Fraunhofer
INT

Annual Report 2023

Fraunhofer Technologies in Space

Fraunhofer Institute for Technological Trend Analysis

Foreword

Dear readers,

Are you sure that you are safe?
Anyone who has followed the news in recent months and listened attentively to the statements of autocrat Putin and his followers in particular is sure to have felt a shiver run down their spine on several occasions. However, it is unlikely to have been the kind of shiver you get in a comfortable movie seat when watching a well-made scary movie. Especially for those of us who experienced the Cold War ourselves, it sounds fatally like a rhetoric of conquest long thought to have been overcome, which sends a cold shiver down the spine. Putin's dreams of a resurrected Russian empire can only be realized at the expense of free, independent – and generally democratic – states. As a compliant tool of the ruler, the Russian military does not shy away from war crimes of any kind or the use of all conceivable weapons, and it is fortunate that the nuclear option has not yet been used on the battlefield. In the war of words, they have long since become one of the usable means of war.

Can the unthinkable become thinkable?
There is no definite answer to this question. The logical conclusion is that only preparation for all eventualities can offer a certain degree of protection. During the Cold War, peace in the form of non-use of weapons was maintained by keeping the risk of major losses incalculable for both sides. The triad of conventional, nuclear-tactical and nuclear-strategic forces enabled a strategy of flexible response and made it impossible for the enemy to predict the response to aggression. The pillars on which the security architecture of the time was built were the real capabilities available and the unrestricted credibility to deploy these capabilities in full for defense. The assured mutual destruction nipped any mutual desire for conquest in the bud. In the end, it was largely thanks to rational thinking at the top of the two blocs that the balance of terror could be resolved.

Unfortunately, the situation today is far more complicated than it was during the Cold War. On the one hand, there are significantly more nuclear powers than there were back then, which considerably increases the opportunities for proliferation. The risk of irrational, fanatical or terrorist forces gaining access to these weapons has greatly increased, but not every "legitimate" owner of a nuclear arsenal can be described as rational either. It is also known from game theory that the number of possible outcomes increases when there are more than two players at the table. The relatively straightforward configuration of a two-sided confrontation has now become a collection of unpredictable players, each with their own, sometimes unknown intentions.

The technological possibilities for building nuclear weapons have also increased since the end of the Cold War. The construction of battlefield weapons with an explosive force between "large" conventional and "small" nuclear tactical

Rest assured: our research will continue to contribute to making the world a little safer"

weapons is once again being discussed. These "mini-nukes" are capable of significantly lowering the nuclear threshold.

There is another point: the above-mentioned triad has become an ominous quadriga. The major technological developments of recent decades have turned cyberspace into a battleground and cyber weapons into effective means of attack. Modern industrialized nations have become extremely dependent on their digital infrastructure and global networking. For an aggressor, this offers the opportunity to weaken a potential victim below the threshold of a shooting war very cheaply and efficiently to such an extent that the use of military forces is only necessary to a limited extent or not at all. If you look closely, you can observe the troll factories and cyber battalions of autocratic states at work in our country too.

Last but not least: questions about military conflicts – especially nuclear weapons and their effects – have not been particularly en vogue in our society over the past three decades. Much of the knowledge acquired during the Cold War has been lost, and dealing with the associated issues has to be relearned. This is a learning process that must be mastered not only in the military, but above all in civilian society. For what has been true since ancient times has been shown to us once again with frightening clarity in the Ukraine war: in war, there is no division between fighting soldiers and uninvolved civilians. Both are affected and the unprotected population is often hit even harder than the soldiers.

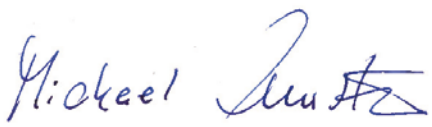
For 50 years, Fraunhofer INT has been conducting research into modern technology developments, including for military applications, disaster prevention, the vulnerability of the digital world to electromagnetic threats and the effects of nuclear weapons.

Rest assured: our research will continue to contribute to making the world a little safer.

This annual report once again provides you with an overview of the numerous forward-looking research results that the Fraunhofer INT has produced over the past year, despite all adversity.

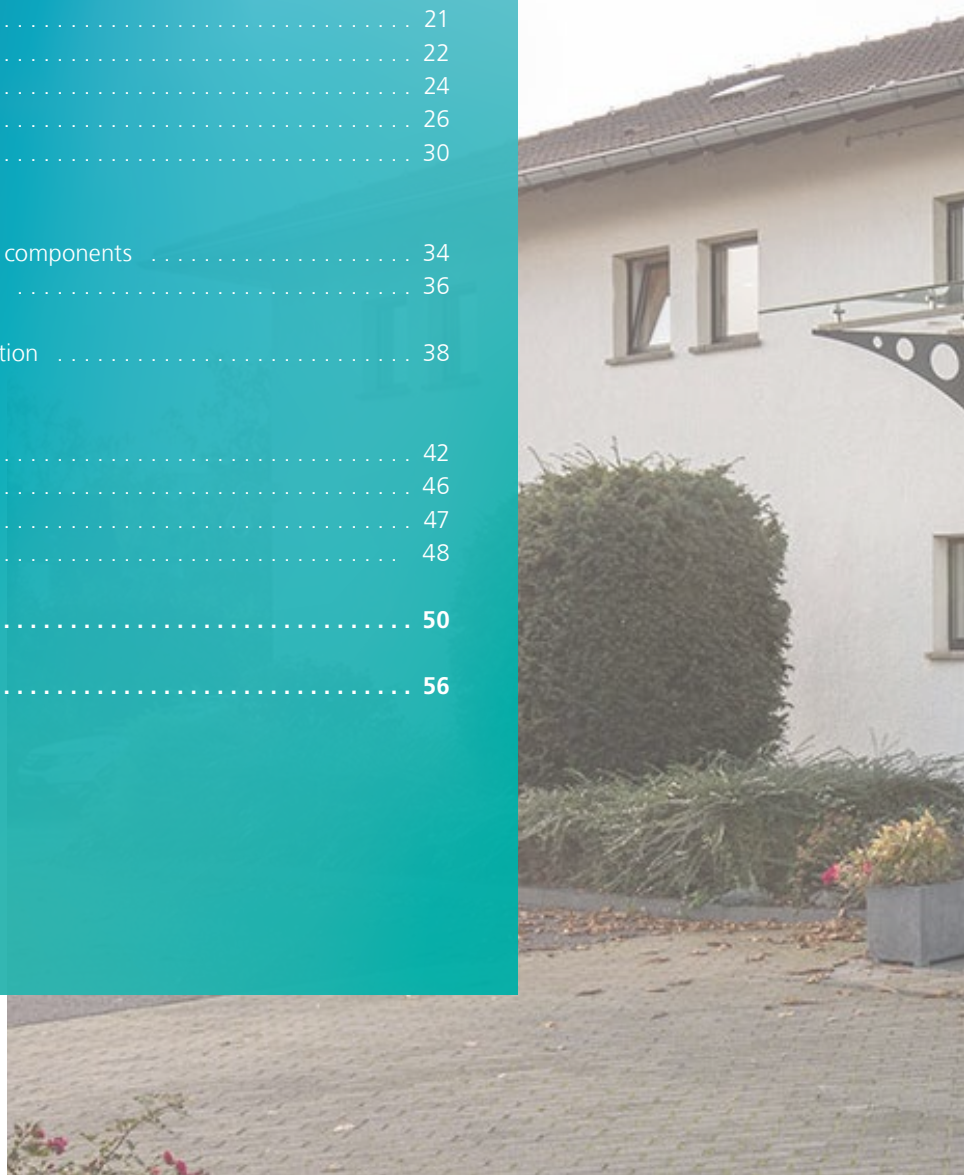
I hope you enjoy reading it. Stay curious and look with us into a hopefully secure future.

Yours sincerely



Prof. Dr. Dr. Michael Lauster

Content



The business units and groups of Fraunhofer INT

Fraunhofer INT's various research activities are organized into six business units. They are supported by three working groups.

6+3

Technology foresight and strategic planning

"Defense Technology Foresight" (WZA)

The business unit "Defense Technology Foresight" (WZA) conducts long-term, technology-oriented future research (technology foresight for public customers in the defense sector, in particular the Federal Ministry of Defense (BMVg) and its subordinate departments.

"Public Technology and Innovation Planning" (TIP)

The business unit "Public Technology and Innovation Planning" (TIP) supports the design of strategic research and innovation planning for public, non-military clients such as the European Commission, the EU Parliament and other national and international actors.

"Corporate Technology Foresight" (CTF)

The "Corporate Technology Foresight" (CTF) business unit conducts technology-oriented future and innovation research and supports organizations in answering strategic questions.

"Technology Foresight and University Hub" (TFU)

The "Technology Foresight and University Hub" (TFU) group tests and develops technology foresight tools and methods and maintains Fraunhofer INT's university connection.

"KATI Lab" (KLAB)

The "KATI Lab" (KLAB) group is continuously developing the KATI (Knowledge Analytics for Technology & Innovation) technology foresight assistance system and is looking at how data can be used for foresight processes.

The contact persons and contact details for the business units and groups can be found on pages 54-55.

Reliability of radiation effects in electronics

"Electromagnetic Effects and Threats" (EME)

The business unit "Electromagnetic Effects and Threats" (EME) deals with electromagnetic fields and their effects on electronics.

"Nuclear Security Policy and Detection Techniques" (NSD)

The business unit "Nuclear Security Policy and Detection Techniques" (NSD) performs theoretical simulations and experimental measurements to research and develop methods for identifying nuclear and radioactive materials.

"Nuclear Effects in Electronics and Optics" (NEO)

The business unit "Nuclear Effects in Electronics and Optics" (NEO) researches the effects of ionizing radiation and performs irradiation tests with electronic, optoelectronic and optical components and systems.

"Scientific and Technical Infrastructure" (WTI)

The group "Scientific and Technical Infrastructure" (WTI) supports the business units with a precision mechanics workshop and an electronics workshop.

Business Administration and Central Services (BZD)

The department handles all commercial and administrative tasks and provides the central infrastructure of the Institute ready.

Science Year "Our Universe": Fraunhofer technologies in space

Fraunhofer INT radiation sensor launches into space on Heinrich Hertz satellite

Planets, satellites and space travel– the motto of the Science Year 2023 was "Our Universe". Since 2000, the Federal Ministry of Education and Research (BMBF) and the initiative "Wissenschaft im Dialog" (Science in Dialogue) have chosen a theme for the Science Year every year. This theme is then used to communicate scientific content throughout the year and numerous activities such as exhibitions, competitions and other dialog formats are carried out. The Science Years promote the exchange between science and society and provide citizens with easy access to research topics. In 2023, the focus was on space and therefore topics such as astronomy, the beginnings and history of the universe and pressing issues of our time such as climate change, environmental protection and new energy sources.

Fraunhofer activities in the Science Year "Our Universe"

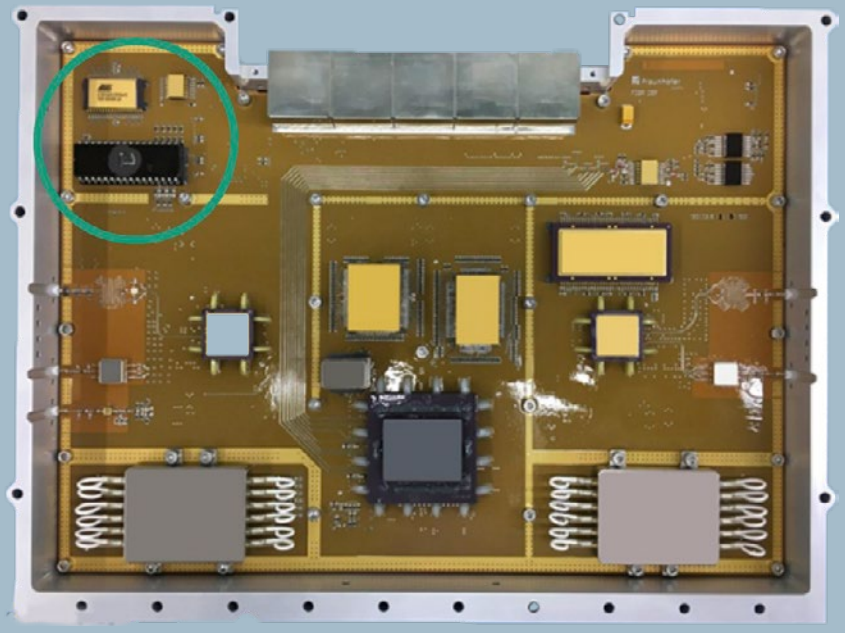
The Fraunhofer-Gesellschaft also took part in the Science Year 2023 with a number of activities. Together with the Fraunhofer AVIATION & SPACE Alliance, Fraunhofer headquarters organized a three-day exhibition titled "Down to Earth Space Technology" at the Fraunhofer Forum in Berlin. In addition to exhibits from the Fraunhofer Institutes INT, EMI and FHR as well as joint exhibits from the Alliance, participants were able to listen to exciting talks, get hands-on in a citizens' lab, take part in a children's reading session and visit a science café. From May to October, Fraunhofer was also represented on the MS Wissenschaft, an exhibition ship that functions as a science center and tours Germany and Austria with scientific exhibitions. Visitors could also view exhibits from various Fraunhofer institutes, including Fraunhofer INT and take part in a citizen science workshop for children during the stop at the Bonn harbor in early August, where they measured the size of a dam using satellite images. In the space-themed Science Year, the biggest highlight for Fraunhofer INT in 2023 was its participation in the Heinrich-Hertz-mission, contributing a radiation sensor installed on board of the satellite.

The Heinrich-Hertz-mission

The aim of the Heinrich-Hertz-mission is to test new satellite communication technologies for their suitability for use in space under real conditions and to carry out experiments on communication, antennas and satellite technology. Satellites are exposed to numerous challenges in space, including extreme temperatures and radiation. In the worst-case scenario, these conditions can cause the technology to fail. To minimize this risk, the satellite undergoes in-orbit verification with this mission. If the components successfully pass the endurance test on this mission, the risk of failure on future missions will be significantly minimized. On July 6, 2023, the almost 3.5-ton Heinrich Hertz communications satellite was launched on board the last Ariane 5 rocket from the European spaceport in Kourou, French Guiana. After reaching orbit, the satellite will circle in a geostationary orbit for 15 years at an altitude of 36,000 kilometers, remaining constantly above the same spot on the Earth's surface. The Heinrich-Hertz-mission is being carried out by the German Space Agency at the German Aerospace Center (DLR) on behalf of the Federal Ministry of Economics and Climate Protection (BMWK) and with the participation of the Federal Ministry of Defence (BMVg).

