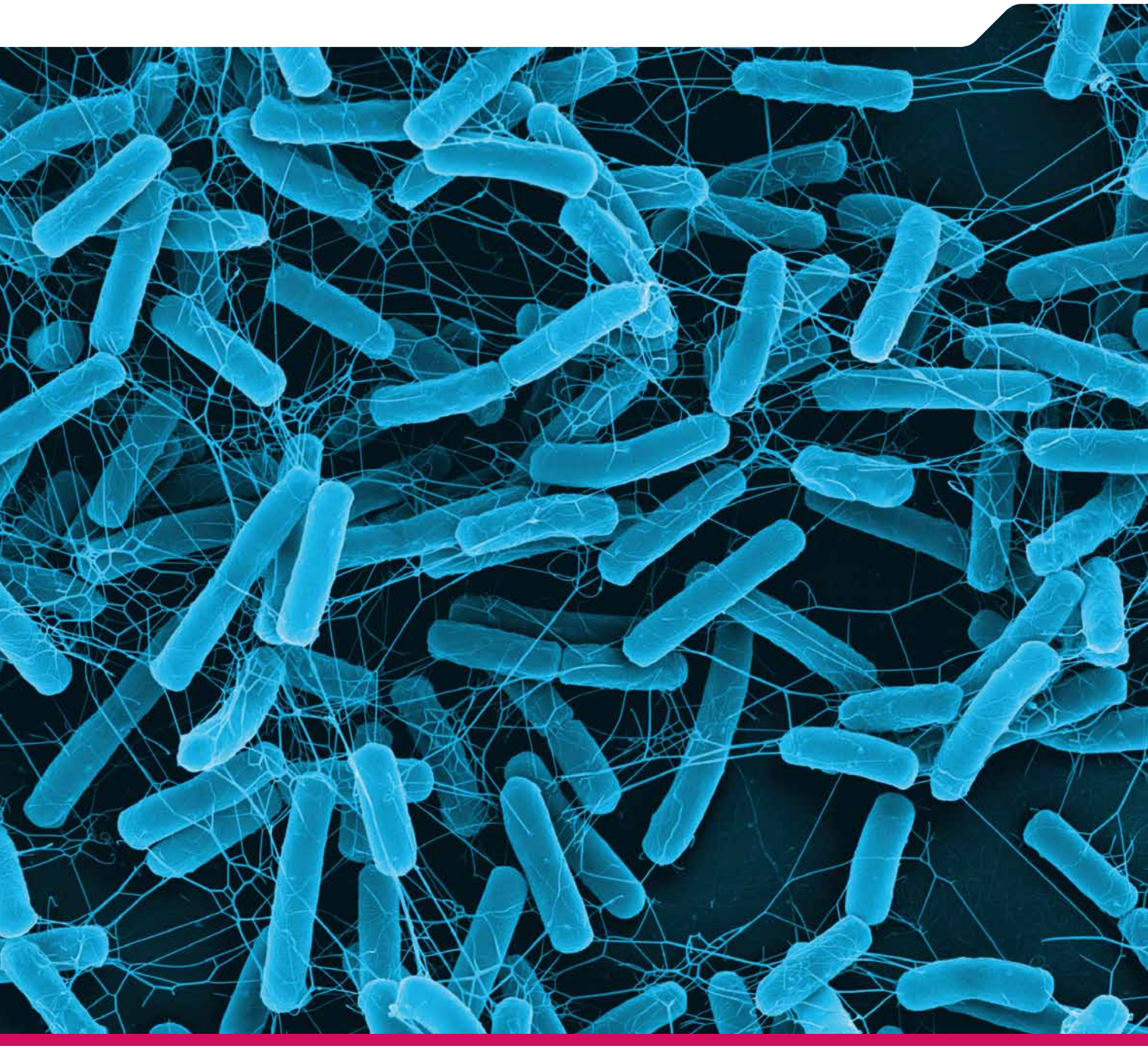
MOSES is a joint initiative of AWI, DLR, Forschungszentrum Jülich, GEOMAR, GFZ, HMGU, HZG, KIT and UFZ. Its focus is earth observation. The objective is to continuously collect data on dynamic natural events, studying their significance for the long-term development of earth and its ecosystems. For this purpose, modular, mobile observation units are used in combination with operational satellites to record sudden dynamic events, which usually take place on a small temporal and spatial scale.

Advanced Earth System Modelling Capacity (ESM)

Earth system models allow extensive exploration of the Earth and the interactions between land, ocean, biosphere, atmosphere and ice masses, taking into account human impact. By addressing this future-oriented research area, the Helmholtz Association is strategically and scientifically expanding its capacity for modelling earth systems. The objective is to provide much more realistic representations and projections of the Earth system. With the help of these new findings, significant progress will be made in solving global environmental challenges.

HEALTH

Health research investigates the often complex causes of important widespread diseases. The objective is to develop new strategies for effective prevention, timely diagnosis, and effective, personalized therapies.



The challenges

Frequent and common diseases such as cancer, dementia, diabetes, cardiovascular diseases, infections, allergies, and lung diseases place an ever-increasing burden both on those affected and on society. Reducing this burden is the major challenge in health research.

Helmholtz sees making decisive contributions to the fight against these and other important diseases as well as playing a pioneering role in translational health research as its responsibility in the coming years. The objective is to develop new strategies for effective prevention, timely and accurate diagnosis, and effective therapies. In addition to this goal, Helmholtz intends to respond flexibly to disease patterns that arise and to developments in the health sector.

The strategy

Helmholtz pursues a systemic translational approach to health research. This means that Helmholtz research, with its five health centers, covers the entire system chain from basic research to clinical research. Researchers are working to understand and clarify disease mechanisms. On this basis, they are developing approaches for new preventive and therapeutic measures, which are to be transferred to clinical application as quickly as possible to facilitate medical innovations. The findings gained in clinical practice will then be used directly for research purposes. Close networking of Helmholtz Centers with university medicine, pharmaceutical companies, and other research institutions is of fundamental importance.

In the long term, it is important for health centers to develop approaches to personalized medicine in which digitalization and large amounts of data will play an important role. Moreover, new scientific findings must be translated into active substances for new therapies. The centers are characterized by their interdisciplinary nature, broad competence, and special infrastructures, all of which support both future research topics such as immunology and ageing processes, and programs aimed at promoting young researchers.

A further challenge is opening up large new thematic areas, such as mental illness, in health center portfolios. The focus is always on social benefits, which is why the transfer of knowledge, in the context of information services, for instance, is a cornerstone of health research at Helmholtz.

