Fraunhofer

magazine 2/20

Coronavirus: what we can learn for the future

Markus Söder: “We need a technological leap”

Prof. Reimund Neugebauer: “This crisis also presents opportunities”

Oliver Zipse: “A digital upsurge will make us more resilient”

Titanilla Komenda, Fraunhofer Austria

#WeKnowHow
FRAUNHOFER VS. CORONA

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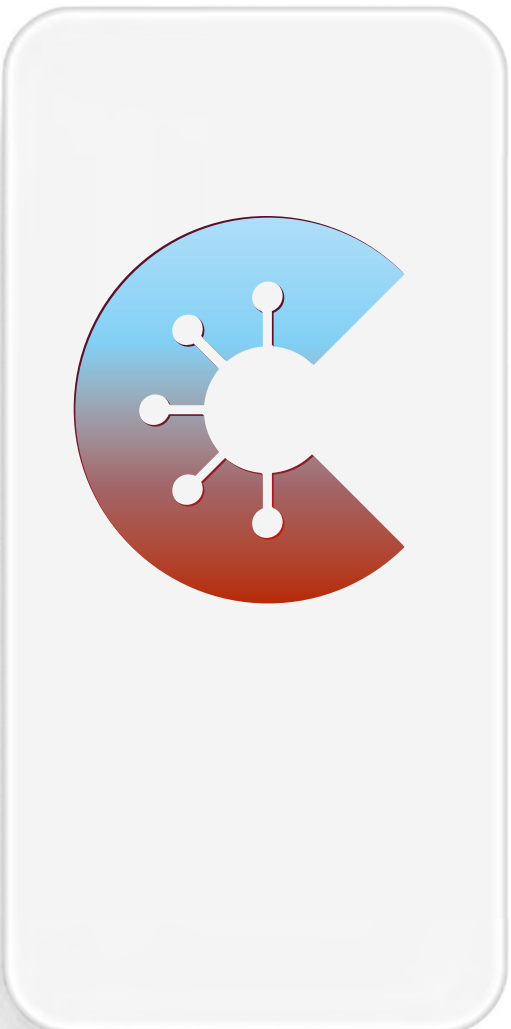

THE CORONA-WARN-APP:

HELPS US FIGHT THE CORONAVIRUS.

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Fraunhofer

The Federal Government

This crisis presents opportunities

Prof. Reimund Neugebauer
© Fraunhofer/Bernhard Huber

It's only been a few months, yet the coronavirus has radically challenged and changed the lives of so many people. In the meantime, we've rapidly become accustomed to a working life almost without travel and entirely without conferences, to a private life virtually without vacation trips, gatherings and celebrations, and to a family life with parents working from home and children schooling online. We've adapted with a speed and efficiency that no one would have really thought possible or even imaginable at the beginning of this extraordinary year.

Many safeguarding measures have been introduced. Social distancing has restricted our movements but not hampered our thoughts – quite the opposite. Indeed, we have seen an agility and a tremendous adaptability in recent months, which has left me feeling very confident. This sense of a new beginning is now the new normal. So let's seize this opportunity for change.

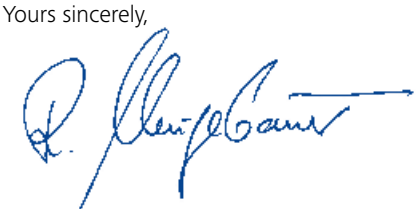
Even under the pandemic restrictions, the Fraunhofer-Gesellschaft has remained operational. This includes our work for the Corona-Warn-App, which launched in June. Fraunhofer provided consultation, reviewed technical documentation, and played a key role in developing various functions and formats. Our researchers also ran tests that have led to further improvements. At the presentation, Jens Spahn, Germany's federal minister of health, rightly applauded the app's "excellent engineering." And Helge Braun, head of the federal chancellery, remarked: "It may not be the world's first coronavirus app, but I'm pretty sure it's the best." In any case, the app is a tool that will enable us to break the chain of infection more effectively. I urge everyone to continue doing everything possible to fight this pandemic. Download the app onto your smartphone! It offers a key opportunity for us all.

The word "opportunity" crops up a lot in the latest edition of Fraunhofer magazine. "There's been an upsurge in digitalization, accelerated by the crisis, which is having a positive impact in many areas of society," notes Oliver Zipse, chairman of the board of management of BMW AG, in a guest commentary. Representing the "voice of industry," he expresses the hope that the pandemic will make us "more flexible and adaptable and therefore more resilient." In our interview with Markus Söder, Bavaria's minister president, he calls for a technological leap in Germany. Söder, who is currently chair of the conference of minister presidents, also reminds us: "We can't just press the reset button for the economy."

To prepare for this restart and to seize the opportunity for a new beginning, the German federal government has put together a bold package of measures to stimulate the economy and chart the way forward. This includes 50 billion euros for future technology and climate protection, for reinforcing Germany's business and research base, and for key strategic areas of technology such as quantum computing, artificial intelligence and hydrogen as the energy carrier of the future. In the words of the coalition committee, the federal government's national hydrogen strategy aims to turn Germany into "the world's supplier of state-of-the-art hydrogen technology." Fraunhofer researchers have drawn up the road map for this.

Coronavirus has changed the world. And the experience of the pandemic has shifted public opinion. According to a representative survey by the Allensbach Institute, published in June, trust in scientific research has grown significantly in recent months. All in all, 54 percent of the population now believe that scientists are an important source of ideas for the future. In other words, this crisis also presents opportunities. Let's be prepared to seize them!

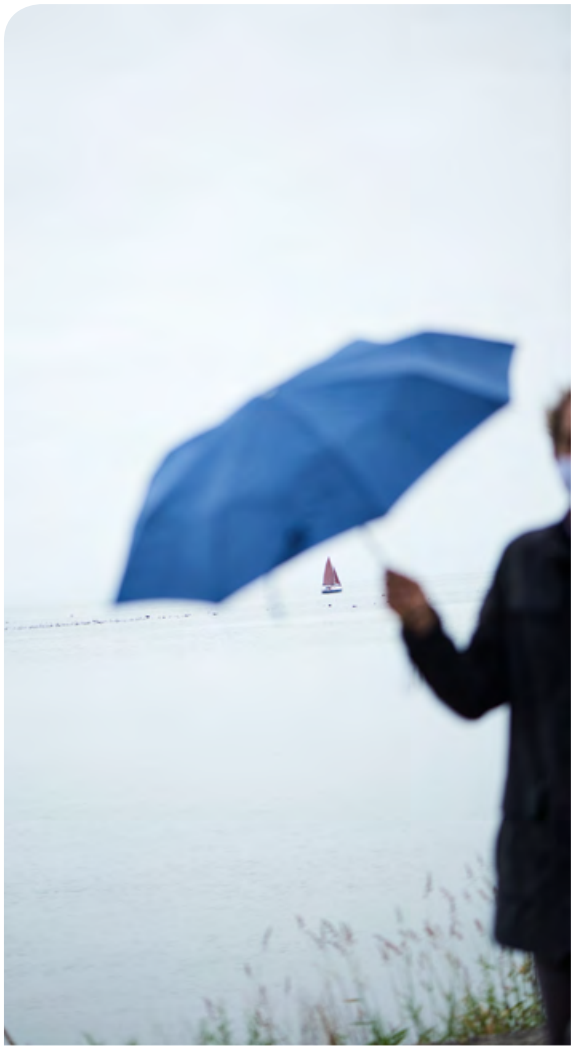
Yours sincerely,



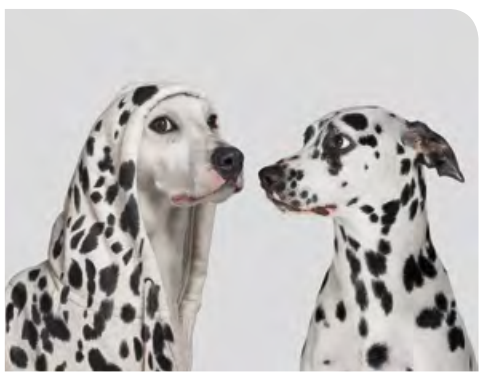
Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

back to page 1

Contents



10 A fresh start in a changed world
As life began to reemerge following lockdown, Fraunhofer magazine took advantage of this transitional moment to question Fraunhofer researchers such as Dr. Florian Roth (pictured at Lake Constance) on the following key issue: what will make our economy, our society and our systems more resilient?



Epidemiologists estimate that a mere 20 percent of those infected with coronavirus are responsible for **80 percent of coronavirus infections.** Germany's Corona-Warn-App, which Fraunhofer researchers helped develop, serves to trace infection chains. **Within 24 hours of its launch,** it had been downloaded 6.5 million times; two weeks later, 14 million users had installed it on their cell phone.

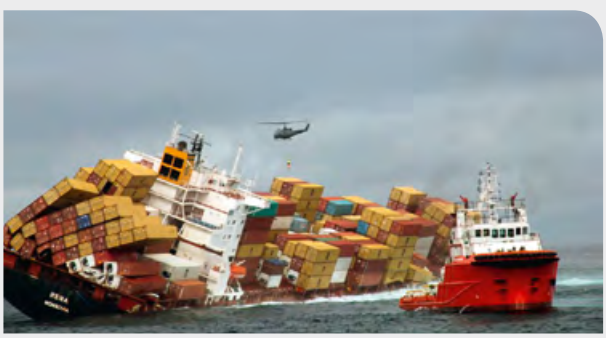
80%

back to page 1

Effectively limiting damage

Storms, fires, reefs - the consequences for increasingly massive container ships in distress can be devastating. Fraunhofer researchers are making sure that rescue workers can get in quickly and provide targeted aid in the event of an accident at sea.

Researchers at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE are currently expanding and improving National Single Window (NSW), the central official reporting system for German shipping traffic. It provides only general, reportable data on fuels and dangerous goods, but information on other cargo is not available. In a hazardous situation, for instance, there is no information about what is located in the vicinity of the dangerous goods. And yet, for ships with loading capacities of up to 24,000 20-foot containers, this information is crucial to enable the German Central Command for Maritime Emergencies to take swift and appropriate action and to keep the financial and ecological damage as minimal as possible.



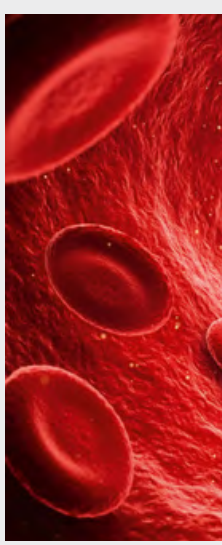
Thanks to Fraunhofer FKIE's innovative development, the German Central Command for Maritime Emergencies can quickly get a good overview. © *ddp images*

The NSW-Plus research project aims to enable all participating stakeholders to enter relevant information into the reporting system and to retrieve such information from there. The Fraunhofer researchers have developed a concept that enables useful preparation of the pooled data while also protecting against cyber threats. A demonstrator has already been created. Its interactive user interface allows rescue workers to view the ship and its cargo from different perspectives (from above, fore/aft, etc.) and to navigate the cargo areas above and below deck, all while gathering important information that can be filtered and sorted as the situation requires.

The enrichment of the NSW with more robust data proved its value in a large-scale maritime emergency exercise in Cuxhaven. The overall concept for the support of the maritime supply chain is expected to serve as a blueprint for other European countries.

Smart coatings for stents

Stents are designed to widen narrowed blood vessels, and Fraunhofer researchers are using optimized coatings to make them more biocompatible.



Stents are fine, stainless steel mesh tubes that are expanded after insertion to keep the blood vessel open and thus prevent heart attacks and strokes. However, an immune response in around 25 percent of all patients causes undesirable effects – inflammation, rejection of the stent as a foreign body or the accumulation of tissue. As a result, the blood vessel closes again.

To improve the stents' biocompatibility, manufacturers are increasingly coating them, often with titanium oxynitride. The chemical composition of the coating, its surface roughness, wettability – everything plays a role in making stents biocompatible. "We were able to specifically adapt these parameters by refining the technology underlying the deposition process," says Dr. Natalia Beshchasna, head of the joint research project at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden.

The titanium oxynitride layers are normally produced using plasma. To do this, a titanium target is bombarded with argon ions in a vacuum chamber, causing atoms to be released from the target. Beshchasna and her team also feed a gas mixture of oxygen and nitrogen into the vacuum chamber. The ideal mixing ratio, the researchers determined, is three (oxygen) to five (nitrogen).

To test whether the coating withstands the flow of blood, the researchers developed a system in which the surface of the stent was exposed to a flow of synthetic blood plasma at different temperatures, pressures and flow speeds. They subjected the coating to this procedure for two months – with success. The project partners, which, besides Fraunhofer IKTS, include Polish stent manufacturer Bolten, Russian company VIP Technologies and the University POLITEHNICA of Bucharest, are now planning to market this innovative product.

Brain to hearing aid: who is important?

Booming music, clanking glasses, a tangle of voices – for some, these are the sounds of a great party, but for those with hearing difficulties, it's a nightmare. A new hearing aid is putting an end to this.

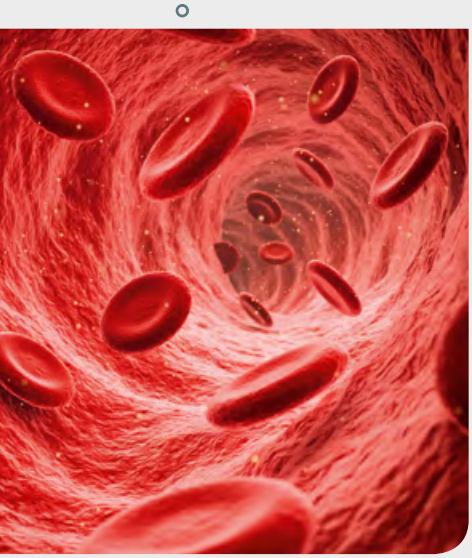
"The cocktail-party effect" refers to the ability to listen to an individual conversation despite of many people talking at the same time. This ability is reduced in people with hearing aids. © *Stocksy/F1 online*

"Even high-end hearing aids have difficulties with identifying and emphasizing the source, especially when two people are speaking at once," says Dr. Axel Winneke, a researcher at the Fraunhofer Institute for Digital Media Technology in Oldenburg. "But brain activity shows who the hearing-impaired person is listening to, and this activity can be measured using an electroencephalograph (EEG)."

Together with partners from industry and research, Winneke and his team are developing a new system that combines EEG, audio signal processing and electrostimulation of the auditory areas. The real innovation is a brain-computer interface that measures brain activity using an EEG. The resulting data is used to determine which speaker the hearing-impaired individual is trying to hear. This information is transmitted to the hearing aid, which then aligns a directional microphone – known as a beamformer – in the appropriate direction. This beamformer amplifies the specific audio signal the hearer is trying to focus on, while filtering out all other sources of noise. The third element of the system is a process called transcranial electrostimulation (tES), which uses this signal to additionally electrically stimulate the auditory areas.

Design studies have already been carried out to visualize what these innovative hearing aids might look like. The design is intended to present the device as an asset for the wearer, contrary to the still widespread stigma attached to wearing a hearing aid. Components developed for the project, including sensor technology, could soon be integrated into a wearable headpiece. Another option would be to retrofit existing hearing aids with these new modules and an EEG sensor.

The real innovation is a brain-computer interface that measures brain activity using an EEG.



In most cases, blockages in blood vessels are caused by arteriosclerosis. Stents ensure that blood can still flow unobstructed. © *istockphoto*

back to page 1

Existing methods for checking temperatures do not allow the required distance to be maintained. © *istockphoto*

Taking measurements without risk

A novel method helps detect fever and dyspnea from a safe distance.

The "Access Checker" developed by the Fraunhofer Institute for Manufacturing Engineering and Automation IPA detects fever, elevated pulse rate and rapid breathing without putting the individual taking the measurements at risk. It is very easy to maintain the required distance of 1.5 to 2 meters.

The method uses a thermal camera to measure body temperature, and microwaves to determine heart and respiratory rates, which is facilitated by a micro-Doppler radar module. A team working with IPA physician Dr. Urs Schneider has been focusing on occupational safety, medical technology, image processing and object recognition for years. Their colleagues at the Fraunhofer Institute for Industrial Engineering IAO did their part to ensure that this technological innovation can be smoothly integrated into existing processes. The Fraunhofer researchers quickly built a prototype and tested it at the main entrance of the Robert Bosch Hospital in Stuttgart.

Interest in the mobile Access Checker is high, and a patent application has been submitted.

Aquatic robot to save drowning individuals

Lifeguards are rare in Germany. The world's first robotic lifeguard is aimed at closing this gap.

A team of researchers at the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB in Ilmenau, Germany, in cooperation with Bäder Halle GmbH, is developing a swimming rescue robot that they hope will one day assist lifeguards. These researchers already designed DEDAVE, an autonomous underwater vehicle that has won numerous awards, and they have a great deal of expertise in underwater robotics.

The bionic design is reminiscent of a stingray and is intended to lend the rescue robot greater speed and agility in water. © *Wasserrettungsdienst Halle/Saale e.V.*

Their plans foresee the robotic lifeguards resting in docking stations on the floors of indoor swimming pools, where they receive data from surveillance cameras on the ceiling. The cameras monitor swimmers and analyze the data in real time. "There are typical body positions that indicate when someone is in danger," says computer scientist Helge Renkewitz, who heads up the project at Fraunhofer IOSB and works closely with the water rescue service in Halle. When the cameras detect an emergency, a nearby lifeguard is notified. Simultaneously, the rescue robot makes its way to the person in danger and brings them back to the water's surface.

Initial trials in the Fraunhofer lab pool took place in July. The robot is scheduled for testing with dummies in a swimming pool in Halle in the fall. If these tests are successful, the researchers plan to further develop the rescue robot for use in open waters.

Editorial notes

Fraunhofer magazine – all about research, technology and innovation
ISSN 1868-3428 (print edition)
ISSN 1868-3436 (online edition)

Fraunhofer

Published by:
Fraunhofer-Gesellschaft
Hansastrasse 27c, 80686 Munich, Germany
Editorial address as above
Phone +49 89 1205-1301
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http://s.fhg.de/magazines

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Layout & lithography: Vierthaler & Braun
Cover image: Philipp Horak on behalf of Fraunhofer
Printed by: H. HEENEMANN GmbH, Berlin
Translation: Burton, Van Iersel & Whitney

Gentle aid for patients on ventilators

Patients suffering from acute respiratory distress syndrome often have to be ventilated using a heart-lung machine. Novel membrane structures are aimed at making this treatment gentler.

When patients can no longer breathe on their own as a result of COVID-19, stroke or other illness, they are put on a ventilator. Their blood is circulated outside the body, where oxygen is added and carbon dioxide is removed via membranes. Artificial respiration saves lives, but it is very stressful for the body and can be used only for short periods.

Special membranes that make it possible to intensify this respiratory support are being developed by researchers at the Fraunhofer Institute for Applied Polymer Research IAP in Potsdam. "We design the membranes with asymmetrical structures whose properties permit much faster gas exchange than conventional, symmetrical ones," says Dr. Murat Tutuş, who manages the working group on membranes and functional films at Fraunhofer IAP.

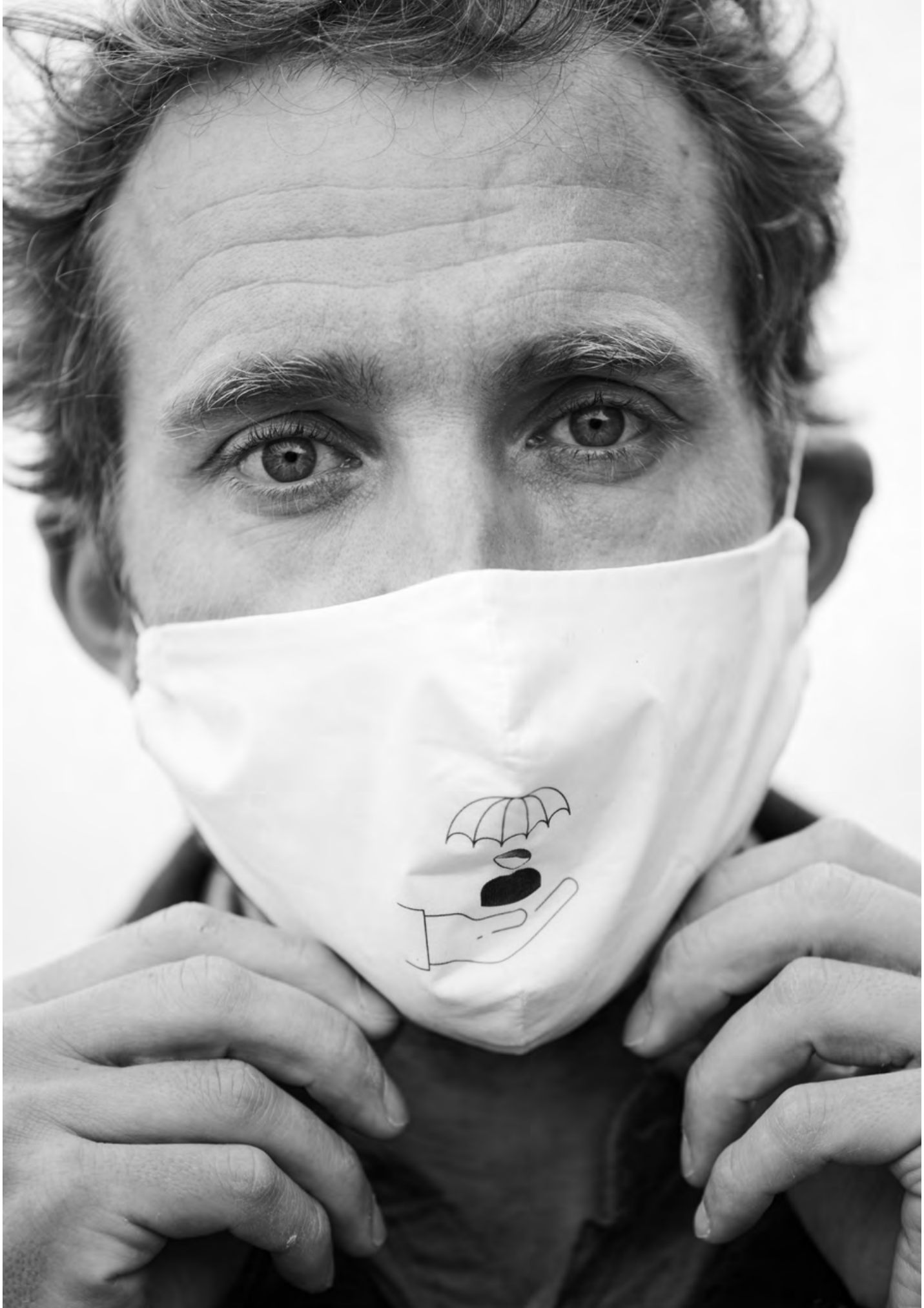
Unlike symmetrical membranes, which are intrinsically homogeneous, asymmetrical membranes are distinguished by their non-uniform porosity. Toward the separation layer, the structure is characterized by small cavities, below which are large cavities that open downward. These large cavities permit the gas to be transported more quickly to the proximity of the separation layer, where it then has only a short distance to travel before it passes over into the other medium via an ultrathin layer.

Tutuş and his team used a variety of polymers to give the membrane the desired structure. "We were able to increase oxygen transport fourfold, and the membranes we produced exhibited a pressure stability of 7 to 10 bar." In the next step, the Fraunhofer researchers hope to scale down these innovative membranes to allow them to be placed in the aorta so as to facilitate oxygenation directly in the body.

