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Editorial

Time for a Reality Check

By Holger Hanselka

Holger Hanselka

There are a lot of news stories circulating these days — including but not exclusively from the United States — that should make one thing crystal clear to us here in Europe: The independence of science, the freedom of research are valuable assets that we may have taken for granted for far too long. What else besides rational argument, knowledge and the search for authentic solutions can help counter populist articles of faith?

It might not come as much of a surprise to hear something like that from the president of a leading applied research organization. But I do have something else to say that might be more surprising: Especially when resources are tight, the freedom of research must not be misunderstood as the freedom to waste tax revenue. Quite the opposite. With Germany's economic output stagnating in the first half of 2025 and GDP contracting by 0.3 percentage points, we can clearly see that we need strategic investments in the future. Innovative strength is the crucial raw material that both industry and the medium-sized business sector in Germany have. But these investments must be targeted and effective.

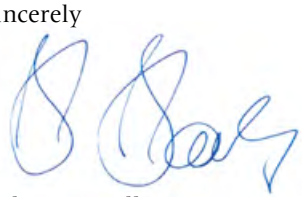
The purpose of the research sector is not to produce the same results from multiple sources. Germany has — and this is a priceless asset — a wonderfully diverse system of science and research that covers everything from excellent basic research to direct transfer to industry. But we do run the risk of very similar requirements applying to all four of the major research organizations at the federal level, especially now. That is not only inefficient for research. It also shifts tax revenue in a direction where competition should actually be the deciding factor.

At Fraunhofer, we know who we are. We know what we can do. And we know what we want. Since 1949, Fraunhofer institutes have strengthened the competitiveness of German industry and of Germany as a hub of innovation — and incidentally, right from the start we also had as one of our core areas of expertise a field that is back in demand today: security and defense (see also pages 10 through 23). Right now, our nearly 32,000 employees are hard at work on solutions to almost every acute issue facing the world today — that's applied research. Contract research for industry is our most important business focus. In this segment, Fraunhofer shines time and again as an important supplier of innovation and expertise for companies of all sizes. Transfer to industry is Fraunhofer's role, our profile and our strength.

The Fraunhofer-Gesellschaft is famed for the Fraunhofer model. Base funding makes up a maximum of one-third of our budget. Year after year, we earn at least two-thirds ourselves through competition. This creates resilience. But it is also a challenge. Our more than 8,000 industry projects a year serve as a reality check. And we reliably pass the test with flying colors.

Let's come together to stand up for the freedom of research. And for a diverse system of science and research where funding is allocated in line with the needs of the market. Transfer for our future as an organization and for Germany's future as well.

Sincerely



Holger Hanselka
President of the Fraunhofer-Gesellschaft

Photo: Fraunhofer/Stefan Obermeier

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Fraunhofer IAP has developed an impressive bio-based adhesive.

Thirty-six percent of all bridges and overpasses on Germany's highways need repairs or rebuilding. About as many bridges managed by cities and towns are dilapidated as well.

Source: Study titled Ausgebaut! (All Built Out) (April 2025), Transport & Environment Deutschland gGmbH

36 %

Front and back cover photos: Jonas Ratermann, IZFP-Fraunhofer, Jian Fan / istockphoto, ESA, plainpicture/cgimanufaktur; Content photos: Jonas Ratermann, Steffen Kugler / Bayer AG, Marina Weigl, Boomeart, Jian Fan / both from istockphoto, Till Melchior / Plainpicture, klosfoto/istockphoto

Brief Report

Accurately recording precipitation in real time also helps zero in on the best ways to counter potentially catastrophic flooding.

Improved Weather Forecasts

An acoustic rain sensor is being designed to improve the accuracy of weather forecasts. The innovative sensor is under development by a team of researchers at the Fraunhofer Institute for Digital Media Technology IDMT working in tandem with an industry partner. As part of their project, named lokalRAIN, the researchers aim to record acoustic vibrations that arise when raindrops strike surfaces and analyze them in real time with AI.

The goal of the sensor system is to record and analyze spatially distributed precipitation. To achieve this, a technology for efficient machine learning is being developed along with cost- and energy-optimized computing hardware for use with the sensor system. Another important factor is ensuring that the precipitation data that has been logged is reliably transferred from individual sensor nodes to the server via connected infrastructure. On the server, the data is combined with an eye to various precipitation parameters, such as volume, drop size and spatial distribution, and then analyzed in real time to help make predictions. To date, reliable precipitation data has only been available for selected locations with weather stations, so weather forecasts have been imprecise. ■

Reliably Monitoring EV Batteries

An innovative measurement method enables optimized battery management in electric vehicles, helping to make them safer and extend their lifespans. Dynamic impedance spectroscopy from the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM analyzes detailed measurement data on the battery's state in real time during operation. The information obtained in this way encompasses much more than simply data about the charge capacity or remaining operating time. It provides a detailed, accurate and in-depth picture of what is going on inside the battery. This also enables the individual prediction of the battery cell's potential lifespan.

Impedance can also be used to make inferences concerning the temperature inside the cell. That is why battery management systems can use impedance data collected while an EV is operating, for example, to register immediately if and when a given local cell heats up sharply and then power it down. Conventional temperature sensors also register that battery cells are overheating, but with a lag. Previously, impedance measurements could only be performed in a resting state. ■

Safety for EVs on the road: Ongoing detailed measurements of battery status allow for better control.

Sustainable Antifouling Coating

The goal of the BioSHIP project is to develop a biodegradable, ecofriendly antifouling coating. These kinds of coatings are used to prevent mussels, barnacles and seaweed from colonizing the hulls of ships. Researchers from the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM are focusing on sustainable formulations, including bio-based polymers and chitosan derivatives, that will degrade in a controlled manner under maritime conditions without leaving any harmful residue behind. The aim of the innovative coating is to use significantly lower amounts of toxic heavy metals than conventional biocidal agents. It will be tested under real-world conditions. Ecotoxicology studies will ensure that the substances developed have no harmful effects on marine life.

A fouled hull — one with marine overgrowth — increases drag, which therefore also increases fuel usage. And that drives up not only costs but also carbon emissions. There is also a risk that ships will transport invasive species to new waterways, which can pose a threat to local ecosystems. ■

Cleaning a ship's hull is a grueling task. So it's better if nothing starts to stick to it in the first place.

New Leadership at the Fraunhofer Future Foundation

Thomas Hirth worked in various roles at the Fraunhofer-Gesellschaft from 1992 to 2015.

Hirth is the new chair of the executive board of the Fraunhofer Future Foundation, one of Germany's largest research-focused foundations. He also serves in the role of Vice-President for Transfer and International Affairs at Karlsruhe Institute of Technology (KIT). He took on his new position in July, succeeding Hans-Jörg Bullinger, who had been in charge of the foundation since 2020.

Hirth, who has a degree in chemistry, is highly familiar with Fraunhofer, having worked in various roles at the Fraunhofer-Gesellschaft from 1992 to 2015, including as a member of the presidium and as the director of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart.

Founded in 2008, the Fraunhofer Future Foundation helps Fraunhofer research scientists develop products, services and business models that make an important contribution to solving global challenges. The foundation gears its funding toward key social and technological issues and capitalizes on collaboration with the research community, the private sector, civil society and government. ■

The Einstein Telescope is to measure gravitational waves all the way back to the Big Bang.

New Infrastructures for Research

Fraunhofer researchers have been shortlisted in the national prioritization procedure for new research infrastructure with two projects. The Center for Gene and Cell Therapy in Regeneration and Transplantation (CREATION), which the Fraunhofer Institute for Cell Therapy and Immunology IZI is participating in, aims to develop "off-the-shelf" therapies and use AI-supported automation to improve production of these treatments. The goal of the large-scale Einstein Telescope (ET) project, which involves the Fraunhofer Institute for Laser Technology ILT, the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and the Fraunhofer Institute for Production Technology IPT, is to develop a revolutionary tool for detecting gravitational waves, thereby unlocking new avenues of research on topics such as how black holes form.

The prioritization process is how the German Federal Ministry of Research, Technology and Space (BMFTR) selects those research infrastructure projects that will make Germany more competitive on the international stage. For the shortlist, a panel of experts selected nine projects from among 32 brief concepts that had been submitted. Plans will now be fleshed out further, in consultation with the German Science and Humanities Council. ■

Gaming Boosts Environmental Awareness

Little Impacts, an award-winning sustainability computer game from the Fraunhofer Institute for Solar Energy Systems ISE, has been well received by kids and teens while also making a difference: A new study has shown that playing the game significantly enhances environmental awareness. For the study, 56 participants were surveyed at gaming events, using a "pre-post" structure. They were asked about their views before playing the game and about one to two weeks later. The researchers identified willingness to change as the category with the sharpest increase.

Little Impacts was developed on behalf of the German Environment Agency (UBA). The game won the TOMMI Award for children's media in late 2024 and was then chosen "app of the month" for May 2025 by Deutsche Akademie für Kinder- und Jugendliteratur e.V., a national non-profit dedicated to children's and young adult literature. The interactive novella charms audiences with its hand-drawn artwork, authentic characters, humorous storytelling and a cozy gaming atmosphere. ■

Making learning fun: Little Impacts shows how.

Editorial notes

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Free subscription:
Phone +49 89 1205-1301
publikationen@fraunhofer.de

Editorial team:
Monika Landgraf
(person responsible for content),
Josef Oskar Seitz (editor-in-chief),
Sonja Endres and Beate Strobel

Editorial assistants:
Janine van Ackeren, Mandy Bartel, Patrick Dieckhoff, Meike Grewe, Sirka Henning, Andrea Kaufmann, Lisa Scherbaum, Kathrin Schwarze-Reiter, Laura Rottensteiner-Wick, Mehmet Toprak, Yvonne Weiss, Ulla Wolfshöfer

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Hopping right along: Bavaria's Hallertau region is the world's largest hops-growing area.

A Toast to Sustainability

Fraunhofer researchers are looking for more ecofriendly ways to produce the 85 million hectoliters of beer brewed annually in Germany.

How can hops — essential to brewing beer — be dried sustainably? Researchers from the Fraunhofer Institute for Casting, Composite and Processing Technology IGCV in Augsburg set out to find alternatives to the fuel oil that has previously been used for this task. In their Grüner Hopfen (Green Hops) project, they simulated various options and analyzed them with an eye to efficiency, greenhouse gas emissions and cost-effectiveness.

From biogenic fuels such as pellets to the use of heat pumps or hydrogen as an energy source: "In all the versions we explored, the technology had to meet the specific requirements involved in drying hops," explains project manager Vincent Kalchschmid from Fraunhofer IGCV.

The simulation study concluded that there is no such thing as one solution for every situation. The requisite heating performance can be achieved and greenhouse gas emissions lowered with each of the three alternatives, but each one also has specific pros and cons. Biogenic fuels are a mature technology but involve a lot of logistical work. Heat pumps are highly efficient and use renewable heat sources, but investment costs are steep, and they are also dependent on external sources of electricity. And hydrogen as an energy source requires costly infrastructure, plus there is considerable uncertainty regarding the market development of this technology.

The size of the operation, infrastructure conditions and availability of renewable energy sources, fuels and technologies at the site: "All of these factors affect the choice of technology," Kalchschmid points out. But it is also certain that the process of drying hops needs to be made greener if people are to enjoy a beer with a clear environmental conscience. Each year, 14 million liters of fossil fuel is needed for the annual harvest in the Hallertau region alone — which, at 19,000 hectares, is the largest contiguous hops-growing area worldwide. That's about as much fuel as 7,000 households consume in a year. ■

Research for Security

Germany is investing in security and defense. There are numerous research projects ready to launch, not only within the Bundeswehr but also in the realms of civil defense and critical infrastructure. Not all challenges have been resolved yet, but the future is looking brighter.

By Mehmet Toprak; photographer: Marina Rosa Weigl

Defense training: Laser expert Thomas Schreiber is working on high-performance lasers that neutralize approaching drones from a distance of several kilometers.

Research for protection

Mission North Sea:
Kai Brune uses drones to transmit real-time images of maritime emergencies to a situation center.

The North Sea is known for both its rough weather and its natural beauty. But what is really interesting is what lies beneath the surface. There are cables and pipelines on the sea floor. The Nordlink cable connects Wilster, in the German state of Schleswig-Holstein, with Tonstad, Norway, transporting green electricity. The NorNed cable, at 580 kilometers the world's longest power cable, also runs through the North Sea on its way from Norway to the Netherlands. And the AquaDuctus pipeline is slated to come online there in 2030, connecting the first major hydrogen wind farm. Energy, data, communication: That's a lot of critical infrastructure — and so far, it has largely been unprotected.

There are no protective measures on the North Sea floor. The situation is just like with energy grid operators' installations and water utilities, just like many bridges, transportation networks and hospitals all across Germany and the whole of Europe. With espionage, sabotage and cyberattacks on the rise, the importance of effective protections for critical infrastructure is becoming increasingly clear. Caroline Schweitzer, managing director of the Fraunhofer Segment for Defense and Security VVS, firmly believes Fraunhofer researchers can help: "We have a broad spectrum of expertise in security research, which is so multifaceted that it can be applied in both civilian and defense contexts."

> "Handled responsibly, civil and defense research both benefit society as a whole."
>
> Caroline Schweitzer, Fraunhofer Segment for Defense and Security VVS

In the German Bight, the ELO project is now intended as the first major step toward protecting the infrastructure. The project is working to develop real-time capabilities for assessing the situation on the ground during maritime emergencies. Images and videos from various sources, including drones, are being used to do this.

This technology is designed to help salvage ships that have run aground or been involved in accidents, but even more, it will also contribute to protecting critical infrastructure points such as harbors and offshore wind farms against illegal activity like sabotage, allowing for early detection of threats and initiation of countermeasures.

The offshore drone campus operated by the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Cuxhaven is involved in the ELO project. Kai Brune and his team are responsible for integrating drone systems into the situation center's operations concept and for automatically generating image and video materials in the German Bight. Transferring smooth, high-resolution images from a moving drone many kilometers away to screens at the situation center is a huge challenge. → See Project 3 | page 22

As the aircraft for use over the North Sea, the researchers use the S360Mk.II manufactured by project partner Hanseatic Aviation Solutions. Its wingspan of 3.6 meters makes this fixed-wing drone perfect for use over the open sea. "We have already carried out several successful flights to Helgoland and back using this system," Brune says, pleased.

When it comes to getting drones ready for challenging flights over the North and Baltic Seas, Fraunhofer IFAM is one of the top partners in Europe. In addition to the location in Cuxhaven, the institute operates the Test Center for Maritime Technologies on the island of Helgoland in partnership with the German Research Center for Artificial Intelligence (DFKI). The center's activities include testing drone technologies for use under extreme offshore conditions.

As soon as a threat to critical infrastructure on the sea floor emerges, it is important to be present there as well with mobile systems. The situation calls for uncrewed underwater vehicles with powerful sensors, long-lasting batteries and AI controls. They need to be rugged enough to go about their dangerous business even at depths as great as 1,000 meters. The Advanced Systems Technology branch AST of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Ilmenau provides a research platform for this. A test pool affords the opportunity to develop and test hardware and software for underwater vehicles and components. A pressure test unit tests component assemblies to ensure that they are well sealed and stable.

Werner Riedel holds the title of Chief Scientist Defense at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI and is also an honorary professor at Furtwangen University and a visiting professor at Nanyang Technological University (NTU), one of Singapore's top universities. He also has decades of experience in civilian and military security research at the EU level. ▶

Riedel welcomes the focus on drone technology. "Drones will be critically important to scenarios in defense and security over the next few years. Here in Germany and across Europe, we need to intensify our research on further development and integration if we are to keep up in this arena."

Protection against drones in the city

Drone expertise also includes knowing how to detect and protect against them when they enter the areas around military sites, airports or power plants without authorization.

So far, this has been done with radar systems or cameras. These systems are technologically complex and require a lot of energy, plus radar is easily detectable by the radio waves it emits. Radar systems also cannot be operated in densely populated urban areas or near hospitals or residential buildings due to harmful electromagnetic emissions.

Christian Steffes from the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE has a solution: passive radar. These kinds of systems do not emit any radiation themselves. Instead, they harness the fact that flying objects also reflect mobile communication signals. Passive radar can use differences between the direct signals emitted by the mobile phone base station and the waves bouncing off the object to calculate values such as distance, direction of movement and speed. This technology does not rely exclusively on publicly accessible cell phone networks but also on LTE 450, a mobile communication standard developed specifically for secure communication for operators of critical infrastructure. It is especially robust, with special failsafes. → See Project 4 | page 22

But there is a catch, of course. "Passive radar is not as accurate as conventional radar systems," Steffes says. "But once a single drone or a drone swarm has been detected and further intel is needed, we use additional sensors such as cameras or active radar." To do this, Fraunhofer FKIE has developed a fusion engine that combines and analyzes the full range of sensor data. These kinds of multi-sensor systems are increasingly playing an important role in security and defense technologies.

> "Drones will be critically important to scenarios in defense and security over the next few years."
>
> Werner Riedel, Fraunhofer EMI

Photo: Kilian Kreb

Precise as a scalpel

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF is developing a technology to neutralize drones. The team of researchers is working with laser technology at a wavelength of two micrometers. High-performance lasers capable of hitting objects at distances of many kilometers have used the one-micrometer wavelength so far. However, at this range, not only the laser beam itself but also the laser light reflecting off of objects is harmful to people's eyes, so these systems are not permitted in densely populated areas.

By contrast, the radiation scattered when a two-micrometer laser is used is absorbed by water, including by the human cornea, which is moist. This makes it significantly less of a risk to people's eyes. To generate this wavelength, the Fraunhofer researchers added thulium, a rare earth, to optical fibers and developed a special lens. Three laser beams are passed through a diffraction grating that combines them into one. This is also made possible by improved methods for cooling the lasers. At the same time, the grating reflects more than 99 percent of the laser light, so it does not heat up as much.

Thomas Schreiber, head of the Laser and Fiber Technology department at Fraunhofer IOF, comments: "Because of the precision effects of the laser beam, we can use it like a scalpel. It has a diameter of about one centimeter at a distance of one kilometer, so with an approaching drone, you could point it directly at the control electronics." German navy frigates could also use the high-performance laser to defend themselves against approaching flying objects. One advantage is that the laser does not require any ammunition that needs to be stored and replenished. → See Project 6 | page 23 ▶

Sophisticated passive radar: Christian Steffes uses reflections of mobile communication signals to detect approaching drones.

Casting a wide net in the search for threats: Hans Peter Stuch is working on a system that collects data from different sources for faster detection of hybrid attacks.

Smart system against smart system

When smart defensive systems go toe to toe against smart drones or drone swarms, there are certain positives as well. After all, no one gets hurt at first when machines fight machines.

However, in the world of AI, software and autonomous systems, threat scenarios are growing more complex. Meaning that hybrid threats are on the rise. Hans Peter Stuch, who leads a research group at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, does not like the word "hybrid." "It's overused. True hybrid attacks are coordinated attacks originating from different domains." For example, there might be a wave of social media posts criticizing the railway operator. Meanwhile, a cyberattack targets a signal box. And unknown parties attack a power line. Each of these attacks seems to be a minor annoyance in its specific domain, like a bee sting, but together, they add up to a significant threat or do huge amounts of damage.

To counter threats of this kind, the team at Fraunhofer FKIE is working on a system that collects information from different domains, including data from physical sensors such as surveillance cameras or radio receivers and from software tools that log malware attacks in the network. There are also structures in place to monitor social media for patterns such as a sudden spike in certain keywords. All of this information is combined to produce a visualization of the situation. This big-picture view makes it possible to see that the different events taking place in different domains are in fact connected, even if they occur with long gaps in between. → See Project 7 | page 23

Misunderstandings and poor management as security risks

To help those responsible for security respond appropriately when faced with a cyberattack, the experts at Fraunhofer FKIE offer regular security training sessions. Their main customers are energy suppliers and grid operators, and interest has been growing in recent years. "In many cases, we see that communication and coordination are the issue. Unclear responsibilities are a risk factor, too," explains Martin Serror, who works as a cybersecurity instructor himself. "Knowing that, we put communication and coordination front and center in our training courses. We offer a true-to-life simulation environment tailored to the specific customer. Typically, we have participants go about routine tasks before facing a sudden cyberattack." → See Project 8 | page 23

> "In many cases, we see that communication and coordination are the issue. Unclear responsibilities are a risk factor, too."
>
> Martin Serror, Fraunhofer FKIE

The HERAKLION project, which is being supported by the German Federal Ministry of Research, Technology and Space (BMFTR), aims to develop heuristic resilience analyses for municipalities using data space functionalities. It might sound like an abstract scientific study, but this can actually save lives. "Take catastrophic flooding, for example. Thanks to HERAKLION, first responders know ahead of time which detours to take because other roads are washed out, how many people, buildings and critical infrastructure points are affected and which gyms and similar facilities are accessible for evacuees," says Kai Fischer, manager of the Robustness and Resilience Analysis group at Fraunhofer EMI.

To gather the information needed for this, HERAKLION efficiently combines data from different sources: population structure, weather, forest fire risk, maps of areas at risk of flooding or heavy precipitation and much more. For maximum real-world utility in the way the information from the data analyses is displayed on the dashboard, the developers worked with disaster preparedness groups and first response planners right from the start. → See Project 9 | page 23

Riedel, an expert in this field, sees the lines between civil defense and defense technology becoming increasingly blurred: "The distinction was always a bit artificial. Resilient infrastructure, protecting the civilian populace and defense ultimately deal with many of the same topics, structures and capabilities."