Fraunhofer INT develops radiation sensor for the Heinrich-Hertz-mission

The on-board radiation sensor (FORS) developed at Fraunhofer INT is on board the Heinrich-Hertz-satellite and is being used



© Fraunhofer IIS
FOBP box from Fraunhofer IIS incl. radiation sensor from Fraunhofer INT

for the first time on this mission. The sensor measures intense radiation events in orbit in order to protect the satellite's radiation-sensitive components depending on the radiation level. Specifically, the FORS measures the dose resp. particle fluxes on carriers for electronic components, the so-called circuit boards. The radiation-sensitive components to be protected are located on close proximity on these boards. During intense solar radiation events in orbit, a sudden increase in particle fluxes can cause considerable damage. The measurements provide information on when adaptive techniques to minimize the radiation effect must be used to protect electronic components of the satellite. The measurements should also help to gain a better understanding of the radiation environment of satellite technology under real conditions. This could help future missions as more accurate data can be provided. Findings from this mission are also extremely important for satellite manufacturers or operators.

The Fraunhofer IIS on-board processor

The Fraunhofer INT sensors are located in the box of the Fraunhofer on-board processor (FOBP). This was developed at the Fraunhofer Institute for Integrated Circuits IIS in Erlangen and is also being used for the first time as part of this mission. Conventional communication satellites were previously limited to receiving and forwarding data. The Fraunhofer on-board processor (FOBP), on the other hand, filters and processes the received information already on board the satellite. It can be reconfigured from Earth and thus adapted to new communication standards at any time. The satellite can thus further develop its capabilities in space during the mission, serving as a test environment for new satellite communication systems.

Irradiation tests at Fraunhofer INT

However, Fraunhofer INT was not only involved in the Heinrich-Hertz-mission with the FORS. In advance, scientists from Fraunhofer INT conducted various radiation simulations on electronic and optical components of the Heinrich-Hertz-satellite. Since cosmic and solar radiation causes increased radiation exposure in space, a number of precautions must be taken in advance for space missions. The radiation can damage parts of satellites such as the electronics or optical components (lenses in cameras or telescopes, laser communication systems, etc.) and render them unusable. These components are therefore subjected to tests before they are sent into space to check how they react to the increased radiation. Appropriate measures can then be taken to protect the components and ensure their functionality. These tests were carried out at Fraunhofer INT using a Cobalt-60 gamma irradiation facility.

Technology foresight and strategic planning

The world is complex, interdependencies are multi-layered and the speed of development is rapid. Recent years have shown that substantial changes can occur rapidly (energy crisis, pandemic), havehlong-term consequences but require short-term action (climate change, demographic change etc.).

Under the influence of these changes, social parameters like norms and values, as well as models of life and work, are continuously evolving. Technology is a central component of this socio-technological regime and technological developments thus influence our everyday lives and our future.

In this complex and dynamic environment individuals in positions of high responsibility must repeatedly make technology-related decisions with potentially major consequences, which are inevitably associated with uncertainties and risks. It is therefore essential to incorporate reliable information about current technological developments and science based assumptions about anticipated technological developments into decision-making processes. Due to this reliable and unbiased information about technologies and their future are important resources for of long-term, strategic planning. The scientifically based development of this information is the subject of applied, technology-oriented future research. With this goal in mind, Fraunhofer INT has been operating its technology analyse and strategic planning support unit for more than 50 years.

"Technologies are a central component of our everyday life, and technological advancements influence our daily lives and our future."

Planning and crisis management in pandemic management

The EU project PANDEM-2

PANDEM-2
PANDEMIC PREPAREDNESS AND RESPONSE

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This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 883285.

Pandemics pose a major threat to the health and safety of societies. To protect the population, it is thus essential to be prepared with effective responses to pandemics at regional, national or international level. The task of pandemic managers is to assess the severity of an emergency, identify the best responses and measures to minimize harm to society and individuals, and then initiate the implementation of those measures. This includes preparing for the next pandemic – a particular challenge given that the impact of a future outbreak cannot be predicted in advance. Additionally, while the spread of a virus does not stop at national borders, the pandemic response strategies of different countries vary significantly.

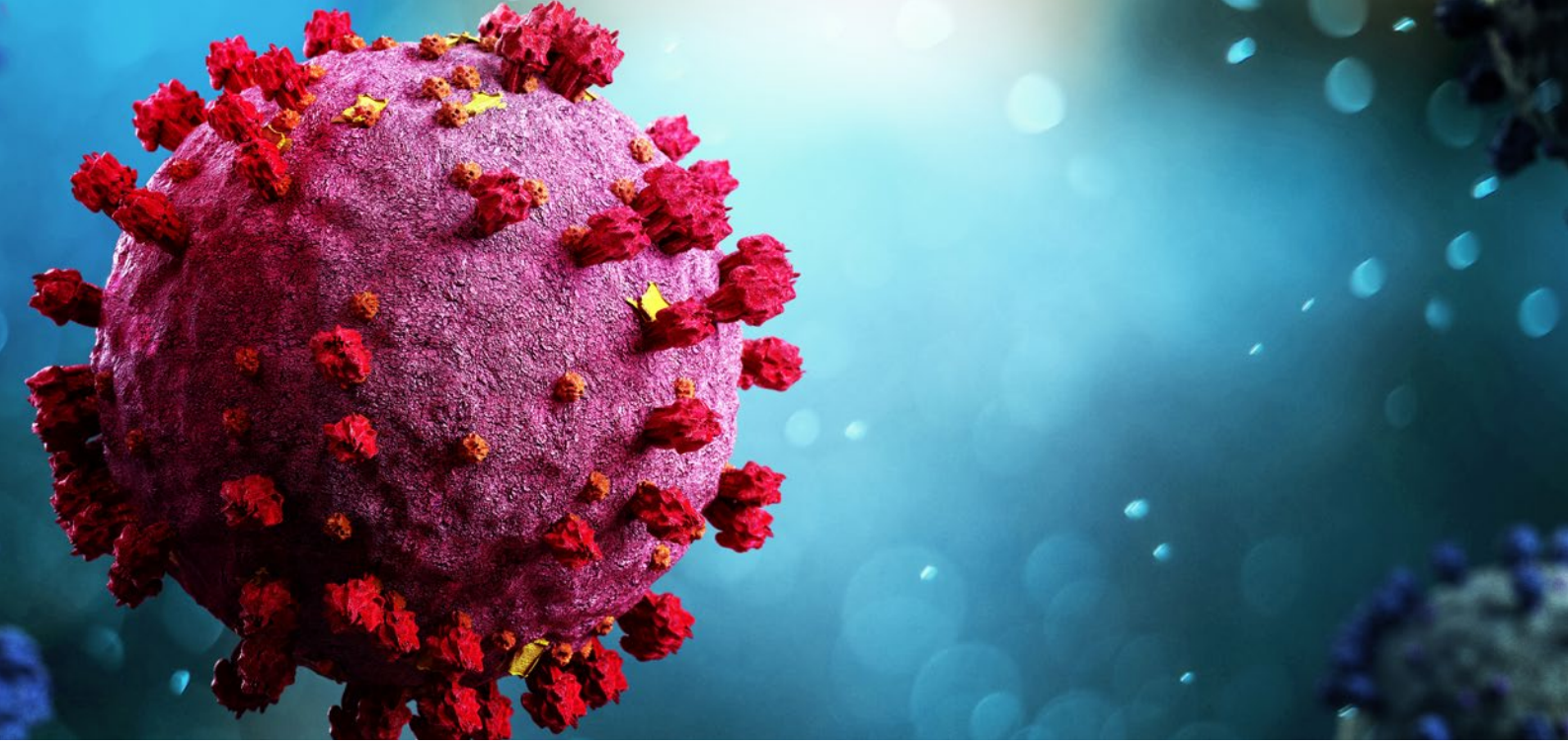
Support in pandemic management

The main problem addressed by the EU-project PANDEM-2 is that effective pandemic management requires a comprehensive, cross-border approach. Pandemic managers need to utilize data from a variety of sources, analyze it and derive actions. They must ensure that hospitals and other public health actors have the right equipment, sufficient staff and resources to meet the challenges of a potential pandemic. The required resources vary from disease to disease, ranging from very deadly ones like Ebola to less deadly but highly infectious pathogens like the recent Covid-19 variants.

As the successor to the PANDEM project (2015-2017), PANDEM-2 developed an IT-system prototype to support planning, situational awareness and decision-making processes in EU pandemic management. Pandemic-relevant data was collected and integrated from international laboratories, databases and social media to help track the health, social and economic consequences of a pandemic. The integrated data was compiled in real time on an internet-based dashboard and made available as a decision-making aid. The PANDEM-2-systems were tested in various demonstrations together with national, European and international pandemic managers and healthcare providers.

Communication during a pandemic

At the same time, pandemic managers must build trust with the public, communicate effectively and involve the population in a way that they follow the experts' advice and can thus actively contribute to the fight against the pandemic. Communication and information sharing with the public must be precise, timely and clear. This is of particular importance as social media increasingly becomes an ideal environment for spreading misinformation and deliberate disinformation. The willingness to cooperate with society and prompt action are of immense importance, as could be seen during the Covid-19 pandemic.



Appropriate measures such as lockdowns, school and business closures and travel restrictions must be implemented in relation to their impact on the pandemic. The damage to the economy, quality of life, mental health, healthcare and numerous other components of society should be kept to a minimum. Fraunhofer INT has analyzed communication strategies and, together with experts and health authorities, developed recommendations to provide users in health care and civil protection with practical, modifiable communication materials.

In addition to the official communication from public health authorities, a number of "key opinion leaders" emerged during the Covid-19 pandemic, significantly influencing public discourse by supplementing official messages. In interviews and workshops with such opinion leaders, PR experts, scientists and science journalists, Fraunhofer INT was able to highlight the complementary role of independent communicators and public health actors. The insights gained highlight the importance of good science communication, a basic understanding of science within the population and the need for active dialog between both sides to overcome a pandemic.

PANDEM-2 Website

Scientists disagreeing is healthy, because science is not black and white [in the pandemic]. So, it is not bad in terms of the political discourse. Scientists not knowing how to communicate is the biggest problem."

Project INDY – Energy supply for military camps

Pioneering project for the use of green energy in the defense sector

INDY Energy Independent Energy Efficient Deployable Military Camps

Funded by the European Union

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INDY Website

The project INDY (Energy Independent Energy Efficient Deployable Military Camps) is about creating a roadmap to realize more energy-efficient military camps that are as independent as possible from energy supply. The project is financed by the European Defense Fund (EDF) of the European Union. More than 20 partners and other subcontractors from a total of 13 European nations are cooperating in this project under the coordination of the Slovenian innovation cluster for green technologies and energy-efficient solutions TECES.

In this project, Fraunhofer INT is responsible for identifying operational scenarios and user requirements for military field camps, also in conjunction with a survey of the participating national defense ministries, and for identifying and analyzing relevant emerging technologies in cooperation with the participating research institutions. This work, which is fundamental to the project and very extensive, began with the project kick-off meeting in Maribor, Slovenia, in February 2023. It was completed on schedule in September for the Mission Definition Review and the second General Assembly in Ede, Netherlands. Building on this, the subsequent work packages will now focus on aspects such as the future energy mix, planning and simulation of future field camps. Fraunhofer INT will be involved in various other work packages and will work with the partners to develop new findings on the emerging technologies and integrate them into the "Dynamic Library of Emerging Technologies" created during the first project phase. The project is expected to be completed in January 2025.

DIVE – Dashboards for Interactive Visualization and Exploration

Making tools and methods tangible

For many years, Fraunhofer INT has been using and developing tools and methods to support the technology analyses carried out at the Institute. Increasingly easy access to different types of data such as publications, patents, research funding data or unstructured text data allows for more detailed technology analysis, but also increases the complexity of this analysis. In addition, there are possibilities from the fields of machine learning and artificial intelligence, which are increasingly coming into focus when it comes to data-driven technology analyses. With DIVE (Dashboards for Interactive Visualization and Exploration), Fraunhofer INT provides its scientists with an internally hosted platform that takes on three central tasks in this context: Distribution and exploration of tools and methods, as well as knowledge management. For example, DIVE provides quick and easy access to the specially developed "Search Query Translator" (distribution of tools and methods). This translates search queries between different publication databases such as the Web of Science and Scopus, in a similar way to how Google Translator works with languages. Experimental methods such as "Semantic Document Clustering" or "Topic Modeling" enable the exploration of data. All tools and methods are explained and documented on DIVE, including possible limitations (knowledge management).

The idea is therefore to provide information about complex tools and methods and offer easy access in order to evaluate their usability in the context of technology analyses. Further development then takes place on this foundation.

DIVE can be accessed at Fraunhofer INT as a browser-based web application and is based on Python and the programming language R. The modular structure of the platform allows the development team to react quickly to the scientists' ideas and challenges.

DIVE
by Fraunhofer INT

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Employee portrait – Philipp Baaden

The work of a research associate at Fraunhofer INT

What topics do you deal with at Fraunhofer INT?

Roughly speaking, anything that has to do with technology and innovation management can land on my desk. The classic requests are usually to outline the evolution of a specific technology or technological topics. In recent years, for example, I have dealt with topics such as synthetic biology, nuclear fusion, smart farming, autonomous driving and many more. Here, I always work together with colleagues who are familiar with the respective technology or topic. Together, and usually iteratively, we develop exciting insights. It is particularly important to me to make things measurable. This means that I use targeted methods and analyses to extract information from various data sources that is relevant in the respective context. We call this "advanced analytics", by which we mean a portfolio of methods from the fields of natural language processing, machine learning and statistics. In recent years, the DIVE-platform (see p. 15) has also emerged from the field of advanced analytics, where we provide information about various methods and make them available within the institute. I am also doing my doctorate in cooperation with the Chair of Entrepreneurship and Innovative Business Models at Ruhr University Bochum and researching the emergence of new areas of knowledge.

What does your day-to-day work look like?