Measures (selection)

Personalized Medicine

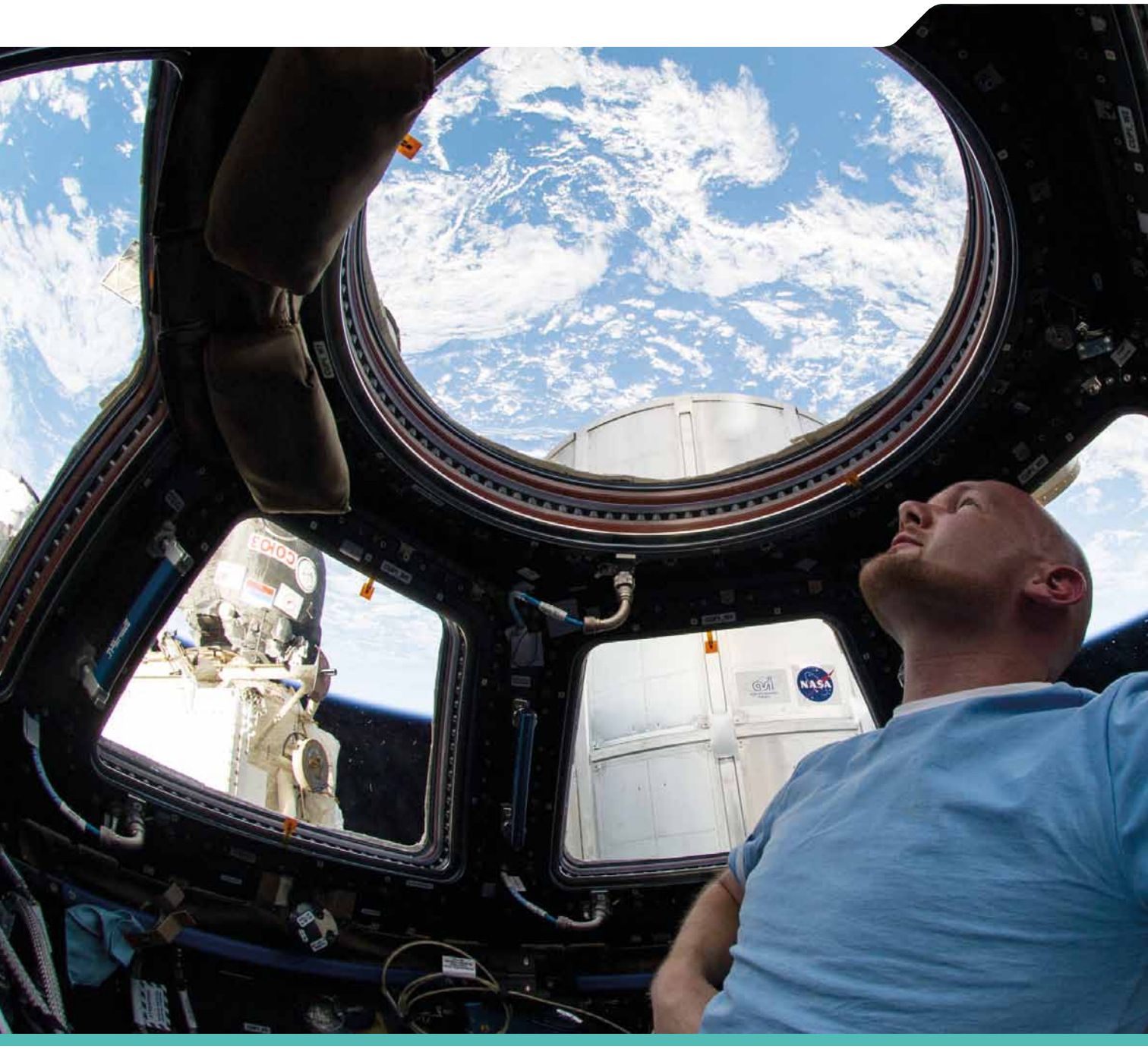
Helmholtz's iMed Personalized Medicine initiative is a unique network of six participating centers with the objective of networking and coordinating research activities in this field. The joint activities focus on molecular diagnostics, risk stratification, and primary prevention as well as individualized therapy and secondary prevention for complex diseases such as infectious, metabolic, cardiovascular, lung, and neurodegenerative diseases and cancer. The participating centers cooperate closely with university partners in Germany, Europe, and elsewhere in the world, and with local clinical partners and translation centers. This enables rapid transfer of research results into clinical practice.

Immunology and inflammation

The scientific breakthroughs of the last decade have made immunology a driver of groundbreaking therapies. At the same time, the pivotal role of the immune system in the pathogenesis of numerous widespread diseases has been established. By linking and enhancing immunological expertise, Helmholtz aims to position itself nationally as an important player in this field and to further increase its international visibility.

AERONAUTICS, SPACE, AND TRANSPORT

Mobility, information, communication, resource management, environment, and security are decisive factors for the economic, ecological, and social development of a modern economy



The challenges

The aeronautics, space, and transport research field is oriented towards these global challenges. It addresses the essential issues associated with them by developing effective concepts and technological system solutions. The issues of digitalization, Big Data, security research, intelligent mobility, and global change monitoring will characterize the research field in the coming years. Moreover, the development of environmentally compatible technologies is one of the major challenges in aviation and transport research. The research field addresses these topics both through focused research and the systematic use of cross-program synergy potential.

In all three areas – aeronautics, space, and transport – the concern is, above all, to implement technical achievements in harmony with the benefits and needs of society.

The strategy

If demand-oriented and sustainable mobility is to be achieved, the societal component must be incorporated into research activities. This factor will be decisive for success, especially in the area of autonomous driving.

In order to further strengthen competitiveness in the areas of aviation and transport, Helmholtz is investing in the digitalization and virtualization of test systems and vehicles. New simulation systems will not only increase the efficiency of research and development in this area, but also make transport safer in the future – both in the air and on the ground. In cooperation with other research fields and industrial partners, more eco-friendly systems will be developed and attention given at an early stage to the impact of new innovations on environment, economy, and society.

Space travel can also benefit enormously from new technologies. Robots and virtual realities increase the efficiency of maintenance and repair work while reducing costs. The overall challenge in the coming years will be to continue to research this field, develop new technologies, and jointly implement them. A close link between basic and application-oriented research is crucial if this is to happen.

By assuming a bridging function that ranges from basic research to innovative applications to the preliminary stages of marketable products, the research field occupies a key position that is unique in Germany.

Measures (selection)

New evaluation procedures for space travel

By the end of 2017, the European Copernicus program's Sentinel 1, 2, and 3 satellite missions generated a daily data volume of more than 20 terabytes. In order to pool these data volumes, scientists at DLR's Earth Observation Center (EOC) have developed a TimeScan processor.

Electric passenger aircraft

DLR researchers have developed the propulsion train for the world's first four-seater passenger aircraft to be powered solely by a hydrogen fuel cell battery system. The next goal, developing a hybrid electric 19-seater, will be pursued in cooperation with industry and universities.