Schweitzer, the managing director of Fraunhofer VVS, adds: "Handled responsibly, civil and defense research both benefit society as a whole. At the same time, they both help with efficient use of financial resources." ▶

One good example of civilian technology being used for military benefit is RISK.twin. This joint project being conducted by the Fraunhofer Institute for Experimental Software Engineering IESE, the University of the Bundeswehr in Munich and software company NetApp, aims to generate digital twins of bridges and highway overpasses to enable smart maintenance management.

The structures are equipped with sensors to detect values such as vibrations, expansion and temperature. Together with the base data on the specific structure, this makes it possible to gauge capacity utilization and load-bearing capacity. The sensor data can even be updated hourly on a dashboard at a situation center. NATO troops moving around Germany in a defense operation could use this information to better plan their routes. After all, military vehicles are often on the heavy side, so the functionality and load-bearing capacity of structures like these are important pieces of information. The sensors installed on bridges that have been damaged in attacks provide information on the maximum weight they can still bear without risk.

Beyond smart sensors, software tools and dashboards, a research organization like the Fraunhofer-Gesellschaft can make even more of a contribution to future safety, Riedel points out: "Thanks to our insight into cutting-edge research, we can explore which technological topics will be relevant a few years down the line and also see where there are gaps in industry projects. And then we can zero in on those gaps with our pre-competitive research, such as dissertation topics. This approach also distinguishes the innovative strength and creativity of Fraunhofer researchers."

Puzzling plasma effects and radar over the horizon

Right now, hypersonic weapons are one of the biggest unanswered questions in defense. Hypersonic flying objects move at speeds of Mach 5 or more, faster than 1700 meters per second. They are not only fast but can also fly low to the ground and are extremely maneuverable. So far, defending against these objects has been very difficult. That is because in the hypersonic realm, everything changes: fuel, airworthiness, materials, aerodynamics, sensors, navigation — everything has to be rethought. For example, the control electronics get very hot, with friction heat reaching temperatures as high as 3,000 degrees Celsius. The plasma that forms on the object's surface also adversely affects radar signatures.

When it comes to how to track and defend against these objects nonetheless, Daniel O'Hagan has answers. His résumé is very impressive. He wrote his dissertation ▶

A matter of survival: Hypersonic weapons have posed major challenges for defense so far. Daniel O'Hagan is working on ways to successfully defend against these deadly flying objects.

on radar technology and currently works as a research scientist at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, is the chief scientist and coordinator for hypersonic technology at Fraunhofer VVS and Chair of NATO TG SET 296 Radar Against Hypersonic Threats. In cooperation with the Bundeswehr, he has also established an international workshop on the topic. His calendar has always been packed, but it is even more so now, since the start of the war in Ukraine and since Russia began using hypersonic weapons.

O'Hagan places his hopes in a multi-layered multi-sensor system to defend against hypersonic missiles, linking radar sensors and electro-optical and infrared cameras (EO/IR) together. One key element of early warning is Skywave over-the-horizon radar (OTHR). Because they can fly low to the ground, hypersonic weapons are late in appearing over the horizon, where they become visible to traditional radar systems. At such high speeds, this leaves little time to respond. Over-the-horizon systems take advantage of the fact that radar at wavelengths of between three and 30 megahertz is reflected by the earth's ionosphere, which "illuminates" even areas beyond the horizon. By registering the reflected waves, these systems can even detect objects that are actually flying outside the direct radar range. → See Project 1 | page 22

"No system on its own can cover all the functions needed to detect and track hypersonic flying objects," O'Hagan says, tempering expectations. "Much like with drones, the key lies in combining different technologies, for example in the interaction of satellite monitoring with various ground-based and airborne radar systems."

The Fraunhofer researchers view these technologies for civil defense, critical infrastructure and defense as more than just a technological challenge. They are also a social responsibility. As Steffes puts it: "We need to reassure people in Germany and elsewhere in Europe that we can respond swiftly and effectively in a crisis. And that will dispel the sense of uncertainty as well."

Once that is achieved, people setting off into the North Sea by boat can do so secure in the knowledge that the cables and pipelines on the sea floor are well protected.

Duty calls: Photographer Marina Rosa Weigl poses Hans Peter Stuch and Daniel O'Hagan in unconventional settings.

Defending Air Sovereignty

Airborne danger incoming? An innovative drone defense system helps security personnel effectively protect buildings, events and people.

By Beate Strobel

Angela Merkel in their sights: In 2013, when a drone about 40 centimeters in size approached Germany's then chancellor at a CDU election event in Dresden and fell to the ground a short distance in front of the speaker's podium, Merkel merely gave an amused smile.

But in fact, it was a wake-up call. The incident in Dresden turned out to be a protest by the Pirate Party, a rival political faction. Today, Hans Peter Stuch, a communications engineer and head of a research group at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, calls it the "mother of all drone defense scenarios in Germany." The attack came as a rude awakening for many security agencies, which suddenly realized they did not have many tools in their arsenal for dealing with a potential drone threat. At the same time, these high-tech flying objects are increasingly common in civilian and commercial applications, such as delivery of packages, medications or food. The more crowded the air becomes, the greater the need to tell "good" and "bad" drones apart.

Building on the results of four projects carried out with Fraunhofer's involvement, the IDAS-PRO flagship project launched by the Federal Ministry of Research, Technology and Space (BMFTR; at that time the German Federal Ministry of Education and Research, or BMBF) in 2023 has become a true all-around approach to fighting drones: The innovative drone defense system incorporates multiple different radar systems, radio direction finders, remote ID sensors and miniaturized cameras, all of which help to pinpoint the drone's location and predict its flight path. The sensor data is fused together and then displayed in an overall picture of the situation; at that point, smart algorithms support users with suitable options for actions to take. "IDAS-PRO suggests countermeasures in real time," Stuch explains. "After all, when you have a drone approaching at a speed of 70 kilometers per hour, it doesn't leave much time to decide on the right countermeasures to take."

For active drone defense, the system includes two effectors. The first, a jammer, is automatically aimed at the target object by the situation display. It sends out signals that disrupt radio communication between the remote control and the drone, so the flying object hovers where it is. The second feature, a collection drone, launches automatically to net the targeted drone and take it to a safe location. This allows for forensic examination of the drone that has been repelled.

This project, for which Fraunhofer FKIE is a co-lead, is impressive not only for its functional demonstrator but also for how it got there: The German Federal Criminal Police Office (BKA), the German Federal Police, the Bavarian State Criminal Police Office (LKA), and the Baden-Württemberg, Brandenburg, North Rhine-Westphalia and Rhineland-Palatinate police departments were all closely involved in the research right from the start as future users of the technology. Stuch comments: "Working together like this allowed us to identify specific user requirements and develop test scenarios that really reflect real-world conditions."

IDAS-PRO was designed as a universally usable system, so Stuch also points out further possible user groups and scenarios: "Our solution enables flexible use. It can be used to protect critical infrastructure or secure large events or used in a military context." And because the research was conducted with significant input from users, it will not take long for the technology to find its way into real-world practice: "The first IDAS-PRO components are scheduled to become available with official item numbers in early 2026." ■

IDAS-PRO at work: more info on the innovative defense system

Hans Peter Stuch makes sure attacking drones cannot reach their targets.

A Growing Protective Shield

Detecting, analyzing and defending against threats are the goals for various research projects at the Fraun-hofer institutes. Here are ten projects working to safeguard critical infrastructure and the general public.

1

Defending against hypersonic weapons

Existing technology is practically helpless to defend against them. Researchers from the Fraunhofer Segment for Defense and Security VVS are hard at work on multi-layered combined radar systems and electro-optical and infrared (EO/IR) cameras to improve capabilities for detecting and tracking hypersonic objects. Another issue is that the lower to the ground the objects fly, the faster they disappear from the range visible on radar. Over-the-horizon systems help with this, using radar technology at wavelengths of between three and 30 megahertz. Much like shortwave radio, these waves are reflected by the ionosphere, so they cover a much larger area.

https://s.fhg.de/hypersonic-EN

2

Missile launch warning

The Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB is using electro-optical sensors on satellites to provide early warnings of ballistic missile attacks. The researchers are working on behalf of the German defense ministry to develop corresponding design concepts. The sensors register infrared signals from the missile's exhaust plume and convert them into electronic signals. Image processing algorithms analyze the data and provide exact target information to interception systems. This technology could be an effective addition to ground-based air defense. A prototype of the sensor was developed for the ERNST research satellite, which was launched into space in August 2024. The small satellite from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI demonstrates the feasibility of missile detection from orbit.

https://s.fhg.de/EO-sensors-EN

3

Real-time information on offshore situations

From vessels in distress to attempted espionage, researchers from the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM who are working on the ELO project visualize maritime emergency scenarios in the German Bight. For their live information on offshore situations, the Fraunhofer experts rely on a variety of tools, including drones with a wingspan of as much as 3.6 meters, which can carry various sensors depending on their mission. They can remain airborne for up to seven hours. The project also involves making them more rugged for the challenging conditions found offshore.

https://s.fhg.de/ELO-EN

4

Detecting drones

Active radar systems are limited in their uses in urban areas, as they emit harmful radiation. The Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE is working on passive radar instead. These systems analyze for example the signals of mobile phone base stations that bounce off of flying objects. The system uses information such as delay, Doppler shift and angle of arrival between the direct signals from the mobile base station and the signals reflected from the flying object to calculate data, including the position, direction of travel and speed of flying objects. Mobile communication based passive radar does not rely exclusively on publicly accessible mobile networks but additionally on LTE 450, a mobile standard developed specifically for secure communication for operators of critical infrastructure.

https://s.fhg.de/passive-radar-EN

5

Detecting drones by sound

Drones make noise, which can give away their presence. The Fraunhofer Institute for Digital Media Technology IDMT in Oldenburg is researching ways to use high-performance microphone arrays and audio signal processing to detect approaching drones early on and assess the po-

tential threat they pose. The researchers are also using machine learning methods. This makes it possible to identify the flying objects even in environments with high background noise and take countermeasures where needed.

https://s.fhg.de/drone-detection-EN

6 Drone defense

How can flying objects be neutralized in densely populated spaces without placing people in jeopardy? The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena is using lasers with a wavelength of two micrometers, which is largely harmless to human eyes, to do just that. The team of researchers equipped optical fibers with thulium, a rare earth, to generate this wavelength. They also devised a diffraction grating that combines three laser beams into one. This allowed the team to increase the power to 1.91 kilowatts, almost twice as much as in a conventional system. The laser can zero in on the control electronics in an approaching drone at a distance of one kilometer.

https://s.fhg.de/lasers-EN

7 Hybrid threats

Hybrid threats are often so complex that their destructive impact is not recognized until it is too late. The researchers at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE are developing a system that collects and analyzes data from different sources, such as security software alerts, images from surveillance cameras and data from radio receivers. The system also monitors social networks, where disinformation campaigns against operators of critical infrastructure can be launched. Looking at all of the data together makes it possible to discern connections between attacks from different domains and identify the pattern as a coordinated attack.

https://s.fhg.de/cyberspace-EN

8 Training for energy suppliers

The Fraunhofer Academy is teaching energy suppliers how to defend against cyberattacks. The training sessions, which are overseen by experts from the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, are much like role-playing exercises, in which participants are placed in a realistic environment where they go about everyday tasks before an attack is launched from the web. Technical expertise is a factor, but so is communication between the affected departments and the management.

https://s.fhg.de/cybersecurity-EN

9 What is the situation?

When a river overflows, the power grid breaks down or a pandemic spreads, first responders need a nuanced and detailed overview of the situation — and they need it fast. The HERAKLION project collects and analyzes the information needed for this, such as weather data, roadmaps, population structure and flooding maps, and visualizes it on a dashboard. This way, first responders know in time which roads are flooded, which bridges are still passable and which assembly points or gyms are still accessible. For this project, researchers from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI worked with rescue agencies and first response planners.

https://s.fhg.de/heraklion-EN

10 A nose for explosives

Specially trained dogs are often better at detecting explosives than measuring devices. The Fraunhofer Institute for Chemical Technology ICT has extensive expertise with explosives and offers scientifically backed training options for the dogs, most of which are German or Belgian shepherds by breed. The options offered include scent training courses to condition the dogs to new substances and realistic scenarios such as vehicle, luggage and building checks. The experts at Fraunhofer ICT can produce the explosive substances themselves without needing the markers that the law requires, which are intended to make detection easier but also change an explosive's scent signature. These training methods allow for studies of the dogs' olfactory capabilities.

https://s.fhg.de/detection-dogs-EN

Globally Interconnected, Globally Vulnerable

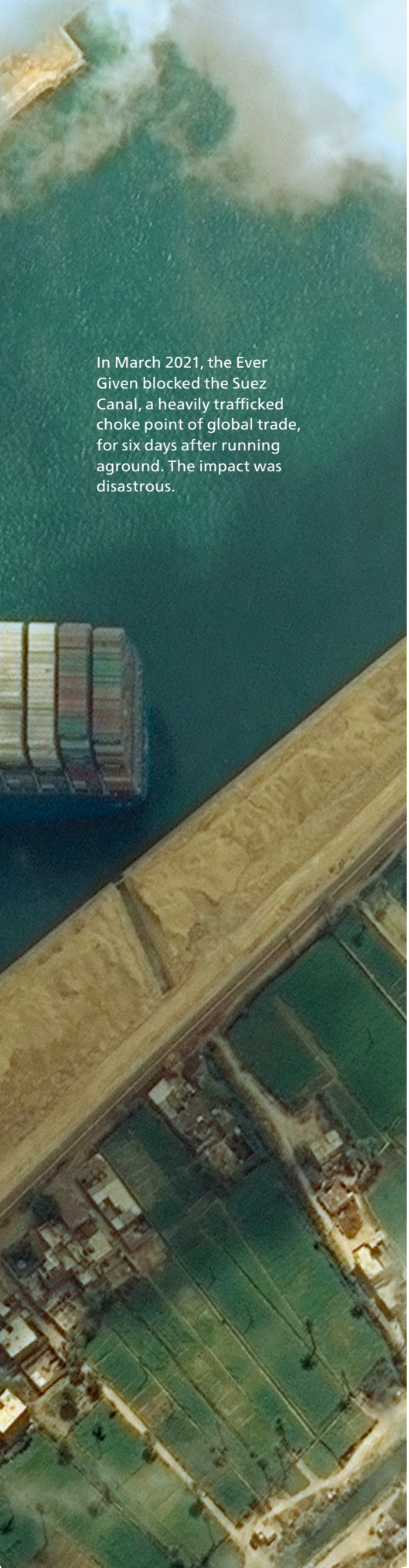
We hear practically daily about just how vulnerable global trade is. Now, companies are looking to AI to protect themselves. And demand is rising.

By Sonja Endres

Trump's threats of tariffs, terror attacks on container ships in the Red Sea, wars: Day after day, global trade is under threat. Supply chains are fragile. Eduardo Colangelo and his team at the Fraunhofer Institute for Manufacturing

"Resilience is always a balance between impact and likelihood of occurrence."

Eduardo Colangelo, Fraunhofer IPA



In March 2021, the Ever Given blocked the Suez Canal, a heavily trafficked choke point of global trade, for six days after running aground. The impact was disastrous.

Photo: Maxar Technologies / AP / dpa

Engineering and Automation IPA in Stuttgart are studying how companies can harness AI to detect disruptions quickly, preventing production stoppages. Colangelo, an industrial engineer who has been developing solutions for industry at Fraunhofer IPA for 12 years, has seen rising demand in recent months in particular. "We're seeing accelerating and multiplying crises that are pushing companies to ramp up their investments in resilience," he explains.

Building resilience takes careful, strategic advance work, Colangelo points out. Analyzing individual production conditions is an especially important factor. Which raw materials are needed? How can they be obtained? What suppliers and modes of transportation are there? Are there alternatives? This information is fed into AI models that the Fraunhofer IPA team developed as part of the PAIRS research project. These models detect disruptions along supply routes while at the same time keeping track of critical trends in commodities markets. To do this, they draw on sources including up-to-date satellite images from Copernicus, the European Union's earth observation program, and reports from news portals for their analyses.

Preparation is everything

The AI measures factors such as the density of ship traffic. If cargo ships are lined up outside a port or in a passage, there is probably an issue somewhere. The port might have had to close, or a container ship might have had an accident and is keeping others from proceeding, as the Ever Given did in the Suez Canal in 2021. If the threat poses a risk to the company, the AI issues a warning. Colangelo's colleague Theresa-Franziska Hinrichsen notes: "But the decision whether to take action rests with the human." If the human operator concludes that intervention is not needed, that information also flows back into the AI model. "This way, our AI is always learning and getting better and better at assessing how relevant certain events are to that specific organization," Colangelo comments.

Right now, the research team is also working on simulation models based on individual company data. Of course, there are many conceivable scenarios that pose a risk to production, Colangelo says, but there is no need to prepare for every single one. "That would only increase costs unnecessarily. We only simulate the ones that are likely and critical. Resilience is always a balance between impact and likelihood of occurrence."

The AI models from Fraunhofer IPA could strengthen not only industrial resilience but also disaster preparedness and response. In collaboration with the German Federal Agency for Technical Relief, the team of researchers plans to use scenario analyses to identify high risks so that targeted investment decisions can be made. "But to train the AI models, we need the relevant data in the first place. And unlike in industry, that data is hardly available in a structured form," Hinrichsen explains. With that in mind, the researchers' first step was to develop a tool that makes it easier to gather relevant data in the event of a disaster. The tool has various uses, including simple monitoring of stock levels at emergency response sites and smart planning for needed materials. "There isn't much time and effort involved, but the benefits are huge," says Hinrichsen. In addition to information on response efforts, other types of data, such as meteorological data, information on the availability and range of communication networks, infrastructure data and historical data about disasters, can be highly valuable in planning relief and preparedness measures. This information can also help to answer important questions. How did the weather conditions and the speed at which river water levels rose influence a flood disaster? How did a crisis situation change when certain factors interacted? "The data is a treasure trove just waiting to be explored. Once that happens, AI will be really helpful for disaster preparedness and response," Hinrichsen says. And we will be able to learn from past crises. ■

A voice from the business world

Stefan Oelrich is member of the Board of Management of Bayer AG, President of the Pharmaceuticals Division and since June 26, 2025, President of the European Federation of Pharmaceutical Industries and Associations (EFPIA).

Europe's Pharmaceutical Industry at a Crossroads

Reforming pharmaceutical legislation could make the supply of medicines more secure and strengthen Europe's competitiveness.

Stefan Oelrich, President of the European Federation of Pharmaceutical Industries and Associations (EFPIA), shares his thoughts.

When I began my career, thirty years ago, one in every two new medicines originated in Europe. Now it's just one in five. Over the last two decades, Europe has lost a quarter of its share of global pharmaceutical R&D investment, most notably to the U.S. and China.

In today's era of breakthrough innovation and intense global competition for cutting-edge science, the question is not if medical progress will happen, but rather where it will happen. Do we want the European Union to be dependent on innovations from other regions around the world? Or do we want it to recognize the importance of innovation and reward it accordingly? If we take the latter path, it would benefit patients, drive investment, create jobs and spur economic growth.

Europe needs to address its competitiveness crisis and healthcare challenges. There are real concerns about sovereignty, national security and supply chain resilience. Trade tensions are creating uncertainty, inciting European pharmaceutical companies to announce massive investments in the U.S.

But "sweet are the uses of adversity". Today the pharmaceutical industry — the largest contributor to the EU trade surplus and a provider of 900,000 jobs in the region — is finally being recognised as a key strategic sector in significant statements of intent and by decision makers at the highest level. We need now to rapidly turn this intent into policy change if we are to build a healthier and more competitive Europe. The most imminent opportunity to do so is through the General Pharmaceutical Legislation (GPL).

We need a Europe that attracts innovators and investment. Europe is entering the final stages of the legislative process for the GPL, which will define how medicines are developed, authorized and made available across Europe for decades to come. Despite the need for predictable, world-class Intellectual Property (IP) protection to offset the high-risk nature of medical R&D, proposals include a reduction of current regulatory data protection.

Bayer's decisions on research, development and production locations are based on a range of factors that, in combination, afford us the best chance of successfully bringing novel medicines to patients. It is imperative that Europe use this legislation to strengthen its IP in order to be competitive.

"Europe struggles to turn breakthrough science and research into commercially viable products."

Stefan Oelrich

- has represented the biopharmaceutical industry operating in Europe since June 2025 in the role of President of the European Federation of Pharmaceutical Industries and Associations (EFPIA).
- has been a member of the Board of Management of Bayer AG and head of the Pharmaceuticals Division since November 1, 2018.
- spent seven years heading organizational units in Germany, Switzerland and Austria at pharmaceutical and health company Sanofi. After that, he built Sanofi's diabetes and cardiovascular business. Oelrich was named Executive Vice President Diabetes & Cardiovascular and a member of the Executive Committee of Sanofi in 2016.
- joined Bayer AG in 1989, taking on leadership positions of increasing strategic importance in Latin America (Argentina, Uruguay), Europe (France, Belgium) and the United States.
- was born in Wilhelmshaven, Germany, on June 1, 1968. After finishing secondary school, he started vocational training as a commercial assistant at Bayer AG, where he passed the examination for formal certification in 1992.