It's difficult for me to describe a real day-to-day routine given the variety of things that come up in my work. In the mornings, I always try to block some time in which I can focus on my work. Also I don't miss out on coffee. Depending on what I have planned for the week, I then concentrate on a project or write a scientific paper. In the afternoon, I often continue with team or project meetings. I like to use free minutes in the afternoon to research new methods and developments in the context of technology and innovation management and I read a lot of scientific articles in this area. Testing and evaluating new methods then usually happens in a specific project or research context. I usually close my laptop between 6:00 and 6:30 p.m. and put on my running shoes or soccer boots.

What do you enjoy most about your work?

Clearly the flexibility and working in a diverse and harmonious team. In terms of content, I always have to and am allowed to devote myself to new topics. Our projects are usually so different that there is no one prototypical process. Our customers are also very diverse. They range from industrial customers to

ministries. I also enjoy a lot of freedom when it comes to my doctorate. I also conduct research with colleagues from the fields of computer science, social sciences, linguistics and natural sciences on topics that are not directly related to my dissertation. Working in such an interdisciplinary environment is inspiring and gives me great pleasure.

How did you come to Fraunhofer INT?

I was looking for a partner for my Master's thesis and therefore searched for Fraunhofer Institutes in my area. Fraunhofer INT responded immediately to my unsolicited application and invited me to join. Even during my time as a research assistant, I was regarded as a fully-fledged member of the institute and was allowed to take part in conferences and projects. In my opinion, this appreciation for young scientists is crucial. Early on, I was also informed that the institute would support me with my doctoral studies and together we searched for a suitable cooperation partner.

What tips do you have for someone who would also like to work at Fraunhofer?

From my experience: Don't just wait for job advertisements – just apply. If you have the feeling that your profile fits well with an institute, then don't wait. Fraunhofer, as I know it, is an employer that is very interested in the further development of its employees. If you are motivated and willing to keep learning, you have a good chance at Fraunhofer.

What is an upcoming project or task that you are particularly looking forward to?

I would have to say the further development of the DIVE-platform. We have already achieved initial successes in projects with the platform and have just drawn up a roadmap for 2024. The feedback we get from our colleagues is valuable and we are looking forward to delivering further added value at Fraunhofer INT.

TFU-Website

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KSaRo – Small Satellite Roadmap 2030

Status and further development needs of the German industrial and research landscape with regard to small satellites

Small satellites – a success story of the "New Space"

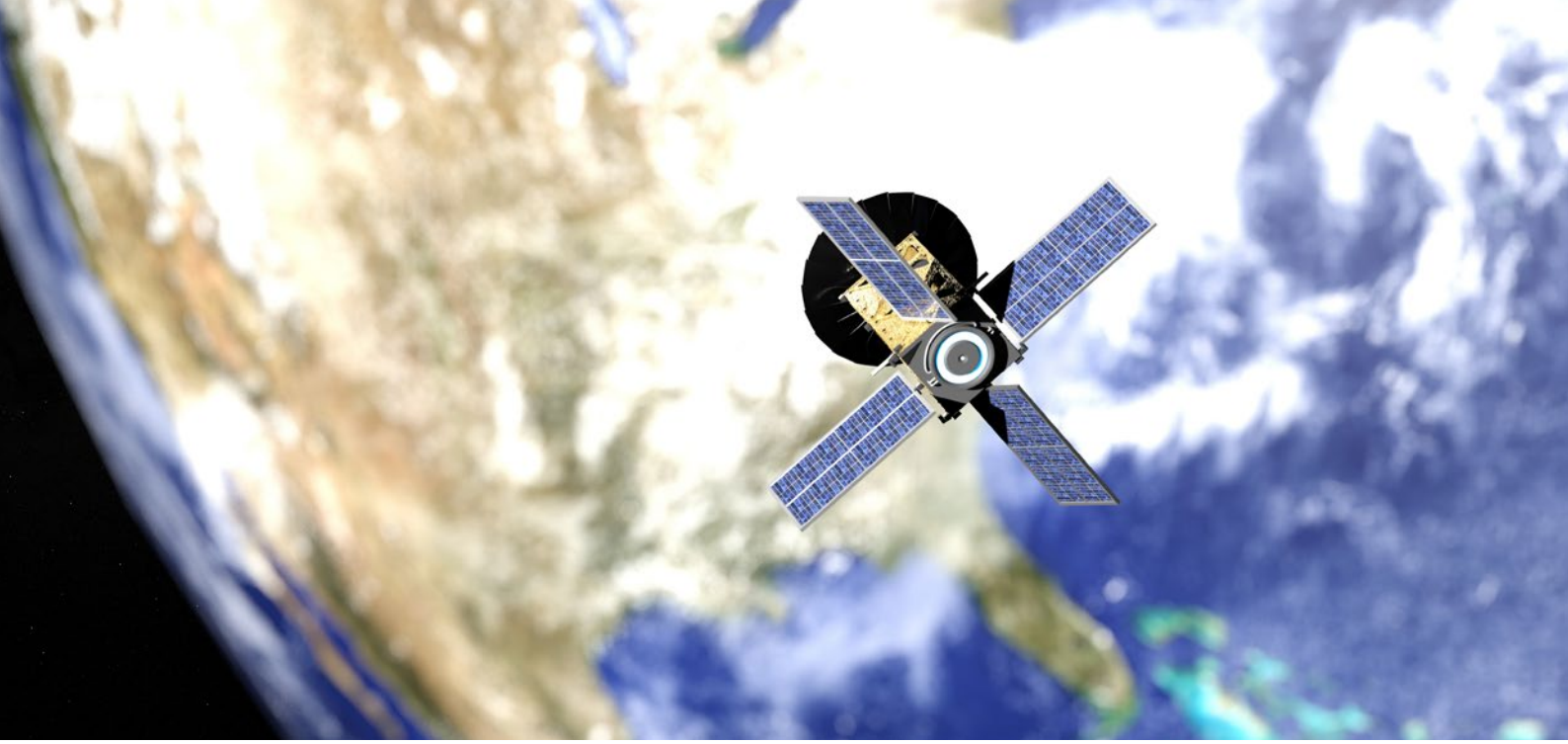
The increased use of small satellites is one of the key features of applications in commercialized space travel, which is often referred to as "New Space". Small satellites are increasingly being used in areas such as satellite communications and earth observation. Although the idea of a miniaturized satellite is not new, it has gained considerable momentum, especially in the last decade. Due to the reduced size and weight (<500 kilograms) and the associated relatively low costs for the construction and launch of small satellites, they have significant advantages over conventional large satellites. This means that small and medium-sized enterprises (SMEs) and start-ups can participate in space missions with a manageable financial risk and demonstrate new technological advances. In the course of the increasing commercialization of space travel, further rapid growth is predicted for small, mass-produced satellites. Current estimates assume that over 90 percent of satellites launched will be small satellites by 2030.

The small satellite roadmap as an instrument for identifying funding priorities

German companies also want to benefit from this growth market and are trying to assert themselves in the international New Space market with their expertise in the field of small satellite technology. Ideally, they would be able to cover the entire value chain, i.e. all stages from development to production and operation of the satellite or satellite constellation. However, this would require SMEs and start-ups in particular to be able to develop and mass-produce internationally competitive small satellites and the associated subsystems and components.

Against this backdrop, the German Space Agency at the German Aerospace Center (DLR) launched the twelve-month "KSaRo" project at the end of 2022 to create the first version of a technology roadmap for relevant small satellite technologies up to 2030. The overarching aim of the project was to strengthen Germany's capabilities in the field of small satellites by using the roadmap to identify good funding priorities. The project was carried out by Fraunhofer AVIATION & SPACE, Fraunhofer INT and Fraunhofer EMI. Together, the partners contributed the necessary technical know-how regarding small satellites as well as the methodological know-how for roadmapping.

The starting point for the project was the implementation of a Germany-wide survey investigating the status quo of the national small satellite landscape regarding the key



players (including universities, non-university research institutions, suppliers and integrators). By approaching the players directly, it was ensured that up-to-date data on the performance of their technologies, products and services was available and summarized in a database. A subsequent analysis of international scientific publications, patents, public funding activities and relevant market studies made it possible to compare national activities with international efforts. From this holistic view, it was ultimately possible to draw conclusions about future (technological) development requirements. These were separately prepared for each of the main subsystems relevant for small satellites. By presenting the status quo as well as the expected development over the next few years, the space agency will be able to close gaps in technological development and extend its technological lead in selected areas.

The project partners also developed a concept for updating the roadmap by maintaining the underlying database. This will enable the German Space Agency to monitor progress in this highly dynamicsector at regular intervals.

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EU project SHAPES – Innovation for smart and healthy ageing

Final report: Horizon 2020 project SHAPES (Smart & Healthy Ageing through People Engaging in Supportive Systems) ended in December 2023

SHAPES Website

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This project was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857159

SHAPES

This goal of the EU innovation action was to enable long-term healthy and active ageing while maintaining a high standard of living. Among the results of SHAPES is the development of a standardized, open EU platform that provides a wide range of digital solutions, including the Internet of Things (IoT), big data platforms, robots, online communication tools, cognitive stimulation and rehabilitation solutions, and virtual assistants.

One of the central initiatives of SHAPES was the pan-European pilot campaign, which involved over 840 older individuals, caregivers, and care service providers at 15 pilot sites in 11 European countries. The pilot campaign was led by Fraunhofer INT. The institute developed the evaluation method and conducted eight foresight exercises to integrate new technologies and influencing factors for European-wide integrated care into the SHAPES ecosystem. The researchers also led the project's innovation and knowledge management, significantly contributing to its strategic direction.

Overall, the SHAPES project comprised a consortium of 36 partners from 14 countries, including research organizations, technology companies, civil society, and public organizations.

Into the future with Star Trek?

Science fiction thinking as a method of futures studies

Futures studies is probably the only science that has its own literary and cinematic genre. While materials science or biotechnology play a role at most in the margins of a novel or thriller, science fiction, whether in book or film form, is for many people their first encounter with the future and what it might look like. It is also well known that science fiction films in particular have at least inspired technological developments.

However, there are other links between science fiction and futures studies, which are summarized under the term science fiction thinking. These diverse cross-connections were the topic of a three-day workshop at the Xplanatorium in Hanover in July 2023. The participants from the fields of futures studies, literature, political science, economics, digital humanities, computational linguistics and some more approached the topic from different angles. This diverse group spent three days discussing, abstracting, sifting and then making the results tangible again. This resulted in several research projects from different perspectives.

Science fiction thinking encompasses many aspects. One very central aspect is to give impetus to innovation processes for new ideas and to initiate creative thinking. After all, science fiction represents an extensive archive of ideas from which inspiration can be drawn, but which also contains possible future options. Science fiction thinking is therefore an important competence when it comes to exploring and shaping possible futures. As part of the research projects developed in Hanover, the various approaches are to be brought together and systematically integrated into foresight, innovation and other future-oriented processes.

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PtX.Country Scoping

A methodology for identifying a sustainable PtX future

Power-to-X in the context of international cooperation

Power-to-X (PtX) stands for concepts and processes for converting electricity (power) based on renewable energies into chemical energy sources, raw materials or directly into heat, where X is a placeholder for various forms of energy and applications. The PtX Hub of the Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) is commissioned by the German Federal Ministry for Economic Affairs and Climate Protection (BMWK) and implemented by GIZ GmbH. The PtX Hub project team is working on the innovation topic of sustainable electricity-based fuels in the context of sustainable development in countries of the Global South with the aim of helping them achieve a global breakthrough. To this end, the PtX Hub develops sustainability frameworks, builds international networks, advises countries and works with them to produce studies and reports on the topic of PtX.

PtX Hub Website

PtX.Country scoping as a methodological approach

Fraunhofer INT has developed the PtX.Country Scoping methodology on behalf of and together with the PtX Hub. The application of PtX.Country Scoping enables the development of a fundamental understanding of GIZ's cooperation countries, including their geographical and economic potential for PtX, their political strategies and social drivers as well as possible obstacles. In addition, PtX.Country Scoping includes a concept for identifying country-specific PtX potentials together with the partner countries on an equal footing. The next step is to identify implementation scenarios that contribute to achieving the desired future.

Involving the local population as the basis for sustainable technological change

Successful, sustainable technological change in countries of the Global South requires a comprehensive understanding of the country, its people and their self-image. It must be directly oriented towards the needs, challenges and abilities of the people living there and consider both the drivers and the barriers in the country. It can be inspired from outside, but must be driven from within the country itself. For this reason, the project adopted a methodological approach that combines traditional research and analyss with guideline-based interviews, online surveys, workshop formats and country-specific scenarios.

PtX.Country Scoping workflow

As part of the project, a comprehensive concept with step-by-step instructions for implementing this specific country analysis was developed. Design thinking, strategic foresight, scenarios and the three-horizon method can be cited as key methodological core elements. PtX.Country Scoping includes detailed

instructions on (1) the preparation of a country report, (2) the implementation of dialog formats based on this country report and finally (3) the preparation of a summarizing presentation. For a PtX Country Report, there is a structured list of criteria and questions to be answered that are directly or indirectly relevant for the assessment of PtX potential. In order to compile the necessary information from the dimensions of geography, politics, economy, society and technology, data-oriented research is carried out in freely available sources. On the other hand, interviews and surveys are also used to gather opinions from the country itself in order to reflect the reality of life there. Workshop formats have been set up for further partnership-based exchange, in which representatives from the partner countries develop sectoral PtX visions together with external PtX experts. Plausible future visions (scenarios) for the country are selected and ways to implement these visions are developed. In the end, narratives (PtX. Country narratives) are created, which on the one hand represent a short and concise summary of the entire analytical PtX scoping process and on the other hand can serve as a guide for the most important stakeholders (politics, business, society – inside and outside the respective country).

Conclusion

The present PtX.Country Scoping methodology promotes a well-founded and direct exchange with the people in partner countries to understand their needs and living realities and to jointly identify and (further) develop country-specific PtX concepts and value chains.

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On the pulse of science with KATI

From the idea to the program – a look back at almost seven years of KATI

KATI Lab Website

As part of its technology foresight activities, Fraunhofer INT has established a kind of science observatory. This means that all fields of science and technology are continuously monitored in order to become aware of new technological developments as well as breakthroughs in already identified topics. The central source of information for this process are scientific publications and patents. When the topic of cognitive computing was hyped a few years ago, Fraunhofer INT came up with the idea of utilizing this approach for technology foresight. This was the birth of the KATI-system.