Holistic concepts for freight transport

DLR scientists have developed a concept for the NGT CARGO railcar train that will make freight transport more attractive. This is particularly important for increasing the sustainability of freight transport and reducing the burden on road infrastructure. The main objective of future activities, in addition to technological advances that enhance automation, speed, and safety, will be to integrate this concept into an intermodal transport chain.

MATTER

The components of matter and the forces acting between them are being investigated over many orders of magnitude – from elementary particles to macroscopic structures in the universe.

The challenges

The focus of closely networked, cross-disciplinary cooperation in the matter research field is the decoding of the structure and function of matter, materials, and biological systems as far down as the quantum level. Research activities therefore range from research into the quantum universe to the design of new materials and active ingredients. To this end, the Helmholtz Centers in the research field use and operate a unique portfolio of research infrastructures.

The challenge lies in the increasing granularity and complexity of the research objects and the associated questions, which require completely new interdisciplinary approaches. In the future, more attention will be paid to the interdisciplinary matters of information and Big Data, materials research, and structural biology.

The strategy

The scientific portfolio in the matter research field ranges from elementary particle and astroparticle physics to hadron and nuclear physics to solid state, atomic, plasma, molecular, and biophysics.

Research is based on particle accelerators, on light, neutron, and ion sources, on high-field magnetic laboratories and on telescopes for measuring cosmic particles such as neutrinos. These large-scale research facilities, which are developed, built, and operated as part of many years of research and development activities, are of exceptional importance for scientific work in these fields. They are used by a large number of researchers from all over the world.

The development of technology in the fields of accelerator and detector physics and information technology forms an essential basis for the refinement of scientific and technical instruments in the research field.

The program structure of the matter research field optimally pools research and development activities: Three Helmholtz programs of the third programming period form the strategic framework. After repositioning and modification, they are meeting challenges in the best possible manner. They are supplemented by a forum on matter, which is intended to enhance future activities in the field of precision physics while supporting theoretical methods, innovation, and outreach.

Measures (selection)

BESSY-VSR and the Joint Lab for Electrochemical Interfaces (BelChem) in Berlinn

The HZB is planning to modify the BESSY II synchrotron system for variable pulse lengths in order to better research electrochemical processes at interfaces, for example, in association with the Berlin Joint Lab on Electrochemical Interfaces (BelChem).

PETRA IV and high brilliance synchrotron radiation

At DESY, the conversion of PETRA III into an ultimate diffraction-limited storage ring is planned. This would allow, for the first time, a diffraction-limited three-dimensional X-ray microscope for materials and active ingredient research.

High-performance laser-based ion accelerator at the ELBE

At HZDR, the expansion of the ELBE radiation source into a unique accelerator and laser-based source for synchronized, high-intensity radiation pulses is planned. Among other things, it is to generate the strongest THz fields at a high and flexible repetition rate, opening up new research opportunities in the field of solid state surface chemistry and the structural analysis of bioinorganic element complexes.

INFORMATION (formerly Key Technologies)

In view of the digitalization of science, business, and society, information-oriented research is becoming increasingly important. Helmholtz focuses on this development with holistic research into the conceptual, technical, and sociological aspects of the issue of information.

The challenges

Science, business, health care, and society are facing a massive increase in digitalization. While there are completely new opportunities in almost all aspects of modern society, our digital world requires new information technologies if it is to keep up with user needs. Research into the conceptual, technical, and sociological aspects of information is a crucial factor for our prosperity.

The strategy

The Helmholtz Association is meeting this challenge by refocusing the key technologies research field on information. While this field has so far developed generic concepts, methods, and technologies in the three focal areas of information technologies, materials, and life sciences, the information research field will focus on information and create a framework for Helmholtz-specific research objectives that deal with fundamental concepts of information, its processing, and thus its use. Information-oriented research is addressed at all levels, from the study of biological and physical information processing systems to the provision of new materials and components to the design of a new generation of high-performance computers and embedded and ubiquitous information processing systems.

In order to generate new knowledge from data, scalable methods, algorithms, and tools for data-intensive science are being developed, and the analysis of Big Data with supercomputers and large data infrastructures advanced. Aspects of security, privacy, and reliability play a major role in this process, which is accompanied by new ethical and socio-economic questions that need to be answered in interdisciplinary research formats. The understanding of the fundamental principles of information processing in biological and physical systems up to and including the human brain is the basis for the development and introduction of new technologies. The insights gained in this way form the basis for translation into various fields of application, such as concepts for the next generation of computers, powerful neuro-inspired learning methods, and new approaches to the diagnosis and treatment of neurological diseases. New technologies are fundamentally based on more efficient, “intelligent” and cheaper materials developed in the interplay between experimental work and digital design. The exchange of information and the interaction between technology and artificial and biological materials play an important role in this process, as does digitalization in manufacturing.

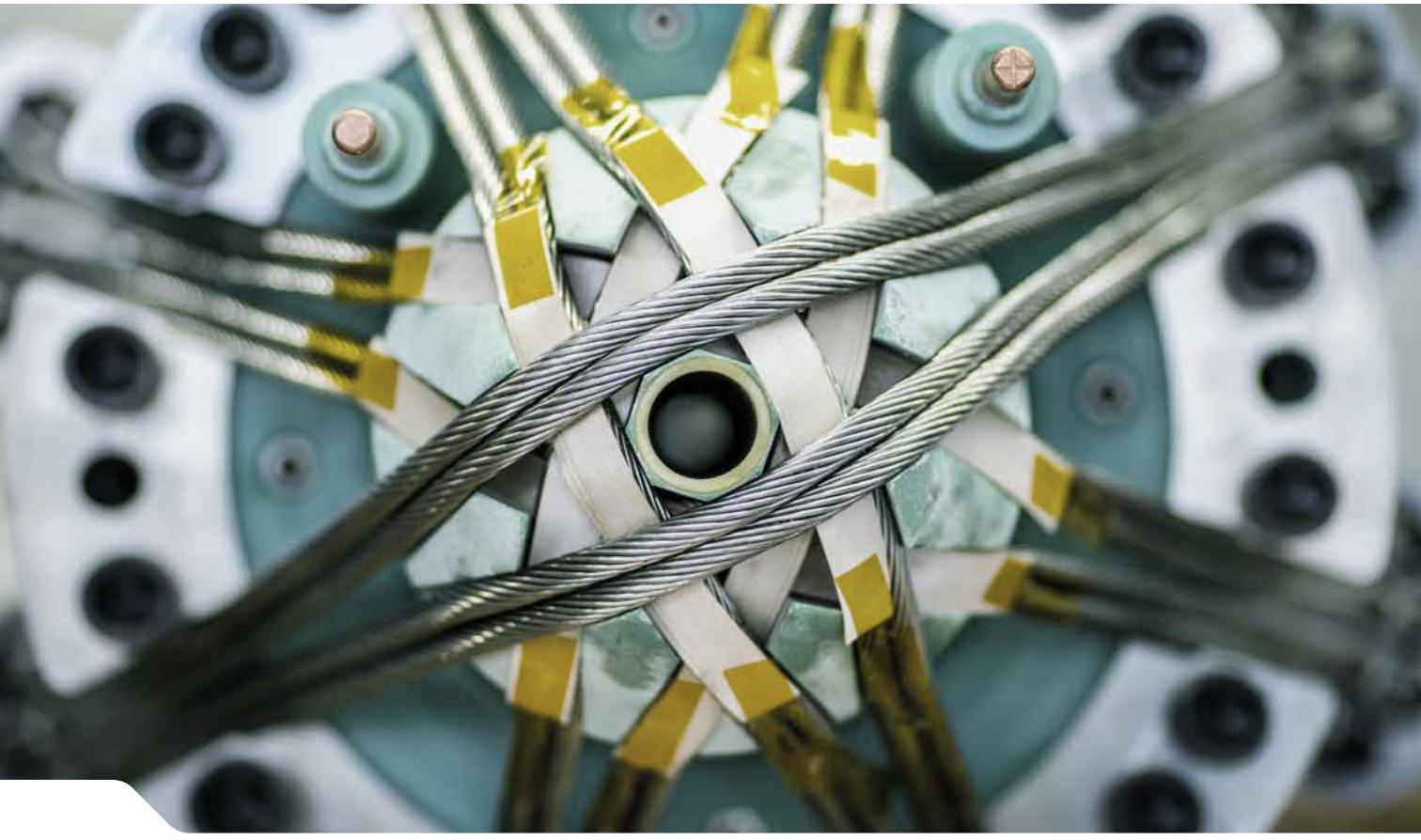
Measures (selection)