We need a Europe that accelerates the translation of ideas into applications. Europe has world-renowned academic institutions and a highly skilled workforce. Yet it struggles to turn breakthrough science and research into commercially viable products. One way to improve this is to foster life science hubs, as in San Francisco or Boston, where all stakeholders across the public and private sector can flourish. We need to nurture our start-ups so that they do not need to look abroad for financing or fail before they have the chance to deliver for patients. Indeed, if Europe is to remain an engine room of innovative medicine, we need to reinvigorate financing at all stages of development.

We need a Europe where Europeans get fast and equitable access to medicines. It is unacceptable that patients in the EU have access to less than half of all approved innovative medicines. Nor that the average time from approval to patient access now amounts to 578 days. These delays and disparities arise from a combination of factors largely tied to Member States' medicine access and reimbursement processes. Urgent and real dialogue among industry, European institutions, and national policymakers will be essential to create harmonized EU mechanisms and national access strategies that value and reward innovation and ensure medicines are accessible to everyone in Europe.

We need a Europe that acknowledges health expenditure for what it is: an investment in our collective future. The healthcare industry helps people live longer and feel better, while driving prosperity, resilience and security. Yet, in Europe, policymakers and society at large often view innovative medicines solely as a cost rather than an investment in health and the economy. This perception needs to change. Only by doing so will Europe remain at the forefront of medical research, development and manufacturing. I am confident that it will. ■

Photo: Steffen Kugler/Bayer AG

Less Is More: Solutions for Raw Material Shortages

A paradigm shift in materials research: A Fraunhofer flagship project aims to use AI and innovative recycling methods to make the material supply both crisis-proof and sustainable.

By Kathrin Schwarze-Reiter

It starts with little things here and there. An automotive manufacturer pushes back the ship date for its new electric models. Construction of a wind farm is paused. A hydrogen factory cannot begin operating on schedule. The reason: a lack of essential raw materials — nickel, cobalt, rare earths. All of them are both coveted and essential. Right now, the effects are being felt in isolated instances. But the energy transition and advances in technology are causing demand for raw materials to skyrocket.

The global economy is a well-oiled machine. For decades, people could count on materials to continue to arrive. But recently, the flow of raw materials has been disrupted by various factors. Wars, crises, trade barriers erected by Trump and others — all proof that supply chains are on shaky ground. "Existing value chains are highly optimized, but that also means they are extremely susceptible to disruptions," explains Dr. Dirk Helm from the Fraunhofer Institute for Mechanics of Materials IWM. "An unexpected event like a pandemic or geopolitical conflict can shake entire industrial sectors."

The issue is especially acute with rare raw materials such as rare earths used in electric motors and nickel for stainless steel bipolar plates for fuel cells. All of them are both finite and in high demand internationally. Exploration is ongoing, but new mines are often located in politically unstable areas. Miners also have to dig deeper and deeper to get to the minerals. Faced with this dire situation, industry is increasingly turning to recycling. But streams of recycled and used materials are often contaminated with paints, plastics or foreign metals. Cleaning them is an involved technical process, which also makes it expensive. How can we also ensure that recycled materials are just as safe and will perform just as well as "fresh" ones made from raw material?

Fraunhofer combines forces for safe raw materials

This is where Fraunhofer's ORCHESTER flagship project comes in. Six Fraunhofer institutes will be spending four years working to make the supply of materials more resilient. Their objective is no less than a radical change in materials research. ORCHESTER aims to harness artificial intelligence, digital models and innovative recycling methods to reduce dependency on critical raw materials and unlock new material solutions. A digital platform is intended to help companies find alternative materials, such as steel with less nickel but no loss of quality. One year after it was launched, the project is still in its initial phase, but the direction is clear: The material supply of the future should be more sustainable, more flexible and crisis-proof.

> "We're rethinking the entire system, from raw material to the finished product."
>
> Jörg Kaspar, Fraunhofer IWS

The Fraunhofer institutes involved in the project have combined their expertise to this end. Fraunhofer IWM is coordinating the project and developing new material design strategies. The Fraunhofer Institute for Material and Beam Technology IWS is researching innovative alloys. The Fraunhofer Institute for Systems and Innovation Research ISI is considering the economic and geopolitical aspects of the supply of raw materials, while the Fraunhofer Institute for Machine Tools and Forming

The metallic elements lanthanum, yttrium, cerium, neodymium, europium and samarium are classified as rare earths.

Photo: Alexander Stein / JOKER / dpa

Technology IWU is developing new or adaptive production processes for recycled materials. The Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS is optimizing recycling methods for critical raw materials, and lastly, the Fraunhofer Institute for Nondestructive Testing IZFP is working on sensor technologies to assure the quality of secondary raw materials.

A paradigm shift in materials research

What sets ORCHESTER apart is the new way of specifying materials. Previously, materials have been defined primarily by their chemical composition. This means that if a raw material is lacking, the product cannot be produced. ORCHESTER turns that approach around. "We focus on the function a material is supposed to perform and then look for alternatives that can take over in that role," explains Dr. Jörg Kaspar from Fraunhofer IWS. For example, bipolar plates in fuel cells and electrolyzers contain large amounts of nickel, a critical raw material. ORCHESTER is studying how the proportion of nickel can be reduced without adversely affecting material and component performance. A combination of experiments, computer simulations and high-speed tests makes it possible to find suitable alternative materials quickly.

Another big goal of the flagship project is to give materials available on the local market a "second life" through recycling while at the same time addressing the associated quality fluctuations. The Fraunhofer institutes are developing methods of analyzing contamination and adjusting material compositions. In the case of recycling aluminum alloys for compressor wheels in the hydrogen infrastructure and in heat pumps, for example, ORCHESTER aims to maximize the proportion of secondary (recycled) materials without causing quality to suffer. "We use simulation-based screening methods to test different alloys that can then be used by industry," Kaspar says.

One especially exciting line of inquiry is recycling of permanent magnets, which are used in electric motors and wind turbines. They contain rare earth metals, which are expensive and difficult to produce: neodymium, praseodymium, terbium and samarium. A large proportion of these chemical elements come from China, a country that is not always a reliable trade partner. On top of that, recycled magnets have thus far often been less powerful than new ones. ORCHESTER is using artificial intelligence and simulation methods to understand how contamination affects magnetic performance and which mixtures of materials work in spite of this. "Our goal is to reduce the use of rare earths from primary sources by at least 25 percent," Helm notes. That would not only reduce environmental impact but also make Europe less dependent on imports of raw materials.

The digital future of materials

In addition to new material solutions, ORCHESTER is also tasked with creating a digital platform that links together data on material properties, production processes and recycling methods. Companies can access the platform to obtain data-driven recommendations of sustainable materials. "We're rethinking the entire system, from raw material to the finished product," Kaspar says. The digital models consider the question of materials early on as part of the product design phase and propose alternatives if a certain raw material is in short supply. High-throughput screening methods are additionally used as a fast, efficient way to investigate new material mixtures. In this way, the researchers aim to quintuple the selection of materials available to use, increase the share of recycled materials in process routes by at least 50 percent and boost material resilience by 30 percent.

Through close collaboration with industry, government and the research sector, the project aims to help ensure in the long term that material shortages no longer act as a drag on innovation. As Helm puts it: "Our goal is to ensure a robust, sustainable and independent supply of materials — not just for today but for decades to come." ■

A Nose for Whisky

Fraunhofer researchers have developed an AI algorithm that can tell Scottish whisky and American whiskey apart. But the research scientists are working on much more than just spirits.

By Beate Strobel

More than just taste: A whisky's scent — its "nose" — tells connoisseurs a lot about its origin and age and how it was produced.

The world's most expensive whisky to date comes from a distillery in Scotland. In 2023, Sotheby's auctioned off a bottle of The Macallan 1926 with a rare label designed by painter Valerio Adami, which ultimately fetched a whopping 1.5 million pounds sterling. But even below that record, whisky enthusiasts and collectors are known to pay eye-watering prices for rare bottles. That makes it no wonder some people refer to whisky as "liquid gold."

But does every bottle labeled "Scotch" actually come from Scotland? Professional tasters are largely able to distinguish Scottish whisky from American whiskey by smell: While bourbon tends to have notes of vanilla and caramel, Scotch often pleases connoisseurs with a smoky, peaty or woody bouquet. Testing by whisky masters or at least an appropriately trained panel requires the involvement of a lot of people, plus it takes time, both of which make it expensive, Andreas Grasskamp explains. A neuroscientist at the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising, Grasskamp worked with a team of experts to develop new technologies for the field of analytical sensors as part of the Campus of the Senses, a joint project of Fraunhofer IVV and the Fraunhofer Institute for Integrated Circuits IIS that received funding from the Bavarian state economics ministry.

Teaching AI to smell is exactly what Grasskamp and his team managed to do. A beverage's smell is the product of volatile molecules evaporating from the liquid into the air, where they enter the nose. These molecules can be designated individually by using suitable analytical methods. "Gas chromatography mass spectrometry, or GC-MS for short, is an established method of analyzing volatile compounds," Grasskamp explains. "We can use it to detect and identify scent-active molecules and have specially trained people characterize samples in sensory terms at the same time."

Expanding machines' senses

But a much bigger challenge is the fact that an overall olfactory impression is generally much more than the sum of the individual parts involved. Gas molecules can both supplement each other and contrast with each other. And the nature of the medium they are in — air, water or oil, for example — affects the aroma profile as well.

When it comes to whisky, the untrained nose quickly reaches its limits due to the practically infinite variety of aromatic interactions involved. Instead of training people for this task, the researchers used an AI algorithm called Olfactory Weighted Sum (OWSum) that was developed at Fraunhofer IVV to determine the origin of samples of Scottish whisky versus American whiskey. They also used a type of artificial neural network known as a convolutional neural network (CNN) to assess the olfactory quality of the samples.

The results were impressive: "Our digital solution was able to predict key olfactory impressions at least as reliably as an average human tester," Grasskamp says. OWSum also distinguished between American whiskey and Scottish whisky with greater than 90 percent accuracy. The combination of OWSum and the CNN was also at least as effective at predicting key descriptions of the spirit's aroma as a panel of professionals was, based solely on lists of molecules.

Smart blending for recycled products

So what's next? For one thing, the AI tool can help distilleries with product development and quality control in the future, especially in detecting counterfeit labeling. For another, the technology can be adapted or further developed for other drinks or foods.

But the Fraunhofer researchers are looking to a much wider field of application as their next objective. "Our whisky project garnered a lot of interest worldwide, but it was primarily intended to show what the technology can actually do: reliably and quickly assess smells," Grasskamp says. "In fact, we're not just interested in whisky alone but in all kinds of foods and consumer goods." For example, new EU regulations call for a greater proportion of recycled plastics to be used in products going forward. But anyone who has ever opened a recycling bin and caught a whiff knows that used plastic tends to smell unpleasant. That is not tolerable, especially when it comes to high-quality plastic products such as packaging. Grasskamp explains: "Our in-house database consists of a large number of odor active molecules. We can use it and relevant samples to train an AI in such a way that it could be used to do things like develop specific mixtures of recycled material that don't have an unpleasant odor."

Grasskamp sees a second field of application in efficient contamination analysis of imported plastic products, for example: Do volatile molecules indicate that they might contain substances that should be viewed critically on environmental or health grounds? Unlike when it comes to whisky, humans are happy to leave this job to machines: "For one thing, the human nose simply isn't sensitive enough for perfect detection, and for another, many dangerous components don't have any smell at all," Grasskamp says. But a properly trained algorithm could provide an early warning, leading to improvements in product quality and safety alike. ■

Photos: Till Melchior/plainpicture, BlackJack3D/istockphoto

Who's speaking, please? Fraud and attempted fraud using AI-generated audio clips is on the rise — and the fakes are getting harder and harder to spot.

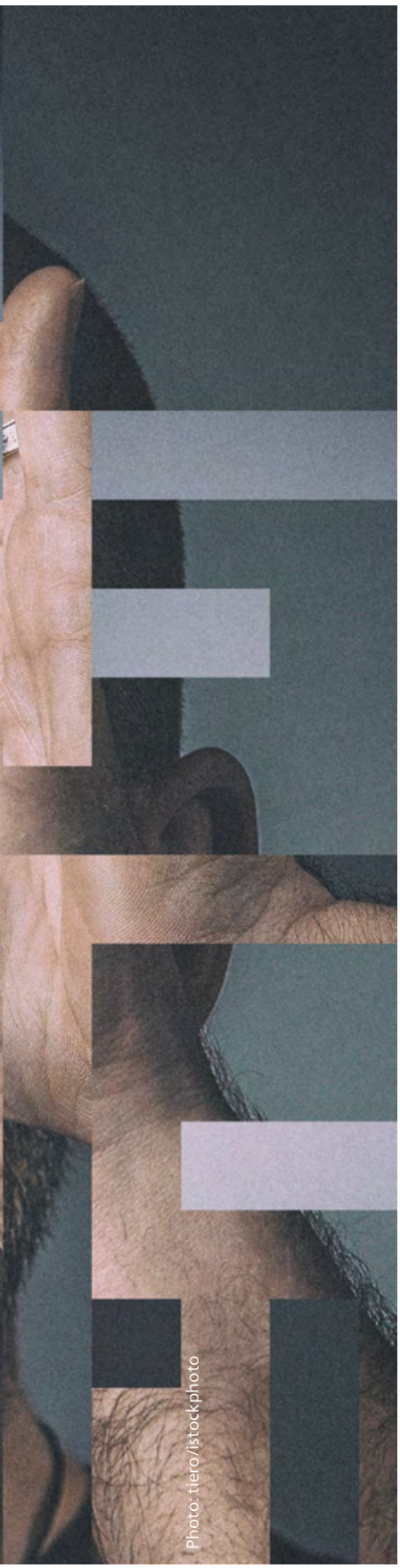


Photo: tiero/istockphoto

Dial F for Fake

Nowadays, just a few seconds of a person's recorded voice is enough to copy their voice and have them say anything you want. Rapid advances in voice cloning technologies are expected to have serious consequences for industry and society. The most important tools in the fight against it are education, a trained ear and even better training for detection systems.

By Mandy Bartel

An audio clip in which British prime minister Keir Starmer allegedly admitted to duping his voters racked up 1.4 million hits on the social media platform X (formerly Twitter). Carmaker Ferrari barely escaped deepfake fraud last summer, when a prudent-minded manager responded wisely to a suspicious call from a voice that sounded deceptively close to that of the company's CEO: He asked a question to which only the real boss would know the answer.

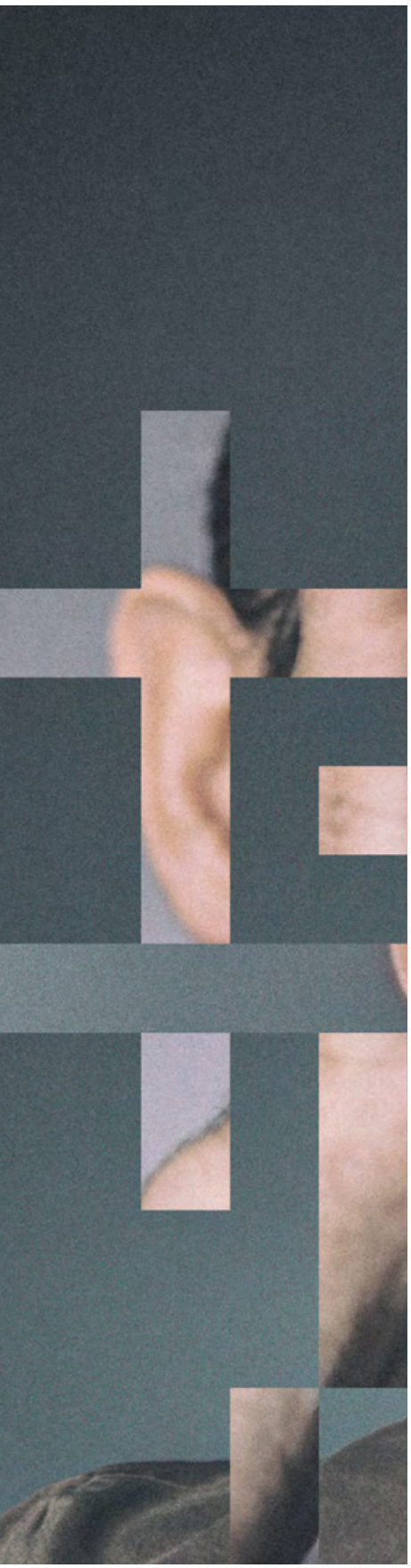
Deepfake audio is driving a surge in disinformation, fraud and industrial espionage around the world. According to the Identity Fraud Report published by the Entrust Cybersecurity Institute, an attempt of this kind was made every five minutes in 2024. Security provider Signicat registered a 2,137-percent increase in these kinds of attacks targeting banks, insurers and payment specialists in Europe within just a three-year period. At the same time, AI-generated speech technology is unlocking a wide range of new possibilities, bringing not only risks but also opportunities, from reconstructing the voices of people with health problems affecting their speech to new developments in movie dubbing and even digital preservation of the voices of departed loved ones.

One thing is certain: Deepfake technologies are poised to have an increasing impact on our media reality, as a study titled Deepfakes und manipulierte Realitäten (Deepfakes and Manipulated Realities) from the Fraunhofer Institute for Systems and Innovation Research ISI confirms. The authors recommend that governments take action to regulate platforms and that appropriate education options be provided to help hone a sense of responsibility at the individual level. Media outlets can uphold high standards of journalism in helping audiences recognize fraud and know what to do when it occurs. Companies and organizations should also conduct internal risk assessments and take preventive and reactive measures to prepare for the increasing spread of deepfakes.

Human vs. AI: Who is better at detecting fakes?

Unlike deepfake videos, which still require a lot of time and effort to make, audio content can already be manipulated with relatively little outlay of either, with high-quality results. At the same time, these products are harder to identify, since visual cues are lacking. How good are people at detecting these kinds of manipulated audio clips? Nicolas Müller from the Fraunhofer Institute for Applied and Integrated Security AISEC conducted an experiment to find out. He pitted 472 human participants against an AI algorithm in a game with the objective of telling real audio samples apart from fakes. Human participants and the AI "listened" to an audio clip and were then asked to decide whether it was real or a deepfake.

The outcome after almost 15,000 files were listened to? "Untrained humans can detect about two-thirds of fakes, but with a little practice, they can get up to 80 percent," Müller says. "The AI success rate, always depending on the level of difficulty, is well over 95 percent." But that wasn't the only valuable finding from the experiment. For example, older people are easier to deceive with deepfakes ▶



than younger ones. Native speakers have a significant advantage over non-native speakers, but IT professionals and laypeople perform about the same. "These insights could help with developing more effective training programs for cybersecurity and improving detection algorithms," Müller explains. With practice being such an important factor in detecting AI-generated audio fakes, he and his team posted their interactive Spot the Deepfake game on their platform, Deepfake Total (see QR code), where anyone can access it.

Detecting fake audio: diversity is a plus

Müller and his team developed their Deepfake Total platform as a public detection tool aimed at fake audio. Anyone can upload suspicious audio clips there and have them analyzed by AI. Unlike other commercial detection tools available on the market, the Fraunhofer platform is free of charge — and hosted in Germany. The researchers train their AI model on both public and internally generated data sets containing samples of original and fake audio. The reliability of detection depends on the quality of the training data used. The goal is not just to compile as much data as possible but also to combine it wisely and prepare it in a balanced way so there are no undesired learning effects. "The only distinguishing characteristic in a good training data set should be whether an audio clip is authentic or fake," Müller explains. "So we need to prevent things like the AI learning that men's voices are fake more often than women's, for example, or distinguishing between data sets based on background noise, accent, length or volume." But because the data comes from such disparate sources, that is a tall order. "You need to understand what specific information these audio clips contain and then arrange them in such a way that the irrelevant characteristics are as balanced as possible. With videos, it's already possible to effectively analyze which part of the image the AI uses to tell what is and isn't fake, but that's still tougher with audio."

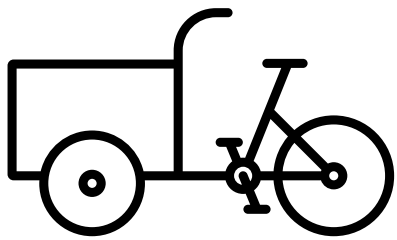
> "We are on the cusp of a deepfake era, which we will only be able to navigate successfully with a combination of better technical detection, education and greater awareness at the population level."
>
> Nicolas Müller, Fraunhofer AISEC

The researchers at Fraunhofer AISEC are continuously developing and refining just this kind of dataset: the Multi-Language Audio Anti-Spoofing Dataset (MLAAD). It serves as the basis for training their AI detection model and is also publicly available to the research community. The challenge is that there are many different text-to-speech systems that can be used to manipulate audio clips, and each has its own specific characteristics. While some are good at generating emotional language, others achieve near perfection in duplicating the target person's voice. To cover as many of these features as possible, the MLAAD currently encompasses over 90 of these systems and is constantly being expanded to include the latest ones. This allows the tool to achieve high detection rates even when facing new and as yet unknown audio deepfakes. Alongside its technological diversity, the data set covers more than 35 languages, so it also provides the largest linguistic spectrum currently available compared to the other publicly available data sets, most of which contain only English or Chinese audio clips.

Diversity and balance are the keys to success, not only in terms of the data used to train AI detection tools but also in the fight against the negative consequences of fake audio. "We are on the cusp of a deepfake era, which we will only be able to navigate successfully with a combination of better technical detection, education and greater awareness at the population level," Müller says with conviction. ■

Use the Deepfake Total platform to detect deepfake audio free of charge — including a training game.