Today, several years and many hours of development, programming and testing later, the initially rather vague idea of KATI has become an important tool for the daily work of scientists at Fraunhofer INT. And KATI is not only used there – since last year, the system has been available to all employees in the Fraunhofer-Gesellschaft. In addition, with the support of funding from the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw), a new field of research has emerged. This new field, focused on data driven foresight, is the focus of the KATI Lab and addresses the central question of how foresight processes can be made better, more effective and more insightful through the use of data. In a certain sense, KATI is a tool for data-driven foresight that focuses on publications and patents as data sources.

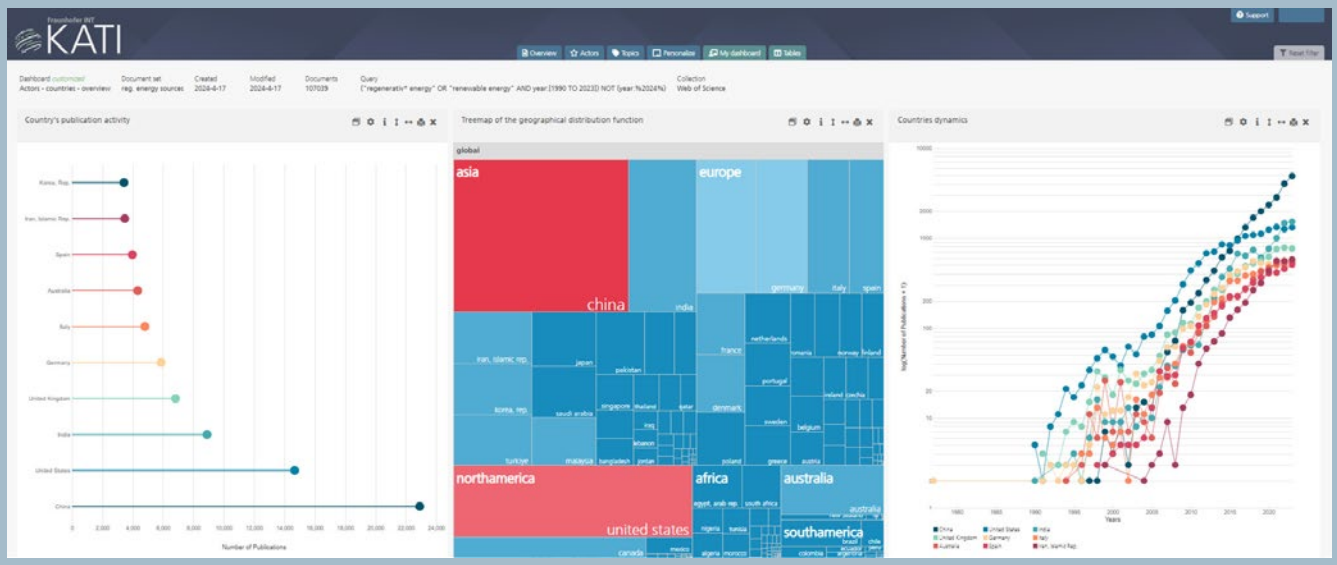
Data – lots and lots of data

When KATI was presented to the wider public for the first time in August 2017, the database contained the metadata of almost 60 million publications. In the course of 2024, the mark of 80 million publications will be exceeded. An important design decision was to make this data accessible using a graph database. The data model, which was developed by the KATI team at a very early stage of the project, has since then proved very successful. On the one hand, it can be adapted for other data sources. These include, for example, publication data from Dimensions or patents. On the other hand, this approach simplifies a large number of analyses and facilitates explorative and interactive data analyses.

As part of the development of the KATI-system, the team is focusing on close integration with specific questions and use cases of the users, as they arise from the daily work in the various projects. The focus is therefore less on exploring additional possibilities and more on identifying what is needed to support a foresight process as efficiently as possible. This has an impact on several levels.

The development process

First of all, this results in specific analyses that are implemented in the system. One such exemplary use case is the question of which publications you should read in order to familiarize yourself with a topic as quickly and comprehensively as possible. The reference citation plot was implemented to identify such



User interface of the KATI system

so-called key publications and has proven to be very useful. Other use cases relate to topics such as actor analyses or the identification of potential new fields of application.

This use case-specific approach is further supported by the flexible user interface. This makes it possible to compile individual perspectives on a specific topic. For example, if the research focus of a particular institution is to be analyzed, the corresponding bar chart can be used as a filter to take a closer look at the keywords for the publications of an institution and thus generate an insight into its research focus.

Finally, the needs of the users also play a central role in the design of the graphical user interface. In addition to an appealing design, the KATI team's development work focuses on simple and intuitive usability. The aim is to ensure that the KATI-system provides its users with as much added value as possible. A current example of this is the implementation of a query editor, which offers the visual option of using the KATI-system's comprehensive search options via drag & drop. In this way, users are able to design complex search queries simply and intuitively.

Future prospects

The KATI-system will celebrate its seventh birthday in 2024. However, development is far from complete and is constantly being driven forward. In addition to the continuous expansion of the methodological portfolio, the focus here is on tapping into additional data sources. And with large language models, there is already the next hype in the field of AI research, the use of which for technology foresight represents an exciting scientific issue that is also important for the development of the KATI-system.

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Defense Technologies Forecast

Recommendations for research planning

13
technological future topics

The Defense Technologies Forecast is commissioned by the Federal Ministry of Defense (BMVg) and generally covers 13 technological future topics per year. These interest-independent analyses of the state of research, future potential and implications for BMVg planning serve to support the contracting authority in its planning process. In 2023, nine individual technologies were analyzed, two visionary future concepts were addressed, and two technologies were subjected to an updated assessment. Three topics are presented here in brief as examples:

Active muon radiography – investigating large objects and structures with transportable muon sources

High-energy particles, called muons, are produced in the atmosphere by the effects of cosmic radiation and can penetrate almost any substance over great distances. For decades, this natural muon radiation has been used to elucidate underground structures, especially in the context of geological and archaeological investigations. Increasingly, muon radiography imaging techniques are now also being researched for applications in the fields of industry and security. Artificial, transportable muon sources with a higher intensity could significantly speed up these procedures, some of which require days or months of measurement. In addition, transportable muon sources would allow greater flexibility in the installation of the required muon detectors. In general, such active muon radiography could also open completely new application possibilities.

The usual procedure for generating muons consists of directing a beam of extremely high-energy particles at a piece of metal with a high atomic number. However, particle energies sufficient for muon radiography can currently only be provided by large particle accelerators. The use of novel laser-based particle accelerators is therefore being investigated for the technical implementation of transportable muon sources. In view of the current advances in such laser-plasma accelerators, corresponding muon sources appear to be feasible in the near future.

Comparable analyses were prepared for the following individual technologies:

- Metal-air batteries – The long-term goal of battery development
- MXene – Novel 2D materials with a wide variety of designs
- Small Modular Reactors – Transportable energy supply with high performance
- 3D graphene architectures – Materials with a wide range of applications
- Automated machine learning – Creating artificial intelligence efficiently and automatically
- Bio-hydrogen – Biological production and storage of hydrogen
- Wing-In-Ground Effect Boats – A combination of high speed and large transportation capacity
- Neurosymbolic artificial intelligence – A combination of the strengths of two different approaches.

The topics "Future Space Domain" and "Artificial Intelligence in Unmanned Mobile Systems"

were addressed in 2023 as visionary future concepts in which the necessary technologies and their maturity are derived from an overarching perspective.

Artificial intelligence in unmanned mobile systems

Artificial intelligence (AI) is the umbrella term for applications in which technical systems are oriented towards the natural intelligence of humans. The vision described is based on the implementation of AI models in unmanned mobile systems to obtain so-called autonomous systems. These are designed to be broad and flexible in their use and suitable for the autonomous execution of complex missions under the real conditions of an open, dynamic and non-cooperative battlefield environment. This environment is characterized by unexpected external influences and its uncertain and incomplete information situation.

Two technologies already analyzed in the past did require an update, as considerable progress has been made recently. In addition to the "Update: Kinodynamic Motion Planning", the "Update: Electronic Skin" was elaborated.

Update: Electronic Skin

Electronic skin (e-skin) refers to thin, flexible electronics that mimic selected mechanical and functional properties of human skin. For this purpose, sensors and other electronic components are embedded in elastically deformable carrier materials. Through the proficient spatial arrangement of non-flexible components and conductor paths, the insertion of conductive nanofillers or the use of components with intrinsic flexibility, two-dimensional sensors are created that can be stretched, compressed and twisted without any loss of function. Since the topic was originally addressed in 2016, research has demonstrated many new, often multifunctional e-skin concepts.

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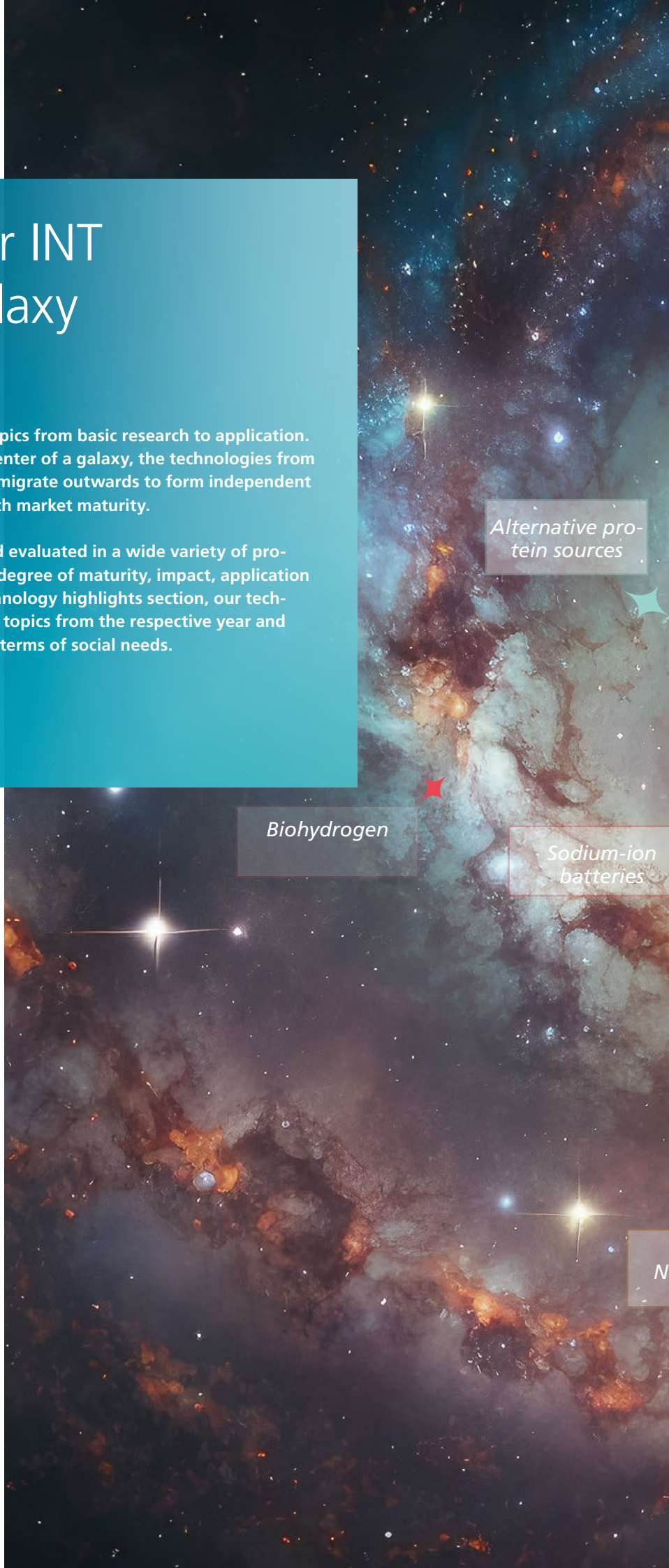
The Fraunhofer INT technology galaxy

Fraunhofer INT monitors technology topics from basic research to application. Just like the formation of stars in the center of a galaxy, the technologies from the large core of basic research slowly migrate outwards to form independent topics on the spiral arms until they reach market maturity.

The technology topics are analyzed and evaluated in a wide variety of projects, for example with regard to their degree of maturity, impact, application or disruption potential. In the new technology highlights section, our technology galaxy shows selected, exciting topics from the respective year and where they can make a contribution in terms of social needs.



