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WERNER SIEMENS FOUNDATION

Our mission

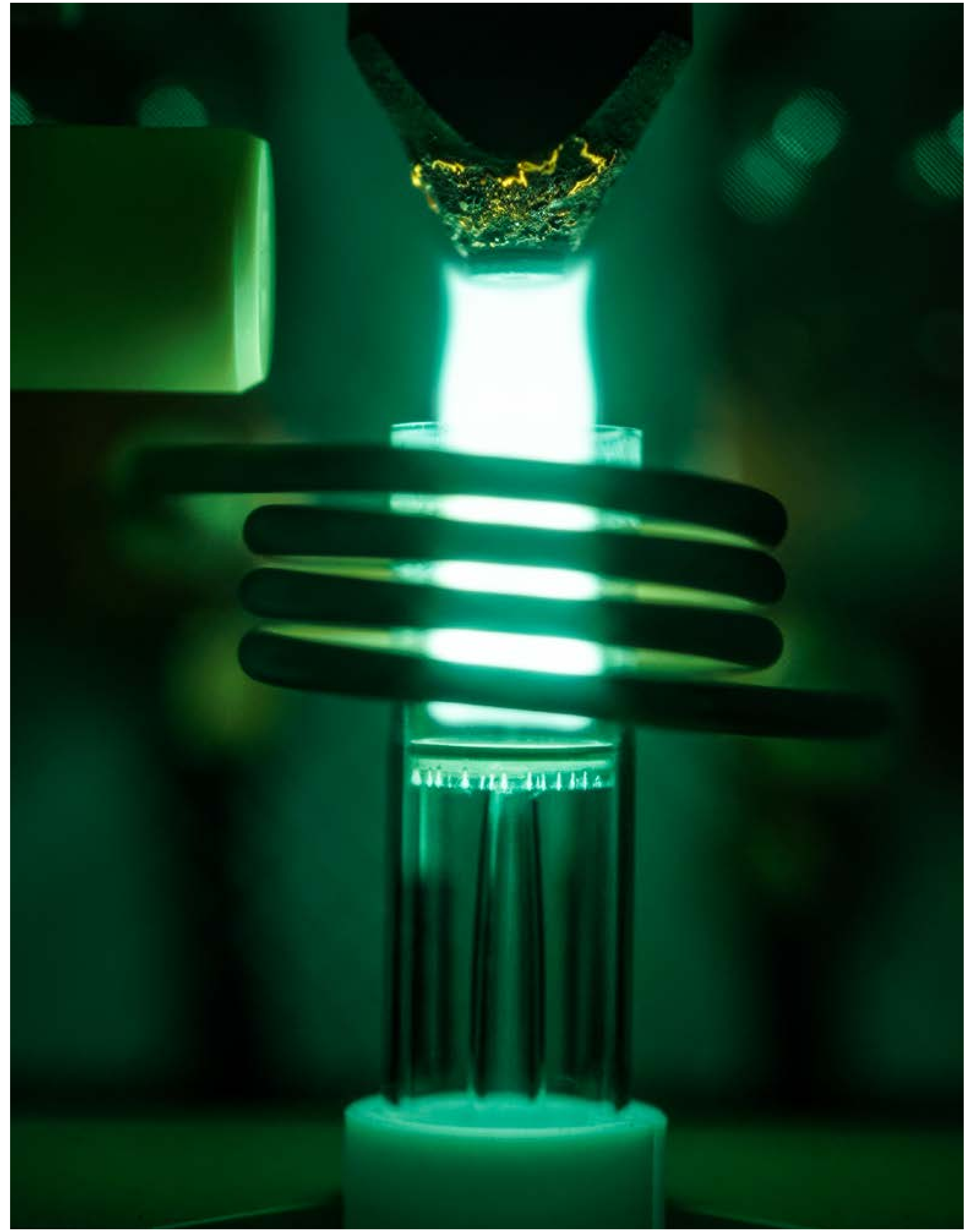
2020 report