> We were able to increase oxygen transport **fourfold.**

Patients who were on a heart-lung machine must subsequently learn to breathe on their own again. © *istockphoto*

back to page 1



During the crisis & after the crisis

"Do I really want everything to go back to how it was before? Or am I ready for something new?" Dr. Florian Roth

Dr. Florian Roth
is a researcher at the Fraunhofer Institute for Systems and Innovation Research ISI. He investigates catastrophe risks and how best to prevent them. In his field, he says, he is used to things happening in cycles.

back to page 1

Information & Intelligence

"It's about money *AND* life. It will also benefit the economy if we can contain the epidemic as quickly as possible, rather than trying to suppress the reproduction factor for years on end with a variety of measures." Prof. Anita Schöbel

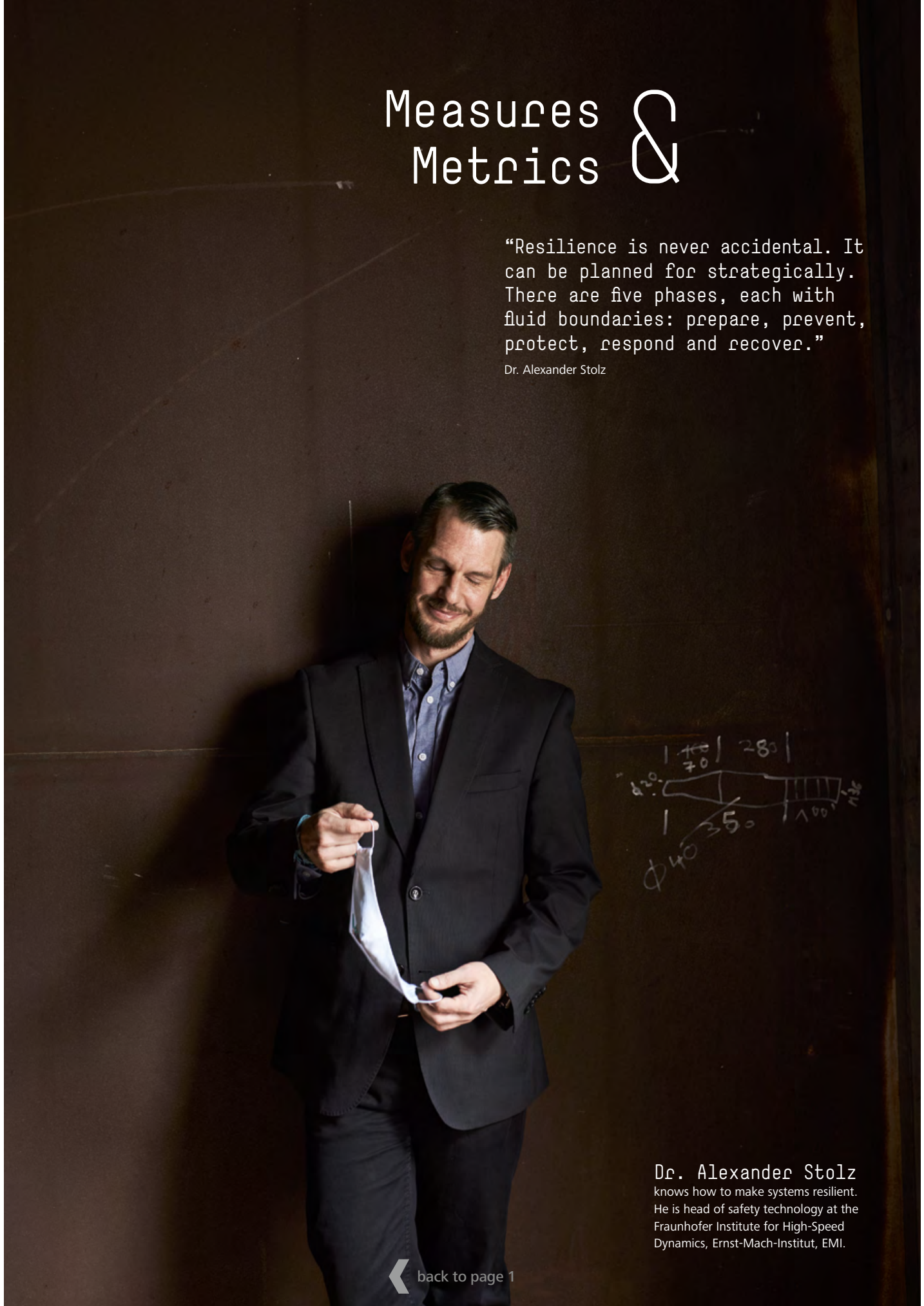
Prof. Anita Schöbel, director of the Fraunhofer Institute for Industrial Mathematics ITWM. As a staunch mathematician, she personally selected the formulae that are inscribed on her mask. They come from different areas of applied mathematics and illustrate the variety of applications and the variety of methods applied in this field.

back to page 1

Measures & Metrics

“Resilience is never accidental. It can be planned for strategically. There are five phases, each with fluid boundaries: prepare, prevent, protect, respond and recover.”

Dr. Alexander Stolz



Dr. Alexander Stolz knows how to make systems resilient. He is head of safety technology at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI.

back to page 1

Robotics & Responsiveness

"Cobots are not enclosed in protective cages. They have major potential to make manufacturing more flexible."

Titanilla Komenda

Titanilla Komenda
is a robotics engineer at Fraunhofer Austria. She expects the crisis to provide a big boost for automation and robotics.

back to page 1

Crisis & Opportunity

››› Toward a more resilient society

After months of lockdown and anxiety, there's growing optimism that the world's current vulnerability might develop into a new source of strength. In our connected world, it no longer suffices merely to overcome a crisis. We must also learn to grow from the experience.

By Mandy Bartel / Photographs: Philipp Horak

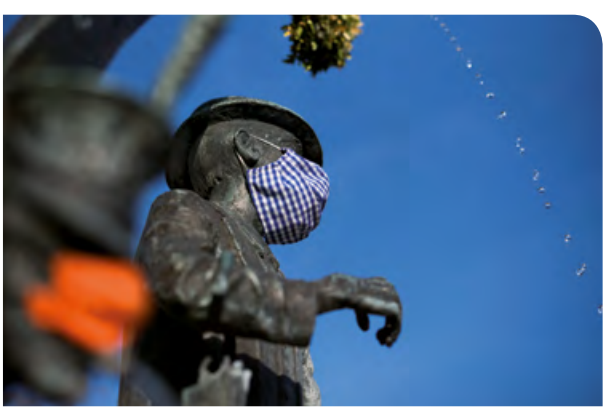
Seldom has a single event had such a direct impact on so many people. Recent months have brought substantial curbs on both working and private life, appreciable changes in the way we associate with our fellow citizens, and predictably severe damage to the global economy. Even experts have been taken aback by the force and scale of the global disruption caused by the novel coronavirus SARS-CoV-2. "The speed with which the crisis moved from the local to the global level has underlined just how vulnerable the world has become in all its complexity and connectivity," says Dr. Alexander Stolz from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI, in Efringen-Kirchen, a town in Baden-Württemberg. For the past ten years, he has been investigating the resilience of various systems to all kinds of disaster and catastrophe. Stolz believes that the past few months of the pandemic have underlined a key lesson: when it comes to an emergency situation that impacts everyone with predictable consequences on so many levels, it is vital to have a resilience strategy. For Stolz, this means that resilience must be measurable.

The status quo. Within a few weeks, the coronavirus had spread around the globe, bringing public and economic life to a standstill in many countries. In April 2020, a total of 178 countries introduced travel restrictions, 157 closed schools, and 145 imposed quarantine and lockdown measures. Management consultants McKinsey calculated that the German economy was losing 15 billion euros a week during lockdown in April. At a loss of 4 billion euros, a substantial portion of this was borne by manufacturing industry, particularly the automotive, mechanical engineering and plant engineering sectors. Next came health care and the social services (1.6 billion euros), wholesale trade (1.1 billion euros), the hotel and catering trade (900 million euros) and arts and entertainment (800 million euros). For 2020, the European Commission is forecasting a fall in GDP of 7.4 percent for the EU as a whole, with Germany (-6.5%) less seriously affected than France or Italy. The EU is providing record funds in order to overcome the impact.

According to McKinsey, it will take until 2028 for Germany to rejoin the path of growth that it would have been on without the pandemic – under one condition: Germany must seize the opportunity to press ahead with digital transformation. Conditions are favorable right now. In response to COVID-19, a lot of companies have fast-forwarded the process of digitalization. Companies that had procrastinated for years have suddenly gone ahead and done it. Microsoft CEO Satya Nadella sums it up: "We've seen two years' worth of digitalization in the space of just two months."

Yet this is not the only aspect of social and economic transformation that can now gain added momentum. More clearly than ever, the coronavirus pandemic has uncovered the vulnerabilities of our system – but also revealed the opportunities we face. "The measures to stabilize and stimulate the German economy need to be geared first and foremost toward achieving greater sustainability," says Fraunhofer President Prof. Reimund Neugebauer. "And this must be done in a way that also substantially strengthens our competitiveness." For Chancellor Merkel, the key lesson of recent months has been the need for Europe to acquire "greater strategic sovereignty." Neugebauer also calls for a rethinking of Germany's current dependences: "The goal is not to achieve total self-sufficiency but rather to have sovereign freedom of choice. And sovereignty depends on smart policy and on a community's scientific, economic and social strength."

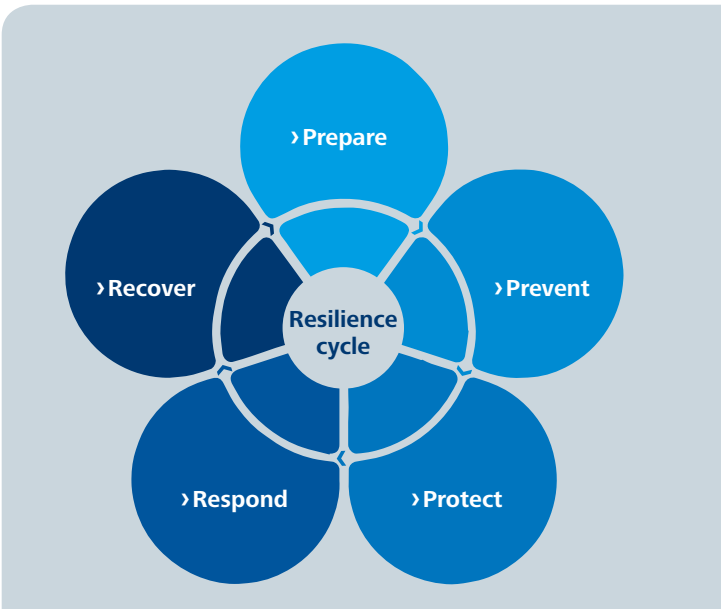
> "The goal is not total self-sufficiency but rather sovereign freedom of choice."
>
> Prof. Reimund Neugebauer



Droplets & Infection

A fountain commemorating German comedian Karl Valentin has stood on Munich's Viktualienmarkt since 1953. In spring 2020, the statue was fitted with a face mask in the blue-and-white checkers of the Bavarian flag. Valentin's legendary sayings are perfect for the present situation: "In the past, even the future was better!" and "Everything has three sides: a positive, a negative and a humorous one!"
© Josef Seitz

back to page 1



"Resilient organizations invest in redundancy, spread their resources widely, are able to organize themselves, factor in the possibility of unforeseen events, and have flexible processes."

Dr. Florian Roth

▶ **Resilience is the measure** of whether societies and organizations are able to overcome critical situations and whether they possess the technological, social and economic means to do this. "What resilient systems and organizations all have in common is that they invest in redundancy, spread their resources widely, and are able to organize themselves; they factor in the possibility of unforeseen events, focus on their own capabilities and strengths, and have flexible processes," explains Florian Roth, innovation and resilience researcher at the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe (see Interview, p. 32). For Roth, it is not enough merely to rebound when adversity strikes or, as the original sense of the word suggests (from the Latin resilire), to "jump back." If we want to make our system more resilient, we must also exploit this momentum and venture a leap forward or, as Roth calls it, a "bounce forward."

For many years now, resilience has been a topic of research in the fields of psychology and the social sciences, engineering and the material sciences, and in economics and ecology. Given the complexity of this subject, the analytical approach of engineering science may well offer certain advantages. "Resilience doesn't come about by accident; you can plan for it strategically," Stolz explains. "Resilience engineering is all about developing the measures and methods required to make optimal decisions before, during and after a crisis. A major emergency event is divided into five phases, all with fluid boundaries: prepare, prevent, protect, respond and recover."

› Prepare

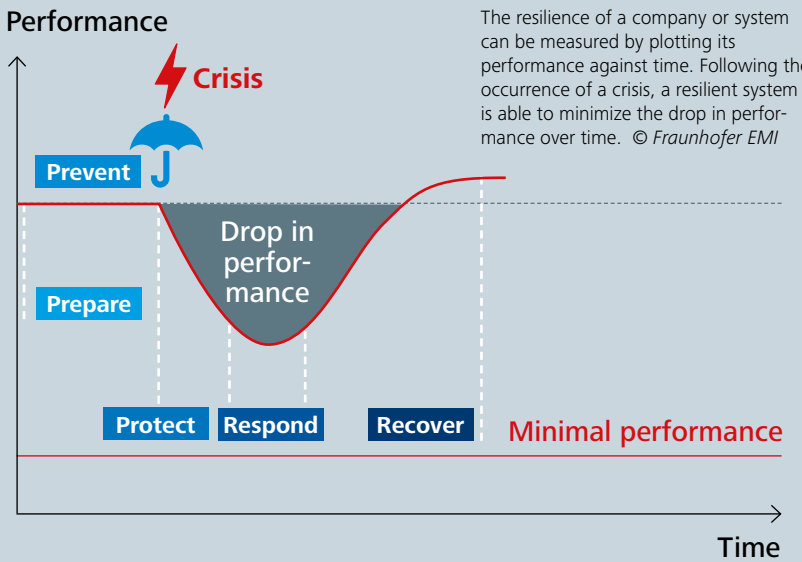
How can companies and countries prepare for a crisis?

First of all, resilience has to be based on acceptance and the right culture. This applies not only to companies but also countries, because resilience cannot be acquired without additional expenditure and resources. This is the key conflict facing every organization that wishes to make itself crisis-proof: the balance between efficiency and resilience. In normal times, companies and societies alike tend to reduce, for reasons of cost, unnecessary capacity and resources – for example, ICU beds or stocks of personal protective equipment. But what might seem a luxury in normal times may well save lives in a state of emergency. Prevention is always cheaper than being caught unawares – that's the lesson of the chronically underfunded and broken health systems in Italy, the UK or the USA, and of crashed supply chains almost everywhere we look. "The best way of achieving this balancing act," Stolz explains, "is to have a metric that shows you how much resilience you can attain by investing a certain amount. Resilience must be measurable." Resilience engineering provides such a tool: "By plotting a company's performance over time, you can calculate the drop in performance that will arise under certain conditions or when certain measures are implemented during a crisis. A comparison of the results then shows which of the options is more resilient."

To find out what works best, alongside a classic analysis of strengths and weaknesses, companies also need to ask themselves the following questions: To what degree do we need to remain functional during an emergency and what is the minimum commitment required for this? This might mean equipping all employees with a laptop for teleworking, for example, or stockpiling important products. Companies should also be thinking: Which suppliers do we rely on, and do we have alternatives? What resources can

Resilience safeguards modern societies

Resilience engineering is all about being able to develop the measures and methods required to make optimal decisions before, during and after a crisis. An emergency event is divided into five phases. Before an emergency, it is wise to make necessary preparations **(Prepare)** and take precautionary measures **(Prevent)**. When an emergency occurs, the priority is to shield and shelter **(Protect)**) and to mitigate severe consequences and maintain critical supplies **(Respond)**. Once the crisis has passed, it is vital to get things up and running again **(Recover)** and to systematically learn key lessons from the experience of the crisis.



The resilience of a company or system can be measured by plotting its performance against time. Following the occurrence of a crisis, a resilient system is able to minimize the drop in performance over time. © *Fraunhofer EMI*

we tap, and where might we create redundancies? Which processes do we need to monitor in a crisis? And do we have enough authorized signatories in the event that some of the workforce is missing? Here, it is less a question of making the system 100 percent fail-safe than of being prepared to do the right thing at the right time. "It is often the case that a small investment in the right preparation brings big savings and cuts losses in a crisis," says Stolz. Ideally, this results in a catalog of measures that organizations can then use to monitor key processes in the event of a problem and respond accordingly.

Scenarios play a crucial role in preparation. For companies and organizations, a key part of planning for a crisis is to think about what would happen if certain events were to occur. In recent years, Germany and other countries in Europe have produced a number of scenarios and contingency plans designed to guide action in the event of a pandemic. It remains to be seen just how helpful these ultimately were in the present crisis. Innovation and resilience researcher Roth warns against confusing the scenario with the risk itself: "By focusing too much on a scenario, it's easy to believe that you're well prepared for the potential threat.

Ring & Roll

The pandemic has shifted our values – occasionally in the direction of bathroom humor. This Berlin graffiti artist pokes fun at the rush on toilet paper at the outset of the crisis: Lord of the Rings character Gollum gloats over his treasured prize of a roll of toilet paper – in place of the ring. © *Getty Images*

back to page 1

▶ But that's a fallacy: a certain degree of abstraction is much more important." For example, companies should prepare for the possibility that 50 percent of the workforce are unable to work on-site. Here, it is immaterial whether this is owing to a pandemic, a major weather event or a system crash. "When you run through a lot of scenarios, you often encounter the same issues," Stolz explains. He also recommends that everyone think through various scenarios, so that we know what precautionary measures to take in preparation for an emergency: "People should be asking themselves how well prepared they are for an outage in the power or water supply over a couple of days. Or whether they can support themselves over a two-week quarantine period."

"Close cooperation with suppliers, right up to sharing resources such as personnel and know-how, is the most effective way of making supply chains more resilient."

Prof. Julia Arlinghaus

How can we strengthen our industry and supply chains? The pandemic has shown just how much we rely on the supply of key goods. This not only applies to medicinal drugs and face masks but also impacts almost every sector of industry. In 2019, 27 percent of electrical imports to Germany were manufactured in China. Almost all the raw materials for antibiotics are produced in China. According to a survey conducted by the Mechanical Engineering Industry Association (VDMA) in May, almost 50 percent of companies were experiencing serious problems with supply chains. Alongside factory closures imposed by the authorities, there were also workforce shortages owing to illness, quarantine and border closures. And, within a couple of days of lockdown, kilometer-long lines of border traffic were causing major disruptions for just-in-time manufacturing.

Supply chain resilience is the research field of Prof. Julia Arlinghaus, director of the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg. Back in 2017, the manufacturing expert carried out a survey of 200 companies. Almost 57 percent said that within the past five years they had experienced massive disruptions to their supply chains that were serious enough to threaten their commercial existence. In other words, companies would have been receptive to a warning of this kind. Modern supply chains are highly complex. While this can lead to problems, there are also good reasons for this complexity: it enables companies to focus on their own operations, avoid expensive inventory in favor of cheap transport costs, and outsource certain tasks to suppliers. Innovation and resilience researcher Arlinghaus does not believe that the current crisis heralds the oft proclaimed end to just-in-time manufacturing. Instead, it will only increase the requirement to improve efficiency. "We're not going to see a reshoring in the manufacturing sector unless the state requires and incentivizes it, and unless customers are prepared to pay more in return for higher availability, since this always involves a loss in efficiency," she explains. "I strongly believe that over the medium to long term, factors like climate change will have a much greater impact on industry supply chains than the current pandemic. As soon as we start to factor in environmental costs, this will increase transport costs, and supply chains will change drastically."

In the short term, however, companies will invest more in making the flow of materials more transparent and in the tools to do this job – namely, digitalization. As things stand, companies often know little more about their suppliers than their current billing address. Greater transparency will not only tell them exactly where their goods are procured but also help improve their ability to evaluate risk. The study also revealed another way in which supply chains can be made more resilient: greater cooperation. The more a company collaborates with its suppliers to share resources such as know-how, personnel or machinery, the less vulnerable it is to disruption. "This is based on the idea of the self-healing network," Arlinghaus explains. "In tight situations, it can even make sense to cooperate with commercial rivals in order to protect an entire supply chain." The advantages of such cooperation are clear. Yet the study shows that very few companies actually make proper use of it. "It's often down to a simple lack of trust or to an uncertainty about who is responsible for coordination should the situation worsen," says Arlinghaus.

The fragile balance between cost and resilience is also a field of study at the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern. Here, researchers are focusing on the question of how to minimize any possible shortfalls in supply at only a minimal increase in cost. Using algorithms, researchers can identify the best balance between cost reduction and risk limitation in the supply chain. This calculation includes factors such as the risk of a breakdown in the supply of specific raw materials, a shift to alternative materials and a stockpiling of key products. Time and again, it turns out that even a minor investment can substantially reduce the level of risk.

Challenging enough for a company, this becomes a mammoth task when implemented on a national level: determining where delivery problems may arise as a result of whole regions or even countries being cordoned off. Individual companies monitor the flow of goods and warehouse stock levels, but there is no centralized, unified source of data that would enable national governments to assess the overall situation and identify impending shortfalls in supply. Fraunhofer Austria is now working to change this. On behalf of the Austrian government, researchers are currently assisting the state department responsible for coordinating national crisis management and disaster management. The project initially involved the standardization of key logistics data from cooperation partners and processing it for analysis. Researchers are now collating this data in a uniform data pool and creating a dashboard to visualize trading relations. In parallel, research partners are working on mathematical models designed to

optimize the flow of goods and warehousing. In the future, this should enable an earlier identification of critical links in the food supply chain and the implementation of appropriate measures.

› Prevent

How can the worst case be prevented?

The curse of preventive action is that while it may save lives, it wins little recognition. Yet recent months have shown just how important prevention is. "If we had rigorously monitored the spread of this novel coronavirus at an early stage worldwide, we could have taken a lot of preventive measures, including an early tightening of border controls, an increase in flu vaccinations so as to avoid parallel waves of influenza and COVID-19, and the stockpiling of protective masks and medication," Stolz explains. In other words, proper monitoring procedures are vital in this phase. However, even a good early-warning system is of little use when information is ignored. News of the emergence of an unknown respiratory disease in China was first issued via the international early-warning system ProMED to recipients including the Robert Koch Institute on December 31, 2019. Yet it was 78 days before the first measures were implemented in Germany.

To identify relevant information in the mass of data, it takes not only efficient software and AI methods but also useful graphics. The Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt develops such visualization tools for doctors, epidemiologists and health authorities. These include data-analysis graphics for population studies and tools for creating and comparing patient cohorts.

Wherever data is patchy and there are no existing sources to make up for this lack, mathematics can help answer key questions (see Interview, p. 38). In the case of a pandemic, such questions include: how will the infection spread, and which measures are best suited and most effective? ▶

There were 78 days between the warning of an unknown respiratory disease and the implementation of initial measures.

Prayer & Reflection

With the coronavirus raging outside, Pastor Klaus-Martin Pothmann still managed to assemble almost a full house in the Church of St. Pancras in Hamm. In moving heaven and earth to bring his congregation together, he was clearly inspired by St. Pancras, whose name comes from the Greek and means "all-powerful." © *Getty Images*

back to page 1

> "In order to be able to impart it, communicate its importance and put it into practice, resilience must be made measurable."
>
> Dr. Alexander Stolz

▶ A major factor in the coronavirus equation is the number of unknown cases. This helps not only to explain differing mortality rates but also to predict future developments and specific measures. In order to determine the number of unknown cases in different regions of Germany, researchers at Fraunhofer ITWM modified a statistical model originally developed for use in vehicle development. Their calculations suggested there were 298,000 unidentified infections in Germany at the end of April, of which 40 percent were asymptomatic.

Mathematicians from Fraunhofer ITWM also developed a special simulation model to help the authorities with decision-making. This model uses time-variable parameters that are estimated on the basis of the recorded number of cases and then matched with further statistical data. This enables an assessment of the impact of specific measures on the rate of infection. In April, working with the Max Planck Society, the Helmholtz Association and the Leibniz Association, Fraunhofer researchers then used various mathematical models in order to determine the most promising strategy for the pandemic: a rigorous containment of new infections until effective contact-tracing becomes possible, followed by an adaptive approach in which new cases are traced back to their origin and measures to limit contact can be introduced.

Carrara & Corona

The Tower of Pisa is 55 meters high and made of 14,200 metric tons of white Carrara marble. Seldom has the UNESCO World Heritage Site been so devoid of visitors as in 2020 – despite the fact that workers in protective clothing have done all they can to keep the deserted Piazza dei Miracoli free of the virus. © *Getty Images*

› Protect

How can critical infrastructure be protected?