Bike Logistics Gets Rolling



Cargo bikes instead of delivery trucks: the RADLÄR project is exploring how this emission-free transportation solution can gain ground in rural areas.

By Beate Strobel

To admire Hofstetten im Kinzigtal in full, you need to push two tables together: The large map of this village of 2,000 in the central Black Forest region shows not only roads and paths but also the industrial zone on the outskirts of town, the local sports club and its soccer field, hiking trails to a memorial chapel and various neighboring hamlets. And all around it, a thick band of fields and even more forest. "Hofstetten ... one step closer to heaven," the village website says. Or, as mayor Martin Assmuth puts it: "Hofstetten is the deepest of rural places."

And that is the very reason that mathematician and economist Sascha Düerkop from the Fraunhofer Institute for Technological Trend Analysis INT finds himself standing now in the meeting room at Hofstetten's city hall, explaining — together with colleagues from Fulda University of Applied Sciences and Frankfurt University of Applied Sciences — how important places like Hofstetten are to the transportation and mobility transition. The village is one of six model regions in Germany that have been selected to participate in the RADLÄR (Cycle Logistics in Rural Areas) project, which will be holding full-day workshops to explore the potential of bike logistics outside urban areas and what the obstacles are. What do rural residents see as possible uses of cargo bikes and similar solutions where they live? And what can be done to help these solutions gain ground in rural areas, as they have in cities?

A 2019 study found that conditions are favorable, Düerkop explains: "While just three percent of urban populations own e-bikes, rural areas are already up to ten percent." However, that does contrast with many people's deeply held belief "that out in the country, you just need a car," as Assmuth comments. Heavy particulate pollution is not an issue here, and neither are things like daily traffic jams on the way to work or looking for parking at the grocery store, so how can doubters be persuaded to invest in a cargo bike? That was another reason Assmuth agreed that the town should participate in RADLÄR: "I'm hoping to hear new arguments and approaches for how we can pave the way for bike logistics in our area."

Assmuth is not alone in that. In a white paper on bike logistics in German cities and towns, prepared in 2023 as part of the iKnowRadlogistik project funded by the German federal transportation ministry, 45 percent of the municipalities surveyed indicated that their knowledge in this field was poor to very poor, and one in five pointed to this information deficit as the reason no bike logistics processes had yet been put in place. While both the research sector and industry have dealt extensively with implementing processes like these in urban areas in recent years, rural areas have gone largely unstudied so far. The RADLÄR project, which is receiving support from the Federal Ministry of Transport out of funds set aside for executing Germany's National Cycling Plan, aims to help close this knowledge gap.

A serious game with opportunities for everyone to win

Assmuth and the RADLÄR research team gather around the map of Hofstetten, joined by Isabella ▶

"I'm hoping to hear new arguments and approaches for how we can pave the way for bike logistics in our area."

Martin Assmuth, mayor of Hofstetten

Illustration: eyewave/istockphoto

Schmider, managing director of local tourism organization Schwarzwald Tourismus Kinzigtal, and Martin Jugel, Sustainability Manager Operations at parcel carrier Hermes Germany. The map is part of a board game that Julian Bickmann, a social scientist at Fraunhofer INT, developed specifically for the project. "'Serious games' are an accessible way to engage with even complex topics," Bickmann explains. "Using different game elements also makes it possible to offer a motivational incentive — for example, by having participants engage in dialogue as equals and, through shared objectives, work together with a solution mindset on ideas to achieve the object of the game."

As the first step, the players bent over the Hofstetten map mark the areas of town that are more residential and those where people tend to work instead. Where are key infrastructure nodes like the train station, bus stops, bike paths and ride-sharing benches? The next task is to work through a set of cards showing logistical "missions." For example, how might a senior citizen get their regular weekly grocery shopping delivered to their home, simply and conveniently?

There are no game pieces per se to move around the board in the RADLÄR game, but there are various fun items such as 3D-printed compact cargo bikes like those used by letter carriers, along with "long johns" — cargo bikes with a cargo bed in the front — and a "heavy cargo bike" with a bent front wheel stemming from a mishap that occurred en route from Fraunhofer INT to Hofstetten. Miniature paper bags, parcels and plastic pallets symbolize the amount of goods being transported. Special "innovation cards" featuring technological upgrades to these vehicles, such as an electric drive, a bigger cargo hold or bed, or the possibility of energy recovery open up additional logistical options for fulfilling the assigned missions.

There is no winner in this game. Or, to flip that around: Everyone wins. As Düerkop explains, "The main thing here is that ideas are born." And on that score, the group comes up with quite a few here on the top floor of Hofstetten's city hall. For example, they realize a local microdepot would be useful as a kind of storage space where goods could transition from one means of transportation to another. A depot like that on the outskirts of town would mean that the famed "last mile" to the end customer could be handled by cargo bike. Another idea is the option to combine goods and passenger transportation by cargo bike, so, for example, older people could choose to be

In a white paper on bike logistics in German cities and towns,

45 percent

of the municipalities surveyed indicated that their knowledge in this field was poor to very poor.

How to get plants to the garden? Cargo bikes can be a sustainable solution for various trades.

Photo: cagobike.com/pd-f

driven to the supermarket that way or have their groceries brought to them at home. Assmuth comments: "This could be an answer to not one but two challenges we face in rural areas — a rapidly aging population and the dying out of local retail."

But the team of researchers gets more than just ideas from the Hofstetten workshop: They also focus on exploring what municipalities and businesses would like to see from the research. For his part, for example, Assmuth would like to have a software program that uses volatile parameters such as distance, gas prices and the costs of buying and maintaining a cargo bike versus a car or van to calculate whether switching to bike logistics is financially worthwhile, and if so at what point. Düerkop agrees, pointing out that the question of cost savings is pivotal to any conversation about bike logistics.

Infrastructure as the real choke point in bike logistics

After the event in Hofstetten, the project team held five other workshops, one in each model region. In all of these events, participants were assigned the same missions to complete using a map of their town. The workshops showed that bike logistics has already been identified as an important topic in rural areas — but there is also a certain level of incomprehension and skepticism about which concrete options would be conceivable and feasible locally, Düerkop notes in his role as the project's manager. For true leverage, however, the desire of local residents is not enough. Initiative on the part of businesses is needed as well. As for industry, bike logistics looks like an exciting option, but there are still many unanswered questions pertaining to funding options, legal particulars and infrastructure. "As researchers, we need to step up to the plate here and not only provide ideas but also act as intermediaries," Düerkop says.

The next step for the researchers is a two-pronged one. First, they plan to draw up feasibility studies for three of the six model regions, and second, they will develop general logistical options for incorporating cargo bikes into regional value chains and test them in a simulation study. The final outcome of the RADLÄR project will thus be a portfolio of scalable recommendations for actions that municipalities and businesses in rural areas can take.

They might even include an idea from a Danish funeral home, which offers to transport caskets to the cemetery via cargo bike — including the possibility of a funeral procession around town, accompanied by the person's loved ones: an emission free and emotional solution for the very last mile. ■

Infrastructure

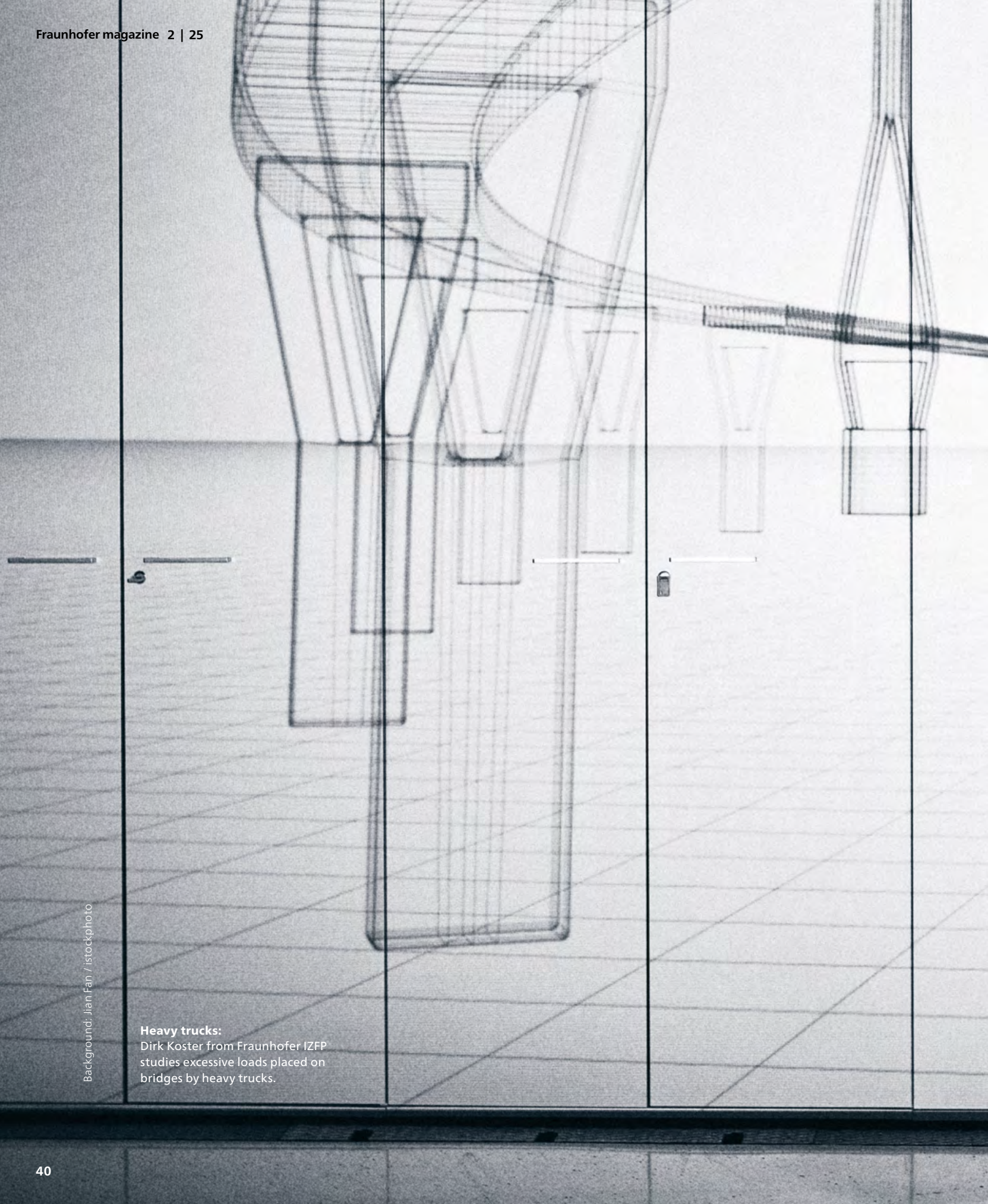
Background: Jian Fan / istockphoto

Data as the solution: Computer scientist Tagline Treichel from Fraunhofer IESE focuses on the digital transformation and digital twins to increase the safety and lifespan of structures.

Germany's Ailing Infrastructure

At least 8,000 highway overpasses and 17,630 kilometers of railway across Germany are dilapidated, but repairs and rebuilding will take time. How Fraunhofer technology is accelerating service and maintenance — so the Carola Bridge collapse in Dresden will remain an isolated incident.

By Janine van Ackeren; photographer: Jonas Ratermann

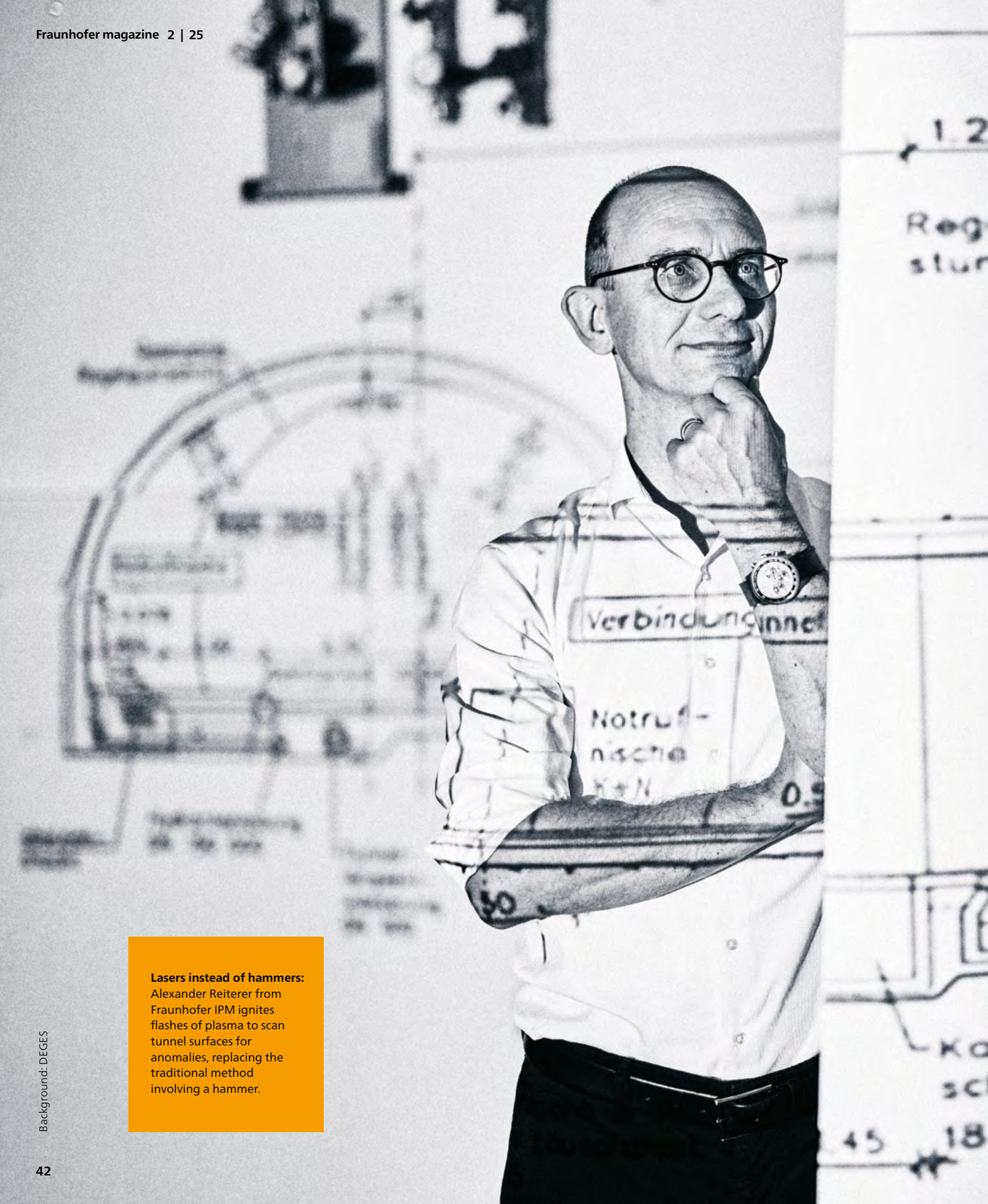


Heavy trucks:
Dirk Koster from Fraunhofer IZFP studies excessive loads placed on bridges by heavy trucks.

Background: Jian Fan / istockphoto

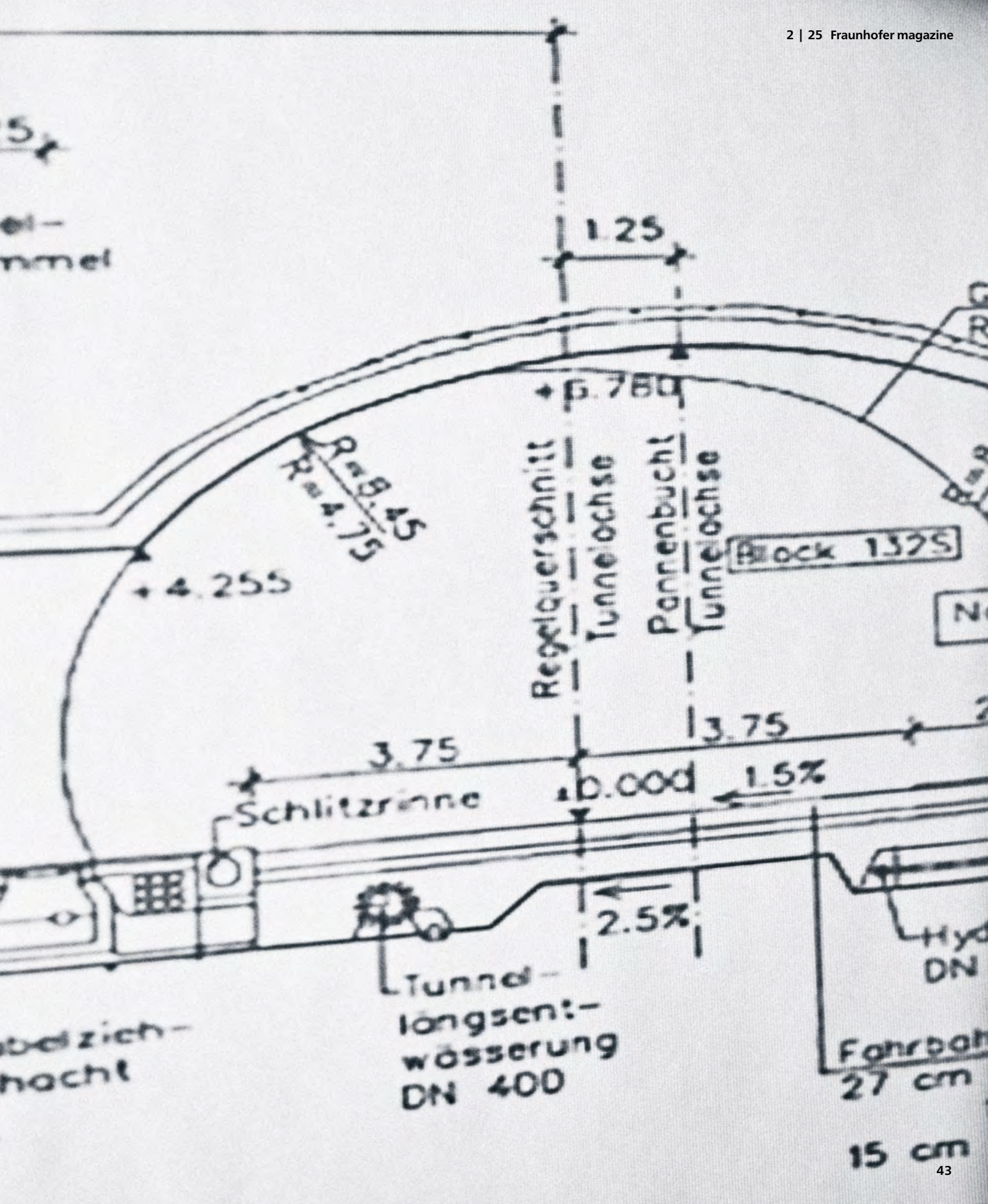
"The main achievements in development lie in data reduction and evaluation right at the sensor and in the data model."

Dirk Koster, Fraunhofer IZFP



Lasers instead of hammers: Alexander Reiterer from Fraunhofer IPM ignites flashes of plasma to scan tunnel surfaces for anomalies, replacing the traditional method involving a hammer.

Background: DEGES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Small network, big impact: The MAUS system developed by Christoph Weingard from Fraunhofer IZFP quickly registers damage to bridges while conserving energy.

Background: Eugene Sergeev / istockphoto

Road trips to far-off vacation spots have always been tough. But the annual chaos on Germany's roads at peak vacation times has taken on a whole new dimension these days. The vacation period around the Pentecost holiday kicked off with a traffic jam from a tunnel construction site on the Tauern Autobahn in Austria that stretched back 45 kilometers to the German border. Vacationers trying to get to Italy were getting a taste of what might become more common in the not-too-distant future: Many of Germany's highway overpasses have reached the end of their useful lives and are of limited use, especially to trucks. And that brings dramatic speed limit clampdowns and long traffic jams. Some bridges are closed altogether or awaiting demolition. Take the Ringbahn overpass in Berlin over the A100 highway, for example: A crack in the load-bearing structure closed the overpass in mid-March, and it was torn down in April.

In a survey of infrastructure conditions conducted in 2022, the German Federal Ministry for Digital and Transport (BMDV) identified 8,000 highway overpasses and 17,630 kilometers of railway as needing repairs. Their condition is hardly likely to have improved since then. Non-profit organization Transport & Environment puts the figure twice as high, at 16,000 overpasses in disrepair. Dilapidated overpasses are also a drag on the overall economy, lowering productivity while driving up costs and deterring investors. According to a study by the German Economic Institute (IW), the Rahmedetal bridge in Lüdenscheid alone, closed in December 2021 and demolished in May 2023, will have cost the German economy 1.8 billion euros by 2026, with the costs of delays due to traffic jams and detours amounting to 1.2 billion.

All this means it is high time for action. The German Bundestag and Bundesrat have approved 500 billion euros in special funding for the next 12 years to fix up the infrastructure. Of that amount, 100 billion will go to states and municipalities, and another 300 billion will be available for federal infrastructure projects. It is a Herculean task, and progress thus far has been slow. According to the German Court of Audit (BRH), at the end of 2024 Autobahn GmbH, the entity responsible for the German highway system, had modernized just 40 percent of the overpasses that should have been addressed by the German transport ministry's bridge modernization program by then.

16,000 bridges and overpasses in Germany need repairs, according to a survey by advocacy organization Transport & Environment.