Smart implants—healing complex bone fractures

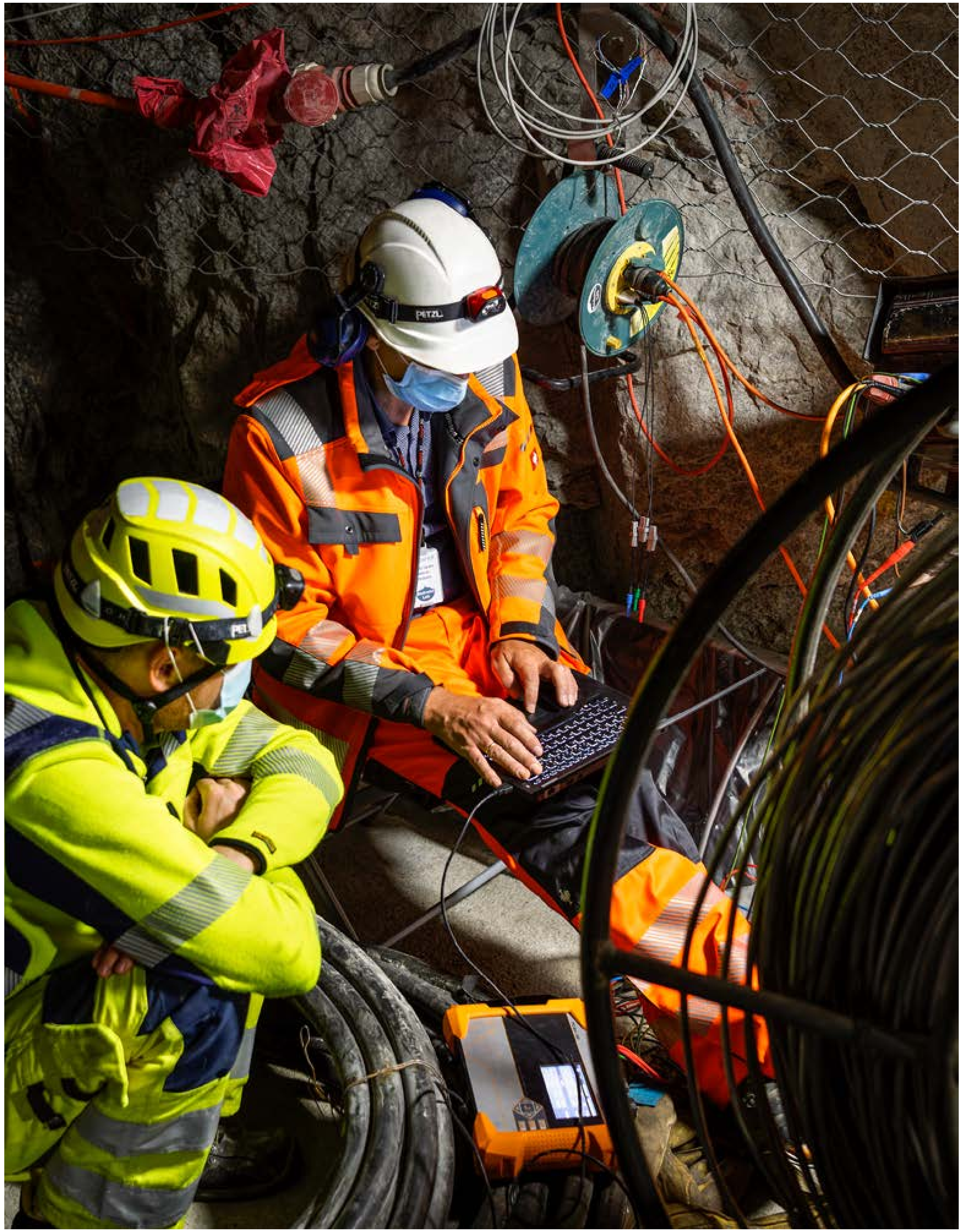
Synthetic Biotechnology—recreating natural substances in the lab