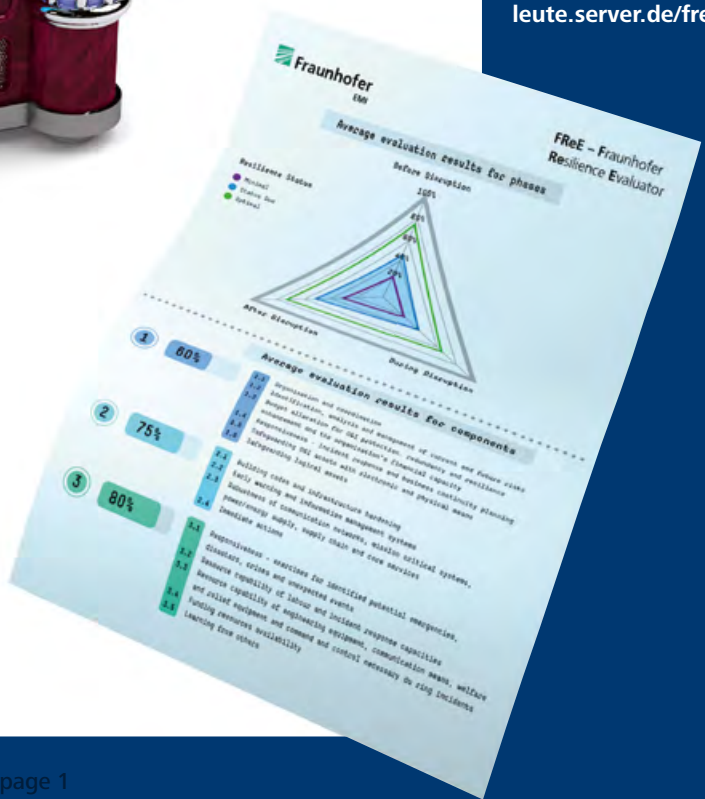
The virus has shown just how vulnerable our society is. What's more, we are susceptible in many other areas as well. In the case of critical infrastructure, such as the power grid, the supply of drinking water, telecommunications or transport, even the smallest glitch can trigger a chain reaction and create major disruption. Given the virtual impossibility of protecting these systems against the full spectrum of conceivable threats, Stolz counsels a different approach: "To achieve resilience along with the requisite flexibility and improvisation, we need to admit a certain degree of uncertainty into the equation." In place of "security by design," we need "resilience by design," which helps us prepare for unforeseen situations.

Systems that can repair themselves are more resilient. The Fraunhofer Institute for Mechatronic Systems Design IEM in Paderborn is investigating whether biological principles of self-healing can be transferred to the connected systems found in industry. Following nature's example, researchers are seeking to make these systems more resilient and thereby increase their autonomy. In effect, this means endowing them with an artificial immune system. "Our research focuses on the mechanisms of the adaptive immune system," explains project manager Michael Hillebrand. "In concrete terms, we use the danger theory and analogues of so-called dendritic cells in order to monitor autonomous robots or automation systems. These cells are able to detect danger within a system on the basis of certain signal patterns. In an open, autonomous system, however, it is impossible to program explicitly and in advance for all possible signals and reactions. We therefore use an algorithm that can recognize dangerous patterns. The algorithm classifies these signals as known/harmless, unknown, or known/dangerous. The signals are linked to a monitor that displays the system's state of health. In this way, the system is able learn – online and quasi autonomously – which signal patterns correlate to a loss in performance and then react accordingly. This 'immune response' is provided by T cell analogues, which simultaneously learn which recovery operation was successful." In this way, other systems could also be taught to become self-healing. ▶

A resilience meter

How crisis-proof is my organization? The free-of-charge Fraunhofer Resilience Evaluator offers an initial assessment. A cleverly constructed catalog of 50 or so questions shows companies their level of resilience in each of the different phases of a crisis. As with the VoteMatch system, it is also possible to punch in individual priorities via a flexible evaluation matrix. At the end of the assessment, companies receive a printout showing their current status and indicating which measures, if given greater priority, would directly result in greater resilience. In addition to this overview, companies seeking a comprehensive resilience audit are also advised to undertake a deeper analysis of specific organizational processes and the overall conditions impacting their business.

More information:
http://www.resilienz.leute.server.de/free



back to page 1

"We draw up a cyber resilience strategy to help organizations remain operational in the event of a cyberattack."

Kai Pervölz, Fraunhofer IAIS

▶ The pandemic has had little impact on critical infrastructure. Yet with so many people now working from home, occasional fluctuations in bandwidth have offered a preview of what a complete crash of the information and communications infrastructure would mean. Numerous Fraunhofer Institutes are involved in projects devoted to enhancing the security of IT systems and telecommunications networks. In the EU project RESISTO, for example, Fraunhofer EMI is investigating the threat posed by cyber, physical and combined cyber-physical attacks on current 4G/LTE networks and future 5G communication networks. Network resilience is a key issue in relation to the Internet of Things, autonomous vehicles and digital transformation. Using a simulated communication network, the research team are applying a standardized process to identify and evaluate critical issues and potential countermeasures. In addition, they are providing network operators with a decision-making tool in the form of a user interface with integrated applications.

A resilience check for IT structures is provided by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS in St. Augustin: "This covers more than just the security of IT systems," explains Kai Pervölz, head of the preventative security business unit. "We draw up a cyber resilience strategy to help organizations prepare for a cyberattack and remain operational." His researchers conduct a comprehensive analysis not only of IT architecture and any security measures already in place but also of organizational structures, processes and of the impact that an attack would have on the value chain. On this basis, they then draw up a catalog of technical and organizational measures. These range from emergency plans to security concepts for critical information assets and business processes to communication campaigns designed to instill greater security awareness throughout the entire organization. This is because the human element is a key factor in resilient systems.

"Resilience is the key to securing the benefits of globalization."

Interview with Prof. Stephen E. Flynn, founding director of the Global Resilience Institute, Northeastern University, Boston, Massachusetts

Interview: Mandy Bartel

"There is much we can learn from less-developed countries."

What makes a society or a country resilient?

Flynn: Societal resilience requires a balanced commitment to advancing: (1) individual, family, neighborhood and community resilience; (2) the resilience of infrastructure and systems that people rely on for their daily lives; and (3) a sustainable and equitable economy. Countries are resilient if in the face of a major crisis, they have strong social capital, infrastructure and systems that can sustain or rapidly recover function, and they possess adequate resources to cover losses and provide a social safety net. Importantly, strengths in one can help compensate for deficits in other. For instance, developing countries that possess significant levels of individual and community resilience can find creative, low-cost ways to work around the loss of infrastructure function or limited resources. Indeed, there is much that developed countries can learn from less-developed countries when it comes to bolstering greater levels of self-reliance.

Which competencies do we need to develop in order to be prepared for future crises?

Going forward, we need to leverage the tools of network science to model and predict how disease will spread. We need to invest in public health education for the general population. We need to bolster the means for international collaboration to accelerate the development of tests and vaccines and for managing the rapid production and sharing of critical supplies where they are most needed. Viruses pay no attention to political jurisdictions. Our approach for managing them needs to acknowledge this reality.

The pandemic has also demonstrated extremely clearly that critical infrastructure comprises more than just technical systems and hardware. Among the most critical factors are the people who work there. As a result of the pandemic, technicians have had to stay at home and look after their children, seasonal and harvest workers have been unable to cross the border into Germany, and employees have been absent either because of infection or quarantine restrictions. If a large portion of the workforce is suddenly unable to work on-site, companies need greater flexibility in their personnel and shift planning. How can companies ensure they have enough employees on-site? How can those employees who are currently unable to come to work be given other important tasks? To answer these questions, Fraunhofer IFF has developed a flextime system that matches the production schedule to shift plans and employee preferences. "This was intended as a social innovation, but it's now proving to be an economic advantage," says Prof. Julia Arlinghaus from Fraunhofer IFF. In the medium term, there also plans to apply the system on an intercompany basis so that a surplus of employees at one organization can be used to make up for workforce shortages at another.

› Response

How can we ensure the best response in an emergency?

In an acute emergency, rapid reaction is essential. The existence of a national disaster management system to coordinate all the emergency service enables swift mobilization and coordination of those forces. Along with partners from the public and private sectors, the Fraunhofer Institute for Open Communication Systems FOKUS in Berlin has created a special facility for enacting a range of scenarios for this purpose. The so-called Safety Lab uses computer technology to generate highly realistic simulations of, for example, an extreme weather event or a major fire. This shows where various agencies are involved in the emergency response and provides a precise breakdown of specific processes. ▶

Stephen E. Flynn is professor of political science and an internationally recognized expert in the field of resilience. He was formerly advisor to the Obama administration on questions of homeland security.

The USA has been badly hit by the pandemic. What conclusions should be drawn?

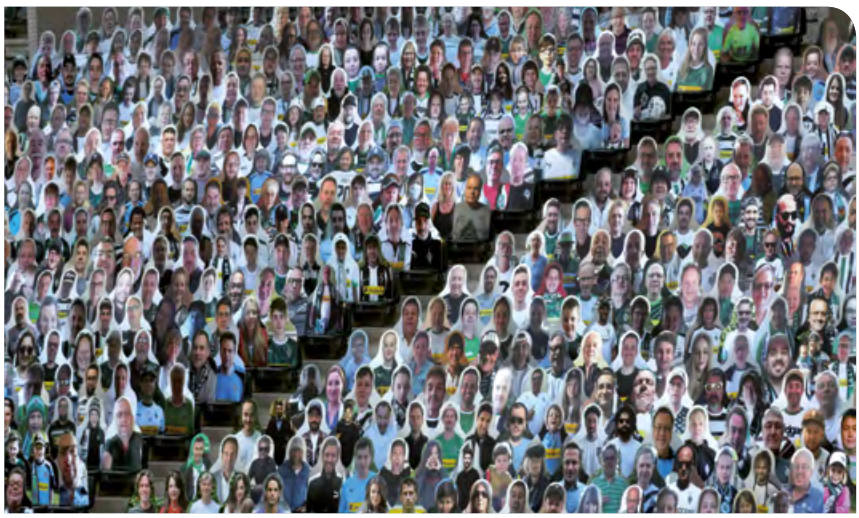
First, the locus of managing a disease outbreak is local, not national. Investment in public health at the local and state levels is key along with stepping up the capacity for local hospitals to be able to quickly surge their capabilities for caring for those who are sick. Additionally, the business model for US health care delivery is being stressed to breaking point, highlighting the need for Americans to embrace fundamental health care reform. Another important lesson is the limit of border controls in managing the pandemic risk – international collaboration at all levels is critical to confronting a deadly disease. Finally, just as with national defense, there must be the political will to invest in preparing for low-probability, naturally occurring disasters that can lead to catastrophic consequences.

How can globalization, economic efficiency and resilience be combined?

The global resilience imperative is animated by the fact that the world has become hyperconnected. This has translated into costly and disruptive consequences when disasters strike, because what were once local shocks can now rapidly generate cascading consequences on a global scale. Over the past three decades, the world has invested heavily in connectivity because of the economic benefits globalization has generated. What we did not do is make a commensurate investment in safeguards to mitigate the risk associated with hyperconnectivity. Individuals and businesses are willing to make a connection only when they believe that the benefit outweighs the risk. When they start to believe that there is more risk than benefit, they disconnect – as the response to COVID-19 has made clear. Accordingly, the key to safeguarding the benefits of globalization is to invest in resilience. Alternatively, a short-term focus on efficiency that disregards the need to anticipate and manage disruption is reckless and self-defeating. Ultimately, generating an equitable and sustainable global economy requires investing in resilience at all levels and across all infrastructure and system sectors. ■

"We need to invest in resilience at all levels."

back to page 1



Lockdown & Lockout

The fans of Bundesliga soccer club Borussia Mönchengladbach are more than just cardboard cutouts. To lift the atmosphere during lockdown, they sent in photos so their team could play to a full house. Yet even in a pandemic, one thing never changes: in May, Bayern Munich was crowned champion of this lockout season, the 30th time the club has won the title *© Getty Images*

▶ "Our lab demonstrates how to connect a wide variety of systems, ranging from control centers at fire departments and control stations for critical infrastructure to information systems for the general public," explains Niklas Reinhardt, research associate in the collaborative safety and security business unit at Fraunhofer FOKUS. "The key question for our research is how to connect these decentralized solutions and, most importantly, how to involve the public in the information process." Not only technical but also organizational and legal issues play an important role here. The Safety Lab has led to the development of technologies such as KATWARN, an international warning system used by millions of people, and KATRETTER, a system to coordinate the use of volunteers to assist the emergency services during crisis situations.

"The central question for our research is how to connect these decentralized solutions."

Niklas Reinhardt, Fraunhofer FOKUS

The global spread of the coronavirus has shown the importance of having unified and coordinated processes for crisis management. The EU is working – with the help of Fraunhofer – to establish uniform European standards in the field of disaster resilience. The Fraunhofer Institute for Technological Trend Analysis INT is part of the STRATEGY project, which gets underway in September. Its purpose is to strengthen technical and organizational interoperability for cross-border crisis management. This will involve tests and evaluation under realistic conditions of current, emerging and future standards.

Flexibility is a key part of the response phase and a key characteristic of resilient societies. As the pandemic unfolded, companies rushed to digitalize their processes so that employees could continue to work from home. At the same time, distilleries switched to producing sanitizers, and clothing manufacturers to making face masks. Automakers modified their additive-manufacturing systems in order to produce ventilators. In the field of resilience engineering, these are known as generic capabilities: the adaptation of available tools and skills for use beyond their actual application in order to be able to react rapidly to a given situation. The more resources and generic capabilities an organization has at its disposal, the greater its agility in implementing a resilience strategy. Researchers at the Fraunhofer Institute for Production Technology IPT in Aachen are experts in the adaptation of often highly specialized processes. On behalf of the company Moss, for example, they helped set up a production line for the manufacture of urgently required surgical face masks. Moreover, much of this work was done from home and in parallel steps. The company, which normally produces large-scale printed fabrics for marketing purposes, is now manufacturing 40,000 of these certified surgical masks on a daily basis. Further production lines are now being set up, the aim being to increase output to several million masks per week.

Digital engineering is the key to achieving greater flexibility in these uncertain times. "We are going to have to get used to the idea of ramping up production and then throttling it back down again whenever regional lockdowns disrupt supply chains or whenever employees or raw materials are in short supply," Arlinghaus says. In the case of some plants, however, it is not so simple to shut them down. One option here is remote maintenance in order to continue operation. "We create a digital twin of the plant," the manufacturing expert explains. "Then, in an emergency, you automatically have all the relevant information at your fingertips, without first having to conduct an inventory." This in turn means that you can simulate – remotely and in real time – how best to modify the production operation.

Whenever supply chains fail or demand soars for specific products, additive manufacturing can offer a solution. A CAD file can be easily shared online, thereby enabling multiple manufacturers at different locations to produce urgently needed items. Dr. Philipp Imgrund from the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT in Hamburg believes that the coronavirus pandemic has shown that additive manufacturing makes us more resilient in a crisis: "It makes us more flexible in a new situation and means we can quickly overcome any shortages in, say, protective equipment or ventilator parts. In recent months, we have seen a lot of projects in which 3D printing has come to the rescue." In the future, having 3D printing as an integral part of the production process may well give manufacturers a competitive advantage.

There has also been a worldwide surge in developments in the field of automation and robotics. In China, for example, delivery and disinfection robots have been in big demand during the pandemic. China is also the world's largest sales market for industrial robots. Here, however, employees in manufacturing still outnumber robots by far. In China, there are 140 robots for every 10,000 employees. In Germany, this figure is higher – 338 robots; and in Singapore, even higher – 831.

Titanilla Komenda from Fraunhofer Austria explains that robotics can help make Europe's manufacturing industry more flexible. Her field of research is the use of collaborative robotics in production. "These so-called cobots interact closely with employees and are therefore not enclosed in protective cages," she explains. "They have major potential to make manufacturing more flexible, because they enable you to adapt the degree of automation to your specific needs. During the pandemic, for example, there was a big rise in demand for face masks and disinfectant, which meant there was suddenly a need for a high degree of automation. But when demand falls and large volumes are no longer required, the use of cobots enables companies to adapt to this change." In this case, the cobots can be easily reprogrammed to undertake lots of individual manufacturing steps. This demands a more intuitive programming. Komenda's ultimate aim is that robots should be simple to reprogram and as easy to use as a cordless screwdriver. However, this may take some time, not least because of the rigorous safety requirements governing human-robot collaboration.

› Recover

How can systems recover and learn from the experience?

Alexander Stolz from Fraunhofer EMI is optimistic: "The financial crisis of 2008, which is perhaps most comparable to the current economic situation, showed that Germany was able to recover very quickly. What benefited us most back then was our flexible and innovative SME sector, our broad manufacturing and research base, and therefore our strong and diverse economy." In addition to having solid economic foundations, one other thing is vital for a successful recovery phase: here, too, strategic planning is essential.

"We should also be thinking about a gradual return to normality during all the phases before recovery – even if there's still a lot of uncertainty about how things are going to develop," Stolz explains. "By establishing simple indicators that enable a continuous monitoring of the impact of the measures so far implemented, we can continue testing the effectiveness of our decisions as conditions change. A daily log will tell you where you're making progress and where there are weaknesses. And it means you can react quickly."

For companies in the recovery phase after lockdown, it is vital to strike a proper balance between two tasks: on the one hand, the need to protect employees and customers; on the other, the need to ramp up production and thereby recoup some of the losses sustained. In the Virtual CoLAB, an online platform launched in conjunction with Fraunhofer Austria, the Fraunhofer Institute for Manufacturing Engineering and Automation IPA is now helping companies restart production and make their operations more resilient. The expert services on offer include assistance with drawing up a systematic package of measures and benchmarking with other companies in order to derive best practice. "It's often the simple things that help most at the beginning: taking people's temperature, managing bus transport, rearranging workspace and analyzing risk," explains project manager Maximilian Dörr. "Those are the first steps. Building on that, we can then draw up a strategy to ensure greater adaptability once the crisis is over." ▶

"The coronavirus pandemic has clearly shown that additive manufacturing makes us more resilient in a crisis."

Dr. Philipp Imgrund, Fraunhofer IAPT

back to page 1

▶ A further challenge for companies is to repair disrupted supply chains and get them running smoothly once again. During lockdown, production stoppages around the world led to shortages in materials. At the same time, the continued delivery of some goods during factory shutdowns caused a backlog of items awaiting further processing. The task now is to resynchronize the supply chain. In a project entitled "Fast ramp-up," the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund is using simulation to help companies with planning and management. "Our Order-to-Delivery-NETwork Simulator – or ODT NET, for short – is a tool suite for simulating and evaluating supply-chain and ramp-up scenarios, so that companies can get production restarted as soon as possible," explains project manager Marco Motta.

Last but by no means least, it is also important to learn from the measures so far adopted and then to adapt this learning before a new preparation phase ushers in the next cycle. This means collating and filing in structured form all the data and observations that have been used to evaluate and manage the crisis. This is no easy task, since such information has accumulated across all phases of the cycle and is therefore extremely heterogeneous and seldom gathered on a unified or centralized basis. Here, AI methods such as machine learning can be of assistance.

Around the world, a number of studies to assess the response to the pandemic are now underway. In CoronaNet, for example, 150 researchers across 18 time zones have investigated and categorized thousands of measures adopted by over 200 countries in an attempt to contain the virus. With the help of machine-learning methods, they analyzed over 200,000 news articles and extracted 16 different types of measure. They also compiled an index to compare when and to what degree different countries introduced specific measures. At the end of April, Germany had a mid-table ranking compared to other countries.

A number of Fraunhofer Institutes have also started research projects in an attempt to learn more from the events of recent months. At Fraunhofer EMI, for example, Stolz is using correlation models to determine the impact of various measures on, for example, the operation of critical infrastructure in selected regions. These models are based on a wide range of data sources: available statistics, information from companies and operators, and also press releases. This diverse data is then processed and structured in such a way that it can be correlated. A project recently launched at Fraunhofer ISI aims to understand and shape the dynamics of system transformation on both a conceptual and analytical level. Here, researchers are developing concepts to help policymakers and companies develop strategies that influence system change.

It is still too soon for a final evaluation. Yet the experience of what may be the greatest natural experiment of our time will undoubtedly help us emerge all the stronger from this difficult period – as will a new-won confidence in the analytical tools at our disposal, the discovery of new potential for collaboration and greater flexibility, and a heightened awareness of our own capabilities. At the same time, this will also give us added momentum to tackle essential processes of transformation – provided we remain committed to rethinking our ways. "In the field of resilience research, we're used to things happening in cycles," says Florian Roth. "The danger is that once measures start to work and the crisis passes, people just carry on as before. But this crisis, I'm sure, is going to remain anchored in our collective consciousness for a long time. And people will realize that it's better to take proper precautions beforehand rather than having to pick up the pieces afterwards." ■

"We can simulate and evaluate supply-chain and ramp-up scenarios, so that companies can get production restarted as soon as possible."

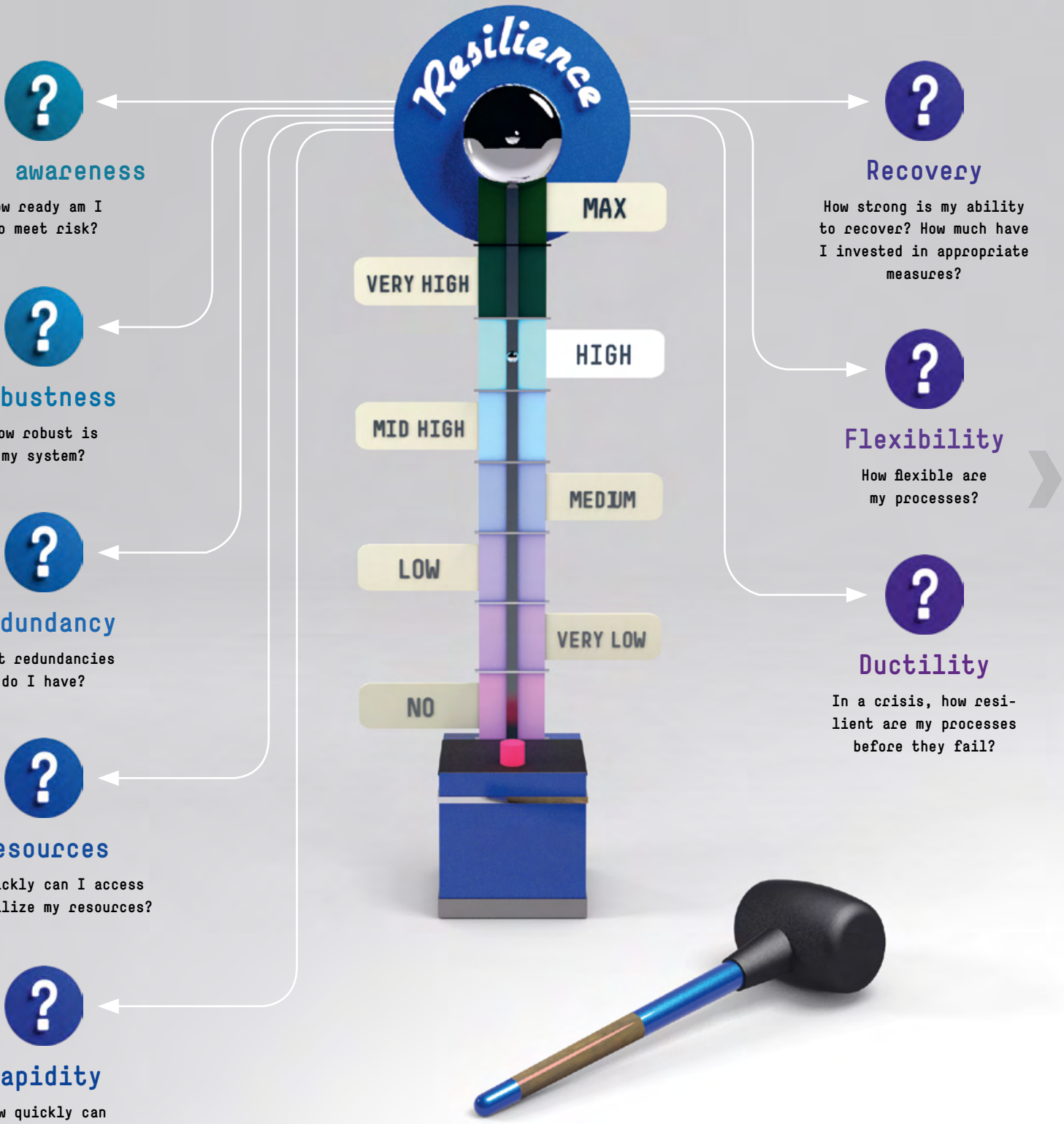
Marco Motta, Fraunhofer IML

Supervirus & Superheroes

With schools and kindergartens closed, families have been struggling with working remotely and homeschooling. A boost in superpowers is exactly what would come in handy now. Here, a young boy studies a work of street art by Kai Wohlgemuth, alias "The Uzey." The coronavirus has helped raise the artist's profile, with newspapers around the world publishing his work. © *Getty Images*

The eight dimensions of resilience

Developing resilience is a feat of strength. Companies and organizations should ask themselves these eight questions. An honest response will tell them how well they are prepared for a crisis.



Risc awareness

How ready am I to meet risk?

Robustness

How robust is my system?

Redundancy

What redundancies do I have?

Resources

How quickly can I access and mobilize my resources?

Rapidity

How quickly can I act and react?

Recovery

How strong is my ability to recover? How much have I invested in appropriate measures?

Flexibility

How flexible are my processes?

Ductility

In a crisis, how resilient are my processes before they fail?

back to page 1

“We should see this crisis as a wake-up call!”

Dr. Florian Roth is a researcher at the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe. At present, he is investigating the resilience of societies and systems. We discussed with him the opportunities and risks presented by the current crisis.