New computing concepts

In addition to the use of the latest generation of supercomputers in all areas of the Helmholtz Association, future technological concepts of modular exa-scale computing will be researched, tested, and applied with industrial partners in order to meet the rapidly increasing requirements of data and information processing. The „Scalable Solid State Quantum Computing“ project focuses on the basics of quantum information processing with the aim of creating the physical and technological conditions for future multi-qubit systems.

Virtual material design

The development of complex high-tech products requires completely new strategies for material development that go beyond future information technology applications. To this end, innovative computer-based approaches to simulating various critical phases of material development are being realized with the help of a „digital twin“. Efficient simulation technologies, high-performance computer infrastructure, and integrative data processing are expected to reduce the time and cost of material development. Thus attention is given not only to the properties in the microscopic structure of the materials, but also to their performance in the production process and throughout the entire life cycle.



INTERDISCIPLINARY RESEARCH TOPICS

One of the great strengths of the Helmholtz Association is the diversity of its research centers and the close networking between the Centers and research fields. Many topics span the six research fields, and different Centers have different focuses when approaching those topics. Bioeconomics, for example, is of particular importance in the context of renewable bioenergy and the sustainable use of raw materials and medicine. Energy storage facilities must also be considered in the context of the energy transition, information processing, and mobility.

Many challenges in one research area can be met only on the basis of decisive developments in others. Progress in space travel, for example, is closely linked to new developments in materials research. Conversely, many new technological developments stimulate research activities in other areas. In order to do justice to this complexity, the Helmholtz Association pursues a wide range of interdisciplinary topics. The topics in the research fields and the interfaces between them must be constantly readjusted and adapted to current circumstances.

The Information and Data Science incubator

Groundbreaking new developments in the fields of digital data processing and complex data analysis are opening up completely new opportunities for data-based research. This rapidly developing field represents one of the greatest challenges for Helmholtz and the scientific system as a whole. Only innovative and interdisciplinary approaches will allow a new quality of data analysis and data integration. To this end, the President of the Helmholtz Association has set up the Helmholtz Information & Data Science incubator, in which experts from all Centers work together. This incubator is:

- **an agile and innovative group of top-flight experts and a platform for networking important disseminators to communicate attractive topics to the Association and think ahead for the long term;**
- **a forum for unique new ideas and a nucleus for groundbreaking, disruptive pilot projects;**
- **a think tank for new ideas for refining the Helmholtz Association research portfolio and structures.**

The incubator will address the Association's objectives in the field of information and data science and create methods to continuously and sustainably develop and process exciting, highly relevant, innovative topics and promote the successful occupation of large-scale research topics in which Helmholtz is or can become the national and international leader.

In addition to innovative, cross-disciplinary research priorities, attention is given to structural challenges in the areas of training and platform networking. A central task in keeping Helmholtz and all German research on the cutting edge of this field will be training a new generation of interdisciplinary information experts. To this end, proposals for establishing a cross-disciplinary, networked Helmholtz Data Science Academy are being prepared.

The incubator will develop effective concepts and options in the highly relevant fields of machine learning & artificial intelligence, image recognition and processing as well as a close connection between research data and research data infrastructures. In order to increase the clout of the entire Helmholtz Association in these core technologies, we will establish platforms and provide offers and connecting links for national and international partners.

The incubator will also discuss topics that social and political players consider important. The members will develop effective concepts and options for action and will continuously provide offers and points of contact for national and international partners.

Its enormous expertise and efficient infrastructure already puts the Helmholtz Association in an excellent position in the field of information research. This applies to a broad spectrum, ranging from supercomputing, chip and memory development, and computer science and software programs to modelling and simulation to artificial intelligence and robotics. In addition, extensive, complex data records are available in all research fields in the sense of Big Data.

TALENT MANAGEMENT

The core elements of the Helmholtz talent management strategy are preparing target group-oriented offers at all career levels, combining academic advancement with clear career prospects, and promoting management professionalization at all levels.

The Helmholtz Association's performance and scientific success is based to a decisive extent on the skills of its staff. A strategic approach to talent management enables the Helmholtz Association to fulfill its mission. It ensures that creative and committed people within the Helmholtz Association work productively, develop themselves further, and remain in the organization or make optimum use of their skills in their future positions.

The promotion of young scientists and administrative and technical talent is a central component of securing the future of the Helmholtz Association and of Germany as a research location. In addition to the promotion of young researchers at the Helmholtz Centers, there are overarching support measures within the framework of the Initiative and Networking Fund at the Helmholtz level. In recent years, these funding instruments have been developed into a comprehensive strategic talent management system that offers attractive conditions for the best scientists at all stations along the talent chain.

For Helmholtz talent management, two main objectives should be emphasized:

1. Recruiting – attracting the best talent for the Helmholtz Association

Key positions are to be filled optimally – either by recruiting outstanding employees externally or by developing talented employees internally.