Bridges and overpasses: a sore spot

The situation calls for the special art of setting the right priorities. When an overpass needs maintenance or timely rehabilitation — before it collapses like the Carola Bridge in Dresden in the worst case — solid real-world data is required. One important criterion in considering how much strain is placed on a structure and whether repairs are needed as a result is the axle load, the force transferred from the vehicle axle to the road and thus to the structure. About half of the more than 28,000 bridge and overpass structures that are part of Germany's federal highway network were built before 1985, when there were many fewer trucks on the road and trucks were much lighter as well. These days, it is not unusual to see gross vehicle weights of 40 metric tons and individual axle loads of ten metric tons. "While it almost doesn't matter how many cars cross an overpass on a given day in terms of wear, excessive truck axle loads can lead to cracks and material fatigue in the structure," says Dirk Koster, Chief Scientist at the Fraunhofer Institute for Nondestructive Testing IZFP.

A joint research project called ImaB-Edge aims to lay a more solid foundation for evaluating these structures. Alongside Fraunhofer IZFP, the Fraunhofer Institute for Photonic Microsystems IPMS and Autobahn GmbH, which is part of the German federal government, seven other partners are involved. ImaB-Edge has received about 5.6 million euros in funding from the German Federal Ministry of Research, Technology and Space (BMFTR). The project's centerpiece is a sensor system consisting of a central node, the edge gateway, to which numerous sensor edges can be connected, each one of them currently capable of serving 32 sensors in turn. "The main achievements in development lie in data reduction and evaluation right at the sensor, using high-performance electronics, and in the data model, which supplies important information so the engineers can make sound predictions ▶

Dirk Koster, Fraunhofer IZFP

of a bridge's condition, including on site," Koster explains. The information the sensors collect in and on the bridge represents a vast amount of data, so it is not sent into the cloud but analyzed and compressed on site using artificial intelligence. All that winds up on the operator's server is compiled information on the condition of the overpass.

The researchers have already put the system to the test under real-world conditions on the Fraunhofer IZFP parking lot. The goal is to continuously monitor the structures to detect any deterioration in their condition early on. This way, the experts will have reliable data at their disposal at all times and can intervene promptly when needed. To achieve this, vibration and temperature sensors built into the roadbed collect 500 gigabytes of data day after day and then transmit the information via LAN or Bluetooth to the sensor edge, where it is pre-processed together with information from the weather station and a connected camera. The vibration data generated when a vehicle passes over the overpass and the conditions of the asphalt and surrounding environment can be used to estimate the axle loads of the vehicles passing by. The camera combines this data with real-world information on the vehicles, such as speed, the number of axles and the distance between them. In the edge gateway, this data and data on aspects such as the results of structural inspections is analyzed by the AI and linked to the digital model of the bridge. The team also plans to incorporate the ImaB-Edge system developed in the project into a highway overpass by late October 2025. Farther down the road, the researchers plan to use their system to detect critical conditions in railway infrastructure, tunnels and dams early on as well.

The MAUS sensor platform: fast, practical bridge monitoring

ImaB-Edge is a high-performance system that gathers data from dozens or even hundreds of sensors with precision accuracy. But with some structures, complex measurements take a backseat to speed and low power consumption. If there is any sign of a crack emerging in a bridge, monitoring needs to be started right away. Cases like these are where the MAUS monitoring system (short for Multimodal Autonomous Sensor Platform) from Fraunhofer IZFP can really shine. "The MAUS system combines the features of the edge gateway and the sensor network into a single platform, so you arrive at a practical solution within just a few days. Adjustments for successful implementation are possible within a few weeks," says Christoph Weingard, a research scientist at Fraunhofer IZFP. "The only requirements are a power supply, like a standard household 230-volt connection, and a communication channel such as LoRaWan or 5G/LTE." A solar cell can be used to provide power in areas of the structure that are remote or hard to access. Setup and installation is simple, too: The four electronic component assemblies that MAUS comprises — base module with processor core, sensor module, communication module and power supply — can be plugged into each other in any order. MAUS can accommodate not only simple, standard commercially available sensors for aspects such as expansion, displacement, deflection, inclination, moisture, humidity and temperature but also special vibration, acoustic, ultrasonic or eddy current sensors. Depending on the requirements, ultrasound can be used to detect cracks, for example, while acceleration sensors can log the structure's natural oscillation and structure-borne sound sensors detect when tension wires have split. "Using this full range of sensors in bridge construction and simply adding versatile monitoring electronics will make a crucial contribution to solving the problems we are seeing with critical infrastructure these days," Weingard says. The data gathered is encrypted and transmitted directly to the bridge operator. A specific configuration of the MAUS system has been implemented on a bridge in Munich, for example, where it is already helping the operator reduce the time and money invested in monitoring the structure's condition.

"The MAUS system combines the features of the edge gateway and the sensor network into a single platform, so you arrive at a practical solution within just a few days."

Christoph Weingard,
Fraunhofer IZFP

Steel bridges: a special case

"Most monitoring systems are designed for concrete bridges, but there is a lack of technologies for steel bridges," says Christoph Heinze, a research scientist at the Fraunhofer Institute for Large Structures in Production Engineering IGP. That is

probably because 90 percent of all bridges and overpasses in Germany consist of concrete. Even so, the lack of technologies in this area is a problem. After all, steel bridges experience corrosion and fatigue cracking, different kinds of damage than those found in concrete bridges, where major problems include spalling or degradation from moisture. Heinze and his team aim to close this gap. In the BIM-LeB (BIM-Based Life Cycle Assessment for Bridges) project, they are working with TU Dortmund University on an all-in-one solution for monitoring damage in steel and steel composite bridges. "We're looking at the entire cycle, from surveying the structure's current condition to continuously monitoring changes, which we feed into a BIM model, to predicting how the damage will evolve, along with recommendations for actions to take," Heinze explains. The BIM (building information modeling) model describes computer-assisted methods to represent a structure digitally.

There are two key questions. First, how does the bridge change over time? And second, what are the conditions and loads affecting it? "To answer those questions, we are working with the Chair of Steel Construction and the Chair of Computer Graphics at TU Dortmund University to build digital models for measures like load-bearing structure calculations," Heinze explains. The first step involves the researchers taking photos by drone. They then use photogrammetric methods to create a model from the photos. If there are especially strict requirements for the accuracy of the measurements or the structure is difficult to access, they also use other methods, such as laser scanners or mobile mapping systems. With any system, the result is a 3D point cloud, which the researchers combine with information on the individual structures to create a BIM model. The team has already created digital models of four bridges in this way, including a 20-meter railway bridge. The researchers at TU Dortmund University use artificial intelligence to predict how the damage will evolve based on the models and current sensor data. Will the damage remain relatively confined over time? Or will there be a rapid deterioration?

Digitalization: a tool to fight dilapidated bridges

A team of researchers at the Fraunhofer Institute for Experimental Software Engineering IESE and the University of the Bundeswehr in Munich also view digitalization as the solution to the bridge dilemma. Specifically, they see digital twins as the answer. A digital twin is intended to combine all of the data that exists about a specific bridge in a single location, where it can be accessed at any time. This includes everything from details on planning and construction to operational data and information on dismantling. Which materials were installed where and in what way? "A digital twin opens a window on a bridge's current condition while also allowing for predictive analysis and efficient lifecycle management," says Tagline Treichel, a computer scientist at Fraunhofer IESE. "Certainty increases, the structure's lifespan is extended and predictive maintenance becomes possible."

> "A digital twin opens a window on a bridge's current condition while also allowing for predictive analysis and efficient lifecycle management."
>
> Tagline Treichel, Fraunhofer IESE

Digital twins are familiar from manufacturing, where they are used to depict current conditions and predict how a system will respond to change. For their bridge monitoring activities, the researchers at Fraunhofer IESE use open-source software that they originally developed for digital twins in industry and adjust it accordingly. The biggest challenge is integrating the vast amounts of data involved. Since there are different data formats, many of them incompatible with each other, the researchers translate the data into a single standardized language. This gets even more difficult if the information only exists on paper; the team is also working on another project aimed at ways to transfer this data automatically.

The "translation" has worked so far. The researchers have already digitalized five bridges. The Schwindegg bridge in the Mühldorf am Inn district is one of them. It also contains nearly 140 sensors that gather data on acceleration, expansion, weather and more, which also goes into the digital twin. So is it realistic to think all of Germany's bridges could go digital in the next few years? "It's definitely feasible from a technological perspective. The bases are there, and initial pilot projects show how it could work. The real challenge is coordinating all of the stakeholders involved, since responsibility for bridge infrastructure cuts across different structures at the federal, state and municipal government levels," Treichel says. ▶

Tunnels: detecting voids and water intrusion

Technologies such as sensor networks and digital twins can also be applied to other structures. However, laser technologies are in the lead when it comes to monitoring tunnels and railways as infrastructure elements. With tunnels, the key challenges are voids and water intrusion. How many tunnels in Germany are affected by damage like this, requiring repairs? Solid figures are lacking. The existing practice is to manually inspect tunnels, with construction crews using a specially defined hammer to tap the tunnel's surface and listening to the reverberations. Does it sound hollow? This might sound like a makeshift solution, but it is actually a standardized, state-of-the-art process. However, localizing damage is quite imprecise, as inspectors can only roughly map it on tunnel diagrams.

"We're replacing mechanical hammers with laser pulses," says Alexander Reiterer, a department head at the Fraunhofer Institute for Physical Measurement Techniques IPM, describing the LaserBeat project, on which he is working in tandem with Fraunhofer IGP. "To do this, we focus a laser beam so tightly that a plasma flash ignites before it hits the tunnel surface, and that in turn induces a shock wave on the surface itself." It is almost like the researchers are tapping the surface without actually touching it. A laser microphone records the sound this makes. Just like with manual inspections, the question here is whether there is a hollow sound. The tunnel surface can be analyzed over a distance of two meters in any direction from a given site — with precision localization and, unlike in human hearing tests, objectively.

While the researchers at Fraunhofer IPM focus mainly on hardware and parts of the software, their colleagues at Fraunhofer IGP use AI to analyze the data generated. The team has already surveyed the eight-kilometer-long Albvorland Tunnel between the cities of Stuttgart and Ulm, and now two other test tunnels are to follow. Their method is not limited to tunnels, either. It is suitable for all kinds of concrete structures. "The interest we are seeing is a sign that the market has been waiting for this technology," Reiterer says. The "laser hammer" for tunnel operators and others in the field could be ready for use two years from now.

"We're replacing mechanical hammers with laser pulses."

Alexander Reiterer, Fraunhofer IPM

3D laser scanner measures moisture

In monitoring any structure, from bridges to tunnels and train tracks, one goal is constant: to disrupt traffic as little as possible. With tunnels, this could mean that instead of having to close the tunnel at least in part for inspections, the measurement units would be carried by trains that are passing through anyway, or in the case of road tunnels, by inspection vehicles. Making this a reality is what Reiterer is working on via new laser scanning methods. "We can now map several million 3D points per second using ultrafast modulated laser light and special rotating mirrors. One key point is that not only the geometry but also other features such as moisture can be determined," Reiterer explains. And it can all be done essentially while simply driving by.

Railways: from trackbed to train

These kinds of methods from Fraunhofer IPM are also used for railways, especially to determine their movements. If the ballast under the tracks sinks, the position of the tracks themselves may change as well. As one example, defective concrete ties seem to have been responsible for the Burgrain train derailment in the summer of 2022, in which five people were killed and 78 people were injured, some of them severely. Installed on a train, the laser scanner can detect these kinds of displacement with outstanding accuracy. The system is functional and is already in use by Deutsche Bahn and by other operators and companies outside Germany. So far, the scans are still being performed from measurement vehicles, but the researchers are working to move the system to regularly scheduled trains. "The first step was to shrink the installation space needed. We've done that, and next comes the evaluable phase," Reiterer explains. Initial tests of the miniaturized system in live railway operation are scheduled to take place over the next six to nine months. After that, the goal is to install it on regular trains serving routes around the country.

If these inspection systems are to be installed on regular trains in the future, data analysis is also needed to go with them. With trains being constantly in use, the data needs to be analyzed in real time and transmitted via radio. The MUM-Mini

system from Fraunhofer IPM can achieve this. Only about the size of a shoe box, it incorporates multiple laser scanners, a camera system and a processing unit for data analysis. The system was originally developed for roads, where it detects objects such as street lights, manhole covers, curbs and different road surfaces. The researchers adjusted many different factors to adapt this initial version to railway settings and miniaturize it for use on regular trains. "Among other things, we integrated a measurement method that uses ultra-tiny mirrors to capture the reflected laser light," Reiterer says. But the biggest challenge lies in using AI to analyze the data right in the measurement unit itself in real time. One to two years of development work will still be needed before the system can be used in regular trains.

Inspecting rail heads from regular trains

Beyond that, another elementary aspect of track maintenance is wear affecting the upper part of the rails themselves. Known as the "heads" of the rails, these parts undergo abrasion over time, especially on the inward-facing side. Travel gets bumpier, which contributes to further wear. If microscopic cracks form, the track can crack open for hundreds of meters, a scenario that must be avoided at all costs. The current practice is to use special measurement trains for this as well. Sensors on the underside of the train project a laser line onto the rail head, and a camera takes pictures of the line. Deformation in the laser line reveals just how the rail heads are doing, with accuracy to within a fraction of a millimeter. "Less-expensive measurement technology has allowed us to significantly reduce the system's costs, plus we have a new algorithm that analyzes the data right in the system," Reiterer says. Thus, the technology is paving the way for the test systems to be used on regular trains for inspecting rail heads as well.

If the costs are still too high, the next place to look is substitutes for the optical systems. One option is the low-cost acceleration sensors found in any cell phone these days. Over the next few months, Reiterer and his team plan to study how they can be used. "If the head is in a poor condition, the car rocks back and forth.

> "Climate change is causing tracks to heat up to more than 60 degrees Celsius in some cases, a few degrees higher than was assumed when they were originally designed."
>
> Michael Becker, Fraunhofer IZFP

The characteristics of this motion can be used to calculate the condition of the heads," Reiterer explains. So should we just stick three or four acceleration sensors onto every high-speed train to know how the tracks are doing? It's not quite that simple. Data analysis is crucial. "The data from the sensor has a different structure with intact tracks than if spots are missing, but these patterns are individual. This means it takes huge amounts of data to train the AI," Reiterer says. The researchers plan to obtain this data from a secondary rail operator that will allow them to attach sensors to passenger trains.

Climate change in railway operations

Roads and bridges are increasingly jam-packed, but that isn't all. According to current forecasts, passenger and freight traffic on the railways is also expected to double between now and 2040. Österreichische Bundesbahnen (ÖBB), the main Austrian rail operator, is looking to digitalization as the answer. How can the entire track network be scanned, evaluated and predicted using digital tools? To find out, ÖBB teamed up with about 20 partners from industry and the research sector for the Rail4Future project. The company brought Fraunhofer IZFP and the Chair of Road, Railway and Airfield Construction at the Technical University of Munich on board for the Smart Rail subproject. "Climate change is causing tracks to heat up to more than 60 degrees Celsius in some cases, a few degrees higher than was assumed when they were originally designed," says Michael Becker, who was in charge of the subproject. "This means the tracks are under greater longitudinal tension than expected." And that can cause warping, especially where tracks are permanently connected to the ground below them, like at stations or bridges, which in turn can prompt rail cars to jump the track.

As a result, rail operators want to know the exact local neutral temperatures for the entire track network, meaning the temperature at which a section of railway is under no tension at all. "The neutral temperature is between 20 and 30 degrees when the track is installed, but it can change over the operating lifespan," Becker says. Commonly used measurement methods take about 30 to 40 minutes per site, which would normally make measurement impossible without track closures. But ÖBB would prefer to schedule the measurements for existing gaps in the regularly scheduled train service. ▶

As the first step, the researchers examined existing methods of measurement: Can they be adapted for analysis on the track? Are the inspections sufficiently fast and accurate? Ultrasound and magnetic measurement methods emerged as the top contenders. This was followed by calibration in the lab at the Technical University of Munich. The researchers clamped a two-meter section of track in a test bench and used hydraulics to apply a tensile and compressive load of 70,000 kilograms. In the case of ultrasound, they especially tinkered with ways to tell material differences between track sections apart from tension in the track. For magnetic measurement, the challenge lay in making different unknown track sections comparable to each other. Once these obstacles were overcome, a week of large-scale testing followed at the track bed near the town of Rasdorf. The results are impressive: Measurements take only two minutes and require nothing more than a small measurement unit and a laptop. The methodological development is complete, and the next phase involves validation on the various rail networks.

Sensor-equipped trains monitor trains and tracks alike

Obtaining accurate and reliable measurements without impeding rail traffic was also the goal for the SenseTrain project, concluded in January 2025, on which the Fraunhofer Institute for Laser Technology ILT collaborated with DB Systemtechnik and three other partners. The key here was that the sensors measure track wear from inside a component — in this case, a wheel bearing cap on a high-speed train. "We've developed a technology we can use to incorporate sensors into 3D-printed components," explains Tim Lantzsch, a department head at Fraunhofer ILT. "There are two key advantages. First, we get measurements from inside the component instead of just from the surface, and second, the sensors are protected against oil and other hostile environmental conditions." Because the data not only yields information on the tracks but can also be used for predictive planning of train maintenance cycles, first-generation high-speed trains were chosen as the test fleet. The sensors measure the forces arising in the wheel truck underneath the train. If higher strain is measured only on certain sections of track, it is highly indicative of track wear. But if high forces are always found exclusively on right turns, for example, the train is likely the cause. The system has already successfully completed its first test drive, which found that recording data from a moving train works.

> "We've developed a technology we can use to incorporate sensors into 3D-printed components."
>
> Tim Lantzsch, Fraunhofer ILT

Securing wheel sets

Infrastructure maintenance concerns more than just the track network. It is also about the trains themselves. For example, wheel sets require inspection at regular intervals. This can be done manually, by removing the wheel sets and using a small handheld device to inspect them via ultrasound — at 16,000 to 17,000 euros, a reasonably priced version that takes about 20 to 40 minutes per wheel set. But the data is not stored, which can bring legal difficulties for inspectors. Fully automated AURA wheel set testing devices offer an alternative. They store the data collected but require about a million euros in investment, plus the necessary infrastructure.

Semi-automated, traceable tests

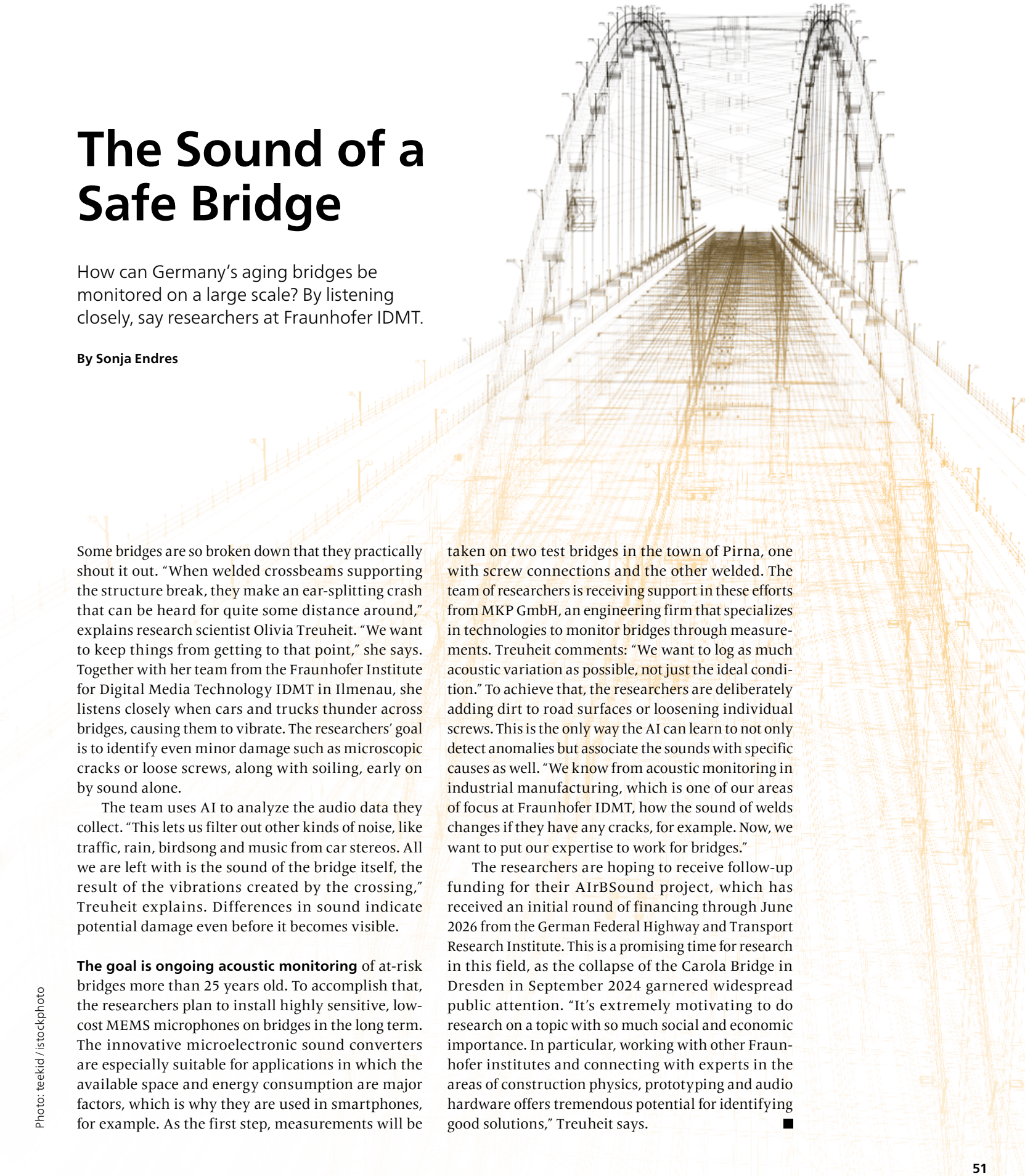
Researchers from Fraunhofer IZFP worked together with RailMaint GmbH and Evident GmbH on a project called PASAWIS, in which the partners developed a semi-automated version that comes at a price of only about 250,000 euros. "The test data is stored in DICONDE format, an open standard, so inspectors know they are on the safe side," says Stefan Caspary, a research scientist at Fraunhofer IZFP. Inspection takes just 15 minutes, making it almost three times faster than the manual version. Another advantage is that while fully automated testing requires two types of tests — ultrasound and eddy current — so employees need training in both, the PASAWIS system developed in the project uses ultrasound alone. "But what really makes it special isn't so much the testing method as the software," Caspary points out. "The inspector is guided through the tests from start to finish, and the results are automatically stored in reports digitally signed by the operator. All of the testing data is also recorded, so it can be loaded again anytime, from anywhere." The researchers have built several PASAWIS units in the meantime, and the VPI- and DB-certified system is now available from industry partner Evident.