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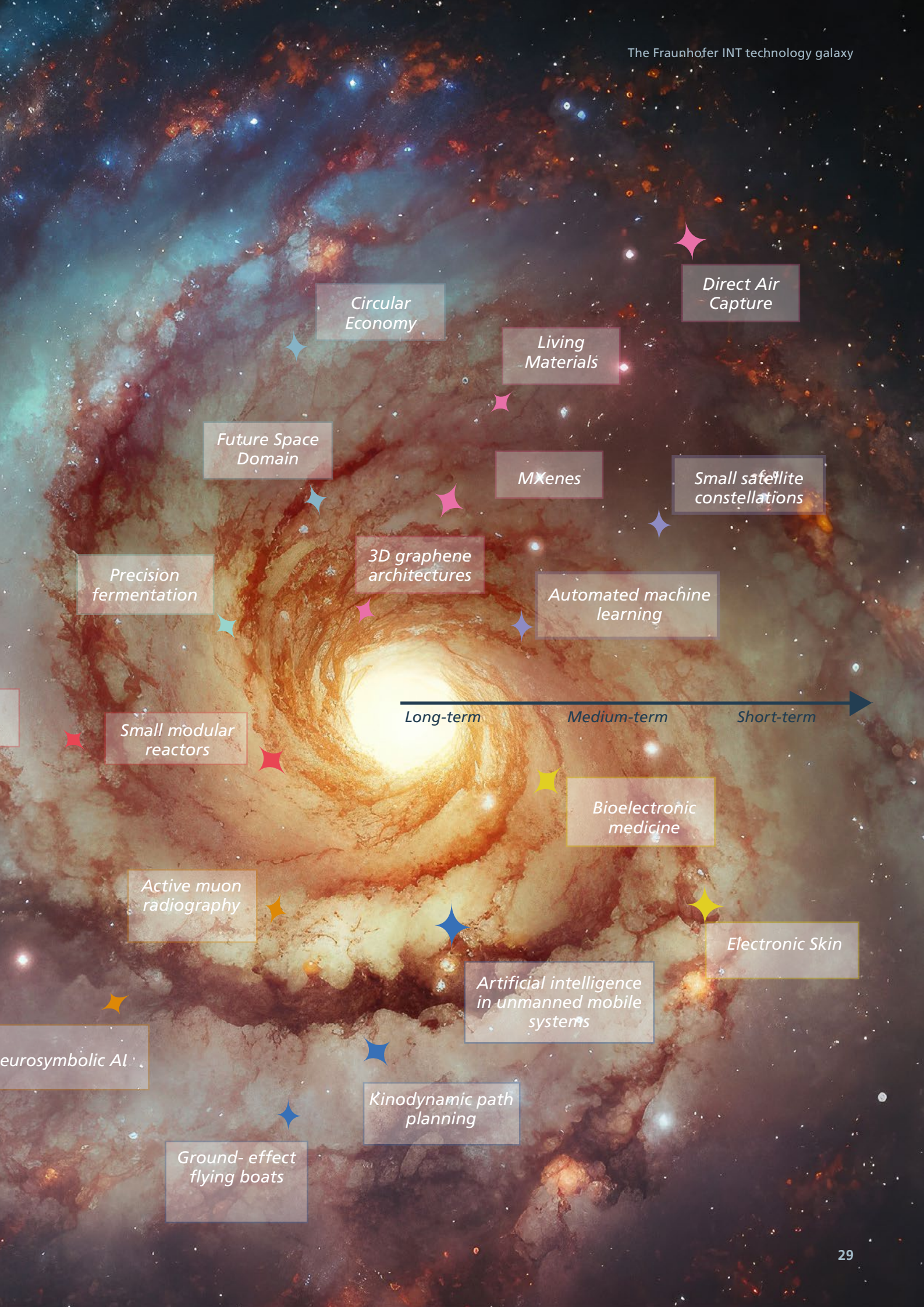

Direct Air Capture
Circular Economy
Living Materials
Future Space Domain
MXenes
Small satellite constellations
3D graphene architectures
Precision fermentation
Automated machine learning
Long-term
Medium-term
Short-term
Small modular reactors
Bioelectronic medicine
Active muon radiography
Electronic Skin
Artificial intelligence in unmanned mobile systems
eurosymbolic AI
Kinodynamic path planning
Ground- effect flying boats

The Fraunhofer INT technology galaxy

Our Top 20 highlights in 2023

Nutrition

Precision fermentation
Precision fermentation is a biotechnological production process on an industrial scale that uses customized production organisms and intelligent bioprocesses to manufacture targeted products.
Applications: Alternative production of chemicals, active ingredients and foodstuffs

Alternative protein sources
A protein deficit will be addressed at a global level in the future. Plants (legumes, cereals, oilseeds), animal products (insects, animal cell cultures) and other sources such as micro and macro algae, fungi, bacteria and yeasts are of interest as alternative protein sources.
Applications: More cost-effective, alternative protein sources

Availability of raw materials

Future Space Domain
The use of space is set to undergo profound changes towards physical and economic exploration, e.g. in the form of space mining and manufacturing, space-based solar power, new space and thein-space economy.
Applications: Including new sources of raw materials and energy

Circular Economy (CE)
CE describes an economic system based on business models that replace the concept of »end-of-life« with the aim of achieving sustainable development that includes the creation of environmental quality, economic prosperity and social justice for the benefit of present and future generations.
Applications: Sustainable resource management

Natural resources

MXenes
Materials from the family of 2D metal carbides or nitrides, which are obtained from so-called MAX phases. They exhibit unusual mechanical, electrical and optical properties as well as a switchable light-induced shape change.
Applications: New materials for catalysts, battery electrodes

Living Materials
Living materials are technical materials that consist of living cells that form or assemble the material itself or modulate the functional performance of the material in some way. This is the result of integrating synthetic biology tools into materials research.
Applications: Sustainable high-performance materials

Direct Air Capture
Technical approaches for capturing CO^2 directly from the atmosphere, for example by passing air through equipment with suitable binding agents that can absorb CO^2. Subsequent ontrolled separation in concentrated form allows for either storage or use of CO^2 as raw material.
Applications: Resource/climate protection

3D graphene architectures
3D graphene architectures are non-graphitic 3D-structured graphene materials. Their walls consist of fewer than ten graphene layers, which is why the general properties of graphene are largely retained in the 3D structures.
Applications: lightweight construction, remediation, battery electrodes

Communication and networking

Small satellite constellations

Small satellite constellations are swarms of <100 to up to 1000 small and micro satellites that have been developed to ensure global coverage, e.g. of telecommunications networks or earth observation data.
Applications: Global data exchange and digitalization

Automated machine learning (Auto ML)

Auto ML combines automation and machine learning (ML) to reduce the manual effort involved in generating powerful ML solutions. It supports experts but should also enable them to create automated solutions for their own needs without any prior knowledge.
Applications: Fast, cost-effective and flexible creation

Health

Bioelectronic medicine

Electrically active implants that overwrite signals from natural sensors and organs in the human body can offer alternative treatment methods to conventional pharmaceutical solutions.
Applications: New treatment methods

Electronic Skin

Electronic skin refers to thin, flexible electronics that mimic selected mechanical and functional properties of human skin and is of interest as a sensory component for robotics and medicine.
Applications: Sensitive sensor technology, e.g. for tactile and haptic information

Security

Neurosymbolic AI

Approach that combines methods based on artificial neural networks with methods from the field of symbolic AI.
Applications: Secure, intelligent networking

Active muon radiography

Radiography of even very large structures with high-energy muons from natural cosmic radiation, with the aim of detecting the internal structures of buildings or facilities, for example, but also nuclear materials.
Applications: Social security

Mobility

Ground- effect flying boats

Ground effect flying boats bridge the gap between ships (extreme payload, but slow) and airplanes (very fast, but low payload). They theoretically enable large payloads (e.g. 5 to 10 times that of today).
Applications: New mobility concepts

Kinodynamic path planning (KDPP)

KDPP comprises computer-based processes that enable robots to plan movements independently in such a way that not only obstacles but also the forces acting on the robot during movement are taken into account.
Applications: accident prevention, safe use of autonomous systems

Artificial intelligence (AI) in unmanned mobile systems

Trends in AI research that will help unmanned systems achieve a certain degree of autonomy under real operating conditions, e.g. back-up AI models, learning from data streams, adaptive AI models or concept drift.
Applications: Autonomous mobility

Energy

Small Modular Reactors

Small Modular Reactors are small nuclear reactors that are small both in terms of their dimensions and in terms of their output (electrically up to 300 MWe; thermally less than approx. 1000 MWt). They are to be manufactured industrially in series and assembled at the site after transportation.
Applications: Cost-effective, climate-neutral energy and heat generation

Biohydrogen

Hydrogen obtained from biomass or with the help of living biomass (microorganisms). Biohydrogen is seen as a promising but not yet competitive approach to sustainable energy generation.
Applications: Sustainable energy generation

Sodium-ion batteries

Rechargeable battery, comparable to the widely used lithium-ion battery (LIB). Required materials are readily available and inexpensive compared to LIB (sodium instead of lithium, aluminum instead of copper, no nickel or cobalt), therefore an potentially environmentally friendly alternative.
Applications: Sustainable energy storage

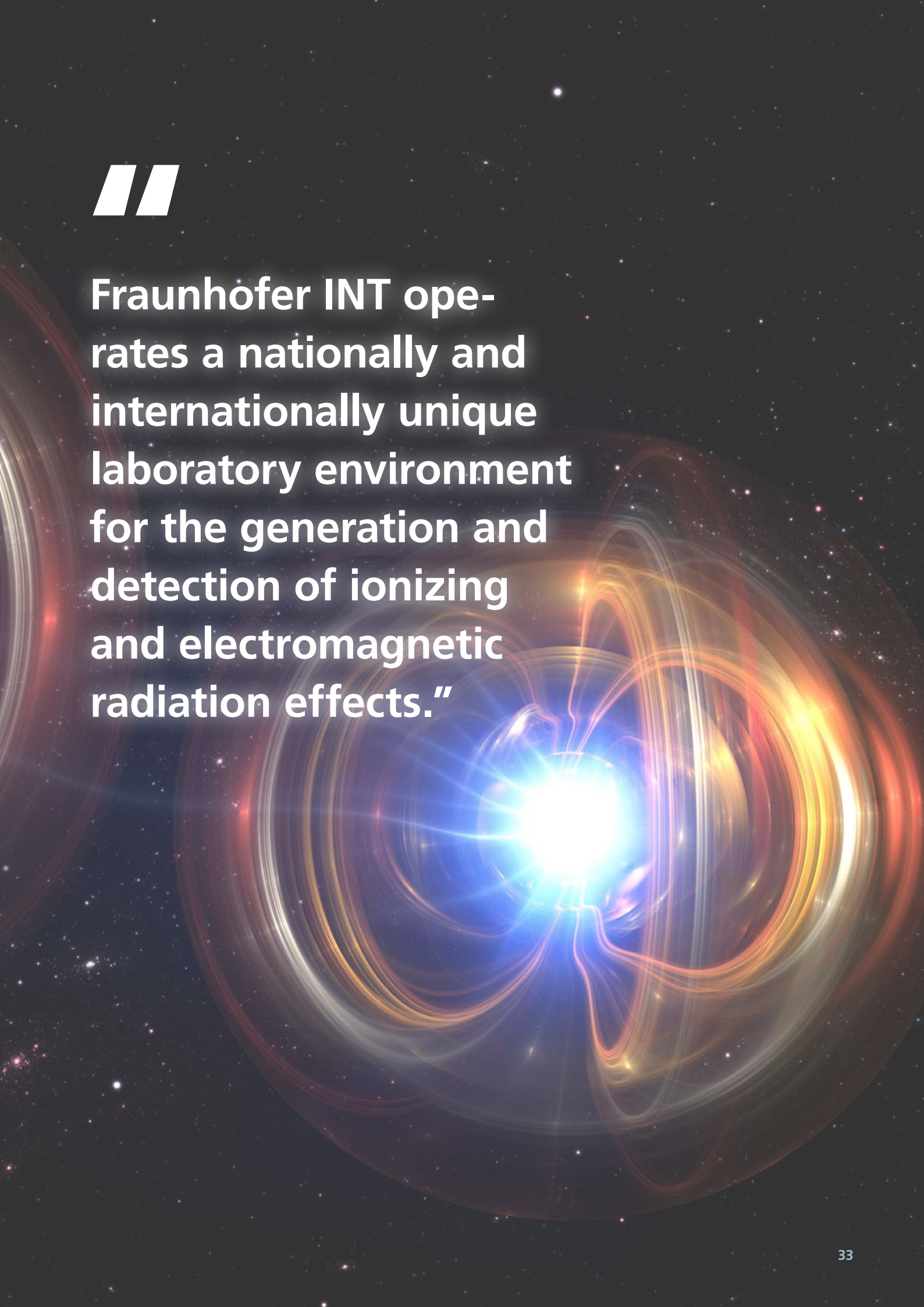
Radiation effects

As part of the research field "Reliability of electronics", Fraunhofer INT conducts specialized research on nuclear and electromagnetic radiation effects that is unique in Germany. This includes:

- Investigation of the influence of deliberately caused electromagnetic interference effects on electronic systems
- Investigation of the effect of ionizing radiation on electronic, optoelectronic and optical components and systems
- On-site detection and identification of nuclear and radioactive materials and analysis and assessment of nuclear and radiological threats.

The focus is on scientifically and economically relevant topics related to microelectronics in order to meet the advancing trends of miniaturization, increasing complexity of electronic component circuits, increasing system integration and bandwidth as well as the use of new semiconductor materials (e.g. wide bandgap). The exposure to ionizing radiation or high power electromagnetic fields in emergent applications such as autonomous driving, electric propulsion, AI systems, quantum computing, or 5G/6G mobile communications will be investigated. This is done for a wide range of uses, from satellite reliability to critical infrastructure protection for both civil and military needs. The main focus is the identification of techniques to protect against these threats.

For this purpose we operate a unique laboratory environment, both nationally and internationally, for the generation and detection of ionizing and electromagnetic radiation and ist effects in a broad energy range and particle spectrum. The impact of the radiation effects on the behaviour of the electronic components and systems is detected with state-of-the-art measurement technology, which is continuously developed further as a particular aspect of the research activities.



Fraunhofer INT operates a nationally and internationally unique laboratory environment for the generation and detection of ionizing and electromagnetic radiation effects.”

New possibilities for opening electronic components

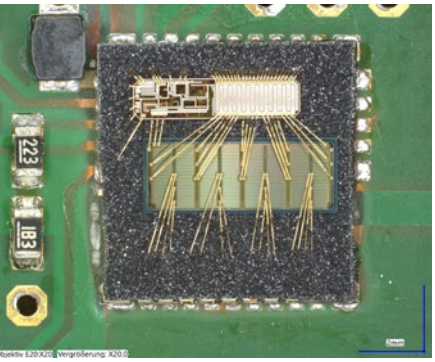


Fig. 1: A component opened using the plasma process. Note the excellent condition of the die and the bond wires.

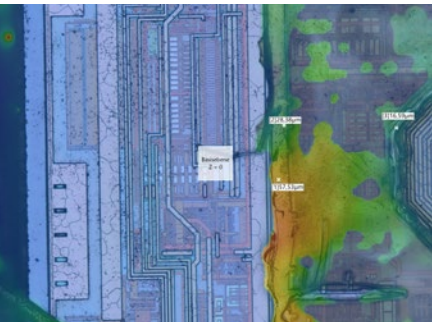


Fig. 2: Measuring the thickness of material residues on a die with the VHX-7000 microscope

Single event effects (SEE) are playing an increasingly important role in the investigation of radiation effects in electronic components. SEEs occur when particles of cosmic, ionizing radiation from space strike electronic components. This can cause both temporary malfunctions and permanent damage that renders an electronic device irreparably inoperable.

The investigation of SEEs caused by heavy ions is one of the most challenging areas of radiation effects research. On the one hand, SEEs are very diverse and require extensive test environments. Secondly, heavy ion beams are required to test the components. Alternatively, the effects of heavy ions can also be simulated using short pulsed lasers. These require direct optical access to the sensitive areas of the components.

Whichever method you use, a direct access to the die of the component is required, without the casing being in the way. For this, the casing must first be opened. Especially COTS (commercial off-the-shelf) components, which are mass-produced for commercial use, pose significant resistance. They are typically fully encapsulated in an epoxy resin casing.