2. Career support – giving the best people optimal support for their further development

Talented individuals should be optimally supported in their careers so that they have excellent starting positions for activities outside the Helmholtz Association or are in a position to take on important positions at Helmholtz Centers. Helmholtz offers them career orientation and support in the form of transparent career paths and personnel development tools. In the interest of achieving these goals, talent management encompasses three dimensions:

I. ACADEMIC PROMOTION

The promotion of young scientists has come to include instruments at all stages of their careers:

- Doctoral candidate support at graduate schools and colleges, the doctoral award, and, in the future, international Helmholtz colleges
- Young scientist research groups with extended measures to make the family phase more flexible and to better reconcile work and family life as a means of supporting young people as they establish themselves professionally
- Promoting recruitment through the W2/W3 program for excellent female scientists and the Recruitment Initiative at the W3 level
- Promoting experienced researchers via the Helmholtz-ERC Recognition Award and the Helmholtz International Fellowships

II. MANAGEMENT TRAINING

Qualification for management and leadership positions places an emphasis on the refinement of the Helmholtz Academy with its services for the Association and the scientific system.

III. CAREER COUNSELLING AND CAREER DEVELOPMENT

ECareer counselling and development make up a key element of strategic talent management. The new Helmholtz Career Development Centers for Researchers (HCDCR) are a focal point for post-doctoral consulting and career development at the Helmholtz Centers. Other target group-specific services include the Helmholtz Academy and mentoring.

Helmholtz Management Academy

Further development and management training are central elements of Helmholtz talent management. Since 2007, the Helmholtz Management Academy has been implementing a forward-looking concept based on a targeted approach aimed at equipping managers in science, infrastructure, and administration with general management skills. On the one hand, the Academy trains young talent, and on the other, it trains experienced managers from research and science management in their leadership tasks.

The Helmholtz Academy has established itself as an integral part of the Helmholtz talent management system, its attractiveness extending far beyond the Association. The program is unique in Germany because it teaches management and leadership skills that meet the special requirements of a scientific working environment. A core element is the precisely tailored, individual continuing education for participants from science and administration of different career levels, supported by the principle of joint learning. The objective is to promote an integrative understanding of leadership among all participants.

STRATEGIC PARTNERSHIPS AND COOPERATION

The challenges facing our society are becoming increasingly complex as a result of globalization and ubiquitous digitalization.
The ideas and expertise of individual scientists are often no longer sufficient to contribute to meeting these challenges with scientific insights. Instead, the problems of today's world require strategic partnerships, the pooling of expertise, and exchange of ideas across organizational and national borders.

In order to continue to contribute actively to solving problems, Helmholtz has set itself the goal of cooperating with the best scientific partners. The objective is a targeted combination of varied expertise and infrastructures.

To this end, the Association has formulated four objectives:

1. Contribute to the development of top locations through cooperation

Thanks to their critical mass of bright minds, financial resources, and infrastructures, these top locations are to work together on major current research topics. In this way, the local network of university and non-university research institutions aims to achieve greater international visibility and increase attractiveness for future recruiting.

Examples:
KIT – Top location for technology:
Karlsruhe Institute of Technology (KIT) was created in 2006 as a result of a merger of the Karlsruhe Research Center and the University of Karlsruhe. This cooperation is unique in the German higher education and research landscape. Today, the "Research University in the Helmholtz Association" regularly achieves top positions in research rankings in patents and spin-offs, combining the traditions of a technical university and a large-scale research institution. KIT remains a unique model in Germany. Within the framework of the amendment to Article 91b of the Basic Law for the Federal Republic of Germany, it can now be further developed into a single entity.

Science park on the DESY campus
In the Hamburg metropolitan region, the DESY campus in Bahrenfeld is to be expanded to create an international science park. The European XFEL X-ray laser, the University of Hamburg, the European Molecular Biology Laboratory (EMBL), and the Max Planck Society are all involved. The aim of this top location is to share infrastructure, set up a young talent program, fill professorships jointly, and pursue an overarching innovation strategy.

2. Facilitate joint work on topics of national importance through targeted, visible cooperation between the most important national partners

Large, interdisciplinary national consortia are to enable faster results and applications in practice in order to meet current societal challenges.

Examples:
The German Centers for Health Research (DZG)
In 2009, the German Center for Neurodegenerative Diseases (DZNE) became the first of today's six DZGs to open: It pioneered a new model of institutional cooperation that combines a Helmholtz Center with university hospitals and other partners in order to improve the prevention, diagnosis, and treatment of certain widespread diseases. There are now six DZGs in Germany, which, in addition to neurodegenerative diseases, focus on diabetes, infection research, translational cancer research, lung research, and cardiovascular diseases. At more than 90 locations, more than 100 participating partner institutions work together at the DZGs to bring research results to patients more quickly.

German Alliance for Marine Research (DAM)

A network encompassing three Helmholtz Centers (AWI, GEOMAR, and HZG), non-university research institutions, and universities in Northern Germany is currently being formed under the name "German Marine Research Alliance" (DAM). It aims to pool expertise in ocean, coastal, and polar research. The alliance's goal is to develop science-based courses of action for sustainable management of seas and oceans and to play an active role in their implementation.

3. Complement and strengthen the research portfolios of individual Centers by means of targeted cooperation in selected areas

To this end, Helmholtz Center branch offices are founded on the campus of a university. Known as Helmholtz Institutes, they form the basis for close, long-term cooperation.

There are currently seven such Institutes:

- Helmholtz Institute Erlangen-Nürnberg
- Helmholtz Institute Freiberg
- Helmholtz Institute for Pharmaceutical Research Saarland
- Helmholtz Institute Jena
- Helmholtz Institute Mainz
- Helmholtz Institute Münster
- Helmholtz Institute Ulm

In 2016, the Association decided to establish four new Helmholtz Institutes:

- **HIRI:** Helmholtz Institute for RNA-based Infection Research (HZI and Julius-Maximilians-Universität Würzburg)

- **HIFMB:** Helmholtz Institute for Functional Marine Biodiversity (AWI and Oldenburg University)

- **HI-MAG:** Helmholtz Institute for Metabolic, Adiposity, and Vascular Research (HMGU and Leipzig University)

- **HI-TRON:** Helmholtz Institute for Translational Oncology (DKFZ, Johannes Gutenberg University Mainz, and the Mainz university medical department)

4. Use large research infrastructures for attractive new applications and cooperation projects

An outstanding feature of the Helmholtz Association is its research infrastructure, much of which is unique. It attracts cooperation partners from all over the world. Building on this, the objective is to develop more user and application platforms for science and technology in the future.