The special funding means that money is available. The task now is to put that money to work as soon as possible and where it will have the biggest impact. Fraunhofer technology can help with this — and with minimizing the inconvenience to travelers. ■

The Sound of a Safe Bridge

How can Germany's aging bridges be monitored on a large scale? By listening closely, say researchers at Fraunhofer IDMT.

By Sonja Endres



Some bridges are so broken down that they practically shout it out. "When welded crossbeams supporting the structure break, they make an ear-splitting crash that can be heard for quite some distance around," explains research scientist Olivia Treuheit. "We want to keep things from getting to that point," she says. Together with her team from the Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau, she listens closely when cars and trucks thunder across bridges, causing them to vibrate. The researchers' goal is to identify even minor damage such as microscopic cracks or loose screws, along with soiling, early on by sound alone.

The team uses AI to analyze the audio data they collect. "This lets us filter out other kinds of noise, like traffic, rain, birdsong and music from car stereos. All we are left with is the sound of the bridge itself, the result of the vibrations created by the crossing," Treuheit explains. Differences in sound indicate potential damage even before it becomes visible.

The goal is ongoing acoustic monitoring of at-risk bridges more than 25 years old. To accomplish that, the researchers plan to install highly sensitive, low-cost MEMS microphones on bridges in the long term. The innovative microelectronic sound converters are especially suitable for applications in which the available space and energy consumption are major factors, which is why they are used in smartphones, for example. As the first step, measurements will be taken on two test bridges in the town of Pirna, one with screw connections and the other welded. The team of researchers is receiving support in these efforts from MKP GmbH, an engineering firm that specializes in technologies to monitor bridges through measurements. Treuheit comments: "We want to log as much acoustic variation as possible, not just the ideal condition." To achieve that, the researchers are deliberately adding dirt to road surfaces or loosening individual screws. This is the only way the AI can learn to not only detect anomalies but associate the sounds with specific causes as well. "We know from acoustic monitoring in industrial manufacturing, which is one of our areas of focus at Fraunhofer IDMT, how the sound of welds changes if they have any cracks, for example. Now, we want to put our expertise to work for bridges."

The researchers are hoping to receive follow-up funding for their AIrBSound project, which has received an initial round of financing through June 2026 from the German Federal Highway and Transport Research Institute. This is a promising time for research in this field, as the collapse of the Carola Bridge in Dresden in September 2024 garnered widespread public attention. "It's extremely motivating to do research on a topic with so much social and economic importance. In particular, working with other Fraunhofer institutes and connecting with experts in the areas of construction physics, prototyping and audio hardware offers tremendous potential for identifying good solutions," Treuheit says. ■

Photo: teekid / istockphoto

Lasers Help Counter "Forever Costs"

Germany has a glowing inheritance: 600,000 drums of radioactive waste — well documented, in the case of the more recent ones, but less so for older waste. Fraunhofer is working on a solution to bring the invisible to light. Without opening the drums.

By Patrick Dieckhoff

Back in the 1960s, there was a lot of faith in progress through atomic energy but little skepticism. Nuclear power was viewed as the technology of the future — inexhaustible, clean. But what about radioactive waste? It was sealed away inside drums to be dealt with later. To this day, there are about 600,000 of these barrels stored at facilities around Germany. Some of them have now been there for over half a century.

"No one knows exactly what's inside the drums," says Hans-Dieter Hoffmann, a department head at the Fraunhofer Institute for Laser Technology ILT. "In the best case, it's construction debris, irradiated clothing or other artifacts left over from the early days of nuclear engineering." On the other hand, it would be a much more serious matter if the barrels contained extremely long-lasting radioactive isotopes. Or even simply water, which can lead to leaks due to corrosion.

Opening the drums to check their contents that way would be laborious and time-consuming due to the sheer number of containers involved, plus there would be safety risks. The costs would run to some 100,000 euros per drum. To address this situation, Fraunhofer ILT in Aachen is working on an alternative as part of a joint research project. Making radiation visible without coming dangerously close to any of the nuclear waste drums is the idea behind PLANET (Portable Laser-Driven Neutron Source for Non-Destructive Testing). Focused Energy, a company based in Darmstadt and the holder of the key patent, is responsible for managing the project. In addition to Fraunhofer ILT, the Helmholtz-Zentrum Dresden-Rossendorf, mechanical engineering group TRUMPF, the Technical University of Darmstadt and Photonis Germany, which has expertise in imaging, are all involved. Some 20 million of the project's total volume of 27.1 million

Uncertain contents: There are 16 disposal sites for highly radioactive waste across Germany.

euros comes from public funding, making this one of the largest sums awarded by the German federal government.

To permit nondestructive testing of nuclear waste containers, PLANET aims to develop the world's first neutron source that is both laser-driven and maximally compact. This is because neutrons are important helpers in nondestructive material testing: They are able to penetrate deep into metals and are highly sensitive to individual chemical elements and isotopes. These properties make neutrons perfect for use in imaging methods such as tomography and radiography studies.

High tech in portable form

But so far, generating a neutron beam has required a stationary particle accelerator — huge, expensive, immovable. "Generating a stable neutron beam in tight quarters is a real challenge," Hoffmann explains. But that is exactly what PLANET has set out to do, fitting a technology that previously required large-scale facilities that cost billions to build and operate into a single shipping container so it can be moved around.

> "Generating a stable neutron beam in tight quarters is a real challenge."
>
> Hans-Dieter Hoffmann, Fraunhofer ILT

The solution consists of three chambers. In the first one, a high-frequency laser emits pulses up to a hundred times per second. In the second chamber, the laser pulse hits a self-regenerating surface known as the "liquid leaf" target. Hot plasma is generated there. In a space of just millimeters, the electrically charged particles are accelerated to extreme speeds, then converted to directed neutrons and X-rays and, in the third chamber, pointed at the container that is being scanned. The beam produced in this way can be used to look inside opaque objects, much like the principle behind X-ray imaging. In the final step, a highly sensitive detector translates the beam signal into an image, revealing what is inside the drum — without opening it, and without any risk.

The bases of this technology were developed at the Technical University of Darmstadt. Now the task is to translate this functional principle into a tool suitable for real-world use. "Our institute's main job is to develop a high-performance laser preamplifier," Hoffmann explains. When the project concludes, in May 2028, the researchers aim to have a finished prototype: a mobile neutron source that nondestructively penetrates through shipping containers, concrete or steel drums. "There would be many potential uses for a device like this," Hoffmann says. Possible future applications include customs inspections of shipping containers or scans of bridges to see where there may be invisible cracks. Or, of course, analyzing radioactive waste.

Focused Energy is already making plans for after the PLANET project is complete and working on a technology that not only generates neutrons to take measurements but also fusion energy. A pilot plant is being built for this in the town of Biblis, in the central German state of Hesse, where there is a decommissioned nuclear power plant nearby. And that means Biblis, which became a household name across Germany for its nuclear power facility and is now home to two radioactive waste disposal sites, could soon stand for a new beginning: producing energy without "forever costs." ■

Photo: klenger/istockphoto

Mission: Space-Age Patches

In the StellarHeal project, researchers are working to develop innovative wound care solutions for use in space. It is an idea that could also benefit many people on the earth.

By Beate Strobel

Houston, we have a problem: Injuries can occur even in zero G — where they have a harder time healing.

Photo: ESA

Gentle movements, floating bodies, slow motion: In space, everything seems to move with ease. But looks can be deceiving: Even in zero gravity, astronauts on board spacecraft or on the International Space Station (ISS) can hurt themselves at times. Things like sharp objects and burns are often to blame. Wounds that need little more than disinfectant spray and an adhesive patch on earth can quickly become a problem in space. Radiation damages DNA and impairs cell division, while microgravitation curbs cell migration and growth, resulting in delayed wound closure and poor formation of scar tissue. Conditions in space also impair the body's natural immune activity, increasing the risk of infection.

Everyday first aid for use in space: In the StellarHeal project, a team of researchers from the Fraunhofer Institute for Silicate Research ISC and the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM are working with ILK Dresden and Hannover Medical School (MHH) on a kind of "super adhesive patch" to be used on astronauts' wounds. "The patch is based on four existing technologies, three of them from Fraunhofer's labs and one from ILK," explains project manager Dieter Groneberg, who is responsible for skin research at Fraunhofer ISC in Würzburg. The idea is not simply to close the wound with a protective patch but first to apply a special padding made of stabilizing silica gel fibers, which stops the bleeding. In addition, after the bleeding has been stopped, the pad is enriched with stem cell-based fibroblasts and macrophages contained in a protective gel. The gel contains sufficient nutrients to keep the fibroblasts and macrophages alive and ready to do their work before they enter the normal blood supply. While macrophages defend against pathogens, eliminate cell residue and actively control wound healing, fibroblasts play a crucial role in repairing tissue damage and rebuilding tissue. All this means that this kind of patch can help support healing in space in multiple ways: The wound closes faster, the risk of infection decreases and less scar tissue is formed.

"Another bonus is that the nutrient medium in which the fibroblasts and macrophages are embedded can be cryonically preserved, meaning that it is preserved by freezing," says Groneberg, a biochemist by training. "A wound healing paste that can be stored securely for years is a big plus for space stations, which can't exactly get supplies from the earth quickly."

Thinking a bit farther ahead, the innovative adhesive patch technology could even allow for personalized wound care for astronauts, and thus even better healing. To achieve this, space crews would need to give samples of cells before their mission launches. The cells would be reprogrammed into pluripotent stem cells and then used as a source for the necessary fibroblasts and macrophages. And even farther into the future than that, this could be an exciting solution for making it safer to colonize the moon or Mars.

However, there are plenty of people who could benefit from StellarHeal right here on earth. "In Germany alone, there are more than 400,000 people with chronic wounds, often as a result of conditions like diabetes or bedsores," Groneberg explains. "The costs of medical wound care for these patients come to about eight billion euros a year." Wound care materials account for about 40 percent of that amount, and the costs of chronic wounds are expected to rise in Germany to nearly ten billion euros between now and 2030.

The researchers hope their new super patch will both alleviate suffering and lower healthcare spending. The macrophages embedded in the patch can be specifically polarized, so they adapt to different wound healing scenarios, Groneberg explains: "Wounds in space react by forming excessive scar tissue, so we use macrophages specifically polarized to counteract excessive tissue fibrosis. By contrast, diabetic wounds, which often involve inadequate collagen formation, could benefit from macrophages with profibrotic effects to support tissue regeneration."

Right now, the researchers are working to optimally combine the individual components of the space patch before the clinical trial phase starts. The interdisciplinary approach taken in the StellarHeal project — combining materials science, biotechnology and cryotechnology — has already impressed the German Space Agency, which is part of the German Aerospace Center (DLR). The research consortium of Fraunhofer and ILK Dresden placed first in the Applied Research for Disruptive Innovation category of the INNOspace Masters 2024 competition organized by the DLR. And that was truly a stellar achievement even before the project got off the ground. ■

Fraunhofer start-ups:
Applying research in industry

Caviar 2.0

Lab-grown fish sticks instead of overfishing: Fraunhofer spin-off BLUU Seafood is harnessing cellular protein production to give the oceans a bit of breathing room.

By Beate Strobel

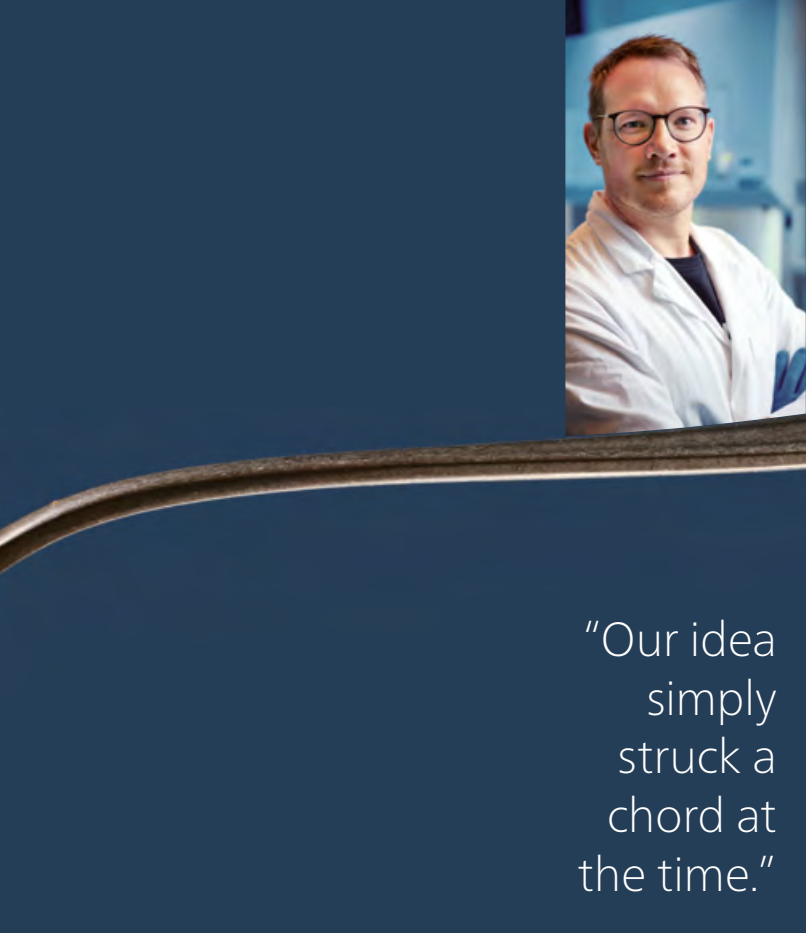
Sebastian Rakers, who has a doctorate in marine biology, tried his first spoonful of fish cells in the test kitchen at the newly founded Fraunhofer Research Institution for Marine Biotechnology EMB in Lübeck. The taste and structure of the cell mass were not yet optimum, and the mouthfeel typical of prepared fish was lacking as well. And yet, that first bite has been engraved in Rakers's memory since 2008 as a very special moment: "I was fascinated because not only did it taste like fish but I could even smell that the cells came from a trout."

Anwendungspotentiale multipotenter Zellen aus Regenbogenforellenhaut (Application Potentials of Multipotent Rainbow Trout Skin Cells) was the title of the dissertation Rakers was writing at Fraunhofer EMB (renamed the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in 2020) at the time. As he recalls, his goal back then was to study the uses of these highly variable cell types for applications in fields such as medicine. "Using stem cells to produce food was viewed as more of an extravagant research approach."

Animal proteins from a bioreactor, low in emissions, free of toxins, environmentally-conscious, animal-friendly and even tasty: "I've been pursuing that vision ever since," Rakers says. And he has made it a reality. In May 2020, Rakers and his colleague Simon Fabich founded a company called BLUU Bioscience (now BLUU Seafood) — Europe's first biotech start-up specializing in culturing seafood. It was a bold swing for a start-up at the time, as there was no product at all yet. Nor were there any suitable technologies for producing cell-based fish on an industrial scale. Or, as Rakers puts it: "We decided to build the plane while we were flying it."

The entrepreneurs amassed seven million euros in their very first funding round. "Our idea simply struck a chord at the time," Rakers says. "My background at Fraunhofer was definitely a help as well. Investors could count on our project being more than just a nice story and instead having a sound scientific basis."

A passionate diver himself, Rakers loves the ocean and everything that lives in it. And he knows just how much stress marine ecosystems are under these days: Some 37 percent of commercially used fish stocks worldwide are viewed as overfished, while 50 percent are just barely sustainable (as of 2024). Hunger for seafood has risen steadily, going from just under 20 million metric tons of wild-caught fish and other animals per year in 1950 to 91 million in 2022. Another 94.4 million metric tons



Enjoy with a clear conscience: No fish are harmed when biotechnology start-up BLUU Seafood makes its products.

Conserving the oceans for future generations: Sebastian Rakers is the founder of BLUU Seafood.

came from aquaculture operations as of 2022.

Cell-based fish could ease the pressure on the world's oceans and help stocks to recover somewhat. Rakers laid the foundations for this during his time at Fraunhofer EMB by isolating cells from trout and salmon muscle tissue — precursor or stem cells, which continuously divide and do not age. Stored in liquid nitrogen at a temperature of minus 197 degrees Celsius, they can be preserved indefinitely. Once the cells are thawed and placed in a special nutrient solution inside a bioreactor, the natural cell division process resumes, and the cells multiply, including in three dimensions. Once "harvested," the fish can then be further processed with the addition of plant-based proteins to produce things like fish sticks or fish balls. "But these kinds of hybrid products are only the beginning for us," says Rakers. "The goal is definitely to put a cell-based fish fillet on people's plates one day."

From Hamburg to Singapore and the U.S. and on to the EU market

Rakers moved away from Fraunhofer EMB in stages: "I was able to work with the cell lines I had developed at Fraunhofer," Rakers says. BLUU Seafood's first offices were within walking distance from the Fraunhofer research unit in Lübeck, and the two entities continued to do research together on joint projects. Two patents have been submitted in the past five years as a result of this work. The start-up now operates its own pilot production facility for cell-based fish in Hamburg. And the reactors have scaled up from five to 500 liters of nutrient solution. Rakers says with pride, "Now we can stand on our own two feet." His company won second place in the Deutscher Gründerpreis competition for start-ups in Germany in 2024.

But some things have gone more slowly than he had hoped. At the start, plans called for the company to launch its first product on the market in 2023. However, obtaining approval for cell-based fish for food production has turned out to be more complicated than the researchers had thought. Even so, the company is on the cusp of winning official approval in Singapore, an especially innovation-friendly market, and BLUU Seafood plans to get the green light for the United States before it embarks on the approval process in Europe. "The EU is thought of as the gold standard, and with that level comes a much bigger investment of time and effort," Rakers explains. "So it could be a while yet before our products hit German supermarket shelves."

Rakers has not regretted his decision to leave the Fraunhofer lab and become his own boss so far, although the psychological pressure was immense, especially during the initial phase after the company was founded. He attended regular professional coaching at the time. "It helped me stay down to earth and build mental resilience." Instead of running through worst-case scenarios in his head, he prefers to look at what the company has achieved. For example, he is delighted that there are now 30 people working at BLUU Seafood, "and they not only enjoy their job but also share our vision of helping to make the world a better place with what we are developing."

The first product BLUU Seafood plans to launch on the market will probably be cell-based caviar, "a premium product that allows for large margins." Rakers has already sampled it. In the process, he got to taste just how far he has come in culinary terms since that first sample spoonful of trout cell mass. "I'm not a caviar connoisseur," he says. "But when a caviar distributor tells me he's never eaten such a good alternative product, I feel like we've really been recognized for our accomplishments. It's fantastic!" ■

Photos: Bluu GmbH, Henrik Gergen; StockFood/Boomeart

Energy transition

Sustainable Batteries for the Electric Car of Tomorrow

Batteries play a vital role in the transition to a climate-neutral future. But how can powerful energy storage solutions be produced in Germany at lower cost and with greater energy efficiency? The patented DRYtraec method is setting new standards in battery cell production.

By Ulla Wolfshöfer

High-quality, low-cost production of battery storage solutions via robust and reliable supply chains is crucial to the competitiveness of the German automotive industry. But Europe is still working to ramp up its battery cell production capacity. There is a great deal of dependence on Asian technology groups, since existing production methods are both energy-intensive and costly.

A team of researchers from the Fraunhofer Institute for Material and Beam Technology IWS in Dresden has developed DRYtraec (Dry transfer electrode coating), a novel method that permits cost-effective, ecofriendly manufacturing of battery electrodes. Benjamin Schumm, Holger Althues and Stefan Kaskel received the Joseph von Fraunhofer Prize for 2025 for this pioneering technology.