Interview by Mandy Bartel

Mr. Roth, how resilient is someone who studies resilience?

Roth: Well, I certainly keep a close eye on my own level of resilience. I look at my strategies for coping, I check my inner resources. I think about the things that give me strength. I ask myself if I really do want everything to go back to how it was before. Or whether I’m ready for something new. And I try to stay as adaptable and flexible as possible – with regard to new technology and tools, for example.

You wrote your doctorate on risk-based policymaking in complex situations. What can this work tell us about the current situation?

I looked explicitly at the interaction between parliamentary politics, the media and public opinion – that’s pretty much the interplay that we’ve been experiencing over the past few months. Risk-based decisions are always made under enormous time pressure. Bad decisions generally have serious consequences for society and for the decision makers themselves. There’s also the effect of so-called sunk costs: if you’re committed to a path of action in which you’ve already invested a lot, then it’s difficult to change course, even if that makes more sense. Interdisciplinary experts should always be involved in the decision-making process. They can assess the situation from a variety of perspectives. Take the compulsory wearing of face masks: a virologist can tell us how the virus spreads when people talk to one another, but a social scientist will also help us understand the psychological, political and social impacts of such a regulation – and explain why it is, for example, that mandatory mask-wearing can result in some people feeling safer and therefore no longer maintaining the required distance to other people. That’s what we call risk compensation.

What’s the secret of successful communication in a crisis situation?

It has to be transparent and based on partnership. What’s counterproductive is the use of so-called nudging, whereby you try and manipulate people to behave in a particular way. As we’ve seen, it’s also vital to know what you want to achieve, and not just what you want to avoid or prevent. In other words, a positive argument in favor of something helps increase its acceptance.

What kind of system is more suitable in a time of crisis: a centralized or a decentralized one?

In our society, knowledge is spread very widely. That’s an advantage. We can learn from the field of ecology here: research into coral reefs has shown that complex ecosystems that are rich in species turn out to be more resilient. That isn’t completely applicable to our situation, but it tells us that systems that avoid centralizing knowledge and resources are better able to deal with crises. They can utilize the ability of individual elements within the system to detect signals or changes that remain below the perception threshold of the system as a whole. A system is therefore able to react more quickly and prevent an information overload. It’s therefore vital to institute proper decision-making powers right across the entire system. This means giving not only central bodies but also smaller units the power to make decisions. Empowerment is very important here.

“This means giving not only central bodies but also smaller units the power to make decisions. Empowerment is very important here.”

Dr. Florian Roth wrote his doctorate on risk-based policymaking in complex situations. At Fraunhofer ISI, he is investigating processes of social transformation and the development of socio-technical resilience.

In Germany, what do we need more of in the future: a strong state or more individual responsibility?

We see both tendencies here, but that isn't necessarily a contradiction. It's important to have an effective, fully functional state to navigate through a crisis. And it's certainly the case, as studies show, that a full-blown crisis tends to reinforce people's trust in state institutions, at least in the short term. But over the past few months, we've also seen a lot of grassroots initiatives, ranging from neighborhood help on the local level to the creation of digital platforms for scientists and private groups. This participation generates greater self-confidence, a sense of self-efficacy and also a greater willingness to be involved in decision-making. This is an opportunity to strengthen an active civil society, which will then help us deal with future crises.

"In our society, knowledge is spread very widely. That's an advantage."

How can we ensure that we move forward after a crisis rather than backwards?

Basically, we need to recognize the opportunities rather than just falling back into our old ways. We're at a critical juncture right now. Before, it was already pretty clear that things needed to change. Now, the question is how to create a system that is sustainable and successful over the long term. We must also bear in mind that such processes of transformation can also create losers. It's the task of politics to create the requisite compensatory mechanisms to ensure that this disruptive transition remains socially acceptable.

Is the coronavirus crisis a catalyst?

All the big challenges have been around for quite a while: digitalization, a realignment of education, health and care, transport, decarbonization, structural change in economically deprived areas, adapting to climate change. The pandemic has also intensified some of the structural crises that existed before – in aviation, for example. Right now, a lot of airlines are only surviving because of state intervention. At the same time, they're also a key factor in the climate discussion. Now's the right time to think about how we can steer this process of change in the right direction. In the long run, structural change can also give rise to new opportunities in the areas affected, provided these periods of upheaval are used in the right way. ■

"Basically, we need to recognize the opportunities rather than just falling back into our old ways."

back to page 1

For climate's sake!

We've forgotten the art of doing nothing. Yet researchers say that only a slowdown will bring greater sustainability.

By Dr. Sonja Endres

"The corona-virus caused a system failure, and we had to change our daily routine. "Suddenly, lots of people had lots more time."

Lorenz Erdmann, foresight researcher at Fraunhofer ISI

Modern life is all about using time efficiently: writing a couple of messages while waiting for the train, checking emails while riding the train to work, taking care of the grocery-shopping online. Unused time is wasted time. Smartphones, various apps, delivery services, online commerce, the joys of multitasking – all are supposed to save us time. But instead of being happy about all the extra time, more and more people are complaining about having less and less of it. In a survey by the Allensbach Institute in 2019, 26 million German people said they didn't have enough time.

"The paradox is that, in spite of all this time-saving technology, people's subjective impression is that there's less and less time available," says Lorenz Erdmann, who heads the business unit for Futures and Society at the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe. This so-called rebound effect in the use of time was first described by the sociologist Hartmut Rosa in his 2005 work on the acceleration of time. According to Rosa, the time saved is not used in order to make time for other things such as relaxing or seeing friends. Instead, it is invested in even greater productivity. ▶

back to page 1

"I think I've become more aware of what can rob you of your time."

Lorenz Erdmann

▶ With the result that lots of people today feel like they're a character in MoMo, the world-famous children's novel by Michael Ende: the faster they work, the less time they have – a rat race that becomes faster and faster, and from which there is apparently no escape. "Life just keeps on getting fuller and fuller," Erdmann agrees. Together with partners from TU Berlin and Leuphana University Lüneburg, he is seeking to empirically test Rosa's thesis and investigate what impact it has on society, the economy and sustainable consumption.

Most people want to sleep, relax, do some exercise

Erdmann and his colleagues are developing a simulation model that is fed with data from studies on time use by Germany's Federal Statistical Office, and with information on CO_2 emissions, diet, mobility, digital media, e-commerce etc. Another key source of data is a representative survey conducted for the project Time rebound, time wealth and sustainable consumption (ReZeitKon). Erdmann und his team wanted to find out, for example, how people spend their time, how much they suffer from a lack of time, what and how they consume, and what they would do if they had an extra hour per day at their disposal. The most common answers to these open-ended questions paint a picture of a drained society: sleep, relax, read, exercise, meet friends.

The survey was carried out in February, before the coronavirus pandemic put Germany into lockdown. The virus created whole new opportunities for the project. "The coronavirus caused a system failure, and we had to change our daily routine," says Erdmann. "Suddenly, lots of people had lots more time." The team therefore decided to carry out a second survey. They wanted to find out what people were doing with this newly won time. Initial results show that sleeping and relaxing are no longer top priorities. Instead, home repairs and gardening are the most common responses.

Do we have a problem with suddenly having nothing to do? "It's not that simple," Erdmann says. "We all have our daily routine, and it's not so easy to suddenly change it. There are events in life that open up a time window. That's when routines get shaken up and reconstituted. The coronavirus could well be such a window."

But not for everyone. Erdmann emphasizes that it is important to look more closely at the survey results and differentiate according to demographic, situation and lifestyle. "Obviously, the coronavirus pandemic has a different impact on people with lots of time and money on their hands – those of independent means – than it does on those with little money and little time – i.e., people who are precariously employed, with two children and two jobs, and still barely able to make ends meet. These people are under substantial pressure in terms of both time and money. If they're out of work as a result of the coronavirus, they may not be short of time, but they've now got bigger money worries. Those with little time but lots of money – high-earning graduates who attach great importance to their profession – have quite possibly noticed a slowdown, but only if they haven't had children to look after at home."

Our attitude towards time may be in the process of changing. "But as the crisis tapers off, I suspect there will be a powerful tendency to fall back into old ways," says Erdmann.

Nature's burnout

Yet that would risk the next catastrophe – the climate catastrophe. Erdmann and colleagues are convinced that the time-rebound effect has major consequences for sustainability. Adrienne Goehler from the Institute for Advanced Sustainability Studies (IASS) in Potsdam agrees: "Sustainability requires a slowdown." A study by Griffith University in Australia shows that people who slow down find it much easier to close the value-action gap on climate change – i.e., the discrepancy between knowing what to do for greater

The art of achieving time wealth

ReZeitKon is an interdisciplinary project involving economists, political scientists, environmental psychologists, sustainability researchers, humanities scholars and social scientists. Its aim is to come up with recommendations to defeat the men in gray from the time-saving bank, as depicted in the novel Momo, and to help people achieve greater time wealth. According to researchers, this is the case when the following five criteria are met:

1 You experience your pace of life as appropriate. 2 You are able to plan your time. 3 You can decide yourself how to use your time. 4 You have enough free time for spontaneous use. 5 Your own time and external time are synchronized.

Travel bans and home improvements

Empty autobahns reminiscent of the Sunday bans during the oil crisis of 1973. In order to contain the pandemic, Germany closed its borders and asked people to stay at home. Many used the time for gardening or for home repairs. The result was long lines of people outside DIY stores and garden centers. © *Getty Images*

sustainability and actually doing it. At the opening event of last year's inaugural Munich Sustainability Conference, TV presenter and astrophysicist Prof. Harald Lesch led a discussion with researchers working on the subject of time. Their topic: "Time is honey – a sustainable culture of time and the limits of nature." There was general agreement that our nonstop society is intensifying the ecological crisis and that our massive consumption of energy and resources, which underpins our accelerated lifestyle and economic system, has now gone beyond nature's capacity and system boundaries.

Although ReZeitKon has yet to deliver robust results, Erdmann has been able to identify initial patterns on the basis of the available data: "For example, those who say their life is rushed actually use more gas than others for the same number of kilometers. The feeling of having not enough time is reflected in a faster style of driving that uses more fuel. Or people who frequently eat fast-food also opt for the quickest mode of transport." Hurrying home in the car to eat a microwaved pizza from the freezer or cycling back to a self-cooked meal that's easy on the environment – a lack of time has consequences for the environment on many levels. Erdmann and his colleagues hope that their simulation model will yield information on a key factor that has been neglected in previous environmental impact studies: how people use the time they save and its ecological footprint.

In modern societies, according to Erdmann, there is a splitting up of people's own time – i.e., time they can use as they wish – and of external time – i.e., other people's time and that of external temporal requirements such as shop opening hours or fixed working hours. Depending on the person and their life situation, some have greater difficulties than others with synchronization. Some things accelerate this process, such as the expectation that people should react quickly to emails, while other mitigate it, such as flexible working hours. "When we talk about time wealth, people often devalue their own time, but it's a vital component. If you don't take your own time into account, it's difficult to make good use of other time such as work time, time with children or social time. It's a key resource."

From time shortage to time wealth

To help people shift from an acute shortage to a wealth of time, Erdmann and his research colleagues propose various measures: the teaching of time-management skills, training in mindfulness and the piloting of new work-time models. They are also planning intervention studies at schools, in various companies and with members of the public. The idea is to develop a help manual on time and sustainability.

And does Erdmann himself now have more time wealth as a result of his research? "I think I've become more aware of what can rob you of your time. I've become much more focused in my use of digital media. I've switched off the signal for incoming messages, for example, because I don't want to be disturbed while I'm working. My own time is sacred, and I expect others to respect that. It's always very tempting to manage time like a savings account. However, unlike money, you can't hoard time. It just slips away." ■

back to page 1

“It’s about money and life!”

When major decisions have to be made on the basis of complicated data, that’s when mathematics comes into its own. Prof. Anita Schöbel, director of the Fraunhofer Institute for Industrial Mathematics ITWM, is delighted about the growing popularity of her subject. We talked to her about the power of math and its limitations.

Interview by Mandy Bartel

“The problem is, once you’ve prevented the worst, people don’t appreciate the effort behind it.”

How can mathematics help us make informed decisions in times of crisis?

Schöbel: Math is a helpful tool, particularly when you’re dealing with a lot of unknowns. First of all, we analyze which data and information is uncertain and how big an influence this uncertainty has on our methods. Then we use models based on either robust or stochastic optimization in order to calculate the best and the worst case. This helps us specify complex problems to a much finer degree. It gives you a much clearer picture of the consequences and a more solid basis for planning. In a pandemic, the number of unknown cases has a substantial influence on the further spread of the disease. We were able to calculate that even with a very high number of unknown cases, it would take between two and three years to achieve herd immunity on the basis of a controlled spread of infection. It would therefore be a very bad option to wait until then. Instead, rapid and rigorous containment is the best option.

How reliable are such predictions?

A model is only ever as good as the assumptions used to calculate it. Besides, something unforeseen always happens: a new medical discovery, or basic immunity turns out to be higher than originally assumed, or a vaccine or new drug is developed. You can only ever say that the predictions are reliable under the current assumptions. In applied mathematics, we try to estimate missing parameters in such a way that they conform to events so far. There’s a real art to modeling. It’s about creating mathematical models of a real problem. Unfortunately, it’s not taught nearly enough at university. There, you only learn how to calculate with a given model and you assume that the model is correct.

From a mathematical perspective, would you say that the right measures have been applied?

The measures were sensible and appropriate. They came at the right time and, happily, weren’t as strict as in other countries. The problem is, once you’ve prevented the worst, people don’t appreciate the effort behind it. They just think it was all a big fuss about nothing. It’s difficult for people to imagine what exponential growth actually means. It can happen alarmingly quickly, so that all of a sudden there are not enough intensive-care beds.

To what extent is it possible to calculate the influence of political decisions within complex systems – for example, their impact on the economy?

That’s what we’re discussing right now at the institute and with economists as well. Unfortunately, it’s not that easy to juxtapose epidemiological and economic modeling, as there are a lot of factors that are extremely difficult to gauge. For example, how do restrictions of differing type and degree effect the continued performance of the economy? What effect do relaxations have on different sectors of the economy – and on the reproduction factor, which then has to be coupled with economic factors? There are many aspects to this problem. These currently make it difficult to produce a robust calculation.

Can you calculate the moment at which a measure has a greater negative impact than that which it is intended to prevent?

There are mathematical disciplines for this. In the field of multiple criteria optimization, for example, we simultaneously observe a range of objective functions and find the best com-

Prof. Anita Schöbel has been director of the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern since 2019.

"We've developed some visualization tools with which you can actually to see the relationships between different factors."

promise. That gives you concrete help with decision-making. At Fraunhofer ITWM, we've developed some visualization tools with which you can actually to see the relationships between different factors. A good example of this – in a completely different context – is the use of radiation therapy for cancer. We can precisely calculate the radiation dosage required to destroy a tumor without substantially compromising the surrounding organs.

How can multiple criteria optimization help in the current situation?

Things get difficult once you have a number of complex systems – such as heath care, the economy and the social system – interacting with each other. That's even more so when we lack data – as we do here, since we've never had such a lockdown. But we can learn a lot for future crises. In public debate, it's often presented as if there were two options – making money or preserving life – and these are in opposition to one another. They're not! It also benefits the economy if we can contain the epidemic as quickly as possible, rather than trying to minimize the reproduction factor for years on end with a variety of measures. In other words, it's about money and life! Our strategy aims to find the best compromise between protecting public health and safeguarding the economy.

What kind of data should we be collecting so as to learn how to deal with future challenges?

From an epidemiological point of view, we need to learn which measures help prevent the spread of a virus and how effectively they do this. We also need to analyze the impact on economic factors such as productivity or unemployment. And it's useful to evaluate movement data and contact data so as to learn how and in what way specific measures modify patterns of movement. In the future, this will help us prevent the spread of infection more efficiently.

Which kind of areas are going to become more important than previously?

We're going to have to rethink supply chains and inventories, so that in the future we're not dependent on other countries. Right now, we need more face masks, but in the next crisis we'll maybe need different products altogether. We need to be thinking on a more general level. Also, there's bound to be a review of reporting chains so as to ensure that key information is handed on more quickly. Workforce planning, for example, at health authorities will have to become more flexible. And we'll be more aware about the need to travel, especially on business, because what the crisis has shown is that it's possible to discuss a lot of things digitally. ■

From lockdown to reopening

Photographer **Philipp Horak** took the images for the lead story, including the cover photo – a flicker picture, or lenticular print – and the portraits of Fraunhofer researchers. Equipped with **personalized masks** for each of his subjects, he set out to document the switch from lockdown to the lifting of restrictions. Work began the first week in which travel was once again allowed. Fortunately for him, he had already come through an infection with the coronavirus unscathed.

Born 1976 in Vienna, Horak works for Austrian and German publications, including Die Zeit, stern and Geo. "On the road for *Fraunhofer Magazine,* there was a real sense of reopening," says Horak. Coming from Vienna, there was one thing he really missed during lockdown: "The **coffee houses** were shut!"

back to page 1

Voice of industry

Leadership, data, innovation – our path to greater resilience

Europe's greatest strength lies with its citizens – in their inquiring minds and pioneering spirit, in their creativity and their freedom of thought. If we are given the scope to develop and flourish – and there is greater investment in education and research – Europe can emerge stronger from this crisis.

A guest commentary by Oliver Zipse, chairman of the board of management of BMW AG

"There's been an upsurge in digitalization, accelerated by the crisis, which is having a positive impact in many areas of society."

The coronavirus has stopped the clocks. Over a period of many weeks, public life has literally ground to a halt. We now have a crisis of global proportions that has both a public health dimension and an economic one. It is still unclear just how the pandemic will play out. But one thing is certain: the global economy will slide into a deep recession this year. The IMF forecasts a contraction of three percent. A lot of companies are in dire straits; some have already had to file for insolvency. In addition, there are stark regional differences, as evidenced by the figures for automobile sales: in the UK, for example, there were virtually no new vehicle registrations for the whole of April and well into May; in the Chinese market, however, sales for the BMW Group over the same period were higher than the previous year. In this situation, we need to ask ourselves about what might guide us in our attempt to steer companies and national economies back onto the path of growth and normality.

In a time of deep cuts and great uncertainty, decisions can have far-reaching consequences. It is therefore all the more important to ensure that the right decisions are made. Growing uncertainty can also lead to conflict about what is – or might be – the right way forward. It is up to those who lead to guide us across this unfamiliar terrain, to resolve conflicts and, especially now, to make sound decisions in preparation for the future.

Comprehensive data can help improve decision-making

Today, more than ever, we have access to the kind of extensive data that can help us improve our decision-making is better than ever. We need to take current market-forecasting models and supplement them with general data on, for example, the current status of pandemic research, best practice in crisis management, and measures adopted by individual regions. Live data on people's mobility and purchasing behavior as well as analytics on consumption, mobile working, travel and the use of public transit can all provide indications on the return of economic and social life. There has been an upsurge in digitalization, accelerated by the crisis, which is having a positive impact in many areas of society. It will make us more flexible and adaptable and therefore more resilient following this crisis.

Worked his way to the top: Oliver Zipse joined BMW as a trainee in 1991. He's been with the company ever since. In August 2019, he became chairman of the board of management of BMW AG. *© Thomas Meyer/Ostkreuz*

Oliver Zipse

...became a chairman of the board of management of BMW AG, responsible for production in 2015. He was previously director of the Mini plant in Oxford.

...studied IT and mathematics in Salt Lake City and mechanical engineering at the Technical University of Darmstadt, graduating with a degree in engineering.

...was born in Heidelberg on February 7, 1964, and grew up in Bensheim, a town in the State of Hesse. He is married and father to two grown-up sons.

Lots of companies are facing sharp cutbacks – including the BMW Group, which is now reviewing a host of projects. It is vital, however, to continue with the advance development of technology. Technology that is now at an early stage will provide us with an innovative edge in years to come. But any projects that are halted now may well be lost for ever. This means investment in vehicle software, including next-generation operating systems and connectivity. It also means investment in digital infrastructure and, as a concrete example, quantum computers, a project that Fraunhofer is helping to take forward on the European level. By contrast, traditional investment in fixed assets is easily postponed, without weakening a company's innovative strength. On the political level, this means that the current state investment to safeguard the existence of companies must be supported by a framework that will enable companies to grow of their own accord and without state support, and that will create a climate in which innovation can flourish. After all, the reason why many industries are now in difficulties is not because their business model has failed, but rather because decisions made by the authorities have prevented them from going about their business.

Europe's greatest strength lies with its citizens – in their inquiring minds and pioneering spirit, in their creativity and in their freedom of thought. We should encourage this and give them the greatest possible scope to develop and flourish, so that Europe emerges stronger from this crisis. This means positive initiatives rather than blanket bans, and greater investment in education and research instead of a future redistribution of income and wealth.

Opportunity for a real educational advantage

Adjusted for purchasing power, Germany's expenditure on education per full-time student is higher than the OECD average. Yet measured in terms of economic output, Germany's spending on establishments of formal educational represents 4.2 percent of GDP, well below the OECD average of 5 percent. So there is room for improvement, especially in the area of digital skills, where we can achieve a real educational advantage. That will make our economy more adaptable, more responsive and better equipped for the future. We therefore have what it takes to build up a high degree of resilience. ■

"We have what it takes to build up a high degree of resilience."

back to page 1

“The coronavirus is a stress test for our health care system, the economy and for society. So far, I think, we’ve all done pretty well.”

Markus Söder

Always a step ahead in the current crisis: Dr. Markus Söder (53), minister president of Bavaria, in the state chancellery, Munich.
© Niels Starnick/ Bild am Sonntag

“We can’t just press the reset button”

During the COVID-19 pandemic, Bavaria’s minister president Markus Söder has shown his qualities as a crisis manager. In an interview with Fraunhofer Magazine, he calls for a technological leap forward that will enable Germany to seize new opportunities.

Interview by Josef Oskar Seitz

Minister President Söder, it’s seldom so evident just what an enormous responsibility politicians have for protecting human life. How have you been sleeping in recent months?

Söder: There’ve been quite a few bad nights, particularly at the beginning of the pandemic. Back then, it wasn’t clear at all whether we would be able to cope. With the border to Austria and people returning from ski holidays, we had a high infection rate here in Bavaria and a lot of people dying every day. I was extremely worried – and there were many nights I didn’t sleep well at all. But we’ve achieved a lot in Bavaria over the last two months. The key indicators of infection have now improved to an extent where we can say that we have the virus under control. Bavaria has emerged from this crisis much better than others. That’s also thanks to the prudence and patience of its people. Since then, I’ve been sleeping a bit better.

Talking about resilience – how do you relax and refocus in these turbulent times?

It took a major effort on behalf of the entire Bavarian cabinet to overcome this crisis. We worked more or less around the clock. I managed to find time to relax and reflect while cycling or walking the dog. My family’s also been a real source of strength. And sometimes a prayer helps you gather your thoughts.

According to the opinion polls, you’ve done a great job in your role as a crisis manager. Did you feel that you had adequate support from the scientific community?

Definitely. We’ve followed medical science all the way. We’re in permanent contact with our specialist advisors from the fields of virology, epidemiology and from medicine and the university hospitals. I really can’t thank them enough for all their advice. I don’t really understand this criticism of the guidance given by virologists. You can’t criticize a doctor for the fact that you’re ill or that you don’t like the cure. The virus is the problem, not the virologists! We’ve also created a monitoring group for legal issues – with a theologian and two former presidents of the higher regional court in Bavaria. And we’re consulting with experts from the business world as to how we can best get the economy restarted after the crisis.

Science became part of the discussion perhaps more quickly than ever before. In which areas could the relationship between science, politics and the public be improved?

It’s an unprecedented crisis, and I think everyone has done a pretty good job so far. Sure, looking back, you can say that a few things could have been done better. Some people maybe wish that the scientists would hurry up and produce a vaccine, others that politicians might say something more long-term – about the summer vacation, for example. But it’s a new situation for us all. The coronavirus is a stress test for our health care system, the economy and for society. So far, I think, we’ve all done pretty well.”

“I was extremely worried – and many nights I didn’t sleep well at all. But we’ve achieved a lot.”

Markus Söder

It’s never been easier to gain access to information. So what’s the origin of the current craze for dubious stories, fake news and blind allegiance?

Perhaps that’s the problem: it’s now so easy to access information, but not all of it is trustworthy. You can get information quickly, but you still need to be able to handle it properly. You have to be willing and able to sort through that information. This means knowing what you can trust in the Internet, and what you can’t. In times of crisis, some people take refuge in simple answers. But they need to learn that the world is not that simple. And then there are those who deliberately stir things up and spread conspiracy theories in order to harm our country. These people are enemies of democracy, and we must combat them.