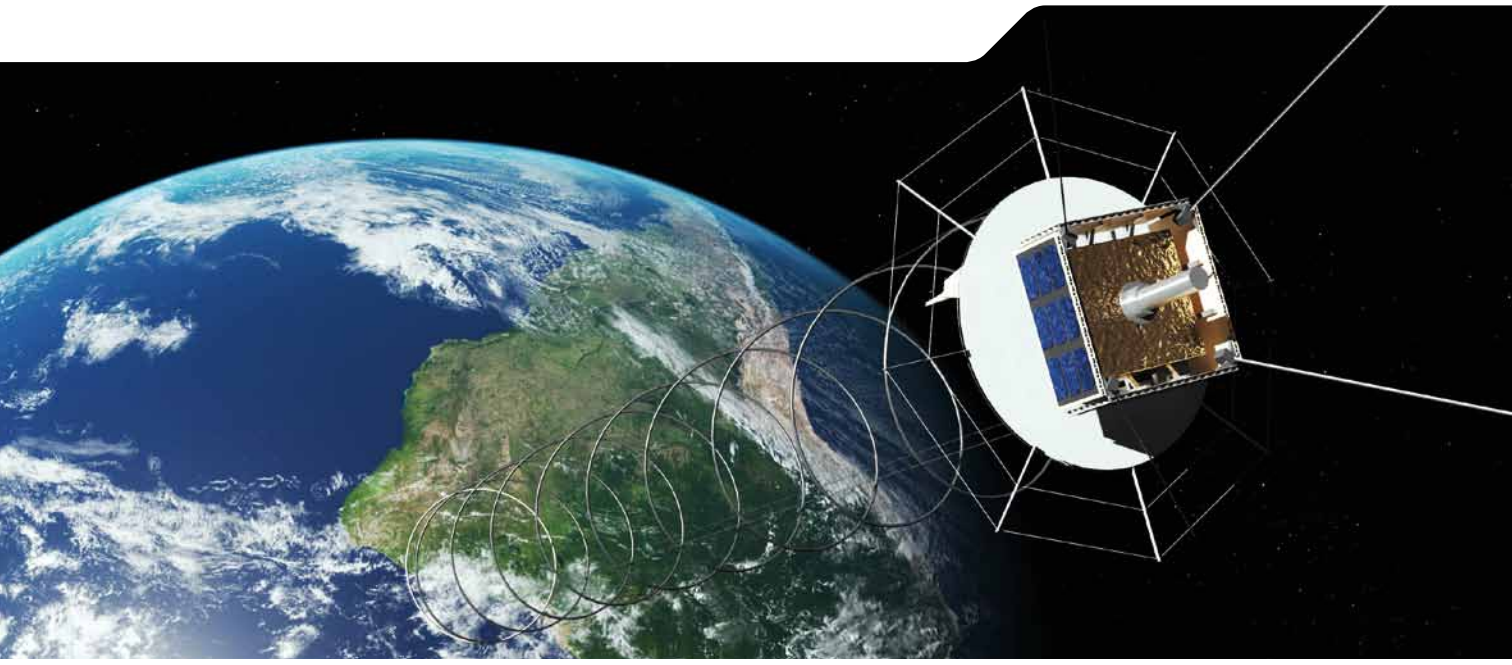
Examples:
HALO research aircraft

The DLR HALO (High Altitude and Long Range Research Aircraft) offers an ideal combination of range, altitude, payload, and comprehensive instrumentation. The HALO is the only research platform of its kind anywhere in the world. In spring 2012, the research aircraft took off for its first scientific mission and since then has facilitated fascinating experiments by filling the gap between earthbound observation stations and satellites. The operating concept is available to a broad user community and has therefore opened up new dimensions in environmental research, climate research, and earth observation in Germany and Europe.

"Helmholtz Energy Materials Foundry"

As a research platform for energy materials, the "Helmholtz Energy Materials Foundry" (HEMF) will focus on the synthesis of high-performance materials for energy conversion and storage. To this end, six Helmholtz Centers (DLR, Forschungszentrum Jülich, HZB, HZG, HZDR, KIT) plan to set up specially equipped laboratories which are also to be deliberately operated as a user and service platform for scientific and industrial partners. The focus of the research is, among other things, solar cells, fuel cells, batteries, and refinements in thermoelectricity.

INTERNATIONAL COOPERATION



Internationalization is not only a significant part of Helmholtz's mission; it is also an indispensable prerequisite for research that is strategically relevant and of the highest scientific caliber. The large-scale research infrastructures operated by the Helmholtz Association function as special catalyst and attract talented scientists from all over the world. Creative thinkers not only find unique working and research conditions here, but also maintain a wide variety of international partnerships – within the research infrastructures both in Germany and abroad.

By cooperating at the international level, the Helmholtz Association plays a significant role in strengthening Germany's competitiveness and its position as an international hub of science.

For this reason, internationalization is a key component of the President's agenda for 2016 to 2020 – and comprises four specific strategic goals:

1. Expand international strategic partnerships

The Helmholtz Association uses a sustainable approach to develop and maintain cooperative relationships with selected international strategic partners. These partnerships have a proven impact and aim to help the Association and its Centers make optimal use of their portfolio, gain access to unique infrastructures, and work with the best researchers.

In order to promote strategically relevant international partnerships in a targeted way, the new funding instrument 'International Labs' has been added to the Initiative and Networking Fund so that International Labs can be established with strategic partners all over the world. These labs will strengthen strategic international cooperation over the long term.

The pilot project for the 'International Labs' is the Weizmann-Helmholtz Lab (WHELMI) in Israel, which was founded in a joint effort with the Weizmann Institute of Science and the Helmholtz-Zentrum Dresden-Rossendorf (HZDR). Countries in which the Association has long enjoyed intensive and successful cooperation with excellent partner institutions include the US, Canada, France, the UK, and China.

Given this context, Israel is set to become a particularly important partner country. The Helmholtz Association will open an office in Tel Aviv in fall 2018 to strengthen cooperation with this outstanding research nation and facilitate joint research projects with local partners. Is-

rael will then host the Association's fourth international office, in addition to Brussels, Moscow, and Beijing.

2. Conduct joint cutting-edge research at the European level

The Helmholtz Association actively and successfully engages in European partnerships with the goal of identifying effective solutions for global challenges faced by society, science, and the economy. It brings its powerful infrastructures and innovative ideas into play to strengthen the cohesion of the European Research Area.

The Helmholtz Centers have been particularly successful in the EU Research Framework Programmes, utilizing synergies with European partners and coordinating strategically important joint and flagship projects within Europe. One example is EU-PolarNet, a Horizon 2020 project coordinated by AWI. Twenty-two leading research institutions based in 17 European countries work together in this consortium, the world's largest in the field of polar research.

The Association also strives to enhance cooperation with the new EU member states as well as structurally weaker countries and regions. It will provide these systems with targeted support in the future – thanks in part to the new funding instrument 'Helmholtz European Partnering' for cooperation activities with institutions in Southern, Central, and Eastern Europe.