Fraunhofer INT already has extensive experience in opening such casings using hot acid. This method has the advantage that the components can be opened very quickly (often in less than a minute) and large quantities of components can be opened in a short time. However, there are some serious disadvantages. The acid not only harms the packaging material, but also other components. The bonding wires in particular are at high risk as they are only a few micrometers thick. Gold bonding wires are normally resistant to sulphuric and nitric acid. In the COTS sector, however, there has been a trend towards other materials such as copper or silver for years. Such bonding wires can only withstand brief contact with cold acid and even then, are already partially corroded, which can impair their electrical properties. The interesting components from the automotive industry in particular have very resistant housings that cannot be opened with acid without rendering the die unusable.

These disadvantages can be avoided by dissolving the plastic casing using a plasma process. In 2023, Fraunhofer INT therefore procured a new device that works with a patented, oxygen-only process that is fundamentally incapable of damaging the die or the bond wires. An example is shown in Figure 1. The disadvantage of this process is its slowness (several hours), so that acid methods are still used for large quantities.

In order to assess whether the component opening was successful, precise optical images are required that can resolve structures down to the micrometer range. A recently

acquired digital microscope has capabilities even beyond this. The software is also able to obtain three-dimensional information by superimposing images with a slightly different focus. In this way, for example, the thickness of material residues on the die can be determined. Figure 2 shows an image of a die surface after an etching process on which material residues with a height of up to 60 micrometers were measured. Material of this thickness can significantly distort the results of a SEE-test.

SEE-tests on a die opened from the top increasingly lead to problems. The metallization layers are becoming thicker and thicker and thus slow down the ions considerably. With a SEE-laser-system, it is even impossible to penetrate through metallic layers. Additionally, components built using the flip-chip method cannot be opened from the front at all. In this case, the backside of the component must be exposed, the heat sinks need to be removed and the silicon substrate must be uniformly thinned down to a few micrometers. For this purpose, a special precision milling machine is required.

Thinning the substrate to a few micrometers is a major challenge in practice, as the dies are often thermally stressed on the housing, i. e. they are not flat but curved. If the substrate is milled flat, a substrate layer with thickness differences of up to several tens of micrometers remains at the end. These can lead to dramatic differences in the irradiation tests and therefore to incorrect results.

To take this into account, the new milling machine at Fraunhofer INT carries out a mechanical 9-point curvature measurement of the surface before milling and uses this to create a map of the curvature, which the milling head then follows. Figure 3 shows such a map.

Once the chip has been roughly thinned and polished, the milling machine can perform an interferometric thickness measurement of the remaining substrate. The display of the spectrometer can be seen in Figure 4. Here, a residual thickness of 29 micrometers was determined. This measurement is then carried out over the entire chip and the curvature map is corrected for precise further processing.

Opening components often reveals unpleasant surprises about their inner structure. This leads to a number of components being destroyed before a non-destructive method can be found. It is therefore important to know the inner structure of the component before the first opening attempt. For this reason, an X-ray machine was also procured, which can X-ray components with micrometer accuracy. The images can be imported into the software of the milling machine and placed as an overlay over the camera image. If the component is rotated, the X-ray machine can also be used to reconstruct details of the component using computer tomography.

Thanks to the new equipment for component opening, Fraunhofer INT is now able to successfully perform SEE-examinations on components that are difficult to open and has multiplied its options in this respect.

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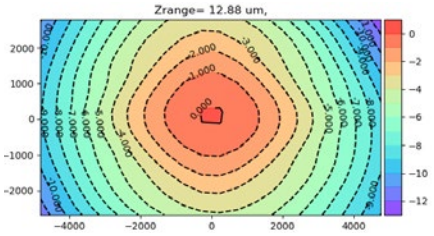

Fig. 3: 9-point curvature measurement of the surface of a substrate.

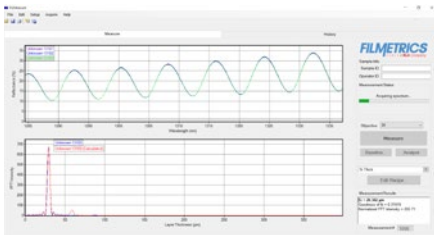

Fig. 4: Interferometric determination of the residual thickness of the silicon subbeam.

Crisis management needs EU-standards

Dangerous substances and their path into the laboratory – EU-project STRATEGY leads to European standards

Acute crises triggered by natural disasters, industrial accidents or acts of terrorism require a rapid, coordinated and efficient response. This requires organizations that often vary greatly in their structures, processes and methods of communication. Crisis management is particularly complex when it transcends national borders. Different legal regulations, languages and cultural circumstances can lead to delays and misunderstandings in an emergency and ultimately endanger human lives and infrastructure. The importance of European standards in this context is obvious: they provide a framework that enables consistent and efficient cooperation across national borders. For example, samples of unknown substances taken locally must be transported properly, safely and quickly to an appropriate laboratory. Digital tracking could make this much easier. This in turn requires a Europe-wide standardized scheme for such a "digital chain of custody" (dCoC).

The preparation of such standards was the subject of the EU-project STRATEGY (Facilitating the EU pre-standardization process Through stReamlining and vAlidating inTEroperability in systems and procedures involved in the crisis manaGement cYcle). In this project, which was completed in October 2023, 23 partners from 14 countries worked together over three years, including user organizations (fire departments, rescue services, police, etc.), companies, national standardization authorities and research institutions. Fraunhofer INT was involved across departments with the business units "Public Technology and Innovation Planning" (TIP) and "Nuclear Security Policy and Detection Techniques" (NSD). Eight subject areas were examined: search and rescue operations, critical infrastructure, emergency planning, command and control, early warning, training, terminology and the threat of chemical, biological, radioactive, nuclear or explosive hazardous materials. Following an in-depth needs analysis, a total of 13 documents, which are intended to serve as preparation for European standards, were developed, tested in practical exercises and fed into the European standardization process. Social media and terms and symbols in disaster management were the topics in which the TIP business unit was involved.

Two of the documents produced were even given the status of "Technical Specifications", which is a direct precursor to an EU-standard. These are two draft standards for the above-mentioned dCoC, in which the NSD business unit played a key role. The "Technical Specifications" for the dCoC provide guidelines for the workflow of digital data management for sample collection, sample transfer and sample analysis. The concept contains a specific data model structure to describe the unknown substance and the necessary process steps as well as instructions for managing and checking the data. This also makes it possible to identify responsibilities and detect inconsistencies during sample transportation.

STRATEGY Website

Sampling team with two recorders - analogue method (left) and digitized method (right)

All the project's work was accompanied by an extensive evaluation process that extended over the entire duration of the project and considered data from numerous workshops, discussion rounds, table-top exercises and real-life exercises. This enabled the draft standards to be continuously improved and made suitable for practical use.

This evaluation process also accompanied the work on the dCoC and the concept was assessed very positively in the end. This was particularly evident in a test as part of a major final exercise in which a major incident was simulated: sample collection, handover and management of sample information were carried out simultaneously with two recorders, one working with paper forms as before and one with a tablet and software according to the dCoC concept (see illustration). After this exercise, the expert teams attested to the usefulness of the dCoC concept and identified significant advantages over the paper-based procedure.

Another important step for the dCoC on the way to becoming a standard was the involvement of the European technical committee CEN/TC 391, in which the "Technical Specifications" were discussed and finally adopted. In view of this development, the concept developed could actually become a European standard after going through further official processes.

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HPEM detection system FORDES – development, performance and application

Only with a suitable measuring device can interference tests with high-power microwaves provide definitive insights

Wehrwissenschaftliches Institut für Schutztechnologien – ABC-Schutz

Robust measurement system for high-power interference signals

Research at Fraunhofer INT into interference in electronic devices under the influence of high-power electromagnetic signals (HPEM, High Power Electromagnetics) has a history stretching back decades. The phenomena investigated have in common that the affected target objects often exhibit malfunctions such as system crashes or hardware defects, which can also occur during normal operation due to instabilities or wear and tear. The deliberate external influence of the actual cause often escapes human perception. For this reason, Fraunhofer INT has for many years been pursuing the basic idea of a measurement system that is itself robust against interference, but is still capable of detecting high-performance interference signals.

Since deliberate interference tests usually operate at electric field strengths that are at least an order of magnitude higher than the civilization background caused by radio, television and mobile communications, a simple warning device could initially indicate the exceeding of a critical threshold at its location. However, more precise detection of parameters such as signal strength and, depending on the signal form, carrier frequency and modulation characteristics, is required to perform a risk assessment of potential damage and source forensics.

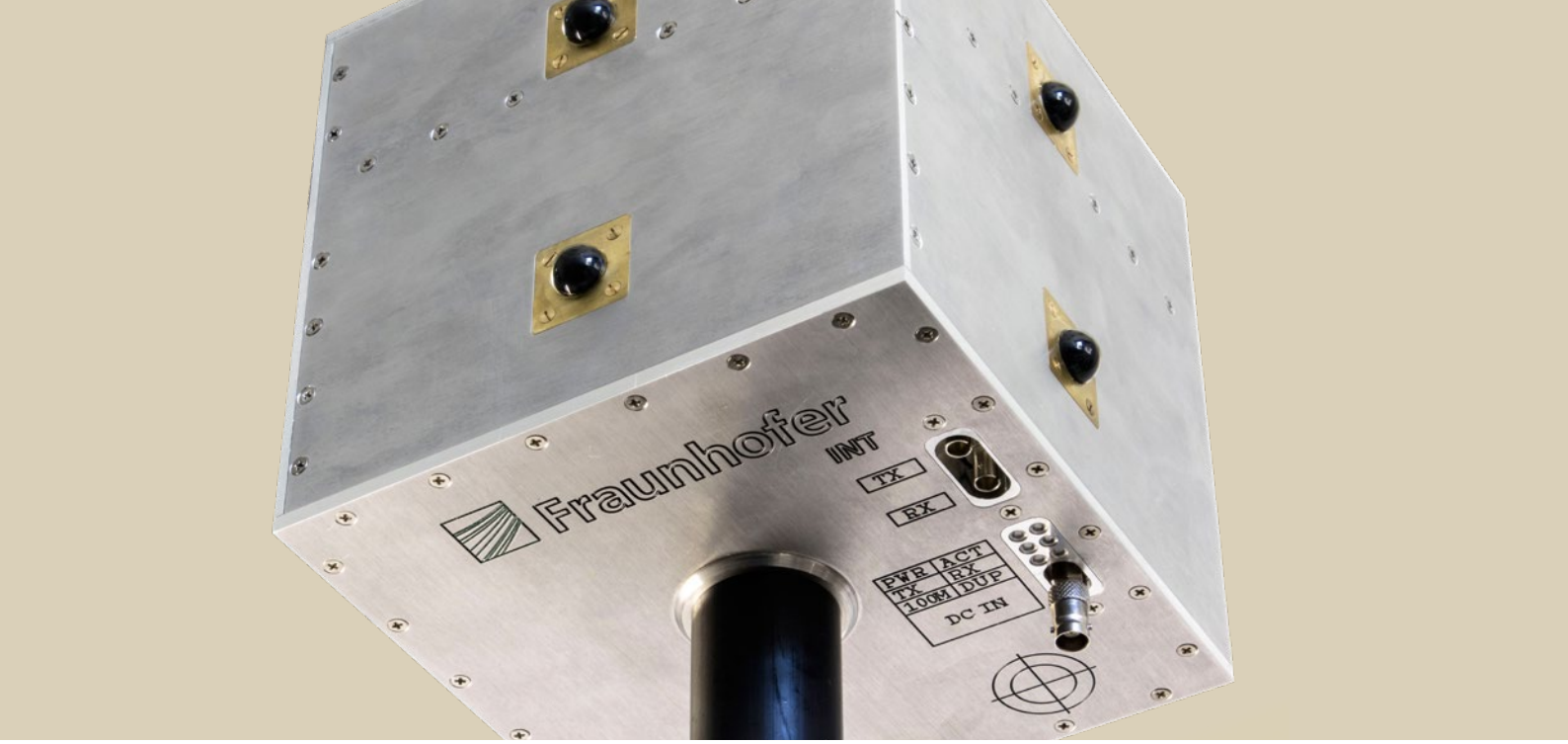
More about research in the field of HPEM

Development goals at Fraunhofer INT

The aim of the development efforts at Fraunhofer INT was to reflect the dynamic range, measurement accuracy and frequency bandwidth of common laboratory measuring devices as comprehensively as possible in a compact, robust and energy-efficient detection system. The aim was to significantly reduce the device volume and lower the acquisition costs by around one order of magnitude. A particular challenge here is the broad spectrum of possible interference signals to be detected. Thanks to its compact design and integrated battery module, the HPEM detector FORDES, developed at Fraunhofer INT, can be installed as a stationary device in a data center or control room, for example, or used as a mobile device in the field for special situations.

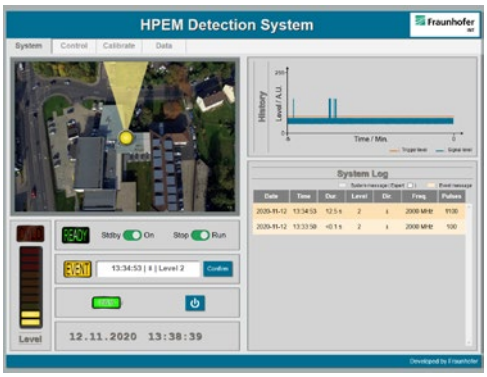
Differentiation from standard market solutions

Due to the basic risk described above, detection solutions that tackle the measurement problem with different focuses have been discussed in the research community for several years and are now also available on the market. The broadband detection of interference signal amplitudes up to ten gigahertz carrier frequencies with the required measurement dynamics remains a challenge. In contrast to simple warning or measurement solutions, FORDES was developed as an FPGA-based system capable of detecting narrowband interference over an effective dynamic range of at least four orders of magnitude



Cube-shaped outer housing of the detection system »with an edge length of just under 20 cm, including connections and display elements on the underside

and also measuring its carrier frequency. This enables frequency response corrections for an accurate reconstruction of the electromagnetic fields present on site and thus a well-founded risk assessment in the event of an incident. An ongoing patent application is also based on the implementation of this unique selling point. Together with a recording of the signal envelopes on time scales of a few nanoseconds, basic source forensics is thus also possible for pulsed signals, which allows conclusions to be drawn about the originator of the respective interference.