Which conspiracy theory is your personal bugbear right now? ▶

back to page 1

> "We must learn to stop looking at problems in isolation and think of them as interconnected. That's the big challenge. We therefore need an approach that's based on technology and digitalization, but we also need to make progress in the areas of climate protection and energy."
>
> Markus Söder

▶ I've every sympathy for demonstrations. Freedom of speech and freedom of assembly are pillars of our democracy. But there's been a clear attempt by some extreme groups to hijack and instrumentalize people's understandable desire for greater freedom. It's just scaremongering. Why, for example, would anyone talk about mandatory vaccination when there's not even a vaccine available yet? We all need to be very careful not to be manipulated. If you're at a demonstration, you should keep your distance both physically and intellectually.

Back to reality: Which strengths have helped us confront the crisis relatively unscathed here in Germany?

We've confronted this pandemic together – without falling into panic but with the utmost seriousness. The Bavarian authorities have worked in harmony with federal government and other federal states, and also with our neighbors abroad, such as Austria. The Bavarian government has worked hand in hand with the municipal authorities, the emergency services and local medical personnel. Everyone has done their job. We were able to ramp up capacity in our health care system in no time at all, while also taking rigorous measures to reduce the infection rate. This would have been impossible without the patience and support of the population throughout Germany. People across the country have played a big part in their support for the measures introduced to fight the coronavirus. I'd like to thank them all for this. We've been thankfully spared scenes like we've witnessed in Italy or Spain, or in the USA or the UK.

More and more people are saying: "Things will never be the same again!" What are we going to lose?

We should be asking: What can we gain? Daily life is not going to get back to normal until we have a vaccine. We're going to have to learn to live with the pandemic. We need to ask ourselves how we can be better prepared for such a challenge next time around. And we need to draw lessons from this crisis and become more resilient.

How can we gain from this crisis? And where might new opportunities arise for us to press ahead with the process of change?

We need a technological leap forward, here in Germany. In recent years, the gap to China and the US has grown – especially in areas such as digitalization, robotics and artificial intelligence. We need to redress that with a massive high-tech program on the national level.

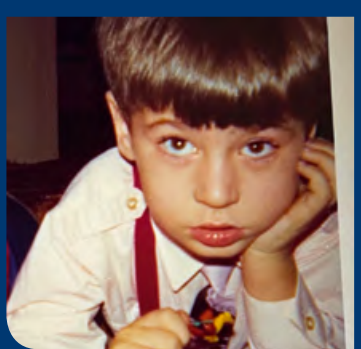
Are sustainability and value creation contradictory objectives?

Both will have to become even more closely entwined. We can't just press the reset button for the economy. Instead, we should be using this crisis as an opportunity to propel the economy in new directions. Those who say we can forget about climate protection, all we need is classic growth at any price will soon see that it's not so easy to do this in an economy that's been changed by globalization. We must learn to stop looking at problems in isolation and think of them as interconnected. That's the big challenge. We therefore need an approach that's based on technology and digitalization, but we also need to make progress in the areas of climate protection and energy.

Innovation is seen as the engine of the German economy. How can we ensure that research and development continue in times of crisis?

First of all, given our export problems right now, it's vital to stimulate domestic demand in Germany – for example, with an innovation premium for the purchase of low-emission cars. This will create further research incentives for the automobile industry. We also want to increase the maximum threshold for tax incentives for research and create other tax allowances. We need to think about ways of providing easily accessible, unbureaucratic support for new companies in their early years. And we need to accelerate our Hightech Agenda here in Bavaria and establish it on the federal level.

1974
Young Markus in a Christmas photo. There was always candy for good grades, recalls Bavaria's minister president, who graduated from high school with 1.3.
© Instagram



1986
Söder completed basic military service at Transport Battalion 270 in Nuremberg. He recalls his superiors attesting to a "lack of inner leadership."
© Instagram

1997
Söder's political career gathers pace – if initially on two wheels. Until 2008, he was chairman of the CSU regional association for Nuremberg-West.
© Instagram

Maintaining physical distance, but closer than ever on political matters – and now on first-name terms: the political protagonists of the coronavirus crisis, Federal Chancellor Angela Merkel and Markus Söder, chair of the conference of minister presidents, at a meeting in Berlin.
© *imago images*

Where does Germany need to be better prepared for future crisis events?

It's vital we continue to strengthen and expand our health care system. We also need greater national sovereignty with regard to certain emergency goods, including medical items, so that we're not dependent on international supply chains. Finally, we must avoid selling off key industries or companies in times of crisis. We need to take appropriate precautions to prevent this.

What can federal government do to support Bavaria – and perhaps other federal states too – in difficult times?

The chancellor has led Germany through this crisis in magnificent fashion. She deserves our full gratitude. In the initial phase of the crisis, the federal government presented an exceptional economic program that was unique in Europe and closely linked to the Bavarian program. The federal minister of finance attended a meeting of the Bavarian cabinet for the first time. We had an excellent, highly informed discussion that ended in an agreement in all respects. The federal minister of health has also been extremely active from the word go, ensuring that medical care has been made available. From our perspective here in Bavaria, this has all worked extremely well. Once again, I must express my gratitude for this support. I hope that this joint spirit continues into the restart phase that is about to begin. But outmoded economic ideas, such as debt relief for municipalities or so-called corona bonds, have no part to play here.

You are often named as a future chancellorship candidate. Does the idea of being able to achieve more for Bavaria and the federal republic as a future chancellor appeal to you?

My place is and will remain here in Bavaria. ■

"We should be asking: What we can we gain?"

Markus Söder

2004
Similar expressions, similar positions: as state secretary under former minister president Edmund Stoiber, acknowledged as Söder's mentor. © *ddp images*

2018
On top in Bavaria: appointed minister president, with 99 of 169 votes cast.
© *ddp images*

2020
On top in Germany: polls give Söder high ratings as crisis manager in the pandemic. In a May survey by Infratest, 53 of 100 respondents said Söder would make a good chancellorship candidate.
© *ddp images*

back to page 1

Keeping pace with the coronavirus

The time between the collection of a human tissue sample and the start of treatment must be kept as short as possible. Several projects at Fraunhofer MEVIS and IIS are giving pathologists a head start in their challenging fight against this disease.

Text: Sabine Spinnarke

The tissue from patients who died of the coronavirus is laid out on five glass slides arranged neatly on the tray resting in Dr. Carol Geppert's hands. A senior physician of pathology at Erlangen University Hospital, he examines the bright red areas in the fine structure of the lung tissue: edemas. "Everything here should actually be clear," says Dr. Geppert. When his colleagues performed autopsies on the first victims of the coronavirus, they found internal bleeding in the lungs and brain. "What we saw is important for physicians treating patients infected by coronavirus. Now they can try to minimize the risk of dysfunctional coagulation," explains the pathologist.

At RWTH Aachen, Prof. Ruth Knüchel-Clarke gathers the data from all post-mortem pathologies in a central register. Connectivity and digitalization are crucial to enabling a rapid and global response to novel viruses or even well-known diseases – but they are by no means a given in German pathological institutes. Dr. Geppert, his colleague Prof. Christoph Brochhausen-Delius, Vice Chair of the University of Regensburg's Institute for Pathology, and additional colleagues are working closely with the Fraunhofer Institutes for Integrated Circuits IIS and Digital Medicine MEVIS. Together, they are looking for solutions to digitalize pathology. "Our projects are aimed to optimize the workflow in the lab, to make AI diagnostic solutions more precise and robust, and to increase the transparency, and thus the acceptance, of AI in pathology," says Volker Bruns. As computer scientist, Bruns manages the medical imaging group at Fraunhofer IIS, where the medical experts are an ideal sounding board for him. Prof. Brochhausen also considers the interdisciplinary partnership to be an asset: "We thought some of the hopes for AI were mere pipe dreams, but then Volker Bruns and his team, with their specialized knowledge, were able to suggest potential solutions to us."

"Our projects are aimed at increasing the transparency, and thus the acceptance, of AI in pathology."

Volker Bruns, Fraunhofer IIS

Before pathologists are able to make a diagnosis, the collected tissue sample is first sent to the lab. This is where the PathoScan project comes in. Initiated by PreciPoint, a digital microscope manufacturer, the project's scientific partners are Fraunhofer IIS, the Technical University of Munich and the Institute for Pathology in Regensburg. "Tissue praparation requires a high degree of specialized knowledge and manual dexterity," says Prof. Brochhausen. The immense variations in the composition of human tissue is the reason why tissue is – unlike blood – very difficult to process in automatic systems. The hand-cut sections are no more than five micrometers thick – a hair is around 60 micrometers thick.

PathoScan maps the entire workflow from sample receipt to diagnostic findings: in the future, all information about the patient, the clinical picture and the requested tests will be digitally documented and evaluated and additional steps automatically and immediately set in motion. "If an examination requires a special stain, for instance, it can be prepared immediately," explains Prof. Brochhausen. This saves a bit of time, as these specimens used to have to wait before being sent to pathology for analysis. The system makes it possible, for example, to run a heart biopsy through the lab faster than a meniscus, which doesn't require treatment as urgently. PreciPoint and HTI Automation are developing systems for transporting and handling samples. Their microscopes and handling units ensure that, at the end of the chain, all samples are digitalized and automatically examined for quality defects. Unlike conventional devices, their systems can change the scanning order according to urgency and reject defective specimens right up until the end. This is an important point for daily routines.

Volker Bruns' team is training a neural network to discern specimen quality. "The AI gradually learns to decide independently whether the specimen is completely unsuitable, merely unsightly or okay," says Bruns. Since the labs at TU Munich and Regensburg University are widely disparate, PathoScan will one day permit universal use.

Cut by hand, the tissue samples are no more than five micrometers thick. The slices are dewatered, embedded in paraffin and covered. *© left Precipoint, right Sabine Spinnarke*

Geppert has now placed one of the glass slides under the microscope in his office. Around him are stacks of boxes and folders full of slides. The pathology department in Erlangen receives some 250 tissue samples daily. The lab's med-tech assistants process each one to obtain as many as 20 sections that are then presented to the 15 specialists for evaluation. In other words, the time available for each finding is short, and Dr. Geppert would love it if more AI solutions were already validated and approved for clinical diagnostic purposes. EMPAIA is expected to simplify this process. A joint effort between Fraunhofer MEVIS, Berlin's Charité hospital and other partners, EMPAIA is an ecosystem for AI-assisted, image-based diagnostics. "The EMPAIA project orchestrates manufacturers, certification bodies, pathologists and researchers to establish practical use of quality-assured AI solutions," says Fraunhofer MEVIS expert Dr. André Homeyer, who is involved in developing EMPAIA.

"A perfect task for AI"

On Dr. Geppert's monitor, marbled surfaces in white, pink and purple appear, streaked through with fine lines and wide lines – a mysterious landscape. The image originates from the camera on his microscope. The shapes and colors alone enable a pathologist to read the clinical picture, visualize the tissue integrated into the body in 3D, and assess which stage of the disease the patient is in. Analyzing shapes and colors – that's exactly what intelligent image processing was predestined to do. Dr. Geppert shows an example of how a Fraunhofer IIS algorithm can distinguish different types of tissue and find adenocarcinomas in intestinal tissue sections. On the associated scan, large areas have been highlighted in yellow with a marker. The physician points to the image: "The algorithm correctly identified the entire tumor here." The different colored markings for adipose, muscle, nerve and cancer tissue help to orient the pathologist. "The idea behind this is to more quickly discern the tumor invasion depth through other structures," he says. The exact resection margin is more difficult for the human eye to determine. "The Fraunhofer research tool may soon reliably find small regions of a specimen that may be relevant for a patient's prognosis, such as blood or lymph vessel invasion by a carcinoma," says Dr. Geppert. That would truly be a help because, if the patient weren't treated in this case, the tumor could continue to grow undetected.

The AI projects are also aimed at better structuring findings. "Automatic tissue phenotypization opens up many opportunities to precisely characterize a tumor and its microenvironment and thus forecast the patient's individual risk," says Bruns. Image analysis reveals its strength in additional projects at Fraunhofer MEVIS, where novel image-based biomarkers are being developed. These are special algorithms that use pathology images as a basis for predicting tumor aggressiveness or treatment outcome. "In pathology, research on image-based biomarkers is still in its infancy," says Homeyer. The algorithms developed at Fraunhofer MEVIS use complex tissue patterns to calculate a score. "This is a perfect task for AI. A human cannot chart thousands of cancer or immune cells and their patterns," says Homeyer.

The combination of AI's strengths and pathologists' store of knowledge and experience is ideal for mastering medical challenges from tumor diseases to novel viruses. For Prof. Brochhausen, it would be enough if, as a first step, he and his colleagues could digitally share and discuss their histological, ultrastructural – the fine structures visible under an electron microscope – and molecular findings. This leaves room for additional interesting projects in a field that Homeyer speaks of in a way that sounds almost like a declaration of love: "No field is more fascinating than pathology. It has been around since the 19th century. Today it uses the latest diagnostic tools, such as immune biomarkers and molecular tests, to thoroughly characterize complex diseases, thus laying the foundation for targeted and successful therapies." ■

"No field is more fascinating than pathology."

Dr.-Ing. André Homeyer, Fraunhofer MEVIS

back to page 1

New life despite drought

Water is a scarce commodity, as recent hot summers have made very clear. Specially treated wastewater can serve as a new source – for instance for growing vegetables.

By Christine Broll

The greenhouse is located on the grounds of the wastewater treatment plant in Wolfsburg-Hattdorf, right next to the clarification tank. Inside, the succulent green heads of lettuce grow in neatly ordered rows of long plastic tubes. Their roots extend, not into soil, but into a special nutrient solution – specially treated wastewater.

The Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB teamed up with 11 partners in a recently completed research project, HypoWave, to investigate the reuse of purified wastewater in agriculture. When the project was launched in late 2016, no one had any idea how dry the summers of 2018 and 2019 would be – the research became increasingly relevant from one year to the next.

The location of the HypoWave greenhouse – on the grounds of a Wolfsburg wastewater treatment plant – was chosen, in part, for historical reasons. "Unlike in the rest of Germany, the Braunschweig/Wolfsburg area has a long tradition of irrigating fields with treated wastewater," explains Dr. Marius Mohr, head of the water technologies and resource recovery innovation field at Fraunhofer IGB and one of the initiators of HypoWave.

But the treated wastewater is not used directly in the greenhouse, as it could contain pharmaceutical residues, heavy metals, industrial chemicals or pathogenic bacteria and viruses. The HypoWave partners tested various technologies for treating the wastewater in Wolfsburg-Hattorf. ▶

Lush green even during very dry periods? The HypoWave project is creating new opportunities by using wastewater in smart ways. © *iStock*

back to page 1

▶ Ozonation and using an activated carbon biofilter proved to be particularly effective. Ozonation eliminates pollutants and pathogens through oxidation with ozone. While ozonation is already used in wastewater treatment plants today, treatment using activated carbon biofilters is new. The advantage of these filters is that they can both adsorb and biologically degrade pollutants.

"We did not detect elevated concentrations of pharmaceutical residues or pathogenic germs in the lettuce we irrigated with water from the activated carbon biofilter," says Marius Mohr, whose team is working to further improve the stages of wastewater treatment.

"We did not detect elevated concentrations of pharmaceutical residues or pathogenic germs."

Dr. Marius Mohr, Fraunhofer IGB

How well the lettuce plants thrive in the greenhouse was the investigation focus of Dr. Jörn Germer's working group at the University of Hohenheim. The fact that the plants are not grown in soil was nothing new – cultivation in nutrient solution, known as hydroponics, is already used on an industrial scale in fruit and vegetable production. The team of agricultural ecologists focused mainly on nutrient supply. "Wastewater contains relatively high levels of nitrogen and phosphorus, but comparatively little potassium and micronutrients such as zinc and iron," says Germer, so these nutrients had to be supplied.

In the first year of the study, water still flowed through the pipes permanently, but in the following year, the research team experimented with a recirculation system. Nitrate sensors continuously monitored the nitrogen content. If it dropped below ten milligrams per liter, the water was reconditioned. "Not only did this enable us to boost our production level," says Germer enthusiastically, "we were also able to remove nitrogen and phosphorus from the wastewater far more extensively than conventional treatment plants."

Studies test acceptance

To get their new technology into applications as quickly as possible, the researchers investigated the levels of interest and acceptance in various regions by bringing together wastewater associations, farmers and sellers. They analyzed how the concept was implemented in a rural area – the district of Gifhorn, north of Braunschweig – and in another case study they looked at the Rhein-Main metropolitan region. In Raeren, a municipality in Belgium, the concept was applied to the cultivation of cut flowers, and in Portugal's Alentejo region, wastewater was used in hydroponics and, subsequently, to irrigate olives, almonds and wine.

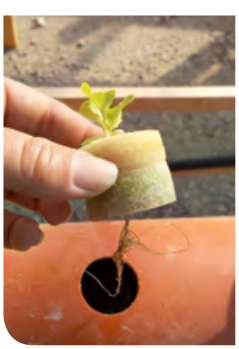
Greenhouses could replace wastewater treatment plants

Interest in Weißenberge, in the district of Gifhorn, was particularly great. Here, one farmer was so convinced of the project that he is prepared to invest in a greenhouse. The Gifhorn wastewater association plans to invest in it too, as they expect the project to yield cost savings. The wastewater from Weißenberge, a town with a population of around 500, is currently fed into a treatment pond where it stays for about 90 days before being discharged into a stream. The long-term plan is to connect the municipality to a wastewater treatment plant, which requires major investments.

"If we succeed in significantly reducing the nutrients in the effluent from the treatment pond in the hydroponic greenhouse, Weißenberge wouldn't need to be connected to a wastewater treatment plant," explains Mohr. He plans to team up with some local partners there in a follow-up project, HypoWave Plus, to explore how that could be done.

"Since the farmers in the Gifhorn district were questioning how they were going to irrigate their fields the last two summers, interest in implementing a project of this kind has risen considerably," says Mohr. The water treatment facility is set to be built and tested next spring, enabling him to run his greenhouse with plenty of water in 2022. He plans to grow cucumbers, tomatoes and bell peppers, and he already knows how he's going to sell them: the local Edeka supermarket is one of the partners in the research proposal and will add his vegetables to its product range.

Marius Mohr is looking to the future. He aims to use the lighthouse project in Weißenberge to make this technology known and get more people interested in it. ■



From seedling to lettuce: the recirculation system is equipped with nitrate sensors to monitor nitrogen levels, and the water is reconditioned as needed. © *ISOE Wikom*

Love the smell, hate the smoke!

Grilled food is trending, also in the restaurant business. Patrons love the taste – and neighbors often hate the smell. Fraunhofer IBP is working on alternative grilling technology to improve air quality and reduce particulate matter – and promote good neighborly relations.

Text: Britta Widmann

Rule of thumb for grill exhaust gas: the higher the fat content, the more problematic the emissions. © *Adobe Stock, istockphoto*

Dr. Mohammad Aleysa, an engineer by profession, carefully places the skewered meat on the grill. As the head of combustion and environmental technology at the Fraunhofer Institute for Building Physics IBP in Stuttgart, the researcher is not grilling for his personal pleasure, but on behalf of the German Environment Agency. He and his team are investigating what pollutants commercial restaurant facilities such as charcoal grills and pizza and bakery ovens emit, as well as what methods could help minimize odors and fumes. ▶

back to page 1

"Our research shows that restaurants are using technically unsophisticated grill technology."

Dr. Mohammad Aleysa, Fraunhofer IBP

▶ **Restaurants are increasingly** offering their customers food items prepared on the grill – or at least many communities are seeing growing numbers of charcoal grills. The problem is that grilling food over charcoal pollutes the surrounding air with particulate matter and many other incompletely combusted exhaust components. Local residents are often annoyed and frustrated by the smoke and unpleasant odors – and concerned about the possible health implications of the polluted air. The staff in these restaurants, too, are directly exposed to any grill smoke that inadequate extraction systems fail to remove. Many restaurants do not use exhaust air treatment systems, and not all systems operate efficiently.

Dr. Mohammad Aleysa is taking on this issue for Fraunhofer IBP. Years of experience in developing and researching combustion technologies and exhaust gas treatment systems have turned him and his team into experts. The results of their tests on the efficiency of commercial air treatment systems will be published in mid-2021.

"We're evaluating how effective standard, commercially available exhaust air treatment systems really are for use in restaurant operations and whether they ensure good air quality in the local vicinity, especially in residential areas," says Aleysa. To perform their experiments, the researcher set up a commercial grill with a one-meter-high, five-stage exhaust air treatment system in the Fraunhofer IBP lab. "This kind of system, which comes in a range of technical specifications, is used by many commercial eating establishments."

"Unsafe levels"

To complete their experiments, the researchers cooked large quantities of fatty meat on the grill. Aleysa's measurements revealed not only nitrogen oxides and carbon monoxide but also particulate matter and benzene as well as polycyclic aromatic hydrocarbons (PAHs), many of which are known to be harmful to human health. PAHs are produced primarily by the incomplete combustion of fats and oil-based marinades. "The higher the fat content of the skewered meat, the higher

the emissions," says Aleysa. The fumes are caused mostly by fat as it gradually smolders and carbonizes.

Of course, the fuel used also contributes to the formation of numerous pollutants through the process of uncontrolled combustion required to create a bed of embers over which food can be grilled. So what quantity of pollutants would a grill typically be expected to produce each year?

A 0.5-square-meter active grilling surface yielded between 400 and 500 kilograms of fine and ultrafine particulate matter. The amount of hydrocarbon measured was three times as high, at 1.5 metric tons. "Those are unsafe levels," says the engineer. "Considering that commercial charcoal grills operate for longer periods, they are approximately 300 times higher than for a normal wood-burning stove."

They plan to run software simulations to show, whether raising the chimney height would achieve better distribution of the pollutants in the ambient air, thus eliminating unpleasant odors. "We suspect that this will merely shift the problem. Instead of bothering the immediate neighbors, the fumes will just annoy the neighbors further away," says the researcher.

Fraunhofer technology improves air quality at lower cost

"Our research so far shows that restaurants are using technically unsophisticated grill technology without an efficient combustion concept, says Aleysa. To address this issue, the researchers at Fraunhofer IBP are currently working on an in-house developed, already patented solution, which they are combining with innovative grill technology. They expect it to reduce the amount of exhaust gas by 90 percent. Their system treats the fat before unpleasant odors arise. Unlike commercially available systems, which can incur costs of up to 70,000 euros depending on their size and technical configuration, the Fraunhofer system can be more cost-effectively. It is currently at the prototype stage, but the team hopes to have it completed by late 2021. ■

The solution? Patented and prototyped, it is expected to go to market in 2021 and reduce the amount of exhaust gas by 90 percent.

A 0.5-square-meter grilling surface yields up to 500 kilograms of fine and ultrafine particulate matter – per year. © *David De Stefano / offset*

back to page 1

Fraunhofer worldwide

ULi is making the oceans safer

Netherlands

To systematically track down mines, bombs or torpedoes on the ocean floor, the key is to reliably identify their characteristic shape. This is no problem for the innovative technology developed by researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM in collaboration with partners from the Netherlands and Denmark.

Conventional measurement methods reach their limits in turbid water, so the partners in the LUXOR research project are pursuing an alternative approach based on LiDAR technology and automated object recognition using artificial intelligence. The Fraunhofer researchers expanded their underwater LiDAR system ULi to include a video mode that also permits large areas of the environment to be scanned with the laser scanner. ULi then delivers 3D video data in real time, even in turbid water. Now the researchers want to convert this technology to an automated process that includes analyzing and providing digital measurement and mapping data of the detected weapons in a data cloud – and thus makes retrieval safer and significantly less expensive.

ULi has a lot to do: there are vast numbers of world-war munitions lying on the floor of the North Sea and the Baltic Sea – 1.6 million metric tons in German waters alone. Not only does their increasing corrosion release chemical substances, there is also danger of explosion. This causes major problems when building wind farms or relocating submarine cables and pipelines.

A clean solution: copper-free brake pads

Copper dust from high-performance brakes enters the water through the sewer system and is considered to be highly toxic. Fraunhofer researchers have joined forces with Danish partners to develop an environmentally friendly alternative.

Sintered brake pads for rail vehicles, wind turbines, heavy construction vehicles, and high-end motorcycles and mountain

Early detection of malaria saves lives

Portugal

Microscopic blood analysis is the main pillar of malaria diagnostics, but it is time consuming and costly. Healthcare in the affected regions is often inadequate, and trained personnel rare. This is precisely the kind of situation for which the "µSmartScope", developed at the Fraunhofer Center for Assistive Information and Communication Solutions AICOS in Portugal, now offers a solution.