Geothermal energy—tapping into the earth's heat

MIRACLE—making minimally invasive bone surgery a reality



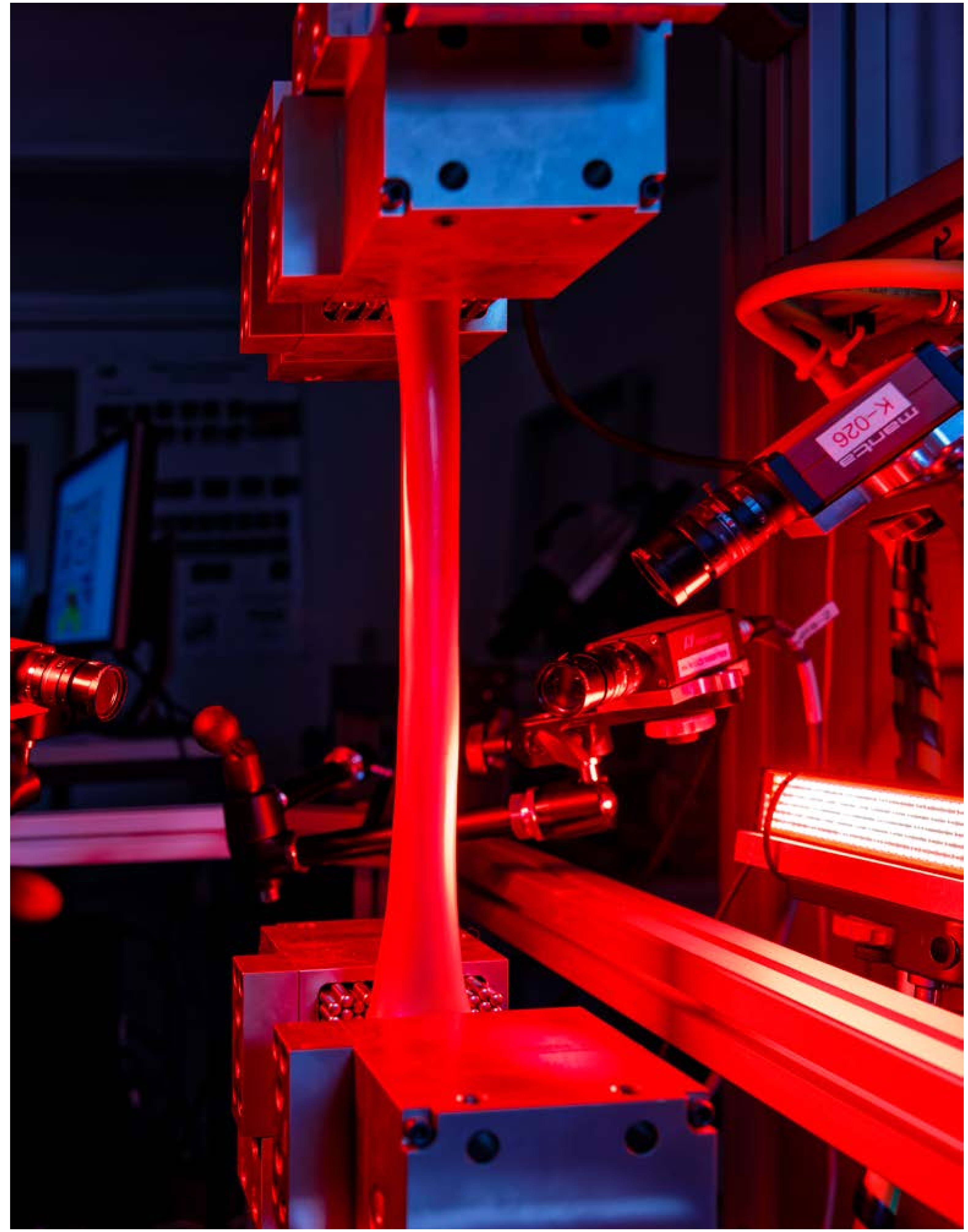
Thermoelectricity—seeking optimal thermoelectric materials