Web interface for control and display

Possible applications

The battery installed in the current FORDES laboratory demonstrator enables the system to monitor the field load at any location for more than ten hours and to record fault events. Using a separately hardened power supply unit, a permanent power supply is also possible in stationary operation, for example, at key systems in critical infrastructure. The system can be controlled and read out from a computer via a web interface using an interference-resistant optical network connection.

The FORDES HPEM-detector is also increasingly being used in a military context, as the systems used are becoming more complex and electromagnetic means of action are constantly being developed further. Due to the increasing relevance of interference tests, efforts are currently underway to instrument FORDES as an HPEM-sensor for a military land vehicle. This requires mechanical and technical adaptations in terms of installation location and on-board electronics as well as the IT connection to the modern NGVA (NATO Generic Vehicle Architecture) standard.

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Others

Scientific and technical infrastructure

Reconstruction after the flood

To investigate various radiation effects, Fraunhofer INT has a comprehensive scientific and technical infrastructure to support the experimental work.
This includes a precision mechanics workshop, where special mechanical parts for the experimental facilities are manufactured, and an electronics laboratory, which is responsible for the production of special electronics, maintenance and repair of the experimental electronics.
Following the successful completion of most of the reconstruction work after the flood disaster, the mechanical workshop was reopened in 2023. There is still a lot of remaining work and procurement work to be done, but a large part of the working capacity has been restored.
In addition, numerous parts and assemblies for the reconstruction of the institute's infrastructure and, above all, the experimental environment were manufactured and assembled in the workshop.
In addition to completing smaller projects in 2023, work also continued on the experimental infrastructure in the electronics laboratory. This primarily included planning, both in the "NE goes digital" digitalization project and to improve the experimental environments.

Future Security

Forum for Security and Defense Research of the Fraunhofer VVS

On February 7 and 8, 2023, the event "Future Security - Forum for Security and Defense Research", organized by the Fraunhofer Segment for Defense and Security VVS, took place at the Fraunhofer Forum in Berlin. The research conference offers a platform for researchers, experts and other stakeholders from science, industry and politics in Germany to exchange views on current topics and trends in security and defense. Prof. Dr. Dr. Lauster, Director of Fraunhofer INT, was session chair of the specialist session "Resilience: Emerging stronger from disruptions", in which Maike Vollmer also participated with her presentation "Becoming more resilient through stronger communication between the population and civil protection organizations - the RiskPACC project". In the accompanying exhibition, participants were also able to try out the KATI-system (see p. 24) and experiment with their own search queries. In addition, Fraunhofer INT presented an exhibit on drone defense using high-power microwaves (HPEM), which illustrated how the electronics of drones can be disrupted using HPEM and thus attacks can be fended off.

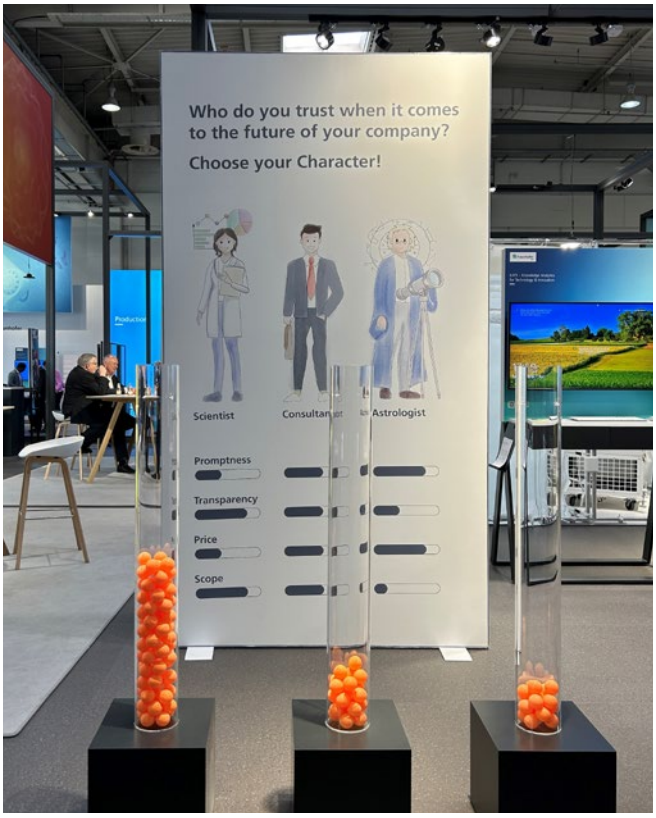
Prof. Dr. Dr. Michael Lauster, Deputy Chairman of Fraunhofer VVS, opens the expert session "Resilience: Emerging stronger from disruptions".

Fraunhofer INT at the Hannover Messe

New technologies and industrial transformation

The annual Hannover Messe took place from April 17 to 21, 2023, where the Fraunhofer-Gesellschaft was once again represented with a joint booth, this time in Hall 16. In addition to the familiar 3D models with analyses of future technologies from the KATI-system (see p. 24), Fraunhofer INT presented the new exhibit "Choose your Character". Visitors were asked on site who they trust most when it comes to the future of their company. There were three options to choose from – a scientist, a consultant or an astrologer, whose various strengths and weaknesses were also presented. Depending on their preference, visitors could then throw a table tennis ball into one of the tubes. If you are interested in how the voting turned out on the individual days, you can watch the #HM23 highlight on our Instagram account.

Under the slogan #WeKnowSolutions, 24 institutes of the Fraunhofer-Gesellschaft were represented at this year's joint booth with exhibits from the fields of production, industrial metaverse, energy and adaptronics, showcasing innovative concepts for future topics such as mixed reality, edge cloud rendering, real-time communication, metaverse technologies, hydrogen technologies, digital ecosystems, biological transformation, hybrid AI and e-mobility. Hannover Messe is the most important international industrial trade fair for new technologies and industrial transformation.



The new exhibit "Choose your Character" with the voting results from day 3.

Sneak Peak Anniversary Year

At the time of publication of this annual report, Fraunhofer INT is celebrating its 50th anniversary.

In next year's annual report for 2024, we will report on how the anniversary was celebrated at the institute. If you would like to get a first glimpse now, you can already find some contributions about the anniversary on our website or on our social media channels (see p. 53).

Fraunhofer AVIATION & SPACE

What does the business unit SPACE do?

Fraunhofer INT operates the central office of the Business Unit SPACE within the Fraunhofer AVIATION & SPACE Alliance. In 2022, the SPACE Alliance, founded at Fraunhofer INT in 2014, was expanded to include the AVIATION area. The AVIATION office is based at Fraunhofer IFAM in Bremen. The two offices work closely together. Due to the thematic division, the alliance also has two spokesmen: Prof. Dr. Dr. Michael Lauster, Director of Fraunhofer INT and Prof. Dr. Bernd Mayer, Director of Fraunhofer IFAM. Since the expansion, the Fraunhofer AVIATION & SPACE Alliance now brings together 30 institutes conducting research into aerospace technologies.

The collective term SPACE covers research and development on technologies related to the operation and use of space-based infrastructure. In order to structure this broad field, the Alliance has divided the technologies into the technology areas "Protection & Reliability", "Surfaces & optical systems", "Materials & Processes", "Sensor Systems & Analysis", "Energy & Electronics", "Communication & Navigation", "Ground Segment", "Launchers" and "Downstream".

The Alliance offers the 30 Fraunhofer Institutes a general platform for exchanging information on the specifics of the industry. In addition, the office coordinates cross-institute activities, ensures a visible and focussed external presence and offers Fraunhofer's customers and cooperation partners a single point of contact for space-related issues.

Fraunhofer
AVIATION & SPACE

Fraunhofer Group for Innovation Research

Understanding change, shaping the future

Innovations are the key to being able to make confident decisions and follow individual paths even in difficult times, and to being permanently resilient against crises. Knowledge of complex interdependencies within innovation systems is therefore critical to the success of business, politics, science and society. Changes in industries, markets and technologies must therefore be recognized and understood at an early stage in order to be able to actively shape the long-term effects.

As a competent partner with a unique combination of socio-economic and socio-technical research, the Fraunhofer Group for Innovation Research provides orientation, facilitates positioning and supports actors in shaping the future of the innovation system. Under the motto "understanding change, shaping the future", around 1600 scientists from the six Fraunhofer Institutes IAO, ISI, INT, IMW, IRB and IIS-SCS work together in the group – with the aim of understanding innovation systems and their change and passing on interdisciplinary knowledge.

The Fraunhofer Group for Innovation Research offers companies a wide range of support options for the design of innovation systems – from practical guides and publications, to methods and tools, to interactive event formats. An overview of the services offered as well as projects can be found in the free newsletter and on the group's website.

Fraunhofer
INNOVATION

Fraunhofer Segment for Defense & Security

We carry out research into the security of mankind, society and the state – for a life of freedom

In times of social and political unrest, defense and security become increasingly important. The Fraunhofer Segment for Defense and Security (Fraunhofer VVS) develops technologies, products and services for the early detection of dangerous situations, so that they can be counteracted, consequential damage can be minimised and, as a result, the overall level of risk can be reduced.

In addition to Fraunhofer INT, eleven Fraunhofer Institutes have joined forces in the Fraunhofer VVS to provide wide-ranging expertise and research for highly practicable solutions and operational support, both at national and international level.

The Fraunhofer VVS pursues research and development in the areas of defense and civil security. With its wide range of expertise and research services, it provides convincing application-oriented solutions through to operational support. In defense research, its excellent judgement and consultancy skills makes it indispensable independent expert and partner of the German Ministry of Defence. The Fraunhofer VVS researches and develops technologies and system solutions for the Ministry, its subordinate authorities and for the German Armed Forces (Bundeswehr). Its technical solutions and systems in civil security are designed to deliver the best possible protection for society.

The Fraunhofer VVS was founded in 2002 and welcomed its twelfth member, the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, in 2023. In the fields of security research, Fraunhofer IOF specializes on encryption technologies for secure communication. In the fields of defense research, Fraunhofer IOF is focused on laser and fiber technology, thus representing an ideal addition to the portfolio of the Fraunhofer VVS.

Fraunhofer VVS

Institute for Technology Analysis and Foresight in the Field of Security Research

Methods of futurology for engineers

The Institute for Technology Analysis and Foresight in the Field of Security Research held by Prof. Dr. Dr. Lauster at RWTH Aachen University complements the classical offer in the curriculum of engineering studies. The aim is to teach students quantitative and qualitative methods of foresight within the framework of application-oriented teaching and learning concepts. This includes both the epistemological foundation of methods and the investigation of the extensive canon of foresight methods with regard to its suitability and optimization possibilities. The research focus of the institute lies in the analysis of the foresight process in technological fields as well as the adaptation, new and further development of corresponding procedures and methods. The continuously generated research findings support scientifically based decision-making on issues related to the temporal development of technologies.

The courses are offered during the semester as lectures or block seminars. The lecture "Methods of Futures Studies - Technology Analysis" and the lecture "Methods of Futures Studies - Technology Foresight" are attended by almost 200 students each semester. In addition to the lectures, seminars are offered, in which specific lecture contents are further deepened. In the summer semester, the seminars "Technology Ethics" and "Security Research and Futurology" are offered. In the winter semester, the seminars "Science and Epistemology" and "Data Driven Foresight" take place.

LTVS | RWTH AACHEN UNIVERSITY

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft, based in Germany, is a leading applied research organization. It plays a crucial role in the innovation process by prioritizing research in key future technologies and transferring its research findings to industry in order to strengthen Germany as an economic hub as well as for the benefit of society.

As an important customer group, small- and medium-sized companies in particular tap into Fraunhofer's expertise and resources to develop new technologies and maintain their competitiveness. For years, Fraunhofer has been one of the most active patent applicants in Germany and Europe. The research organization is therefore developing an extensive, international patent portfolio in various technology sectors, primarily as a basis for transferring technology through research projects, spin-offs and licensing. In this way, Fraunhofer experts support industry partners from ideation to market launch, and Fraunhofer's interdisciplinary and international collaboration in specific market environments addresses social objectives in important technology areas. Fraunhofer also promotes research into key technologies that are vital for society as a whole by applying specific, interdisciplinary and international collaboration geared to the needs of the market. Examples include technologies for the energy transition, cybersecurity and underlying models for generative artificial intelligence. Fraunhofer is an attractive and established party for public-private partnerships and also makes a significant contribution to strengthening Germany as a hub for innovation and ensuring its viability in the future. Its activities create jobs in Germany, boost investment effects in the private sector and increase the social acceptance of new technology. International collaboration projects with excellent research partners and companies across the globe ensure that the Fraunhofer-Gesellschaft remains in direct contact with the most prominent scientific communities and economic areas.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Its nearly 32,000 employees, predominantly scientists and engineers, work with an annual business volume of 3.4 billion euros; 3.0 billion euros of this stems from contract research, which is divided into three funding pillars. Fraunhofer generates a share of this from industry and license-fee revenue to a sum of 836 million euros. This high proportion of industrial revenue is Fraunhofer's unique selling point in the German research landscape. The importance of direct collaboration with industry and the private sector that this requires ensures a constant push for innovation in the economy, while at the same time strengthening German and European competitiveness.

Another share of contract research revenue comes from publicly funded research projects. The final share is base funding that is supplied by the German federal and state governments and enables our institutes to develop solutions now that will become relevant to the private sector and society in a few years.

Highly motivated employees are the most important factor in Fraunhofer’s success. The research organization therefore creates opportunities for independent, creative and goal-driven work. Fraunhofer fosters professional and personal development in order to provide career opportunities for its employees in the private sector and society at large.

The Fraunhofer-Gesellschaft is a recognized nonprofit named after the Munich scholar Joseph von Fraunhofer (1787–1826), who enjoyed equal success as a scientist, inventor and entrepreneur.

Figures as of: April 2024
www.fraunhofer.de

Fraunhofer INT in profile

The Fraunhofer Institute for Technological Trend Analysis INT provides scientifically sound assessments and counseling on the entire spectrum of technological developments. On this basis, the Institute conducts Technology Forecasting, making possible a long-term approach to strategic research planning. Fraunhofer INT constantly applies this competence in projects tailor-made for our clients.

Over and above these skills, the Institute runs its own experimental and theoretical research on the effects of ionizing and electromagnetic radiation on electronic components, as well as on radiation detection systems. To this end, Fraunhofer INT is equipped with the latest measurement technology. The main laboratory and large-scale appliances are radiation sources, electromagnetic simulation facilities and detector systems that cannot be found in this combination in any other civilian body in Germany.