A multidisciplinary team led by Luís Rosado developed a mobile, fully automatic, 3D-printed microscope that is powered and controlled by a smartphone. The blood smear and the smartphone are placed in an adapter, and magnified images are captured using the built-in camera. Artificial intelligence can be used to process and analyze these images and make a preliminary diagnosis, and off-site experts can also be brought on board to offer a remote diagnosis or a second opinion. In the World malaria report 2019, the WHO put the number of new cases at 228 million and deaths at 405,000, most of which were children under five years of age. Only about one in five new cases is detected early. A timely diagnosis can not only prevent severe illness, it can also reduce the risk of transmission.

The "µSmartScope" prototype was also successfully tested with other diseases such as cervical cancer and leukemia. It has the potential to become a fast, precise and economical aid for medically underserved regions.

bikes normally have a copper content of as much as 50 percent. They are far superior to the brakes with organically bonded pads used in cars and trucks in terms of temperature resistance, braking performance, wear and abrasion. To protect the environment, these brakes will no longer be sold in the US states of Washington and California starting in 2021, and by 2025, all brake pads there must be nearly copper free. "It is expected that these rules will be extended to other states, as well," says Gunnar Walther, head of the sintered and composite materials department at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden.

Together with the Danish Technological Institute and industry partners, Walther and his colleagues in the Green Pad project developed an iron-based sintered brake pad, initially for motorcycles. It comes very close to the specific friction characteristics of copper or nickel-based pads and could reduce copper emissions by 600 metric tons annually – that's about 25 percent of all copper brake wear in Europe. "Generally speaking, this could be extended to many other applications," says Walther.

Denmark

Australia

The search for the active ingredient

Scientists all over the world are working on drugs against the novel coronavirus SARS-CoV-2. The greatest obstacle in this process is the so-called valley of death between the discovery of new active ingredients and their development into viable drugs. The iCAIR® research consortium is closing this gap in the drug development chain.

Within this consortium, the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM is working with the Institute for Glycomics (IfG) at Griffith University in Australia, the Hannover Medical School (MHH) and the Helmholtz Centre for Infection Research (HZI) to develop new active agents against respiratory tract infections. Now, iCAIR® has expanded its spectrum to include the search for an effective drug against the coronavirus.

To this end, the researchers are combing through substance libraries at IfG, HZI and Fraunhofer IME to find substances that hinder the propagation of SARS-CoV-2 in cells. Their focus here is on agents that are currently in clinical trials or have already been approved. The selected substances are chemically enhanced, and their efficacy and tolerability tested on human lung slices. To do this, the ITEM researchers use a specially developed infection model with viable lung tissue that permits a detailed analysis of the biological and immunological reactions to the virus in the deep lung – where the coronavirus causes the most damage.

back to page 1

One advantage of using VR technologies in the classroom is that it bolsters the future engineers' visual thinking.
© *Fraunhofer IAO, Ludmilla Parsyak*

Learning in new dimensions

Thanks to technological advances, falling costs and coronavirus-induced urgency, opportunities for digital technology in education are better than ever before. For engineering students at the University of Stuttgart, virtual reality will become a standard component of the curriculum from summer semester 2021.

By Marina Babl

Everyone learns on their own, as students of all ages have come to understand during the current pandemic. This has led to an urgent search for new learning venues that make education and knowledge sharing a social experience once again – especially through the use of virtual reality (VR) technologies.

With an estimated sales volume of around ten million units in 2019, VR headsets are still largely a niche product – approximately 150 times more smartphones were sold in the same period – but demand is clearly on the rise. The past year alone saw an increase of around 20 percent.

With a funding of **1.8 million euros,** Germany's Federal Ministry of Education and Research will support five projects addressing application-oriented research into concepts for learning and teaching using virtual and augmented reality at universities. One of these projects is titled "Virtual reality in university education in engineering," or ViRAI for short. It is being conducted by the Institute of Human Factors and Technology Management IAT at the University of Stuttgart in close cooperation with the Ludwig Uhland Institute, which is the Department of Historical and Cultural Anthropology at the University of Tübingen, and the Fraunhofer Institute for Industrial Engineering IAO.

The use of VR here is not merely a stopgap solution, nor is it a simple gimmick: "Our goal is to use VR as an aid to make our students better designers, better product developers, and thus better engineers," says project coordinator Dr. Manfred Dangelmaier.

He and his team were intent on expanding their digital educational opportunities even before the pandemic began – not least because they were constantly seeing new generations of engineers having difficulties with visual thinking and the proper use of CAD software to develop three-dimensional products such as machinery gears. Using VR in the classroom can help on multiple levels: "Of course students should be introduced to virtual reality as a tool, on the assumption that it will soon become more widely available – also in the workplace. In addition, letting them experience VR will hopefully inspire them to make better and more efficient use of the tools they're already using – that is, 3D-CAD systems," explains Dangelmaier.

It is expected that the new technology will be introduced at the start of summer semester 2021 in the "Fundamentals of product development" and "Virtual engineering" events for students in the bachelor's and master's programs. The university is currently conducting a situation analysis and recording the requirements of instructors and students. The team in Stuttgart is being assisted by the cultural anthropologists at the University of Tübingen, external project partners who want to study cultural changes within digital instruction.

But the greatest challenge for the months ahead, according to Dangelmaier, will be providing the students with the best possible array of necessary equipment. "We have absolutely no experience with this yet." Even if VR technologies now cost only a fraction of what they did twenty years ago, a high-quality graphics workstation and head-mounted display still cost a few thousand euros. So we can't possibly expect students to purchase the equipment themselves, says Dangelmaier. Instead, the university will provide as broad a range of the technologies as possible – not for the large lecture events themselves, but for the corresponding on-site exercises.

This is an ideal environment for students to familiarize themselves with the VR headsets, since the exercises are generally very interactive. The students work in groups, largely independently, on individual projects. "And VR is just another tool they are given to solve their tasks together," explains Dangelmaier. The role of instructors is changing, too. In the context of digital education, they are no longer responsible solely for imparting knowledge, but are increasingly taking on the function of advisor and coach.

Manfred Dangelmaier expects to see increased use of VR in schools in the next few years, too – provided that the costs continue to drop. This would mean, for instance, that field trips to ancient Greece or into the human body would suddenly be within reach. This, in turn, would yield great learning success: numerous study results suggest that the use of VR in the educational context boosts performance and motivation in students, as well as improves their social, motor and cognitive skills.

The engineering students at the University of Stuttgart are already looking forward to the curriculum changes, and Manfred Dangelmaier is optimistic, too: "With ViRAI, we are helping to make VR an essential engineering tool for students." As soon as this project has gotten well underway, he can also easily envisage expanding the concept to other lectures and areas of study. ■

"Our goal is to use VR as an aid to make our students better designers, better product developers, and thus better engineers."

Dr. Manfred Dangelmaier, project manager

back to page 1

Modern-day pirates

Germany's mechanical and plant engineering sector is seeing unprecedented levels of product piracy, with damages totaling 7.6 billion euros annually – up 300 million euros from just two years ago. Yet only a few companies take action against this brazen theft of ideas.

By Dr. Sonja Endres

Similar, but not identical: more than half of all pirated goods put equipment at risk, and a third of them also pose a threat to the operators of that equipment.
© *picture alliance/Jürgen Lösel*

The fight against product piracy is a tedious one. The "Product Piracy 2020" study shows that small and medium-sized companies, in particular, are reluctant to take action against infringers. Germany's Mechanical Engineering Industry Association (VDMA) has conducted this study every two years since 2003 and now, since 2018, it does so in collaboration with the Fraunhofer Institute for Applied and Integrated Security AISEC. The institute provides, for instance, systematic risk analyses and develops individual protection strategies.

Only one third of mechanical and plant engineering companies with fewer than 250 employees take action against this illicit reproduction, despite them, too, seeing an increase in product piracy. In 2016, 55 percent of these companies fell victim to counterfeiters; now that figure has grown to 64 percent. "As sales grow, so too does the incentive for product pirates to get in on this success," says Ferdinand Jarisch, who headed the study for Fraunhofer AISEC. Of the participating large companies with more than 500 employees, 90 percent are affected. Here, however, the infringers can expect to encounter greater resistance: half of all major companies do not stop at a warning letter or a letter from their attorney, but take the matter to court. Among SMEs, only one in ten go that far. The costs and duration of civil proceedings deter them, as do the uncertain prospects of success in foreign jurisdictions. "Companies should consult with specialists who are familiar with the legal framework and who have experts on location. For China, for instance, that's Chinabrand GmbH," says Steffen Zimmermann, head of industrial security at VDMA. The study shows that China remains the country where the largest percentage of counterfeit products worldwide are sold, with 61 percent. Germany comes in a distant second with 19 percent, followed by Russia in third place with 12 percent. China also leads in the manufacture of counterfeit goods, at 82 percent, as the previous study for 2018 showed.

Don't give up – take action!

Even though victimized companies refrain from pursuing legal recourse, they shouldn't let the idea thieves get away with it. "It's like with a child that doesn't get disciplined. If I do nothing, it just keeps getting worse. Counterfeiters always follow the path of least resistance," says Zimmermann. In his experience, even a warning letter that threatens consequences often helps. "Counterfeiters operate more easily under cover of anonymity than when they know they've been caught and are being watched." In most cases, it is competitors who produce the counterfeit goods (72 percent), but customers, suppliers and spare parts vendors also copy products. The resulting loss of sales is not the only damage the affected companies suffer – the loss of image caused by low-quality imitations is considerable as well.

It's best not to let it come to that in the first place. "The earlier companies get us involved, the more we can do. It is advisable to contact us as early as the design phase for new equipment," says Bartol Filipovic, head of product protection and industrial security at Fraunhofer AISEC. Ideally, protection can then also be combined with additional benefits for the customer. "A chip in mechanical components such as sensing arms could, for instance, recognize a part as an original while at the same time helping to align it correctly," Filipovic explains.

In only 36 percent of all cases are entire machines copied; in 64 percent, counterfeiters focus on individual components. "It gets expensive when a machine stands idle for a long time. Using normal channels, spare parts usually require four to six weeks for delivery, making it very tempting to resort to imitations from online shops," says VDMA's Zimmermann. That's why it's better to equip machines with self-protection mechanisms right from the start, enabling them to recognize imitations as imitations. If the machine is damaged by low-quality spare parts, the original manufacturer is stuck with the problem, rather than the repair service that installed the part. The manufacturer must provide proof that the replacement part is not an original.

Equipping machines with self-protection

Encrypting the machine's operating software, otherwise known as firmware, also serves to protect the machine. "Value creation will increasingly be achieved through machine software. Digital protective measures are the future," says Zimmermann.

That is precisely what Filipovic and his colleagues at Fraunhofer AISEC specialize in. The most secure option is to combine software protection with hardware. "The firmware can, for example, process authentication queries from security features in the hardware. For this, we use cryptography mechanisms, which we are very familiar with and know how to implement on a variety of hardware platforms. We offer developers tools they can use to secure their firmware. Not all methods are equally suitable in all areas, but we are well versed in encryption, manipulation-resistant programming and masking critical functions," says Filipovic.

When planning the security strategy, Filipovic and his team identify access routes for attackers. "We work with the customer to prioritize issues and think about where it hurts the most. Then we close those security gaps. There is no such thing as 100 percent protection – that would be too complex and expensive. But we can make it extremely difficult for counterfeiters to have their way." ■

> "Counterfeiters always follow the path of least resistance."
>
> Steffen Zimmermann, head of industrial security at VDMA

back to page 1

Cape Canaveral, Florida, USA, May 30 at 15:22 local time: For the first time in nine years, astronauts are launching from the US, and for the first time, a private company, Elon Musk's SpaceX, is transporting astronauts to the International Space Station (ISS).

Where a screw becomes a hand grenade

Traffic chaos in orbit: how can we protect satellites from collisions with space debris? Fraunhofer FHR has answers.

By Dr. Janine van Ackeren

The world watched in awe as Elon Musk of Tesla fame sent a manned rocket to the International Space Station (ISS) on May 30. A giant leap for his company, SpaceX, with small legacies in space. As with every rocket launch, space debris is left behind. Currently, there are around 750,000 man-made objects larger than one centimeter hurtling through space, which can be dangerous for satellites and space stations. In low Earth orbit, even a simple screw can develop the destructive force of a hand grenade. In the low Earth orbits, where satellites circle the globe, they can collide with a relative speed of up to 28,000 kilometers per hour. ▶

Dangerous debris: some 6500 metric tons of scrap metal are orbiting the Earth – from lost screwdrivers to burnt-out rocket stages. © *NASA*

back to page 1

"We can now determine distance one hundred times more precisely."

Dr. Jens Klare, Fraunhofer FHR

▶ **The US-based Space Surveillance Network (SSN)** continuously monitors 30,000 objects and continually updates their orbits. If the orbiting objects always remain in view, countermeasures can be initiated in good time in the event of impending danger. Satellites can fly avoidance maneuvers to prevent a collision, but this consumes a lot of fuel. If the satellite needs to avoid collision often, this will shorten its service life, as well as entailing high costs. In other words, the orbital trajectories have to be determined as precisely as possible to keep the number of unnecessary avoidance maneuvers low. Only precise data will help provide a reliable response to the key question: would the satellite collide with the projectile on its current orbit, or will it pass a hair's breadth away?

Damage to the Hubble space telescope, which was launched into orbit in 1990. © *ESA*

The space observation system TIRA, which stands for "Tracking and Imaging Radar" and was developed by the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, provides the answers. The system is unique within Europe – it can even still discover objects of just two centimeters in size from a thousand kilometers away. "TIRA combines a tracking radar and an imaging radar with a high-agility, 34-meter parabolic antenna," says Dr. Jens Klare, spokesperson for the security business unit at Fraunhofer FHR. To put it another way, this enormous radar can not only track satellites and space debris, it can also capture images of them.

Now the research team has even enhanced its precision further still: in the EU EUSST project, it developed a new method that enables even more precise measurements of the orbits of these types of objects. "We can now determine distance around one hundred times more precisely than before," says Klare. The researchers use highly complex mathematical methods to merge the data from these two TIRA radars. Previously, only the tracking radar was used to determine the orbits of space objects. A measurement campaign with the German Space Situational Awareness Center has already shown that this approach works – it used TIRA to monitor special reference satellites. Comparison measurements using a laser beam provided the satellite's precise position, and therefore comparison data: the laser beam was reflected off of reflectors mounted on the reference satellite, and its transit time permitted a precise position determination. However, these laser measurements are not suitable for general measurements, as they only work when the sky is free of clouds. Furthermore, space objects have to be equipped with appropriate reflectors to enable these highly precise laser measurements. This shows the key advantage of radar. The researchers aim to further refine the mathematical methods through late 2021. Then this new mode should also be available for routine measurements.

Observing space – with TIRA and GESTRA

Tracking down and imaging satellites and space debris in orbit requires two different radar systems: one that monitors a large section of space and discovers everything that passes through it, and a second one that precisely tracks and images individual, interesting space objects found by the first. The latter can be handled by TIRA, which is located at Fraunhofer FHR and is the only space observation system of its kind in Europe.

In contrast, observing a large section of space requires a special radar with high range and beam agility, which, however, was previously lacking in Germany. That's why the German Federal Ministry for Economic Affairs and Energy commissioned Fraunhofer FHR to build such a phased-array radar. What is unique about GESTRA is that it is mobile. In other words, it can be set up anywhere. On June 30, a heavy-goods vehicle transported it from the Fraunhofer FHR premises in Wachtberg, near Bonn, to Koblenz, where it was connected to the German Space Situational Awareness Center of the German Armed Forces in Uedem, in Germany's Lower Rhine region. This is now the home of the system's remote control center.

Selectively removing space debris

Tumbling rocket stages are a particularly problematic class of space debris, as many still have fuel remnants in their tanks. This often results in explosions that trigger a cascade effect: instead of one large piece, now numerous smaller fragments are floating through low Earth space, increasing the probability that one of these objects will hit a satellite and damage or even destroy it. For this reason, space agencies are now launching initial attempts to remove space debris.

Where it rains rockets: fallen space debris in the boreal forest near the Plesetsk Cosmodrome, the spaceport 800 kilometers north of Moscow.
© *Raffaele Petralla*

The ESA, for instance, is planning a test mission for 2025 in which they aim to capture an adapter for coupling the rocket upper stage and the payload. Both in the run-up to and during any such actual mission, it is important to obtain as much information about the object as possible: How fast is it spinning? In which direction is it rotating? How is it oriented in space? What condition is it in?

With the space observation radar TIRA, Fraunhofer FHR can provide the necessary data for these kinds of missions, as well as assist with both planning and execution. It is already using TIRA to provide support services, both nationally, for the German Space Situational Awareness Center in Uedem, and internationally, for the ESA, for example. "In 2019, we conducted, for instance, a damage analysis on the upper stage of a Japanese launcher," says Nora Egli, a researcher at Fraunhofer FHR. To ensure that the imaging needed to do this is as sharp as possible, the rotation speed of the rocket stage must be known as accurately as possible. This means that we need to determine precisely how fast it is rotating and in which directions. Since it can rotate about several axes at once, its movement can be extremely complex. During a transit, TIRA observes the object from various angles, typically for 8 to 12 minutes.

Using algorithms they developed themselves, the researchers analyze a sequence of radar images to estimate the rotation speed. Using these radar images as a guide, they create a digital 3D model of the object – so in this case, the rocket's upper stage. They then adjust this 3D model using a longer sequence of radar images and estimate the rotation rate based on the sequence of movements. If the movements of the 3D model and those of the radar images coincide throughout the transit, then the speeds are correct as estimated, and if not, then they have to be readjusted accordingly in an iterative process. "In this way, we can, for example, perform condition analyses and rotation analyses of key objects for space debris removal – and answer the question as to the most suitable method for recovering it: a net, or preferably a robotic arm," says Egli. The Fraunhofer researchers are thus helping to make low Earth orbit a little safer for satellites, step by step. ■

"We can perform condition analyses and rotation analyses of key objects for space debris removal."

Nora Egli,
Fraunhofer FHR

back to page 1

Disinfecting cell phones: beware of cheap devices

Smartphones are ideal breeding grounds for fungi, bacteria and viruses. UVC light kills them, but many irradiation devices don't deliver what they promise.

By Dr. Sonja Endres

Hand hygiene also includes cell phones," admonished the Techniker Krankenkasse, one of the leading public health insurers in Germany, in the face of rising numbers of coronavirus infections. But acting on this advice is difficult: Disinfectants destroy the displays' sensitive, oil-repellent protective film. According to a 2019 survey by Telefónica Germany AG, during leisure time, only 22 percent of all respondents put their smartphones down for longer than 60 minutes. Among 18- to 29-year-olds, this figure was just 7 percent.

There are commercially available disinfection devices that use UVC light to kill germs, but they usually give their owners a false sense of security.

"Their output is often far too low to disinfect smartphones in a reasonable timeframe," warns Thomas Westerhoff, who is researching the disinfecting effect of UVC light at the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB in Ilmenau. They frequently have other shortcomings, too, including being lined with non-UV-reflective materials, thus absorbing a lot of the radiation. Or using too small, inefficient mercury-vapor lamps with a long heat-up phase instead of LEDs. "Some devices don't even emit UVC light, but merely violet or UVA light that has almost zero effect," says Westerhoff.

And all of these devices, without exception, have one major flaw: they don't measure the actual radiation dose emitted. "This, however, alongside wavelength, is the key parameter for disinfection efficiency. Measuring the radiation dose is the only way to ensure that the radiation source is operating at full power and that it is also reaching the cell phone," says Westerhoff.

An innovative UVC device developed by Westerhoff and his team in collaboration with physicians at Jena University Hospital offers an alternative. It looks like a microwave, but it really packs a punch: irradiated smartphones are not only largely germ-free in seconds, but actually hospital-standard sterile. Tablets fit in this device, too.

The required radiation dose varies by pathogen. In the case of the widespread Escherichia coli bacteria, for instance, which can cause diarrheal diseases, just 2 to 6 millijoules per square centimeter are sufficient to kill 99.99 percent of them – only then do experts consider it disinfection. For the SARS-CoV-1 coronavirus, this dose will inactivate 90 percent of the pathogens, while disinfection requires around 48 millijoules. At present, no reliable data is available for the current SARS-CoV-2 virus. Until this changes, and because there can be variations within a pathogen type, it is better to irradiate too much than too little.

The optimum wavelength of the UVC light is 265 nanometers. "Here, the radiation energy is equal to the bond energy of the nucleic acid thymine. The thymine's chemical bond is broken, causing adjacent molecules to "stick together" and rendering the DNA no longer readable, so the cell cannot reproduce," explains Westerhoff.

Fraunhofer IOSB's disinfection device is equipped with two UVC LED irradiation modules (top and bottom) with the appropriate wavelength. They achieve a radiation dose of 80 millijoules per square centimeter in just seconds. The smartphone lies between them on a UVC-transparent quartz glass plate that permits the light to shine straight through unobstructed. The interior walls of the device are highly reflective, and the radiation field is homogeneous. "This ensures that every square millimeter of the smartphone gets the same dose," says Westerhoff.

The disinfection operation is monitored by sensors that measure the intensity of the radiation, and it only stops when the minimum radiation dose has been achieved. Since the UVC device was developed for use in clinics, where smartphones and tablets are used for a variety of tasks and are passed from hand to hand, it is additionally equipped with an NFC reader that identifies the smartphone and, via a sensor, measures and logs the dose applied. Each disinfection operation is thus documented and can be individually attributed, ensuring safety.

A prototype of the new device is already available. Fraunhofer IOSB is still looking for a business partner for its commercial exploitation. Furthermore, the researchers have developed a UVC disinfection solution for ambulances that lets users kill germs on surfaces and in the air at the touch of a button. The first ambulances equipped with this solution are set to enter the market in the fall. ■

Cell phones are in use even while **watching TV**: the younger the respondents, the greater the share of second-screen use. Among 18- to 29-year-olds, 57 percent regularly use their smartphone while watching television.

57%

86 percent
of respondents share their digital experiences, photos or videos
while on the go.

More than 80%
of 18- to 49-year-olds use their mobile companion for entertainment and to pass the time while waiting - for example by streaming films and music or playing mobile games.

One in two
individuals in this age group responds to messages within
five minutes.

Only **7%** of 18- to 29-year-olds put their smartphone down for more than 60 minutes during leisure time.

One in every four
18- to 29-year-olds is online with their smartphone for more than four hours each day.

Source: Study by Telefónica Deutschland Holding AG 2019

back to page 1

Living safely in digital cities

Cities are becoming more digital, which means they are also more susceptible to cyberattacks and system failures. Researchers at the National Research Center for Applied Cybersecurity ATHENE are developing strategies to increase security.

By Mehmet Toprak

Last December, malware crippled the Frankfurt am Main city administration. Residents were no longer able to register their residence or to cancel or change their existing registration, nor could they apply for an identity card or request information on businesses – everything was frozen. The city administrations of Bad Homburg, Potsdam, Alsfeld and Brandenburg followed in quick succession. And the list goes on. "When it comes to IT security, many cities and municipalities have a lot of catching up to do, and the threat will only increase going forward," warns Dr. Michael Kreutzer from the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt.

He and his team work at the National Research Center for Applied Cybersecurity ATHENE on security solutions that benefit business, society and government. ATHENE was founded

"When it comes to IT security, many cities and municipalities have a lot of catching up to do."

Dr. Michael Kreutzer, Fraunhofer SIT

Delivery drones, intelligent traffic management, applying for an identity card via smartphone – according to a 2019 survey by Bitkom, Germany's digital association, two-thirds of all Germans want to see their cities speed up their efforts to go digital. © *istockphoto*

in early 2019 as a Fraunhofer-Gesellschaft research institution. It merged various research partnerships on cybersecurity in Darmstadt into one center and made them permanent. Apart from Fraunhofer SIT, ATHENE also encompasses the Fraunhofer Institute for Computer Graphics Research IGD, the Technical University of Darmstadt and Darmstadt University of Applied Sciences. With some 500 employees, it is the largest research center for applied cybersecurity research in Europe, and a key part of Germany's cybersecurity strategy. One important project the ATHENE researchers are working on is entitled "Secure Urban Infrastructures (SecUrban)," which is aimed not only at preventing hacking attacks but also at making digital systems more robust and resistant to failures and outages. At its core is the vision of a smart city – a highly digital urban space that demands a swift response to any crises that may arise.

IT security is a public service

The more complex the digital structures, the more vulnerable they are. Hacks, data breaches, accidents, terrorist attacks, natural disasters or a simple power outage can plunge a city into chaos. No facet of life is left untouched, be it transportation, power and water supply, healthcare, trade and commerce, culture or public coexistence.

"In the past, some cities have made the mistake of responding to cyberattacks only with quick individual measures. Over time, this leads to a patchwork of fixes. We advocate a holistic and sustainable concept comprising preventive measures coupled with rapid detection of and response to outages and hacks," says Kreutzer.