3. Attract talent from all over the world

The Helmholtz Association positions itself as a highly attractive cooperation partner and employer for talent and top-flight researchers from all over the world, especially outstanding female scientists.

To this end, targeted exchange programs and recruiting tools are being (further) developed and implemented with the support of the Initiative and Networking Fund. They are primarily aimed at talented female scientists and include the W2/W3 Program for recruiting at professorship level, for example. The International Research Schools also play an important role in achieving this objective, offering structured doctoral training in the form of a joint program involving the respective Helmholtz Center, foreign partners, and German partner universities.

The Helmholtz International Fellows will also become more closely involved in this area in the future in conjunction with international talent management and will assume an even more prominent role as ambassadors and liaisons. Marketing campaigns focusing on specific target groups will continue to increase Germany's international appeal as a research hub in the coming years and boost the reputation and visibility of the "Helmholtz brand."

4. Science diplomacy – building bridges through research

The Helmholtz Association unequivocally champions effective scientific systems and the preservation of scientific freedom, including and especially in the area of international cooperation.

The Association provides evidence-based policy and system advice as well as consulting services in the international context. It also considers itself a mediator with a role to play in science diplomacy: It is convinced that science can build bridges and serve as an important connecting element in times of political tension. The Helmholtz Association assumes social responsibility and accountability for science policy in the course of its cooperation at the European and international levels.

An example of this is the SESAME project (Synchrotron-light for Experimental Science and Applications in the Middle East). The SESAME synchrotron system in Jordan is constructed, among other things, from former components of the BESSY I storage ring and was inaugurated in May 2017. The system is the first of its kind in the Middle East. Under the auspices of UNESCO, the countries of Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian territories, and Turkey joined together to build and operate it. In addition to performing its scientific tasks, the facility therefore also aims to promote international understanding in the Middle East. DESY is the main Helmholtz Center involved in the SESAME project.

INNOVATION AND TRANSFER

Putting scientific results into practice, creating something that benefits society, and solving a relevant problem together with business are among the many motivations for pursuing transfer and innovation. The Helmholtz Association has also been active and successful in this field for a long time, as evidenced by its more than 2,000 cooperation efforts with companies and more than 400 patent applications per year. Numerous products originate from research a t the Helmholtz Centers. In the last four years alone, 77 high-tech spin-offs have been created. Heavily frequented information platforms are used for consultation and exchange with society.

The Helmholtz Association will further sharpen its profile as an outstanding research organization in the field of knowledge and technology transfer and establish itself as an important partner in innovation.

1. Advance development partnerships and cooperation with the business community

There are already numerous cooperation projects and specific formats for exchange with various companies. These include strategic alliances between Centers and large, research-intensive companies, but also many cooperation agreements with small and medium-sized enterprises. New exchange platforms and matching events have been created. One example is the cross-center Research Days, which have been held since 2012 with a wide variety of businesses.

In the coming years, a special use of IVF funds will be to advance development partnerships, such as early strategic alliances between Helmholtz Centers and complementary business partners. These long-term cooperation models are a perfect match for the high level of system expertise along the innovation chain that distinguishes Helmholtz.

2. Take a leading position in benchmarking relevant transfer indicators

Both nationally and internationally, Helmholtz can be proud of its funding instruments, activities, and successes in the field of transfer, although this is not fully reflected in the development of the classic technology transfer indicators. The objective is therefore to establish new relevant key performance indicators and qualitative criteria that better reflect transfer success. Nevertheless, the goal of improving key performance indicators for spin-offs, the number, quality, and income of cooperation efforts with compa-

nies, and license revenues remains in place. In recent years, instruments such as the Helmholtz Validation Fund, the Helmholtz Innovation Labs and individual center innovation funds have already been set up to this end.

In the future, these activities will be intensified and further expanded. An IVF-funded initiative and cooperation with the Fraunhofer Society are to support projects on the road to clinical proof of concept. The Centers will create additional experimental spaces for innovative research and cooperation platforms, and use an accelerator program to support intrapreneurship and entrepreneurship.

3. Create optimal framework conditions for transfer and enhance the culture of innovation

There has long been an intensive exchange of experience between the Helmholtz Center transfer offices. In recent years, it has been possible to promote the professionalization of transfer offices through such measures as further training, integration of external expertise, and personnel expansion. Key issues papers have contributed to the strategic anchoring of transfer and innovation in the Association and at the Centers.

In the future, the focus will be on the culture of innovation. This focus will include such measures as greater consideration of innovation in recruiting and the expansion of innovation modules at the Helmholtz Academy. The exchange of experience and the transfer of the best models from the newly funded Helmholtz Center innovation funds will also play an important role.

4. View exchange with business and society as an elementary part of the Helmholtz mission

The mission of the Helmholtz Association is to contribute to solving great, pressing questions facing society, science, and business. This mission is more relevant than ever. In order to complete it successfully, however, the target groups outside of the scientific community must be addressed even more precisely than before. In the coming years, we will optimize not only exchange formats and transfer channels, but also incentive systems, with respect to business and society. This includes examining review and allocation procedures. The development of a knowledge transfer indicator system that gives greater attention to transfer concerns than has been the case will be one of the next steps.

5. Enhance knowledge transfer and use new interaction and participation formats

Knowledge is already being transferred by Helmholtz researchers and the Centers' institutional formats: There are health information services, exchange platforms and data portals, or student laboratories at almost all Helmholtz Centers.

These efforts are to be stepped up. To this end, innovative projects will receive targeted support in the future. In addition, knowledge transfer activities within the Association will be documented more systematically in order to establish a basis for better networking players and jointly marketing offers. Knowledge transfer is a bi-directional, dialogue-oriented process and should therefore be focused even more strongly on societal stakeholders and the interested public in the future. In addition to its involvement in planning, designing, and disseminating research, it includes Citizen Science.

THE PATH

With its excellent basic research, innovative and interdisciplinary approaches, and high transfer potential, Helmholtz commands distinct system expertise. This expertise must be strategically aligned with the grand challenges facing science, society, and business.

Research programs with clearly defined objectives, in which scientists from the Helmholtz Centers contribute their respective competencies, form the basis for this alignment. The Helmholtz Association invests a considerable part of its resources in cross-center research programs that are in competition with each other.

By pooling the diverse contributions of various research centers, Helmholtz is in a unique position not only to offer answers to individual questions, but also to answer complex questions from science, society, and business in a holistic manner, and to develop system solutions. The six research fields have the important task of shaping future research areas, framing system solutions together with the best partners, and developing a significant impact on the relevant areas.

Program-oriented funding

The basis of the program-oriented funding is a two-tiered system: The first stage is a scientific review of the Centers and of current programs at the individual center level. The second stage is a strategic evaluation of future programs at the research field level.