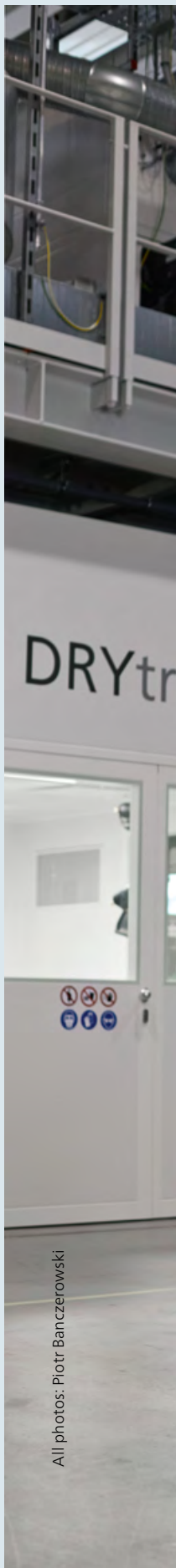
> "With DRYtraec, we offer a promising approach with twice the advantages."
>
> Stefan Kaskel, Fraunhofer IWS

Innovative DRYtraec method for battery cell production

A key component of any battery, electrodes normally consist of a metal foil with a thin coating. This coating contains the active components that are responsible for storing energy. "The conventional coating process uses a wet chemical method that applies what is known as slurry," explains Schumm, head of the Particle Technology department at Fraunhofer IWS. "DRYtraec technology makes it possible to produce an electrode layer directly from a dry mixture consisting of active material, conductive carbon black and binders." Unlike in the conventional slurry method, no solvents are used for this. There is also no need for the energy-intensive drying step. A special roller unit applies shear forces to the dry mixture, thereby mechanically anchoring particles of the active material and conductive carbon black by causing the binder to form fibrils, a process known as fibrillation. This eliminates the need for energy-intensive drying, which also takes up a lot of space, plus both sides of the electrodes can be coated simultaneously. The DRYtraec electrodes produced with without solvents display outstanding performance and stability without any drawbacks compared to slurry-based electrodes.

Patented technology with a bright future

The unique method and approach represented by the roller-based dry film transfer process minimizes production risks while making it easier to scale up to larger coating widths and higher process speeds. The world's



All photos: Piotr Banczerowski

Joseph von Fraunhofer Prize 2025

Research prizes

Since 1978, the Fraunhofer-Gesellschaft has awarded prizes to its employees for outstanding scientific achievements.

Benjamin Schumm, Stefan Kaskel and Holger Althues (from left) from Fraunhofer IWS are paving the way for powerful battery cell production in Europe.

"The DRYtraec method is also suitable for the important battery technologies of the future, such as sodium-ion and solid-state batteries."

Stefan Kaskel, Fraunhofer IWS

first prototype system was designed and constructed back in 2013, and the technology has been steadily evolving ever since. The system enables continuous process control and production of high-quality electrodes in a roll-to-roll process. "For DRYtraec, we realized an R&D platform that offers industry customers a broad range of options, from testing to transfer to commercial use, all along the value chain. Now that we have licensed the technology to a leading company in the European automotive industry, this is paving the way for further scaling all the way up to mass production," explains Althues, head of the Battery Materials department at Fraunhofer IWS.

The DRYtraec method is also suitable for the important battery technologies of the future, such as sodium-ion and solid-state batteries. "Drop-in" capability for electrode production has been demonstrated for these cell systems. Kaskel, Technology Field Manager Battery Technology at Fraunhofer IWS, explains: "We first realized this process for electrodes in lithium-ion batteries and have now adjusted it for lithium-sulfur and solid-state batteries as well. These will be increasingly important in the future, but wet chemical processing actually impairs the materials' performance. With DRYtraec, we offer a promising approach with twice the advantages."

The patented DRYtraec technology is now established as a standard method of dry coating. In this way, Fraunhofer is making a crucial contribution to safeguarding Germany's status as a hub of automotive production and underscoring the significance of production technology as a key to value creation in the transformation of mobility. ■

JPEG XS video codec

Pioneering Standard for All-IP Video Production

The image quality of videos has risen steadily in recent decades. But that also means there is more data to transfer during production. The solution? The JPEG XS video compression format.

By Ulla Wolfshöfer

A new compression codec makes producing high-quality videos faster and easier. It was developed by Thomas Richter, Joachim Keinert and Siegfried Fössel (from left) from Fraunhofer IIS.

Production of professional TV and film content faces mounting pressure to cut costs and move faster even as new media channels and platforms proliferate. High-quality video has to be transferred to a wide variety of screens within an integrated production environment before the finished film can be created. Existing video codecs make certain trade-offs when transferring production data, such as longer lag times or quality downgrades, or they focus on distribution to customers. Beyond that, more computing power is needed for repeatedly decoding the data, which requires expensive hardware and leads to higher energy use. VR headsets and applications in automotive and machine vision have real-time requirements that conventional video codecs often cannot meet.

A team of researchers from the Fraunhofer Institute for Integrated Circuits IIS in Erlangen has now developed JPEG XS, a state-of-the-art and forward-looking image compression format that transfers high-quality images in a production environment with minimal latency, low resource use and almost lossless image quality. Siegfried Fössel, Joachim Keinert and Thomas Richter were awarded the Joseph von Fraunhofer Prize for 2025 for this innovative project.

> "JPEG XS can be integrated into existing computer systems and is able to transfer high-resolution images without any visible delay."
>
> Siegfried Fössel, Fraunhofer IIS

Development of JPEG XS as a new ISO standard

Superior-quality professional videos used to be transferred without compression via special interfaces such as serial digital interface (SDI), CoaXPress or low-voltage differential signaling (LVDS), which required a point-to-point connection with coaxial or twisted pair cables. The stringent quality requirements made it impossible to compress the data without compromising high data rates. Complex transmission protocols were avoided. This resulted in transfer points with powerful converters to Ethernet computers, which slowed down workflows. "Traditional MPEG codecs aren't suitable for this application, since they are geared toward high compression rates and acceptable quality. By contrast, JPEG XS was designed as a professional compression codec — known in the field as a mezzanine codec — to allow the transfer of high-quality videos up to 8k in production quality via Internet Protocol, or IP," explains Keinert, who manages the Computational Imaging group at Fraunhofer IIS.

JPEG XS greatly accelerates the encoding and decoding of images. In film and TV production, JPEG XS enables efficient transfer and processing of image content. "Low latency and high parallelizability make JPEG XS an ideal tool for multi-stage processing of video signals in real time. The codec is optimized for visually lossless compression. It supports color depth from 12 to 16 bits, which means even video signals with high dynamic range and sensor signals like raw Bayer can be transferred," says Richter, Chief Scientist at Fraunhofer IIS.

With an extensive software and patent portfolio, Fraunhofer IIS has established an internationally recognized standard. "The new standard was developed as a visually lossless codec that specifically considers the conditions of high-quality video transfer. Thanks to its advanced algorithms, JPEG XS can be integrated into existing computer systems and can transfer high-resolution images via a low-cost Ethernet interface without any visible lag. This network technology is widespread, facilitating seamless integration into existing infrastructure," notes Siegfried Fössel, head of the Moving Picture Technologies department at Fraunhofer IIS.

Various applications

In addition to its unique position as a technology for transmission of superior-quality images, JPEG XS also offers huge economic advantages for studio technology and other fields, such as machine vision and the automotive sector. In the field of autonomous driving specifically, JPEG XS shows significant advantages in that the data rate for camera networking is reduced with almost no impact on analytical performance in real time. ■

Aluminum production

Ultrasound Reliably Detects Inclusions

Superior material quality is crucial when processing aluminum, but it was previously impossible to detect impurities in molten metal reliably, quickly and at low cost. The solution is a versatile measurement system based on ultrasound.

By Lisa Scherbaum

Large, hard-to-access equipment and high temperatures: Foundries are home to extreme conditions. Working with liquid metal requires a high degree of flexibility and resilience in humans and machines alike. A team of researchers from the Fraunhofer Institute for Nondestructive Testing IZFP tackled this challenge when customers from the aluminum industry contacted the institute looking for a new measuring system to detect contamination in molten metal — an important tool during the production process. Thomas Waschkies and Andrea Mross have now been awarded the Joseph von Fraunhofer Prize for 2025 for developing the innovative ultrasound-based AloX measurement system.

Contaminants as safety risk

"The purity of the molten metal, whose temperature ranges from 600 to 800 degrees Celsius, is hugely important to the final product later on. For example, any ceramic particles that may be present in the melt don't liquefy until they reach a temperature of 2,000 degrees or more, and they remain in the finished component as inclusions if they aren't deliberately removed. This can lead to cracks and holes, and thus in the worst case to component failure," says Thomas Waschkies, Chief Scientist for Sensor Physics at Fraunhofer IZFP. From the start, he headed the project jointly with his colleague Andrea Mross, who now works in the area of strategy and research programming at the institute in Saarbrücken.

After steel, aluminum is the most widely used metal worldwide. It plays a major role in climate neutrality due to factors including its use in lightweight construction. It also requires little energy input to recycle, so it is a pivotal element of the circular economy. Various measurement systems are already available on the market for quality control when working with molten aluminum, but they are expensive, can only be operated by experts or are highly time-consuming to use, so only spot checks are possible. This means the industry needs a low-cost system that can be operated without special knowledge, delivers final results quickly and can be used flexibly in foundry settings.

Ultrasound-based measurement system

This was the background for the idea, born at Fraunhofer IZFP, of a mobile, ultrasound-based measurement system for molten aluminum. How AloX works can be described using an everyday analogy. "It's a lot like a parking sensor in a car in that the system, immersed in the molten metal, transmits signals that then bounce off a reflector. If any particles — meaning contaminants — float by, there is a disruptive signal," Mross explains. Those signals make it possible to take action right there on the production floor to assure quality.

The challenge in developing the system lay first and foremost in the extreme conditions prevalent in the foundries where it is intended for use. The hot molten metal radiates a great deal of heat, affecting not only the system itself but also the entire load-bearing unit. Molten aluminum is also highly corrosive to metal materials. Working closely with industry, the team ultimately developed an initial prototype. The measuring trolley features a measuring unit equipped with special ultrasonic waveguides and built-in cooling, along with a

specially developed software program with a patented analysis algorithm. The change mechanism for the ultrasonic waveguides made from titanium is also patented at this point.

The team is currently working on AloX 2.0, which offers a number of improvements over the first version. But one factor has remained the same: Almost all of the components were developed in-house at Fraunhofer IZFP. "From the ultrasonic sensors to the analysis software, electronics and the mechanics of the housing, AloX is an all-in-one package from a single source," Mross says. The next step for the researchers will be moving the system into broad industrial application, initially in aluminum production. But other potential uses are also conceivable, such as for quality control of other types of molten metal or in production of adhesives and foods. ■

Andrea Mross and Thomas Waschkies with the AloX mobile measurement system, which detects problematic metals in molten aluminum.

Cross-institute collaboration: Frank Neumann, Ricarda-Laura Sack, Joachim Koschikowski and Simone Kondruweit-Reinema (from left) have developed PreCare to bring healthcare to even remote areas. For their work, the team has received the Innovations for a Better Future award, which was first presented in 2025.

Fraunhofer Future Foundation award

Innovations for a Better Future

Medical care

A Healthcare Platform for Off-Road Vehicles

To improve the availability and quality of medical care in remote areas, a team at the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Fraunhofer Institute for Solar Energy Systems ISE has developed a mobile health platform for off-road vehicles.

By Lisa Scherbaum

Around the world, there is a lack of comprehensive medical care for people living in remote areas such as sub-Saharan Africa. Factors include limited mobility resulting from poor road networks and lack of means of transportation, along with a pronounced shortage of healthcare professionals. Across many countries in Africa, it is not uncommon for there to be only one doctor for every 10,000 people. For comparison, there are an average of 44 physicians providing care for every 10,000 people in Germany. To help people in these regions get access to needed care, researchers have developed a rugged health platform that can be installed on the bed of all-terrain pick-up trucks, offering all the infrastructure needed to perform health checks, packed into a tiny space. Even rough dirt or gravel roads are no longer an obstacle to bringing well-equipped healthcare professionals to patients. For this solution, Frank Neumann, Joachim Koschikowski, Simone Kondruweit-Reinema and Ricarda-Laura Sack have received the Innovations for a Better Future award for 2025 from the Fraunhofer Future Foundation.

Basic medical equipment plus technological innovation

"Our platform puts preventive healthcare within reach for everyone, everywhere," says Frank Neumann, Photo- and Electrochemical Environmental Technologies team leader at Fraunhofer IST and the project's coordinator. On the platform, electrical equipment like the built-in refrigeration system for medications, vaccines and blood samples is operated via an independent power supply that relies on solar panels and battery storage. There is even a water purification system on board. A system based on diamond-coated electrodes makes it possible to produce disinfectants from a simple sodium chloride solution while in the field. To compare treatment data and provide telemedicine services, a communication system that uses satellite or mobile networks can be incorporated. Diagnostic equipment such as X-ray and ultrasound units can be added as well.

Versatile design for individual needs

"Our solution is flexible and modular. This lets even people in underdeveloped regions participate in advances in technology," explains Joachim Koschikowski, manager of the Water Treatment and Separation group at Fraunhofer ISE. The mobile health platform is also low in cost, as it is installed on the bed of standard pick-up trucks and can be operated effectively with as little as one driver and one healthcare professional. Ricarda-Laura Sack, who worked at Fraunhofer ISE while the first prototype was in development and is responsible for training and remote maintenance in South Africa, explains: "Ease of operation and low maintenance are really important to us. The goal is to get personnel ready to operate it on their own in just one training session. That's a practical solution even for organizations with a limited budget."

"Our solution is flexible and modular. This lets even people in underdeveloped regions participate in advances in technology."

Joachim Koschikowski, Fraunhofer ISE

Firmly rooted thanks to local network

The project has featured extensive collaboration with a wide range of local stakeholders. The first prototype was delivered to an NGO in South Africa in 2023. Funding from the Fraunhofer Future Foundation subsequently made it possible to develop a second prototype, which is now being operated by an NGO in Namibia. Local partners in healthcare, research, systems construction and logistics in sub-Saharan Africa were included from an early stage. S Mile Solutions (Pty) Ltd, which was founded during the project, is now handling the manufacturing, sales and maintenance. It is Fraunhofer's first spin-off in South Africa. "Our aim is to make high tech available locally for the long term, with low barriers to entry — in Africa for Africa," Neumann says.

To further develop the technology and incorporate it even more into people's everyday lives, the team is relying on new local partnerships. "The system is universal, and it has the potential to incorporate additional technical equipment," explains Simone Kondruweit-Reinema, head of marketing and communication at Fraunhofer IST, who is responsible for communication and marketing management for the project. Adaptation to areas such as disaster relief or veterinary care on wildlife reserves is also conceivable. ■

A sticky situation: Fraunhofer researchers are developing an ecofriendly form of paste.

A Smarter Form of Glue

Starch can do many things — including acting as an ecofriendly adhesive. However, conventional starch paste has not been usable thus far for industrial production of folding boxes. Researchers at the Fraunhofer Institute for Applied Polymer Research IAP are working on a solution.

By Yvonne Weiss

Starch is a versatile biopolymer. It can be used to make foods, but that is not all. About 40 percent of all starch produced in Europe ends up in technical applications, such as manufacturing of paper, dyes, paints and textiles. It is also used as a bio-based adhesive, for instance in production of corrugated cardboard, to glue paper bags together and to adhere labels. However, it has thus far been impossible to use conventional starch paste to produce folding boxes on advanced, fast-running production machinery, which is why the industry relies on petroleum-based synthetic adhesives. Researchers aim to change that.

"We're optimizing existing starch products to make them compatible with present-day production technologies for folding boxes," says Jens Buller, scientist and head of the Starch Modification and Molecular Properties department at Fraunhofer IAP, explaining the aim of the project. Buller is working with industry partners to develop an ecofriendly form of starch paste made from renewable raw materials that can be used to glue together folding boxes, which are produced to hold products like granola and medications. Ultimately, his goal is to create sustainable packaging solutions for use in industry.

"When it comes out of the nozzle, the adhesive needs not to splatter even at high speeds, plus it cannot form threads and has to apply precisely to the packaging material," Buller says, describing the challenge. "To address this, our project is optimizing not only the glue's adhesive force but also its flow properties, which pose a problem with conventional starch solutions." The researchers' first step was to study different kinds of modified starch, which functions as a binder in the later adhesive, and further modify selected types. As the next step, the modified starch was mixed with other bio-based additives to optimize its application properties, ensure long-term stability and prevent the possibility of thickening. The industry partners have already tested how well the adhesive applies, adheres and sets on various types of paperboard.

Buller is pleased at the team's initial results: "We've already successfully applied our adhesive at conveyor belt speeds of up to 300 meters per minute. That's enough for most applications."

Right now, the researchers are working on making it possible to apply the adhesive at even higher speeds of up to 500 meters per minute to permit even broader application. In addition, they are optimizing the stability of the paste, as it still thickens slightly at this time. A big field test is planned for the final phase of the project later this year.

Buller is optimistic as he looks to the future: "I'm motivated by the idea of getting a bio-based adhesive into industrial production to improve the recycling of folding boxes while also complying with food safety regulations." This is one way to reduce packaging waste. It would also benefit the environment in two ways at once. ■

"We've already successfully applied our adhesive at conveyor belt speeds of up to **300 m/min.** That's enough for most applications."

Jens Buller,
Fraunhofer IAP

Photo: klosfoto/istockphoto

Photo & Fraunhofer

Data by the Pallet

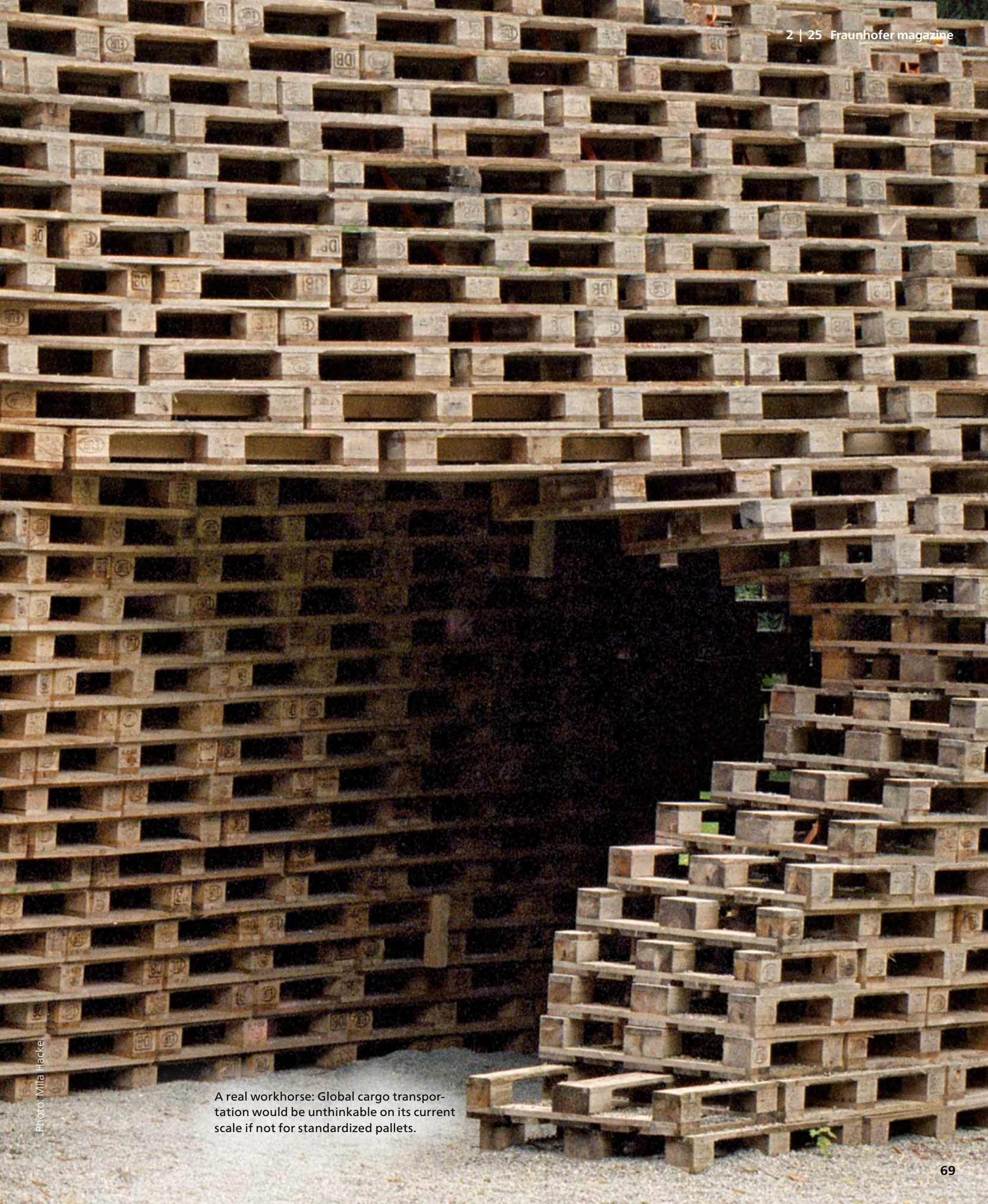
The foundation on which the global economy rests consists of exactly eleven boards, nine blocks and 78 nails. Pallets were first standardized in the 1960s to measure 1,200 x 800 x 144 millimeters. These days, The European Pallet Association (EPAL) estimates that there are more than 650 million in circulation, where they are used to carry goods from point A to point B.

As a logistics specialist, Julian Brandt naturally appreciates the known advantages of standardized European pallets. But in his role as a research scientist at the Fraunhofer Institute for Material Flow and Logistics IML, he also says pallets hold out a wealth of yet untapped potential: "Nothing else that we use to transport cargo could provide deeper insight into the flow of goods than pallets. After all, they get around — through every sector of the economy."