Decision makers in today's smart cities, such as mayors, are convinced that improving cybersecurity is a significant component of modern-day public services. When the ATHENE researchers conduct their security analysis, they cast a critical eye on governance and administration. Who is in charge of what in the event of a crisis? Who is responsible? Who relays information to whom and through what channels? How long does that take? What are potential sources of misunderstanding? Only when these questions have been answered can those in charge respond quickly and smoothly to breaches and cyberattacks.

Smart city: traffic lights, sensors and electricity meters provide data

One way to increase security is to collect and analyze the data that accrues in smart cities. "This enables leaders to quickly detect and localize crises, accidents or attacks," says Florian Kirchbuchner, head of the smart living and biometric technologies department at Fraunhofer IGD.

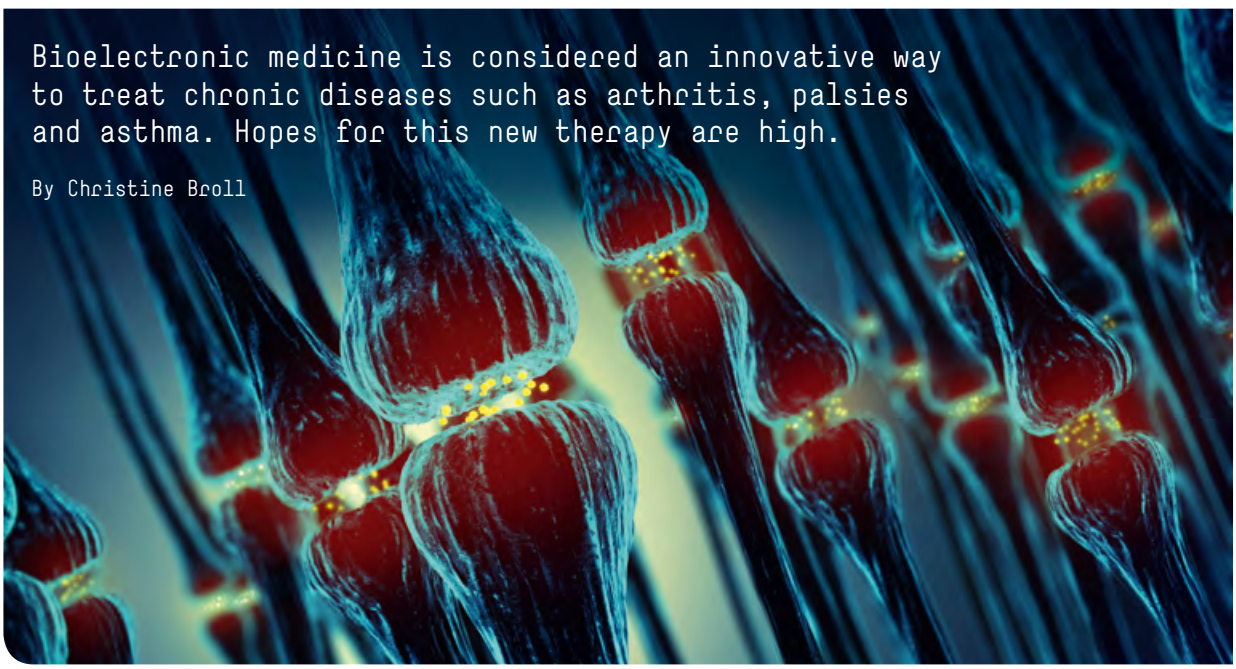
Digital cities are incorporating more and more devices and detectors that generate data – traffic lights, surveillance cameras and distributed sensors that measure such things as air and water quality, just to name a few. More and more electricity meters are digital, providing yet another source of data. Every second, hundreds of thousands of readings and detailed data are produced that reflect life and events in the city. Typical patterns arise, and deviations from these patterns could point to problems. "For example, if all the lights on a particular street go on at 3:00 a.m., this could indicate that something has happened, such as an accident," explains Kirchbuchner.

In practice, however, implementing the technology to collect and analyze this data is still a major problem. The numerous disparate devices and sensors transmit their data in completely different formats to control panels and control centers that, in turn, can't communicate with one another. "That's why we are investigating a technology-agnostic platform that enables data exchange," says Kirchbuchner. Data protection issues have to be taken into account, as well. As Florian Kirchbuchner stresses, "Privacy and security must go hand in hand. We are most certainly not aiming for security at the cost of privacy, which is why we speak of "security and privacy by design" in all of our projects." ■

The more complex the digital structures, the more vulnerable they are.

back to page 1

Smart chips set to replace bitter pills



Continuously measuring nerve activity to counteract deviations from a healthy balance? Science fiction is becoming reality. © *Adobe Stock*

Bioelectronic medicine is considered an innovative way to treat chronic diseases such as arthritis, palsies and asthma. Hopes for this new therapy are high.

By Christine Broll

"Not even medical devices are safe from hackers these days."

Prof. Klaus-Peter Hoffmann, Fraunhofer IBMT

It sounds like science fiction: tiny implants placed at important control points in the body continuously measure nerve activity. They are wirelessly connected and constantly compare actual values with target values. Whenever they detect a discrepancy, they immediately send an electrical pulse to tissue and nerve fibers to restore a healthy balance. Initial spectacular successes in bioelectronic medicine show that this vision can become reality. In the US, patients with rheumatoid arthritis have already been treated by stimulating the vagus nerve.

These smart implants are called electroceutics, and Fraunhofer scientists are pioneers in this field. They are developing not only powerful microimplants but also biodegradable electronics and nanoelectrodes that can make contact with individual cells. The INTAKT innovation cluster, backed by more than 13 million euros in funding from the German Federal Ministry of Education and Research, is taking a huge step toward realizing this vision. Prof. Klaus-Peter Hoffmann, head of main department of Biomedical Engineering at the Fraunhofer Institute for Biomedical Engineering IBMT, is coordinating the consortium's 17 partners. "We are developing a network of interactive implants that can activate complex functions in the body," explains Hoffmann, "facilitating a completely new human-technology interaction."

To find out how that might look in practice, the group is investigating three different scenarios. They are studying the use of implants in the ear to suppress tinnitus. The second scenario involves patients who can no longer move their hands due to stroke or paraplegia. Implants in their arms are aimed at stimulating the muscles in such a way that their hands can once again execute gripping motions, while an eye-tracking system helps the wearer control these movements. In the third scenario, the research team is testing how implants can renormalize gastrointestinal motility. There are many different indications for this, from chronic constipation to care for colorectal cancer patients.

The implants will be the size of a two-euro coin and include a tiny battery that is charged by inductive energy transfer from outside the body. Some problems are man-made. "Not

even medical devices are safe from hackers these days," says Klaus-Peter Hoffmann. To guarantee their safety, optical signal transmission has replaced the more vulnerable wireless transmission.

Patient autonomy is also extremely important to Klaus-Peter Hoffmann. He emphasizes that, "Patients should be able to access implant functions at any time using the external control unit. Physicians and patients should jointly decide on the course of treatment."

Less than a millimeter thick – that's the size of the implants being developed by Dr. Vasiliki Giagka and her Attract research group at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin. Instead of packing the implants' electronic components into rigid capsules, they coat them with a thin protective layer made of, for instance, polymers. This enables them to create the extremely thin and flexible electroceutics.

"Autoimmune diseases are among the most promising indications for bioelectronic medicine," explains the Greek-born electronics expert. "Treatment is achieved by stimulating the vagus nerve." The vagus is part of the autonomic nervous system and is involved in the regulation of nearly every organ. In the spleen, it regulates the production of proinflammatory messengers, which play an important role in autoimmune diseases.

The first successful treatment with a vagus stimulation was achieved by researchers at the Feinstein Institute in New York in 2016. In patients with rheumatoid arthritis, they used an implant to stimulate certain fibers of the vagus. The stimulation reduced the concentration of the proinflammatory messengers, and the joint inflammations were reduced. Vagus stimulation could also be used to treat other autoimmune diseases, such as asthma, Crohn's disease or multiple sclerosis. Since the vagus is also involved in controlling blood sugar, diabetes is also an indication for bioelectronic medicine.

Vasiliki Giagka is working vigorously on making the vagus nerve stimulation as specific as possible. "We use ultrasonic signals rather than electrical, since these enable us to better target individual fibers in the nerve tract," explains Giagka, who heads up not only the Fraunhofer group, but also a research team at Delft University of Technology. She also relies on ultrasound for power supply, as it is more efficient than induction methods at charging implants located deep within the body.

Electronics the body can absorb

Implantable electronic components that can be reabsorbed by the patient's body once its work is done? When the bioElektron project was initiated in 2016, its stated goal seemed to be but a bold vision. After all, how would they manage to get microchips made of silicon and metal to cleanly dissolve? This challenge inspired the research teams from the five participating Fraunhofer Institutes. "For implants that are needed for only a short time, we could spare patients the operation to remove the electrode," says project coordinator Dr. Michael Hoffmann from the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP in Dresden.

This would benefit, for instance, patients who undergo gastrointestinal surgery to implant electrodes to provide short-term support for gastrointestinal motility. Electrodes placed in the cerebral cortex for epilepsy diagnostics could be another use case.

To realize this vision, the electronics had to be completely reimagined. Two different materials were used as the substrate foil. One is polylactic acid, which breaks down into individual lactate molecules. The other is ORMOCER®, a biodegradable polymer developed at the Fraunhofer Institute for Silicate Research ISC. The circuit paths consist of biocompatible, metallic magnesium. Developing the transistors was a major challenge. "We use quinacridone, a pigment that is used in a similar form for tattoos, as an organic semiconductor," says Michael Hoffmann. The isolation layer and encapsulation are made of similar ORMOCER® variants to those in the substrate foil.

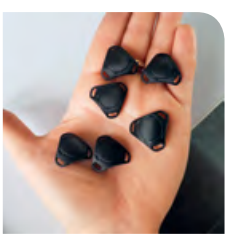
When electrodes communicate with individual cells

Is it possible to communicate electronically with individual cells? Is there a way to interpret and respond to their signals? These are the questions that prompted the ZellMOS project, a collaborative undertaking between the Fraunhofer Institute for Microelectronic Circuits and Systems IMS, the Max Planck Institute for Medical Research and the University of Heidelberg.

Dr. Sonja Allani, a young physicist at Fraunhofer IMS, sought answers. In her quest, she produced a microchip on which she formed vertical nanoelectrodes with a diameter of less than a thousandth of a millimeter. The nanoelectrodes are hollow and are made of ruthenium, a biocompatible metal with good electrical properties. With entire arrays of these nanoelectrodes on the chip, she then cultivated nerve cells. "I was able to observe the nanoelectrode-cell contact under a fluorescence microscope," says Allani. "We even succeeded in recording electrical signals from individual cells." Nanoelectrodes could one day improve the contact between implants and tissue, making them an additional building block paving the way for bioelectronic medicine to become a reality. ■

"For implants that are needed for only a short time, we could spare patients an operation to remove the electrode."

Dr. Michael Hoffmann, Fraunhofer FEP

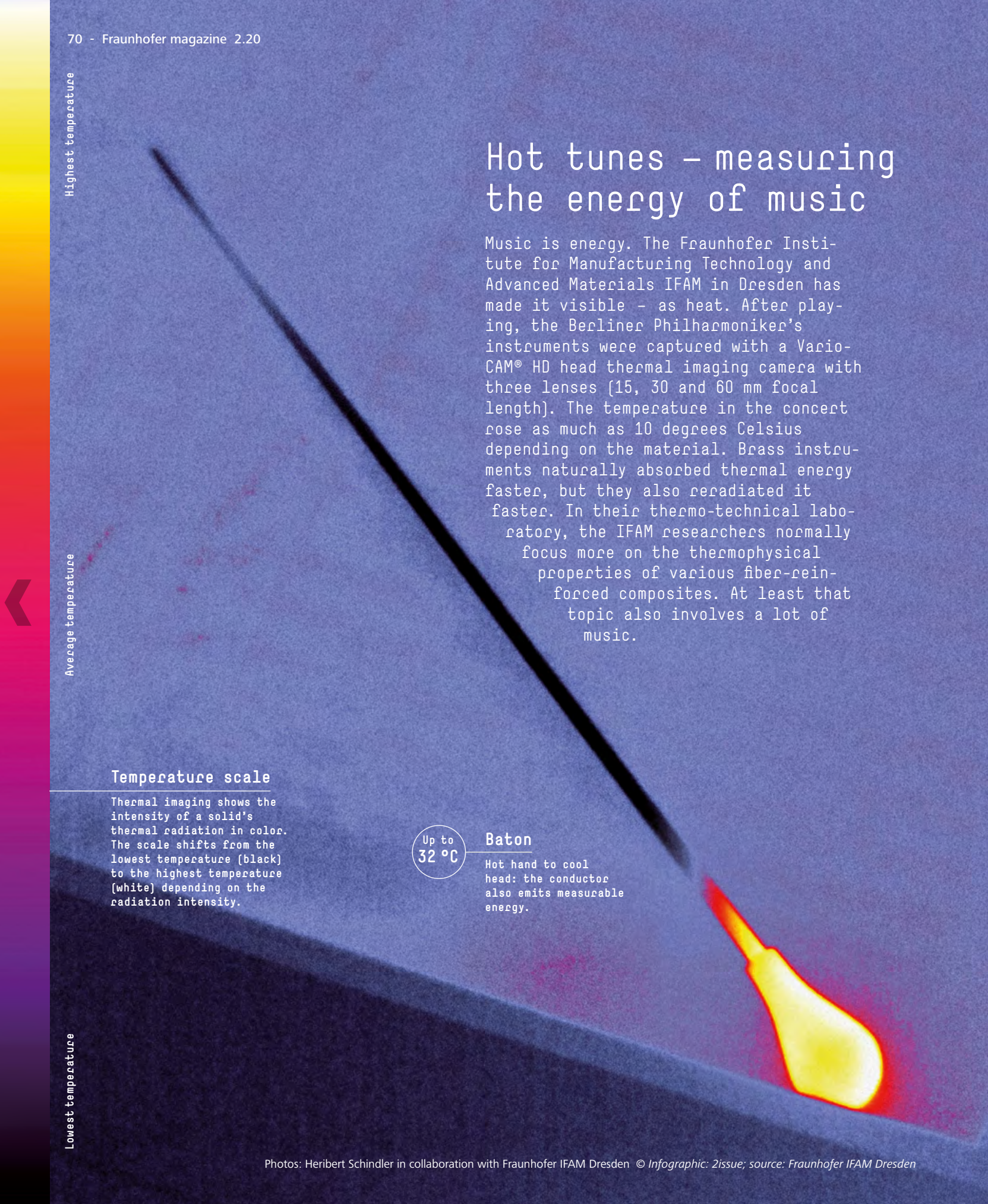


The network of interactive implants is made up of individual units the size of a two-euro coin. © *INTAKT innovation cluster*

back to page 1

Hot tunes – measuring the energy of music

Music is energy. The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden has made it visible – as heat. After playing, the Berliner Philharmoniker's instruments were captured with a VarioCAM® HD head thermal imaging camera with three lenses (15, 30 and 60 mm focal length). The temperature in the concert rose as much as 10 degrees Celsius depending on the material. Brass instruments naturally absorbed thermal energy faster, but they also reradiated it faster. In their thermo-technical laboratory, the IFAM researchers normally focus more on the thermophysical properties of various fiber-reinforced composites. At least that topic also involves a lot of music.



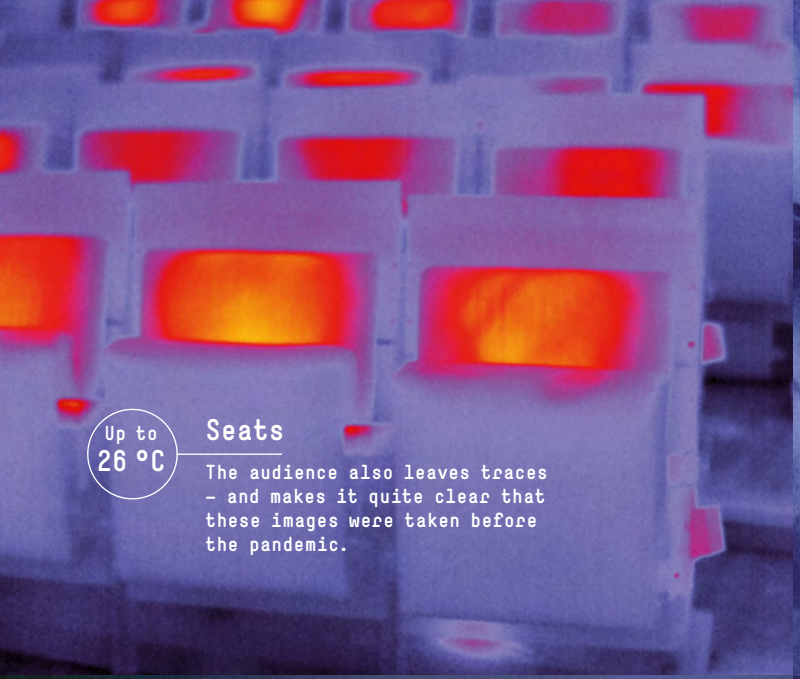
Temperature scale

Thermal imaging shows the intensity of a solid's thermal radiation in color. The scale shifts from the lowest temperature (black) to the highest temperature (white) depending on the radiation intensity.

Baton

Hot hand to cool head: the conductor also emits measurable energy.

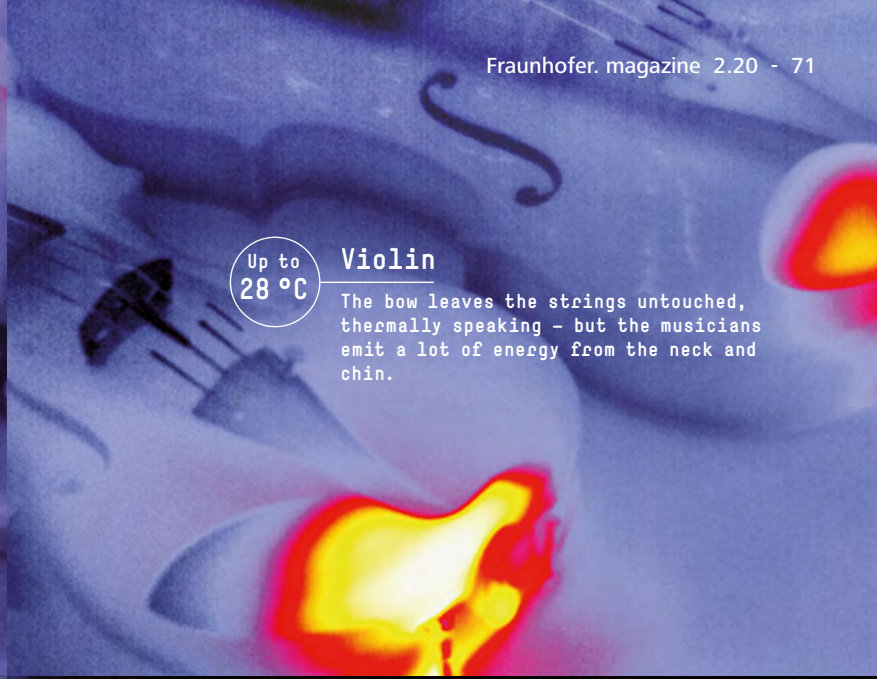
Photos: Heribert Schindler in collaboration with Fraunhofer IFAM Dresden *© Infographic: 2issue; source: Fraunhofer IFAM Dresden*



Up to 26 °C

Seats

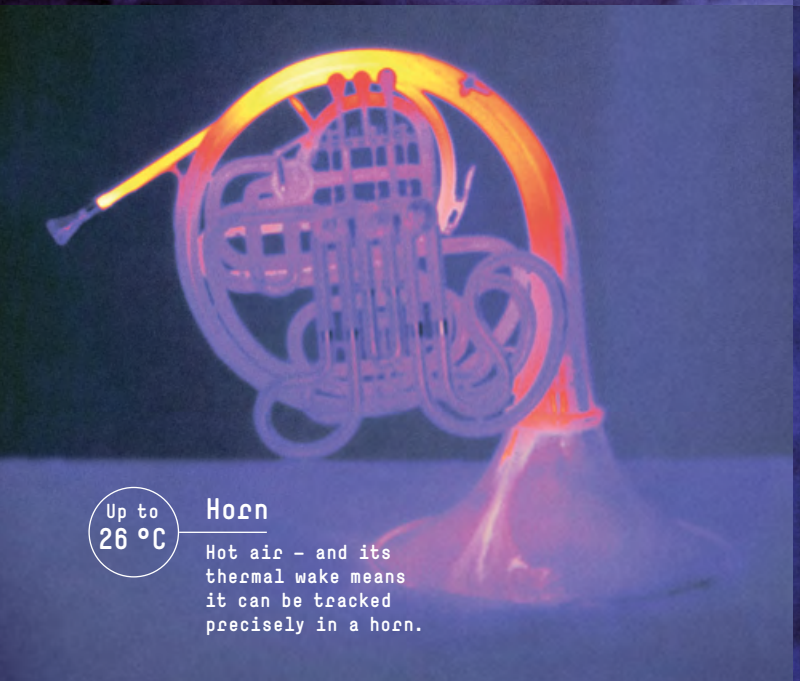
The audience also leaves traces – and makes it quite clear that these images were taken before the pandemic.



Up to 28 °C

Violin

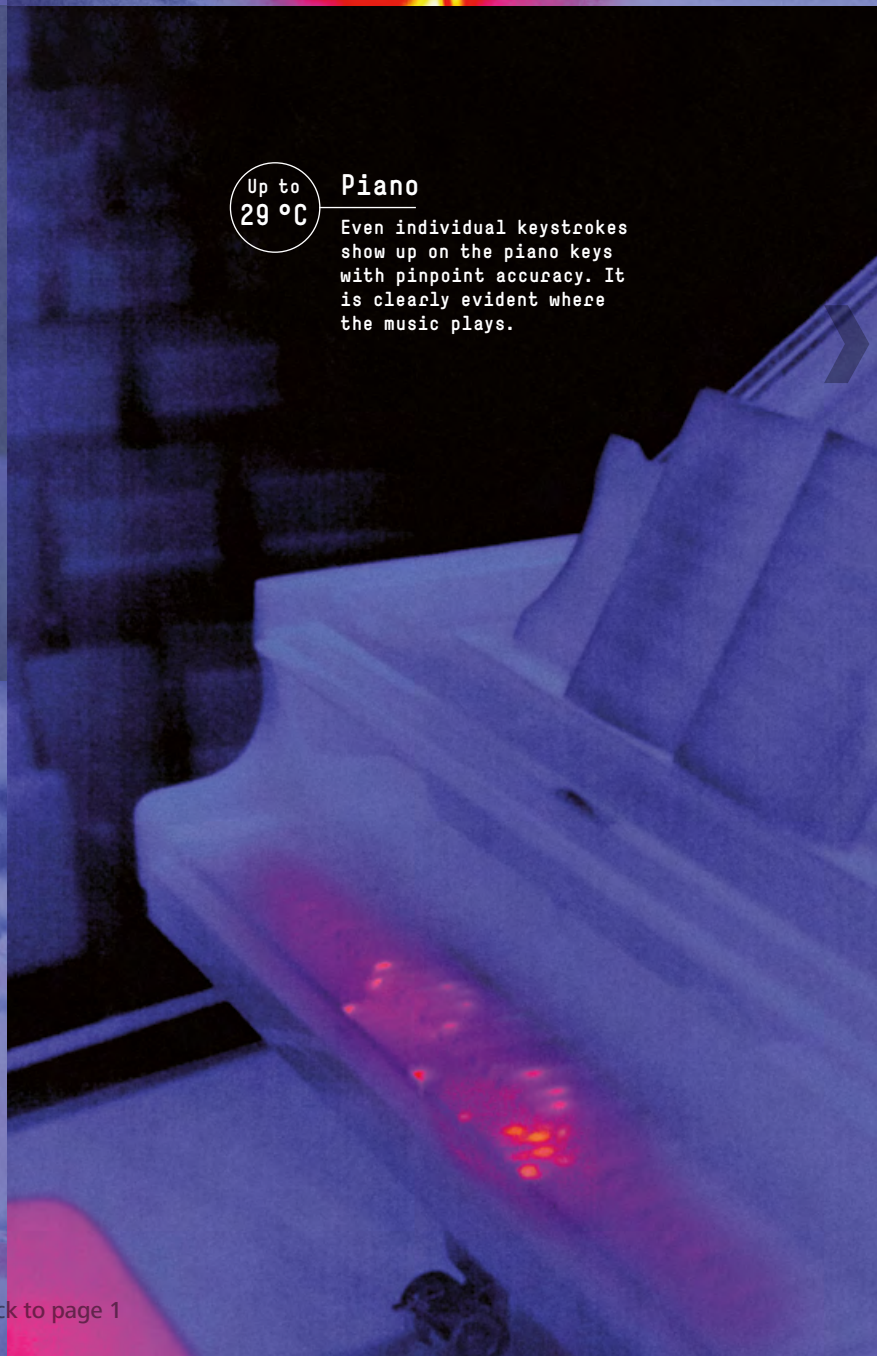
The bow leaves the strings untouched, thermally speaking – but the musicians emit a lot of energy from the neck and chin.