For more than 50 years, Fraunhofer INT has been a reliable partner for the German Federal Ministry of Defense, which it advises in close cooperation and for which it carries out research in technology analysis and strategic planning as well as radiation effects. Fraunhofer INT also successfully advises and conducts research for domestic and international civilian clients: both public bodies and industry, from SMEs to DAX-listed companies.

23nd meeting of the Fraunhofer INT Board of Trustees
Euskirchen, May 4, 2023

Curators

- **Udo Becker**
  Kreissparkasse Euskirchen
- **MinR`n Sabine ten Hagen-Knauer**
  Federal Ministry of Education and Research Bonn
- **VPräs'in Sabine Lackner**
  THW Bonn
- **Dr.-Ing habil. Frank Sabath**
  WIS Munster
- **Britta Schade**
  ESA/ESTEC Noordwijk
- **Prof. Dr. Katharina Seuser**
  Bonn-Rhein-Sieg University of Applied Sciences
- **MinR Dr. Dirk Tielbürger**
  Federal Ministry of Defence Bonn
- **Prof. Dr. Christiane Vaeßen**
  Region Aachen Zweckverband
- **Dr.-Ing Karsten Deiseroth**
  IABG
- **Prof. Dr. Dr. Axel Zweck**
  Association of German Engineers Düsseldorf

Fraunhofer INT in figures

Facts and figures

Human resources

In 2023, we marginally increased our personnel capacity compared to the previous year. We had 149 employees with 118.1 full-time equivalents, including 78 scientists (64.8 full-time equivalents). This means that we cover a broad range of natural and engineering sciences, as well as economics, social sciences and sociology. The researchers are supported by graduate engineers, technicians and administrative staff.

There are also student and research assistants as well as trainees. In addition, Fraunhofer INT has a network of freelance scientists who are regularly involved in the institute's work.

Employees

	2021		2022		2023	
	Occupied positions	Amount of people	Occupied positions	Amount of people	Occupied positions	Amount of people
Scientists	62,1	68	63,7	70	64,8	78
Graduates	30,0	30	28,5	30	30,5	35
Technicians, others	16,1	18	18,1	21	17,5	24
Assistants, trainees	8,1	16	7,0	13	5,3	12
Total	**116,3**	**132**	**117,3**	**134**	**118,1**	**149**

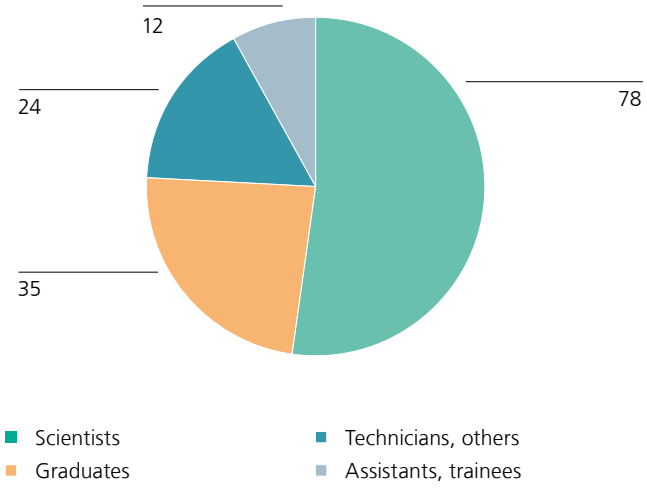
Budget in 1.000 €

	2021	2022	2023
Operating budget	11.790,8	12.693,1	12.986,8
- of which personnel	9.391,2	9.651,2	10.287,1
- of which non-personnel	2.399,6	3.041,9	2.699,7
Capital expenditure	1.416,1	4.299,5	5.813,7
Total	**13.206,9**	**16.992,6**	**18.800,5**

Financing in 1.000 €

	2021	2022	2023
Base funding	8.351,3	11.155,9	10.900,6
Contract research	4.855,6	5.836,7	7.899,9
Total	**13.206,9**	**16.992,6**	**18.800,5**

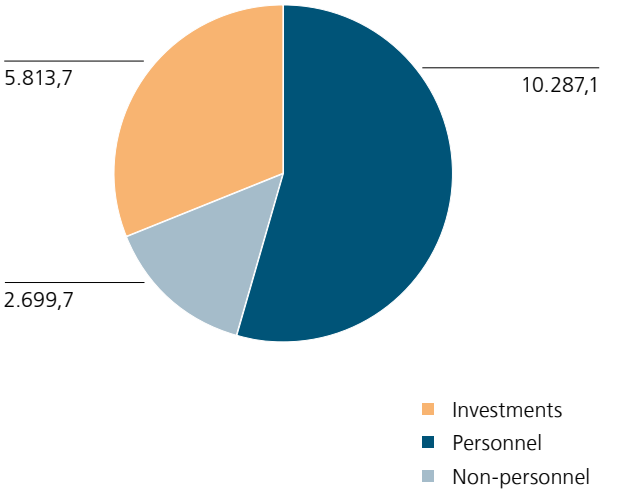
Employees



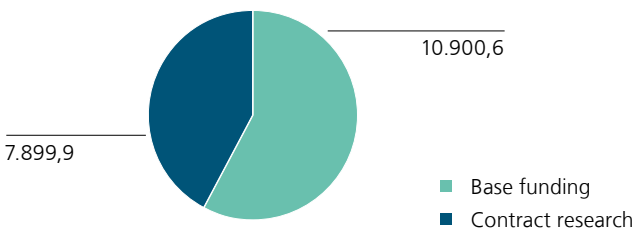
Budget

The operating budget increased only slightly to €12.9 million in 2023. The second tranche of our investment program enabled us to realize an investment budget of €5.8 million. This investment program will renew and modernize the institute's experimental equipment in order to ensure the future viability of our research.

Budget 2023 in 1.000 €



Financing 2023 in 1.000 €



Appendix

Lectures

Baaden, P.: Lecture "Explorative Methods in Entrepreneurship Research", master's degree program "Management and Economics", Ruhr University Bochum, winter term 2022/2023

Bantes, R.: Lecture "Trends in Forschung und Entwicklung", bachelor's degree program "Technik-Journalismus und visuelle Technik-Kommunikation", Bonn-Rhein-Sieg University of Applied Sciences, summer term 2022

Bantes, R.: Seminar "Trends in Forschung und Entwicklung", bachelor's degree program "Technik-Journalismus und visuelle Technik-Kommunikation", Bonn-Rhein-Sieg University of Applied Sciences, summer term 2022

Bantes, R.: Seminar "Sicherheitsforschung und Zukunftsforschung", bachelor's and master's degree program "Maschinenbau", Rhine-Westphalia Technical University of Aachen, summer term 2022

Chmel, S.: Lecture and exercise "Physics", bachelor's degree program "Naturwissenschaftliche Forensik", Bonn-Rhein-Sieg University of Applied Sciences, summer term 2022

Chmel, S.: Lecture and exercise "Measuring Techniques", bachelor's degree program "Naturwissenschaftliche Forensik", Bonn-Rhein-Sieg University of Applied Sciences, winter term 2022/2023

Freudendahl, D.: Lecture "Neue Materialien und Werkstofftrends", master's degree program "Technik-Management und Optimierung", Ravensburg-Weingarten University of Applied Sciences, winter term 2021/2022

John, M., Martini, M.: Seminar "Data Driven Foresight", bachelor's and master's degree program "Maschinenbau", Rhine-Westphalia Technical University of Aachen, winter semester 2022/2023

John, M.: Lecture "Publikationsanalysen als Beispiel für Data Driven Foresight – Eine Einführung in die quantitativen Methoden der Zukunftsforschung", master's degree program "Zukunftsforschung", Free University of Berlin, winter term 2021/2022 and winter term 2022/2023

Jovanović, M., Wiemken, U.: Seminar "Technik, Politik u. Gesellschaft – Prognostik, Szenarien, Folgenabschätzung", master's degree program "Technik- und Innovationskommunikation", Bonn-Rhein-Sieg University of Applied Sciences, summer term 2022

Jovanović, M.: Seminar "Projektmanagement für Studierende", study programs in information science as well as Studium Universale, Heinrich Heine University Düsseldorf, winter term 2021/22

Jovanović, M.: Seminar "Projektmanagement für Studierende", study programs in information science as well as Studium Universale, Heinrich Heine University Düsseldorf, summer term 2022

Lauster, M.: Lecture "Methoden der Zukunftsforschung – Technologieanalyse", bachelor's and master's degree program "Maschinenbau", Rhine-Westphalia Technical University of Aachen, summer term 2022

Lauster, M.: Lecture "Methoden der Zukunftsforschung – Technologievorausschau", bachelor's and master's degree program "Maschinenbau", Rhine-Westphalia Technical University of Aachen, winter term 2022/2023

Lauster, M.: Lecture "Technologiefrüherkennung und Zukunftsforschung", master's degree program "Technik Management & Optimierung", Ravensburg-Weingarten University of Applied Sciences, summer term 2022

Lauster, M.: Seminar "Ethik für Ingenieure", bachelor's and master's degree program "Maschinenbau", Rhine-Westphalia Technical University of Aachen, summer term 2023

Lauster, M.: Seminar "Wissenschafts- und Erkenntnistheorie", bachelor's and master's degree program "Maschinenbau", Rhine-Westphalia Technical University of Aachen, winter term 2022/2023

Metzger, S.: Lecture "Experimental Techniques in Particle Physics", master's degree program "Physik", Rhine-Westphalia Technical University of Aachen, winter term 2022/2023

Wirtz, H.: Lecture "Corporate Finance", bachelor's degree program "Betriebswirtschaftslehre", Hochschule Fresenius, winter term 2021/2022 and winter term 2022/2023

Wirtz, H.: Lecture "Finanzwirtschaft, Rechnungslegung und Controlling", bachelor's degree program "Betriebswirtschaftslehre", Hochschule Fresenius, summer term 2022

Theses

Abdelrahim, Y.: Master's thesis "Strategische Planungsmethoden für KMUs – Entwicklung eines Auswahl- und Bewertungskonzeptes", Rhine-Westphalia Technical University of Aachen, 2022

Butgereit, D.: Bachelor's thesis "Kompetenz- und Akteursanalyse der Fraunhofer-Gesellschaft in den Bereichen Downstream-Technologien und Nachhaltigkeit", Rhine-Westphalia Technical University of Aachen, 2022

Frederick, G.: Master's thesis "Podcasts als Kommunikationsinstrument von außeruniversitären Forschungseinrichtungen am Beispiel des Fraunhofer INT", Technical University of Berlin, 2022

Laschke, P.: Master's thesis "Untersuchung der Anwendung eines datengetriebenen Assistenzsystems zur Unterstützung von RTOs am Beispiel von KATI: eine qualitative Interviewstudie", Bonn-Rhein-Sieg University of Applied Sciences, 2022

Nickels, C.: Bachelor's thesis "Kompetenz- und Akteursanalyse der Fraunhofer-Gesellschaft in den Bereichen Launchertechnologien", Rhine-Westphalia Technical University of Aachen, 2022

Steinberg, A.: Bachelor's thesis "Anpassungsfähigkeit von KMUs auf sich verändernde externe Rahmenbedingungen im Vergleich zu großen Unternehmen und Konzernen am Beispiel des Automotive Sektors", Rhine-Westphalia Technical University of Aachen, 2021–2022

Yesil, E., Kiyildi, A.: Project work "Identifikation von Trends in der ›New Space‹ – Branche", Rhine-Westphalia Technical University of Aachen, 2022

Cesbron Lavau, L.: Heidtmann, G.: Bachelor's thesis "Empfindlichkeitsuntersuchungen an COTS Drucksensoren unter HPEM", Rhine-Westphalia Technical University of Aachen, 2022

Bantes, R.: Niewiadomski, S.: Bachelor's thesis "Wasserstoff als nachhaltiger Energieträger für alternative Antriebe in der Pkw-basierten individuellen Mobilität: Ein Blick auf den aktuellen Stand der Technik I", Bonn-Rhein-Sieg University of Applied Sciences, 2022

Jovanović, M.: Plattner, R.: Bachelor's thesis "Gamifications und Motivation – Eine Studie am Beispiel eines Workshops zur Mobilität der Zukunft", Bonn-Rhein-Sieg University of Applied Sciences, 2022

Jovanović, M.: Rabe, L. R.: Master's thesis "Die Smart City Bonn in den Augen ihrer Bevölkerung. Eine kritische Auseinandersetzung mit der Kommunikation einer Smart-City-Strategie", Bonn-Rhein-Sieg University of Applied Sciences, 2022

Jovanović, M.: Fail, I.: Bachelor's thesis "Eine vergleichende Analyse der Literaturdatenbanken Web of Science und Dimensions durch Topic Modeling", Bonn-Rhein-Sieg University of Applied Sciences, 2022

Jovanović, M.: Keller, D.: Master's thesis "Diskussionen im Techniksektor: eine Datenanalyse der Internetbeiträge von Elon Musk und seiner Online-Communitys", Bonn-Rhein-Sieg University of Applied Sciences, 2022

Martini, M.: Imran, I.: "What is the best (= in terms of usability and utility) way to visualize IPC/CPC classes in Patent Analysis?", University of Siegen, 2022

Committees and networks

B Adami, Ch.: Chairman "NA140-00-19AA Preparation of VG standards VG96900-96907, NEMP- und Blitzschutz"

Adami, Ch.: Member "NA140-00-20-02UA Preparation of VG standards VG95370 ff., Elektromagnetische Verträglichkeit"

Adami, Ch.: Member "WG6, E3AT NATO Susceptibility Test Procedures Against Radio Frequency Directed Energy Systems"

Chmel, S.: Coordinator "Fraunhofer EU-Netzwerk"

Chmel, S.: Head "AG Management", "Fraunhofer EU-Netzwerk"

Chmel, S.: Member "Advisory board of the Institute for Detection Technologies at the Bonn-Rhein-Sieg University of Applied Sciences"

Gabel, O.; Huppertz, G.; Klein, M.: Members "NATO RTO-STG SAS-159 How could Technology Development Transform the Future Operational Environment"

Neupert, U.: Member "Independent Scientific Evaluation Group (ISEG)" of the NATO research programme "Science for Peace and Security"

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