The scientific review focuses on scientific quality as defined in international standards. The results are used to assess the performance of both the Helmholtz Center and the individual programs, most of which are inter-center efforts. Both aspects are equally important: The Centers are the driving force behind the Association. They are where research is carried out. They are where knowledge is acquired. The programs link the research, the findings and results, and develop system solutions.

The strategic evaluation focuses on the program proposals for the next funding period. These proposals are drawn up in line with the research policy objectives. To what extent do they address the challenges ahead, formulate goals for meeting those challenges, and identify ways of achieving those goals? How do the Centers bring together their competencies and

incorporate the recommendations of the scientific review? Does a given program contribute to the implementation of the research field's strategy?

The reviews are carried out by international, independent experts. Their reports form the basis for the Helmholtz Senate's recommendation regarding the amount at which the federal and state governments should support the research programs. They also provide ideas for program and research field refinement. This interplay of quality assurance and forward-looking evaluation puts the Helmholtz Association's research in a great position. Its research results can be measured against those of leading institutes around the world. Research will continue to provide decisive contributions to the complex issues in the coming years.

Modern research management

The Helmholtz Association's special tasks and objectives place the highest demands on science management. The Centers often assume the role of pioneers when technical, organizational, financial, or legal innovations are needed to open up maneuvering space for the German scientific community. This happens at different levels:

- The Helmholtz Association builds new large-scale facilities such as the XFEL X-ray laser, which has never before been designed in this form.
- Helmholtz Centers develop, establish, and manage powerful national consortia such as the German Centers of Health Research or Copernicus Associations in energy research.
- Work with universities results in new and highly successful forms of cooperation such as the Helmholtz Institutes, which build bridges between university and non-university research.

In most cases, these efforts are the work of large teams that combine scientific and administrative expertise. Since its foundation, the Helmholtz Association has been relying on one decisive factor that allows all of this to happen: a commitment to modern research management. This task is reflected in the Association's statutes:

"Due to the mission of the Helmholtz Association, its technical and administrative staff must also meet high standards. ... Promoting professional leadership and management skills is a key focus of the Helmholtz Association for higher career levels in both the scien-tific and the technical and administrative fields."

The objective is for the science managers at the Centers and in the offices to have the following qualities:

- a high degree of professionalization and specialization
- a special appreciation of science
- extensive management skills
- in-depth knowledge of the German scientific landscape
- commercial and organizational expertise

The Helmholtz Management Academy is the most important instrument for imparting these qualifications (see p. 25). It is aimed at all staff members who take on management and coordination tasks in science and administration. The Academy's comprehensive program allows management to be professionalized at all levels.

With the skills they acquire at the Academy, Helmholtz managers make it possible to carry out the complex cutting-edge research for which the Helmholtz Association is known.

Research infrastructures

In addition to the staff, the large research infrastructures are of enormous importance for successful work within the Helmholtz Association. Accelerator systems, telescopes, research vessels, supercomputers – large research facilities make possible essential scientific advances for meeting global societal challenges. This is true of all research fields within the Association. The Helmholtz infrastructures offer excellent conditions for scientists within the Association and for users from all over the world.

The development, construction, and operation of such complex infrastructures are a core element of the Helmholtz Association's mission and one of its unique selling points. Another important building block in this

context is the development of technology for complex infrastructures. This technology is what allows Helmholtz to develop the infrastructures in the first place and remains essential to their support thereafter. The research facilities exemplify the division of tasks in the German scientific system as well as cooperation with German and foreign universities and research institutions.

At user facilities, more than 50 percent of the available measurement time is granted based on a peer review procedure. Researchers submit proposals that are reviewed by experts. As operators of the research infrastructures, the Helmholtz Centers support researchers in carrying out their chosen experiments or conduct them jointly with the researchers. In this way, thousands of visiting scientists are given the opportunity to take advantage of and benefit from the unique scientific opportunities at the Helmholtz Centers.

Foresight processes have been introduced to implement research infrastructures. Established at the Helmholtz, national, and European levels, these processes encompass planning periods of more than ten years. In the future, they will need to be even better interlinked. This can only be achieved in close cooperation with partners in the scientific system.

Prioritization of projects must be based on analysis driven by science and research and must include consideration of societal relevance. One of the challenges is that proposals and applications for new infrastructures originate from a wide variety of disciplines and are therefore difficult to compare. However, this is the only way to identify the infrastructures that will allow excellent science in the long term and contribute to answering the great questions of our society.

Publisher
Hermann von Helmholtz-Gemeinschaft
Deutscher Forschungszentren e.V.

Helmholtz Association headquarters
Ahrstraße 45, 53175 Bonn, Germany
Phone +49-228-30818-0, Fax +49-228-30818-30
e-mail info@helmholtz.de, www.helmholtz.de

Communication and External Affairs
Berlin Office
Anna-Louisa-Karsch-Straße 2, 10178 Berlin, Germany
Phone +49-30-206329-57, Fax +49-30-206329-60

Responsible according to the German press law
Franziska Broer

Editing
Dr. Caroline Krüger, Rebecca Winkels

Text
Dr. Christian Beilmann, Dr. Ilja Bohnet,
Franziska Broer, Dr. Cathrin Brüchmann,
Effrosyni Chelioti, Dr. Stephanie Dittmer,
Eva Maria Heck, Dr. Juliane Kampe, Roland Koch,
Olaf Kranz, Dr. Caroline Krüger, Jörn Krupa,
Dr. Uli Rockenbauch, Alexandra Rosenbach,
Dr. Tobias Sontheimer, Dr. Sören Wiesenfeldt,
Rebecca Winkels

Photo credits
Cover: kjpargeter/Freepik; p. 3: Andreas Heddergott/
TU München; p. 4: A. Book/HZB, Oliver Killig/HZDR,
Susanne Tessa Müller, DLR (CC-BY 3.0), European
XFEL; p. 5: Oliver Killig/HZDR, Arne Wahlers/DLR,
Novatec Solar/DLR, NASA:2Explore, KIT, ESA/HZG,
Markus Breig/KIT, Manfred Rohde/HZI; p. 7: Helmholtz;
p. 8: A. Book/HZB; p.10: Novatec Solar/DLR;
p.12: ESA/HZG; p.14: Manfred Rohde/HZI;
p.16: NASA:2Explore; p.18: Markus Breig/KIT;
p. 20: KIT; p. 22: Oliver Killig/HZDR; p. 24: Susanne
Tessa Müller; p. 25: Helmholtz; p. 28: Arne Wahlers/DLR;
p. 30: DLR (CC-BY 3.0); p. 32: European XFEL;
p. 34: Christian Föhr/H.E.S.S. Collaboration, 2012

Layout and image editing
Stephanie Lochmüller/Helmholtz Association

Printing
ARNOLD group, Großbeeren

Last updated
April 2018