Up to 26 °C

Horn

Hot air – and its thermal wake means it can be tracked precisely in a horn.



Up to 29 °C

Piano

Even individual keystrokes show up on the piano keys with pinpoint accuracy. It is clearly evident where the music plays.

Up to 29 °C

Timpani

The musician's hands leave heat spots behind, clearly defining the activity area.

back to page 1

Taking a look at 5G

5G, the latest generation of mobile communications, is supposed to be up to 100 times faster than its predecessor and permit real-time transmission. Companies are using Fraunhofer testbeds to determine which applications 5G will actually soon render possible – and which ones are still a long way off.

By Mehmet Toprak

"Those who use 5G have to decide which features are important for their individual application."

Matthias Schneider, manager of the 5G4KMU transfer center

With 5G, robots no longer have to rely on the local WLAN network. Their work is not location dependent and they can be used a lot more flexibly. © *AUDI AG*

There's a lot of hype surrounding 5G. Now this technology has to show what it can really do," says Matthias Schneider, who manages the 5G4KMU transfer center currently being set up in various regions of Baden-Württemberg, where small and medium-sized companies will soon have the opportunity to try out their 5G-based business models and innovative product ideas. Fraunhofer experts provide the necessary infrastructure and are on hand to offer support. The Fraunhofer Institute for Manufacturing Engineering and Automation IPA is coordinating the project. The first projects with companies in the logistics, manufacturing, lab and clinical sectors will launch until the end of the year.

5G test environments are currently being set up in Stuttgart, Karlsruhe, Reutlingen, Mannheim and Freudenstadt – each one with different focal areas, from robotics and machine control to smart products and artificial intelligence. All facilities are based on the same principle: companies apply with their idea, which the Fraunhofer experts screen and analyze. The most promising concepts are selected and tested together.

It cannot all be done at once

Theoretically, 5G permits data transmission rates of up to 20 gigabits per second and a latency – the time it takes the signal to travel from sender to recipient – of just one millisecond. In practice, however, it is not yet possible to achieve these numbers. Moreover, 5G cannot fulfill all performance parameters at once, so whoever uses this innovative technology has to decide which features are important for their individual application. "A technology known as network slicing can help with this," says Schneider. "It lets you give priority to different parameters in different defined sections within a 5G network. While one area of the network gives preference to latency, for instance, another section may be optimized for high bandwidth."

To get high-resolution 4K or even 8K videos onto devices without stuttering, an entertainment provider that streams videos over the web, for instance, needs high data transmission rates. They can accept minor losses in reliability and a longer latency. An industrial robot, in contrast, doesn't need high data transmission rates, but low latency to enable real-time control. If hundreds of sensors are used on a large agricultural field to transmit temperature, wind conditions or plant growth data, for instance to control harvesting equipment, then energy efficiency is key, as these sensors need to work for months or possibly even years at a time without requiring a battery change.

5G is particularly advantageous for robotics and machine control. This ultrafast mobile communications technology makes it possible to get the data from a sensor integrated in a machine or component to the machine's control unit practically without delay.

Increasingly intelligent robots must process enormous amounts of data. 5G will make it much easier to move computing capacity to the cloud.

back to page 1

8 subprojects

1 5G multisensor: Multisensor systems are expected to optimize production processes. The sensors measure such values as the temperature, acceleration, forces or position of components.

2 5G AE sensor: Acoustic emission sensors that are attached directly to parts are aimed at detecting in advance when tools used in milling operations are at risk of breaking due to wear or excessive load.

3 5G blockchain: This project is testing whether a completely wireless network is also suitable for a blockchain application for data transactions.

4 5G logistics: A logistics solution demonstrates how mobile systems can use 5G support to navigate on the factory premises.

5 5G robotics: A control system for mobile robots that self-organize when collaborating, using sensor systems to navigate wirelessly.

6 5G cockpit: Setting up a central control platform that monitors processes and sensors at different locations. The data is exchanged via a cloud platform.

7 5G edge cloud: A cloud platform in which production data analysis is connected with the mobile network.

8 5G 3D sensor: Developing a 3D sensor system that scans the geometry of workpieces and can be wirelessly integrated into robots or machine tools.

What's behind that cover, where are repairs needed? 5G networks and edge computing make it easy to transmit high-resolution images to data glasses. © *Bosch*

▶ A more complex structure would also enable, not just individual machines, but the entire manufacturing process to be controlled using 5G-based technologies, ideally across the entire factory premises. It is even conceivable that production could be controlled across different sites. When 5G networks are connected with appropriate routers and antennas, data can travel even further. The testbed at the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart is geared toward smart products and services. "We're working on concepts that combine 5G with data collection and AI-based data analysis," says Dimitri Evcenko from the digital business services team. 5G is of interest for certain data services, such as predictive maintenance in industrial manufacturing. "Based on the collected data, AI then predicts, for instance, when the next maintenance appointment will be needed or when a wear part will fail," explains Evcenko.

Nevertheless, some companies are still hesitant. That may be because the standardization body 3GPP (3rd Generation Partnership Project) is still working on the specifications for 5G and keeps bringing out new releases – the latest one is number 15. So is this standard not even finished yet? "The current release already permits high speeds. It also forms the basis for low-latency, real-time connection and for multi-device connectivity. The existing infrastructure can then be expanded to include new functions in the form of new hardware or firmware updates," says Evcenko. "Those who invest in 5G hardware now need not fear that they will have to replace all these devices again in two years."

Enough space for sophisticated applications

The new 5G standard also offers the possibility to set up a proprietary mobile communications network. The frequency range from 3.7 to 3.8 GHz is reserved for industry. Companies can request a license from the German Federal Network Agency and then set up their own mobile network on their factory premises.

The 5G-Industry Campus Europe in Aachen is also taking an in-depth look at the new opportunities 5G technology offers, and was granted a license to operate a 5G network. Niels König from the Fraunhofer Institute for Production Technology IPT coordinates all the partners and individual projects in this research consortium. One of those partners is RWTH Aachen University, with its Laboratory for Machine Tools and Production Engineering (WZL), IT Center and Institute for Industrial Management FIR. The network and radio equipment is provided by Ericsson, the Swedish mobile communications network supplier.

The research campus has around 7000 square meters of shop floor space – plenty of room to explore even sophisticated application scenarios. A total of eight subprojects are planned (see box). The first projects are already using the functioning 5G network. "We installed the indoor network and deployed the radio cells. The one-square-kilometer outdoor network will follow in summer," says König. The goal is to research and refine the 5G technology for a wide range of use scenarios.

The software plays a key role in controlling and combining all technologies. In the age of 5G and Industrie 4.0, control cabinets with hardwired controls will soon be a thing of the past. Machines and production lines can be reconfigured and reprogrammed quickly, and edge cloud and software control make 5G applications even more flexible. "The charm is that any application can be scaled, adapted and reconfigured quickly and easily," says Niels König. ■

A source of energy and hope

Hydrogen can help speed the transition to a sustainable energy economy. In order to tap the full potential of this key gas, 28 institutes of the Fraunhofer-Gesellschaft are now pooling their expertise in a new Hydrogen Network.

By Mehmet Toprak

A winning combination? Hydrogen can play a key role in helping to bring about the transition to a sustainable energy economy. © *Adobe Stock*

A forthcoming electrolyzer test site at the Fraunhofer Institute for Wind Energy Systems IWES in Bremerhaven is to be powered by green electricity from an 8-megawatt offshore wind turbine. It's the start of a pioneering project that will see researchers couple wind energy with hydrogen technology. The project will investigate how well electrolyzers function when coupled to a wind farm, without connection to the power grid. The idea is to use wind power directly in order to split water into oxygen and hydrogen. This will ensure optimal use of locally generated wind power and help avoid shortfalls in grid capacity.

With hydrogen a key source of hope for the energy transition, 28 institutes of the Fraunhofer-Gesellschaft have now joined forces in a Hydrogen Network. Hydrogen technology is a key strategic field of research at Fraunhofer, alongside quantum technology, artificial intelligence, smart medicine, next-generation computing, resource efficiency, climate technology and bioeconomy. Hydrogen is also a major topic in government circles. Germany's Federal Ministry of Education and Research, for example, has now launched a National Hydrogen Strategy to pave the way for the transition to a hydrogen economy and a sustainable energy infrastructure. This will couple industry with transport and heating as well as integrate all the various systems of generation and distribution. To provide extra impetus, the federal government has also launched a campaign under the "Hydrogen Republic of Germany" banner. The aim is to garner ideas and innovation from science, business and the general public. All in all, funds of 600 million euros are up for grabs.

"There's now a broad, even global, consensus on the need to transition to a sustainable energy economy, and hydrogen is the only way to achieve this", explains Prof. Christopher Hebling from the Fraunhofer Institute for Solar Energy Systems ISE (see Interview, p. 77). Hebling heads the Fraunhofer Hydrogen Network together with Prof. Mario Ragwitz from the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG. This current flurry of activity in the field of hydrogen technology has also spawned a slew of regional projects and strategy processes from a host of federal states. Fraunhofer itself has this year launched the following cross-institute projects from its own funds: HOKOME, started in January, is a project to develop highly efficient and cost-effective manufacturing methods for components of fuel cell stacks; and Neo-PEC, also launched in January, is a project to develop a tandem PEC module that will produce hydrogen directly from sunlight and water in a cost-effective manner.

The benefits of hydrogen are well known. In principle, this colorless, odorless gas can be produced from water in unlimited quantities. It also has a high specific energy: 1 kilogram of hydrogen contains as much energy as 2.8 kilograms of gasoline. Moreover, hydrogen combusts cleanly and can be produced in a variety of processes. These include not only steam reforming of natural gas, which already occurs on an industrial scale, but also the electrolysis of water, which is climate-neutral. Researchers at the Fraunhofer Institute for Factory Operation and Automation IFF are investigating a method to produce hydrogen from biomass using micro-organisms and a fermentation process. Most importantly, hydrogen is extremely versatile. It can be used to generate electricity as well as produce liquid fuels such as methanol or long-chain hydrocarbons. And when used to process iron ore, it can substantially reduce CO_2 emissions in the steel industry.

One kilo of hydrogen contains as much energy as 2.8 kilos of gasoline.

back to page 1

Germany could require as much as 800 terawatt-hours of energy from hydrogen by 2050.

Study by Fraunhofer ISE

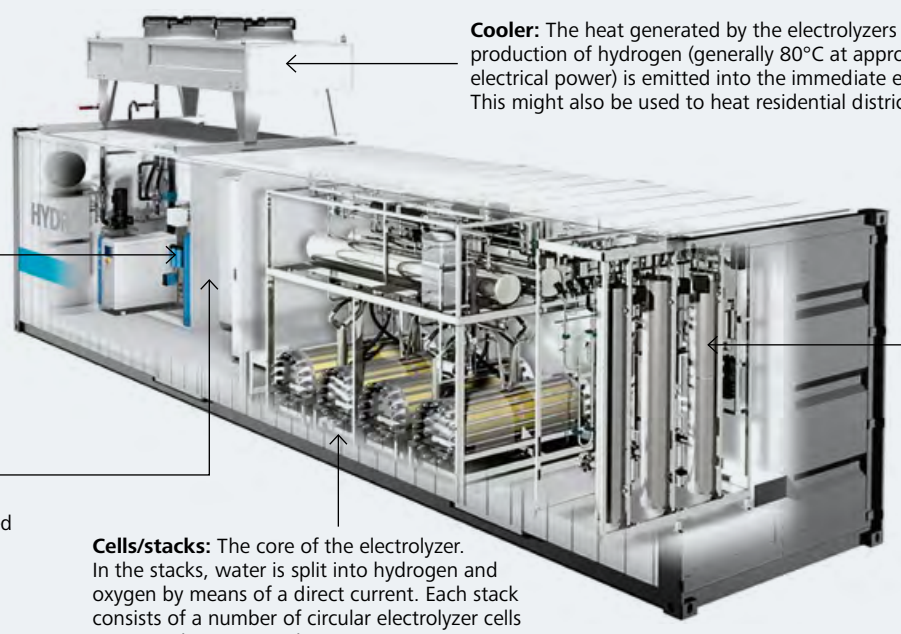
▶ At the Bremerhaven test site, the green hydrogen generated by electrolysis is stored under high pressure in steel tanks. These container vessels can be transported on semitrailers to consumers in the region. Alternatively, the hydrogen can be stored at a lower pressure in an intermediary buffer tank for later conversion back into electricity via a fuel cell. This power is then fed back into the grid, where it helps cushion the fluctuations in generating capacity that are inevitable with wind and photovoltaic plants. This power is generated exclusively from renewable energy, with zero production of greenhouse gases. "Offshore wind farms in combination with a local production of hydrogen would be an ideal building block in the creation of a sustainable energy economy," explains Prof. Jan Wenske, deputy director and technical director at Fraunhofer IWES.

Hydrogen on an industrial scale

Right now, the focus is on electrolyizers. This technology will have to be scaled up so as to produce hydrogen on an industrial scale. A 2019 study by Fraunhofer ISE estimates that Germany could require as many as 800 terawatt-hours of energy from hydrogen by 2050. At the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, researchers are currently working on improving the efficiency and long-term stability of electrolyzers. As Dr. Matthias Jahn, head of the Environmental and Process Engineering business division, explains: "The question of whether or not the production of green hydrogen can be cost-effective depends very much on the general conditions governing the price of power in Germany, including grid charges and the levy for the German Renewable Energy Sources Act. In addition, the production costs for electrolyzers will also have to come down further – something that can be achieved by automating the production process." At the same time, the institute is developing processes that combine the high-temperature electrolysis of water – to generate hydrogen – with the so-called Fischer-Tropsch synthesis so as to produce a variety of feedstocks for the chemical industry on a climate-neutral basis. Such materials include synthetic waxes, which can be used as lubricants in industry. Alternatively, hydrogen from electrolysis can be combined with CO_2 in a P2X process to produce, for example, synthetic diesel or kerosene fuels. The CO_2 required for this purpose can be extracted from industrial waste gases or the atmosphere, thereby creating a carbon cycle. "We're concentrating right now on the ceramic stacks required for high-temperature electrolysis," Jahn explains.

If high-temperature electrolysis is to speed up the transition to a sustainable energy economy, further research will first be needed. At present, the focus is on enhancing the overall plant technology and boosting the electrical efficiency of the electrolyzer. "We still face a number of major challenges: upscaling the electrolyzer, system integration and system coupling," Jahn admits. Other problems, by contrast, are less critical. As Prof. Wenske from Fraunhofer IWES explains: "Companies that would like to install an electrolyzer are finding it difficult to get hold of one right now. Delivery can take up to 15 months." But long waiting times are also an indication of the level of demand. Green hydrogen is therefore more than just an environmentally friendly energy carrier. It is also a source of hope for an imminent transition. ■

Flow chart: electrolyzer



Cooler: The heat generated by the electrolyzers during the production of hydrogen (generally 80°C at approx 25% of electrical power) is emitted into the immediate environment. This might also be used to heat residential districts.

Water treatment: To prevent damage to the stacks, the supply of drinking water to the electrolyzer must be purified of minerals.

Hydrogen treatment: Any remaining water vapor is removed from the hydrogen. For use in fuel cells, in particular, the hydrogen must be extremely pure in order to avoid damage.

Control: The volume of water is adjusted in line with the amount of electricity available (green hydrogen).

Cells/stacks: The core of the electrolyzer. In the stacks, water is split into hydrogen and oxygen by means of a direct current. Each stack consists of a number of circular electrolyzer cells connected to one another.

“Ecologically sound and cost-effective”

Hydrogen is key for a successful transition to a sustainable energy economy. And, as Christopher Hebling explains, it has many more uses than powering fuel cells in transport applications.

Interview by Mehmet Toprak

Prof. Christopher Hebling (photo) has 20 years of expertise in hydrogen. Together with Prof. Mario Ragwitz, he heads Fraunhofer’s Hydrogen Network.
© *Fraunhofer ISE*

Everyone’s talking about hydrogen. Why now?

Hebling: Everyone knows we need to move to a sustainable energy economy, and hydrogen is an indispensable part of that process.

Have we underestimated the potential of this energy carrier in the past?

Yes, I would definitely agree with that. In the past, the interest in hydrogen was driven primarily by its role in environmentally friendly transport. Today, there’s much more at stake – namely, the question of how we can organize our supply of energy and fuel in an ecologically sound and cost-effective manner.

What are the advantages of hydrogen?

It can be produced from water in unlimited quantities, stored for long periods with practically no loss, and easily transported over long distances. In other words, it offers a means of transferring, via the electrolysis of water, power produced from sustainable sources to consumers in the transport sector, industry, the chemicals sector and households. What’s more, it can serve to reduce CO2 emissions from refineries and the steel industry; it can be used to power fuel cell vehicles such as trucks, buses and cars; and it can be used as a sustainable basic chemical in a range of chemical processes. And these are just some of the possible applications. Hydrogen is much more than just an energy carrier in the narrow sense. Its applications also include sustainable chemistry, power-to-x processes and a sustainable raw materials economy.

Does Germany still have a chance to become market leader in this sector?

We’ve definitely got what it takes. But that’s maybe not the key issue here. What’s more important is that we recognize that the global task of creating a sustainable energy industry will provide us with opportunities to cooperate with other countries and to forge new energy partnerships. This way, we’ll be helping to shape a truly global transition to an ecological energy economy. Meanwhile, hydrogen technology may well become a key part of industrial policy in Germany. After all, we have a very strong base in research and industry. But we’re not the only ones to have recognized the importance of hydrogen. I travel a lot, and I see lots of countries launching programs in this field – Japan, South Korea, China, South Africa, Chile, Australia and Middle Eastern countries such as Oman or Saudi Arabia. In Saudi Arabia, Australia and Morocco, for example, there are now huge hydrogen pro-jects underway.

The energy transition will be expensive. Given that hydrogen is a dangerous substance and requires special safety measures, won’t hydrogen technology prove uneconomic in the long run?

All of the Fraunhofer Institutes are working on solutions that will make it possible to build high-tech systems at a reasonable cost. This work focuses on issues such as the lifetime of fuel cell systems and electrolyzers or the entire hydrogen system. If you install a fuel cell drive in a passenger car, then you need to be sure that the total costs won’t exceed those of a conventional car.

Will we see a hydrogen car?

That’s not a question for me: I’m a hydrogen man! In terms of the entire chain, hydrogen is less efficient than the lithium-ion battery, that’s true. But it doesn’t mean we’re not going to see a fuel cell drive for cars. As of next year, companies in Japan and South Korea are going to be producing 30,000 fuel cell cars a year, a substantial proportion of which will be exported to Germany. There are now almost 100 hydrogen filling stations in Germany, and this figure is slated to rise to 400 by 2023.

That’s not very many...

It might seem that way, but a hydrogen car has a range of up to 650 kilometers and can refuel in three minutes. As far as range and refilling are concerned, it’s just as practical as a conventional gasoline or diesel model. What’s more, hydrogen combusts cleanly in a fuel cell; the only emissions are water vapor.

You have 20 years of expertise in hydrogen. How has the discussion changed?

It has changed for the better. In recent months, especially, it’s taken a huge step forward. I’m delighted that the German federal government, with its national hydrogen strategy, has set the right priorities and has adopted many of the points from our position paper setting out a hydrogen road map for Germany. ■

back to page 1

Rapid assistance for buried casualties

For people buried by an avalanche or earthquake, quick rescue can make all the difference. With new mobile radar devices from Fraunhofer, it is now possible to search sizable areas swiftly and effectively.

By Dr. Janine van Ackeren

In an earthquake, collapsing buildings pose the greatest danger to human life. If the rescue operation takes too long, people buried alive risk dehydration, suffocation or death from internal injuries. © *dpa*

The earth shakes as much as several hundred times a day. Most of this seismic activity is of a minor nature, but sometimes a tremor strikes with such devastating force that whole buildings collapse and tsunamis are unleashed, laying waste to large tracts of land. Faced with a disaster of this kind, emergency crews often struggle to locate the injured and rescue them fast enough to save lives. Radar can be of help here, but current systems are only operable as stationary devices with a range of between 20 and 30 meters, depending on the radar specifications. For disasters involving widespread destruction, that's not enough.

A new type of technology from the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR substantially increases the range of such systems. "We've developed a mobile radar device that can detect the pulse and breathing of a person buried alive and thereby pinpoint their location," explains Reinhold Herschel, a team leader at Fraunhofer FHR. "In the longer term, our goal is to mount this radar device on a drone and fly it over the disaster area. That would mean you could search an area of several hectares swiftly and effectively."

"Even areas of several hectares can be searched swiftly and effectively."

Dr. Reinhold Herschel, team leader 3D Sensor Systems at Fraunhofer FHR

The system works as follows: the radar device emits a wave that is partially reflected by debris, while part of it passes through the rubble and is reflected back by bodies and anything else buried beneath. The distance to an object is calculated by measuring how long the signal takes to return to the detector in the radar system. If the object is moving – even if it is just a buried person's skin rising and falling by a few hundred micrometers with each heartbeat – this changes the phase of the signal. The same applies to any movements caused by breathing. Whereas people typically inhale and exhale no more than 10 to 12 times a minute, the human heart beats an average of 60 times a minute. Algorithms serve to distinguish any such changes in signal. It is also possible to determine exactly where a buried person is located. This is enabled by a special type of radar known as MIMO (multiple input, multiple output). MIMO radars are equipped with multiple transmitters and receivers. They therefore create a series of viewpoints that serve to identify the exact location where rescue workers should dig for survivors.

Detection at a distance and in motion

What sets this technology apart is its ability to detect vital signs while the device itself or the target is in motion. On the one hand, the device could be mounted – as already described – on a drone and flown over the disaster area. On the other, this principle can be reversed: when the device is set up at a fixed point, it can be used to detect vital signs of people moving around within range of the radar. This would be useful in a situation where numerous injured people requiring first aid are gathered in a large facility such as a sports hall – following an earthquake, for instance. In this case, the radar device would be used to capture vital signs and identify specific casualties according to who is in most urgent need of attention. Here, the algorithm is used to detect changes such as whether a person's heart is fibrillating or someone is breathing very rapidly. The radar system is able to process the different signals and display them separately. As a comparison with a portable heart rate monitor has shown, the degree of precision is very high, with the device measuring pulse rates to an accuracy of 99 percent. Although more research is required before this system can be used to locate people buried alive, the research team has now successfully trialed the detection of vital signs emitted by people moving within a radius of 15 meters to the stationary radar system. ■

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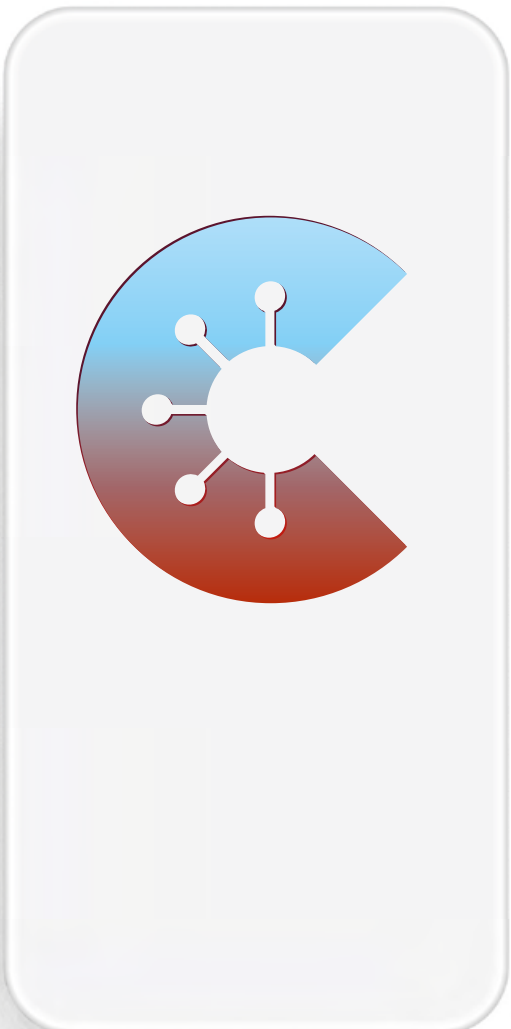

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back to page 1

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