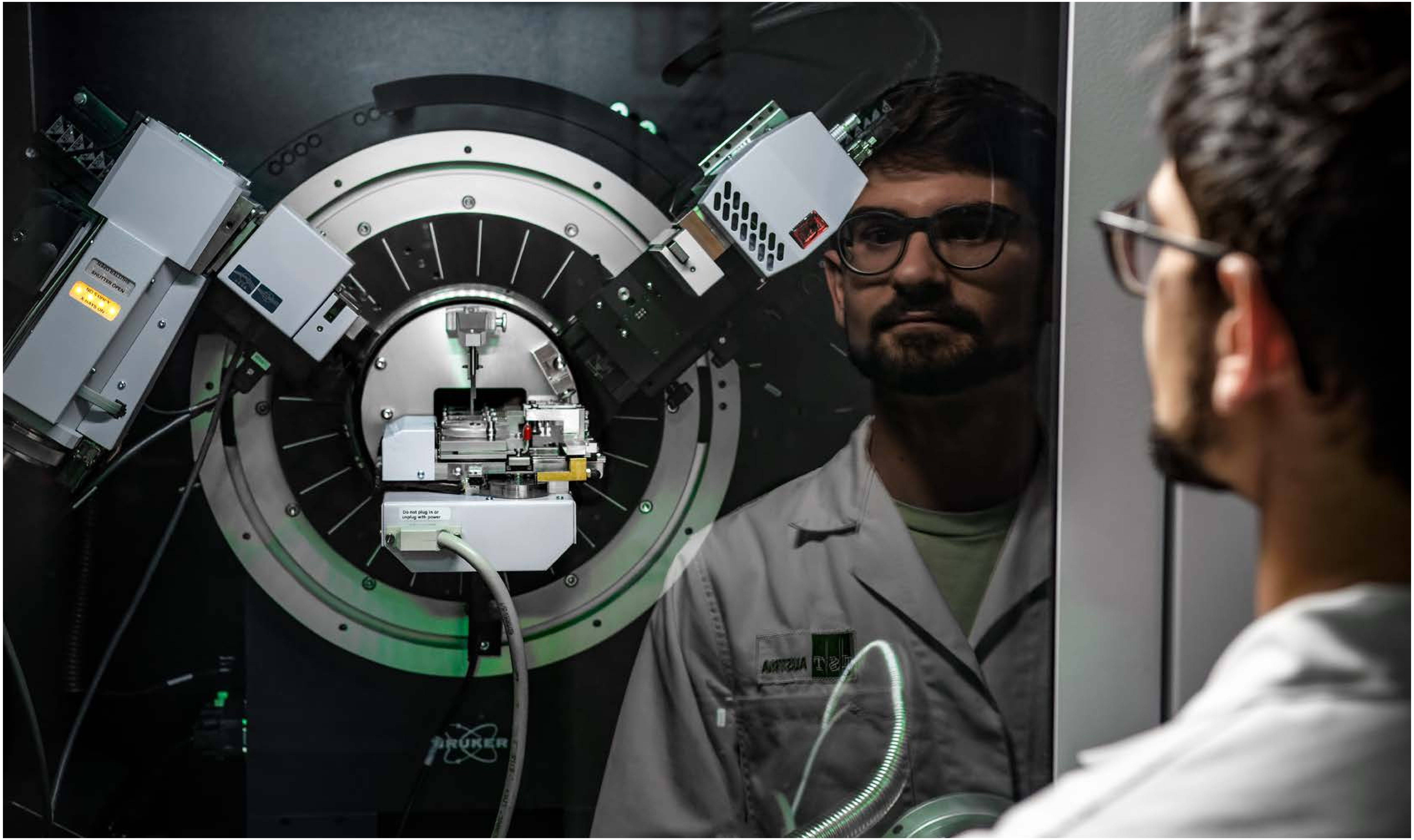


Bedretto Underground Lab—researching deep geothermal energy under near-authentic conditions