To tap into that potential value, Fraunhofer IML started a feasibility study called Pal2Rec ("Pallet to Recognition") under Brandt's leadership in 2024. The researchers used sensors over a series of tests to record every instance of acceleration, deceleration, tipping and rotation that a demonstrator pallet underwent. This data was used to train an AI to recognize typical pallet activities based on the data pattern alone and generate a detailed movement profile.

While existing IoT sensors merely communicate that a pallet was moved at, say, 12:40 p.m., the AI provides deeper interpretation of the data, including comparing the actual process with what should be occurring. The pallet was picked up by a forklift at 12:40 p.m., transported 50 meters and then shelved as planned without incident. Brandt explains: "This brings true transparency to logistical processes. You can't improve what you don't understand — and understanding requires transparency."

This is exciting for companies that want to leverage intralogistics optimization potential and for pallet pooling providers wanting to offer such services. Machinery and plant operators can also benefit, though: The AI can identify vulnerabilities early on and minimize damage and downtime through predictive maintenance.



A real workhorse: Global cargo transportation would be unthinkable on its current scale if not for standardized pallets.

Photo: Mila Hacke

Op-ed

Communication researcher Benedikt Fecher has been the head of the organization Wissenschaft im Dialog since 2023. He is also involved in #FactoryWisskomm, a discourse platform initiated by the German Federal Ministry of Research, Technology and Space (BMFTR) for the further development of science communications in Germany.

Science Communications for a Better Tomorrow

For a quarter century now, the organization Wissenschaft im Dialog (Science in Dialogue) has stood for shaping social change through knowledge. That mission is now more important than ever.

Op-ed by Benedikt Fecher, managing director of Wissenschaft im Dialog

Twenty-five years ago, Wissenschaft im Dialog (WiD) was founded in partnership with the Fraunhofer-Gesellschaft to raise the profile of science and research, highlight them as cultural achievements and bolster trust in both. These efforts have been successful, as confirmed by the figures reported in the Science Barometer, an annual representative survey conducted by WiD: The general populace consistently has high trust in researchers, ahead of many other occupational groups.

But the challenges that exist where science and the public intersect have changed. There are currently three main dynamics: the far-reaching transformation of public communication by artificial intelligence (AI), the role of science in overcoming complex societal challenges and, last but not least, protecting academic and scientific freedom in light of rising animosity toward an open society. Science communications are more important than ever in tackling these challenges.

Communication in flux

Generative AI has become established as a tool, making it faster for people to consolidate research and reducing the burden of administrative tasks. Chatbots are now a major source of scientific content. At the same time, there are risks: Scientific expertise is increasingly competing with plausible-sounding nonsense and disinformation. Dependence on non-scientific infrastructure is also growing. This means AI is affecting the core of communications with and about science and the research sector. We need to empower researchers and the public to use AI technologies confidently and creatively while at the same time thinking critically about them.

WiD is actively helping to shape these changes. Artificial intelligence was a key topic of the Science Barometer for 2023, for example; we initiated a multi-stakeholder process focusing on AI and science communications and implemented various discussion forums. The recommendations that arose from this are available free of charge in our WiD-Perspektiven (WiD Perspectives) publication series. The Forum Wissenschaftskommunikation (Science Communications Forum) coming up in December 2025, the biggest annual conference in the industry — which is organized by WiD — will also be dealing extensively with AI as a topic. And in partnership with the RHET AI Center, we operate an online program called "I'm a Scientist," which brings secondary school students into direct dialogue with AI researchers.

> "Science communication is especially crucial at the points where the research sector intersects with industry."

Transfer requires communication

Climate change, loss of biodiversity, geopolitical conflicts, economic change: The numbers published in the Science Barometer for 2024 show that the majority of the populace expects science and the research sector to engage with the major challenges of our time. The majority of researchers also view social participation as a fixture of their profession.

To overcome global issues, science communication should harness the diversity of scientific perspectives and strengthen interfaces with the public across all walks of life. This is the only way to build the action-oriented knowledge needed to solve societal challenges. Innovation does not automatically arise from patents. Instead, it is the product of mutual understanding, dialogue and partnership. Since the private sector is the source of about two-thirds of research and development spending in Germany, science communication is especially crucial at the points where the research sector intersects with industry.

WiD supports these efforts through continuing education activities like the CZS STEM Impact School, which specifically empowers researchers in STEM to translate their expertise into strategies with wider societal impact and through multi-stakeholder dialogue and a variety of other forums that strengthen trans-sectoral dialogue and knowledge transfer. Effective transfer is possible only through excellent, integrated communication at these interfaces.

Science communications as a protective factor

An open society requires academic and scientific freedom and vice versa. Populism, polarization and disinformation all pose risks to this reciprocal relationship. One of the main tasks of science communication is to fight disinformation and misinformation and devise effective strategies for dealing with polarized debate. It helps to ensure an informed populace with critical thinking skills, which makes it instrumental in cultivating resilience across democratic societies and scientific and research organizations. WiD pursues these aims in numerous dialogue formats. In 2025, WiD's focus for the Science Barometer will be on polarization. This approach is being taken in an effort to devise solutions for effective science communications.

In light of the various dynamics in play, science communications are more important than ever — now, and for at least the next 25 years. WiD is not just a think tank. We are a think-and-do tank, a pioneer and an essential part of the infrastructure of scientific and academic freedom.

Working side by side with strong partners like the Fraunhofer-Gesellschaft, which is deeply integrated into society and stands for applied research, this mission becomes even more impactful. As "the science organization," our mission is to rigorously further develop science communications as an essential and effective part of scientific and research work, together with our members and partners. This has been WiD's pledge for 25 years, and it remains at the core of what we do. Now and into the future, we are an engine, a bridge and a guarantor of effective science communications. For an open society that navigates change armed with the best knowledge. ■

Photo: Ilja C. Hendel / Wissenschaft im Dialog

Tumors in the Cross hairs

Computer-assisted navigation helps to preserve sensitive tissue during surgical interventions. VR headsets are making operations not only safer but also cheaper. Researchers are garnering attention from major tech players around the world with their new approach.

By Yvonne Weiss

Well connected: The human brain is made up of billions of nerve cells, which communicate with each other via synapses.

The neurosurgeon is almost there. On his virtual reality headset's display, the neon green marking showing the tip of his surgical instrument moves through the gray layers of the brain in seconds. He knows that he only has a few millimeters to go before his scalpel reaches the tumor.

This scene could be a reality in operating rooms not long from now. Researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU and the Department of Neurosurgery at Leipzig University have discovered how a standard virtual reality (VR) headset can revolutionize surgical interventions, making operations both safer and cheaper.

"Our technology works much like a car's GPS system," explains Ronny Grunert, a research scientist in the Additive Plastic Technologies and Automation department at Fraunhofer IWU. "In addition to the real-world operating room, the surgeon sees an MRI image projected into their headset. This image is like an anatomical map of the patient. It uses a crosshairs symbol to show in real time where the surgical instrument is located."

Navigation systems in the form of large apparatus and cameras are already used in surgical applications. However, they are bulky and complex to use, and beyond that, they can cost about half a million euros per system. "Our technology saves space, is easy to use and only costs about a tenth of what traditional navigation systems do," Grunert explains. This means even smaller hospitals and physicians' practices should be able to harness this technology for safer operations.

VR headset unlocks real-time views inside the brain

As part of the project, which also involves IT company ISD, the team developed a special software program. The program connects the standard VR headset with an MRI image taken of the patient's brain before the surgery is performed. The Fraunhofer researchers also produce another key component of the technology: a 3D-printed handpiece that attaches to the surgical instrument the surgeon moves inside the patient's body. This piece, which looks like the handle of a screwdriver, acts as the link between the hidden surgical instrument inside the body and the headset.

New technology garners worldwide interest

Grunert and his team have created special markers, also 3D printed: geometric shapes such as triangles that the researchers then attach to the handpiece. If the instrument is in motion, a camera built into the headset registers the markers. Because the geometry of the entire instrument is scanned into the software beforehand, the computer program knows where the tip of the instrument is located in relation to the marker, so it can determine its exact position in the body.

"We've already successfully tested initial prototypes, and now we're optimizing the markers," Grunert says. "We are aiming for precision of one to two millimeters with the headset, the same as is typical of conventional navigation systems."

> "I think it's fascinating to see what is possible in the operating room thanks to state-of-the-art technology, helping both patients and surgeons."
>
> Ronny Grunert, Fraunhofer IWU

The project team is the first in the world to use a VR headset as a navigation system for neurosurgical interventions. With the boney skull that encases the brain, these are particularly suitable for precise navigation. In the long term, though, the technology could also be used to perform surgery on other parts of the body. There is great interest: Last year, Grunert demonstrated the software to Apple using the latest model of the company's own headset. This year, the company invited him to its first conference on social computing.

Grunert is pleased at the team's results: "I think it's fascinating to see what is possible in the operating room thanks to state-of-the-art technology, helping both patients and surgeons. Being a global leader in this field is a huge achievement for us." ■

Photos: plainpicture/cgimanufaktur, satoru takahashi / iStockphoto

EUROPE

Structured Surfaces for Solar Cells

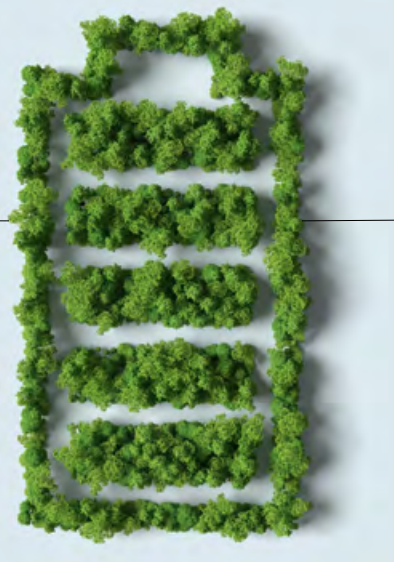
Perovskite solar cells are viewed as a potentially more powerful successor to traditional silicon cells. Their flexibility allows for applications on films or in building facades, among other uses. In the EU-funded PERSEUS project, the Fraunhofer Institute for Electron Beam and Plasma Technology FEP is developing methods of structuring these cells using roll-to-roll nanoimprint lithography (R2R NIL), which is based on embossing and UV curing of special coatings via rotating rollers. This is intended to reduce reflection losses and increase the efficiency of the solar cells.

At the same time, the researchers are also working on the Design-PV project, which aims to develop decorative surfaces for photovoltaic modules built right into facades so solar cells can be aesthetically incorporated into buildings without adversely affecting their architecture. NIL technology permits large-area, cost-effective production of structured films, including for other applications in fields such as antifouling, antireflection and medical technology.

Researchers are working on boosting efficiency in the solar cells of the future and upgrading their look at the same time.

Fraunhofer Worldwide

Locations of the Fraunhofer-Gesellschaft



Sustainability is a factor in the development of innovative solid-state batteries right from the start.

NORWAY/SLOVENIA

Rethinking Solid-State Batteries

In the FUNCY-SSB project, partners from Germany, Norway and Slovenia are developing new materials for solid-state batteries. These types of batteries are of special interest in the transportation sector. Unlike conventional lithium-ion batteries, they contain solid electrolytes rather than liquids. This makes it possible to achieve higher energy density but also poses major challenges in materials research: Solids are more difficult to bond together, and interfaces need to remain stable and conductive. To overcome these hurdles, the project team is working under the leadership of the Fraunhofer Institute for Silicate Research ISC to develop functional surface coatings that improve ion transport and protect sensitive electrolyte components. Sustainability and recyclability are factored in right from the start. The researchers are aiming to devise a material design that could serve as a model for other solid-state electrolytes in the future.

NORWAY/EU

Green Electricity for Green Ships

Shipping generates considerable emissions for various reasons, including because on-board electrical systems are hardly ever designed to work with renewable energy. Led by Norwegian maritime commercial hub Maritime CleanTech, 13 European partners are working together in the STEESMAT project to develop a system based on medium-voltage direct current (MVDC) to replace the present-day standard, alternating current (AC).

As part of the project, the Fraunhofer Institute for Silicon Technology ISIT is developing a simulation-based hardware-in-the-loop model for solid-state transformers (SSTs), which the researchers aim to use to connect DC and AC systems aboard ships both efficiently and safely going forward. This will provide flexibility in incorporating multiple energy sources, such as batteries, fuel cells, solar cells and wind turbines. Fraunhofer ISIT is also designing control strategies for maritime DC networks that remain stable even under changing loads. The technology is currently being tested under real-world maritime conditions on board the research vessel North Star.

Charting a new course: Innovative technologies aim to make ship operation greener.

Another goal of the STEESMAT system is to reduce the ships' weight and energy consumption, thereby lowering emissions by as much as 40 percent. Progress of this kind would put European industry at the forefront of sustainable maritime innovation.

EUROPE

Future-Proof Electrical Grids

Researchers are studying efficient ways to control electrical grids that derive large portions of their energy from renewable sources as part of the TenSyGrid European joint research project, which is being coordinated by the Fraunhofer Institute for Wind Energy Systems IWES. The goal is to ensure grid stability and make the supply of energy more reliable. The centerpiece of the project is a multilinear mathematical model that uses "tensors" to depict electrical grids in simplified terms. This is intended to simulate the complex interaction of decentralized and fluctuating energy feeds more quickly and more accurately than is possible with conventional methods, detect grid problems in split seconds and supply readily interpreted results in the process. This way, operators will be able to evaluate in real time how changes in power generation affect the grid. The goal is for the model to integrate seamlessly with existing grid control systems and software solutions to allow for broad practical application.

Adaptive systems: Fluctuating feeds require maximum flexibility in the energy infrastructure.

EUROPE

Monitoring for Hydrogen Electrolyzers

Green hydrogen is key to the energy transition, but large-scale use of electrolyzers poses considerable challenges: These systems have to be able to follow fluctuations in the energy supply, but they are costly to operate and have a limited lifespan. In the EU-funded DELYCIOUS project, coordinated by the Fraunhofer Institute for Wind Energy Systems IWES, researchers from five EU countries are working on an intelligent electrolyzer management system (EMS) that will optimize both efficiency and reliability. This system is the first to combine different measurement technologies — electrochemical impedance spectroscopy (EIS) and Raman spectroscopy — with data-based models. This allows for early detection of aging processes and safety risks. The technology works with all commonly used electrolysis methods: alkaline, proton exchange membrane and solid oxide electrolysis. Fraunhofer IWES is to perform large-scale (>100 kW) validation tests for alkaline electrolysis at its Hydrogen Lab Leuna. Wind data from Bremerhaven will simulate the fluctuating supply of energy from renewable sources.

Hydrogen will be a part of the energy supply in the EU in the future.

Photos: Franci Leoncio / Westend61 / dpa, enot-poloskum, rangreiss, 1000ways, Just Super / all photos from iStockphoto

A Revolution at Sea

To keep wind turbines standing tall offshore, Fraunhofer IWES scrutinizes the bottom of the Baltic Sea.

By Kathrin Schwarze-Reiter

The Baltic Sea is the scene of an ambitious project taking shape right now. ORLEN, a Polish company, and Canada-based Northland Power are planning an offshore wind farm called Baltic Power, which is to have a peak output of 1.14 gigawatts — enough to supply clean electricity to 1.5 million households. But before the huge turbines are installed, it needs to be determined whether the sea floor conditions are right for them in the first place.

The Fraunhofer Institute for Wind Energy Systems IWES, based in Bremerhaven, has taken up the challenge. The institute is harnessing innovative geophysical measurement methods to study the properties of the sea floor so construction of the wind farm can get started on a sound basis. The researchers view the ocean as one thing above all: a huge lab for the energy of the future.

Hazards and history under water: hidden features of the sea floor

The seabed is mysterious terrain — an invisible world that decides whether an offshore wind farm will succeed or fail. In addition to the boulders of different types of rock left over from the last ice age, the ocean floor is also scattered with shipwrecks, old cable systems, fishing nets and even archaeological relics such as the remains of ▶

"We can find objects about 50 centimeters in size at a depth of up to 100 meters."

Gino Frielinghaus,
Fraunhofer IWES

An estimated 100,000 shipwrecks lie on the floor of the Baltic Sea — just one of many underwater surprises that can thwart construction plans.

Photo: Jonas Dahm, from the book Ghost Ships of the Baltic Sea

prehistoric settlements or places of worship. These traces of human history or industrial use can not only delay construction processes but also require documentation or legal review, which can be quite extensive in some cases, such as when a Stone Age settlement is found. If a significant relic is discovered, construction may be interrupted, or new planning or salvage excavations may be needed.

And sometimes, the world below can also be really dangerous. The North and Baltic Seas both contain huge amounts of unexploded ordnance from the two World Wars, with the North Sea alone estimated to hold some 1.6 million metric tons of bombs, mines and grenades. "All these things need to be charted, which is a costly, laborious and time-consuming process, and most of them need to be removed to ensure safety during construction," says Gino Frielinghaus, head of the Sub-surface Investigations department at Fraunhofer IWES.

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Making the invisible visible: the principle of boulder detection

To prevent any unpleasant surprises, Frielinghaus and his team rely on ultra-accurate measurement technology. A frame-based measurement system specially developed at Fraunhofer IWES detects sea floor archaeological finds and massive boulders up to 100 meters below the seabed itself. The system glides elegantly over the sea floor like a manta ray with fins outstretched to the sides as sensors scan the structures below.

These sensors are built into the towing frame that the ship pulls along behind it, connected to an ultra-precise GPS system. The researchers transmit seismic signals into the sea floor. Like an echo, these waves bounce back to the surface, where they are recorded by ultra-sensitive underwater microphones known as hydrophones. The way these waves are scattered or reflected tells a lot about the shape, position and material of the objects buried in the seabed.

The special feature of the system: This specific form of multichannel seismic measurement makes it possible to detect even small or irregularly shaped obstacles. This yields a three-dimensional image of the ocean floor in astonishing detail. "We can find objects about 50 centimeters in size at a depth of up to 100 meters," says Frielinghaus.

Planning certainty achieved in record time: precise data accelerates construction projects

The data collected in this way has a high value for planners, construction companies and operators alike, since it can save all of them time and money. The information helps with selecting foundation sites, identifying routes for undersea cables and minimizing risks before the construction work even starts. This is especially important along cable corridors, where boulders cannot simply be circumvented. These stones can impede the installation of undersea cables, which is very costly.

Another of the system's strengths is that it works even under difficult geological conditions, such as with soft sediments, hard clay or mixed substrates. "This is exactly the kind of complexity we see in the Baltic Sea," Frielinghaus notes. "And that's what makes our measurement system perfect for use there."

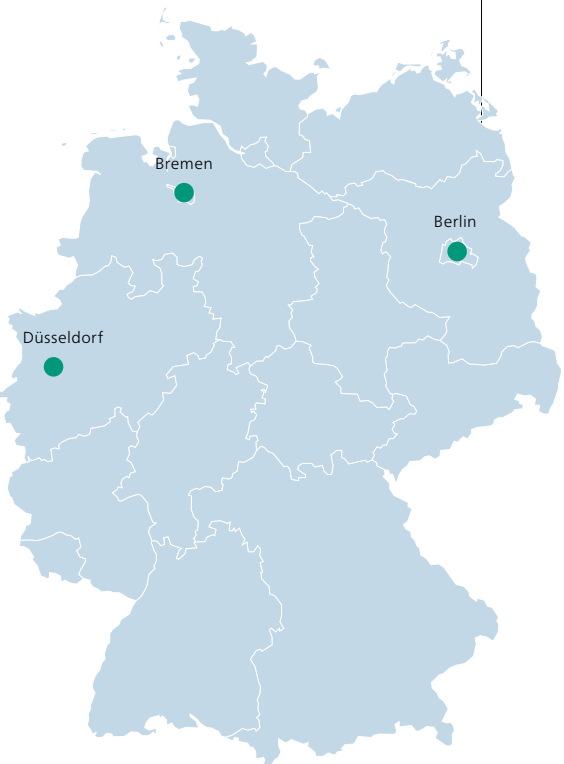
Compared to conventional geophysical surveying methods, the smart technology from Fraunhofer IWES is not only more accurate but also more efficient. The technology is specifically designed to detect any and all geological risks, and it has been instrumental in ensuring that planning for the Baltic Power offshore wind farm could proceed swiftly.

Diving for reliable electrical routes

For the first time, the system from Fraunhofer IWES has also been used along planned undersea cable routes. The researchers systematically studied how many potential boulders were buried in the seabed in the immediate vicinity of the planned cable corridors and where larger groups of boulders were clustered. Installation ships can use this data later on to lead cables around specific obstacles. This lowers costs and, at the same time, is a considerable advantage in terms of infrastructure reliability and durability.

The project has now reached an advanced phase: Offshore surveying activity is complete, and the grid connection has been secured. Installation of the first foundations at sea began in January 2025 — without any unpleasant surprises, thanks to the careful exploratory work done by Fraunhofer IWES. ■

Fraunhofer on the Road



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Fraunhofer makes big moves

How can infrastructure projects be captured in images? Photographer Jonas Ratermann set out on a journey involving technical drawings, a projector and large-format white backgrounds. Ultimately, the photos were produced in black and white to create even more of a sense of connection between the Fraunhofer researchers and the feats of engineering depicted. Dirk Koster (right) from Fraunhofer IZFP provided a bit of inspiration; he loves heavy metal and wears only black.

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