Werner Siemens Imaging Center—using medical imaging techniques to select the best patient treatments

The “antivirotic”—developing a broad-spectrum antiviral drug


Smart implants—healing complex bone fractures



Thermoelectricity—seeking optimal thermoelectric materials

Promoting innovation in technology and the natural sciences

The Werner Siemens Foundation supports groundbreaking projects in the fields of technology and the natural sciences. The selected projects in research and education are generally conducted at universities and higher education institutions in Germany, Austria and Switzerland; key requirements include upholding the highest standards and contributing to solving major problems of our time. The Foundation provides generous seed funding to innovative projects with the goal that, after a few years, the projects can be run independently and the results find industrial application. The Werner Siemens Foundation also promotes education and training projects and fosters young talent, particularly in the fields of mathematics, informatics, natural sciences, technology, medicine and pharmaceutical science.

Foreword

At the Werner Siemens Foundation, we too have felt the effects of the coronavirus pandemic. To be sure, it was fairly easy for our governing bodies to work from home during the 2020 global lockdown—and we have been lucky enough to all remain healthy. Nevertheless, on-site visits to the projects were unthinkable, and all work was relegated to an online setting. In the world of research, the situation was no different. In March, the École polytechnique fédérale de Lausanne (EPFL) contacted us via Zoom to inquire whether the Werner Siemens Foundation would be interested in supporting the search for an antiviral drug: EPFL professor Francesco Stellacci is developing an innovative, broad-spectrum antiviral therapy that damages viruses and prevents them from invading cells. Preclinical studies had already proven successful, and a clinical trial with 20 patients was just about to begin at the time of our discussion.

We asked our Scientific Advisory Board to evaluate the project. Their answer: the approach is highly promising, also with regard to treating Covid-19. And so we took a quick and unbureaucratic decision to fund Francesco Stellacci's research for one year. Readers will find the report on his novel approach to combatting viral infections on pages 23 to 38.

As an independent Foundation, we were able to respond to this urgent funding request within a week's time. It should be stressed, however, that our decision would have been impossible without the expertise of our Scientific Advisory Board, which in many ways is the "conscience" of the Werner Siemens Foundation. The renowned researchers on the Board have long experience in assessing project quality: drawing on their professional networks, they evaluate proposals in terms of innovative spirit, calibre and feasibility.

The researchers on the Scientific Advisory Board are respected professionals who are recognised and in demand outside our Foundation. In 2020, two members were appointed to prestigious positions: Professor Bernd Pichler was named Dean of the Faculty of Medicine of the University of Tübingen, and Professor Gerald Haug was elected President of Leopoldina, the German National Academy of Sciences. In the section "Who we are", we are pleased to introduce the distinguished members of the Scientific Advisory Board to our readers (pages 114 to 117).

Over the course of the year, it became readily apparent that the projects we finance would experience delays due to the pandemic. Those endeavours that rely on fieldwork—research on the Atlantic Ocean or in the deep sea—were particularly hard hit. But projects with international partners also found themselves roughly three months behind schedule. "Covid-19 has made everything very complicated"—what Domenico Giardini said about working in the Bedretto Underground Lab is, to varying degrees, applicable to all other projects we support. Indeed, closed borders are devastating in the world of research, which almost always involves international collaboration. On pages 23 to 107, we show how innovative, resourceful thinking paired with dedication enabled the project leaders to deal with the limitations and, coronavirus notwithstanding, make progress in 2020.

We hope you enjoy reading our report—and that you remain in the best of health.

Our warmest wishes

Gerd von Brandenstein
Chairman of the Siemens Family
Advisory Board of the
Werner Siemens Foundation

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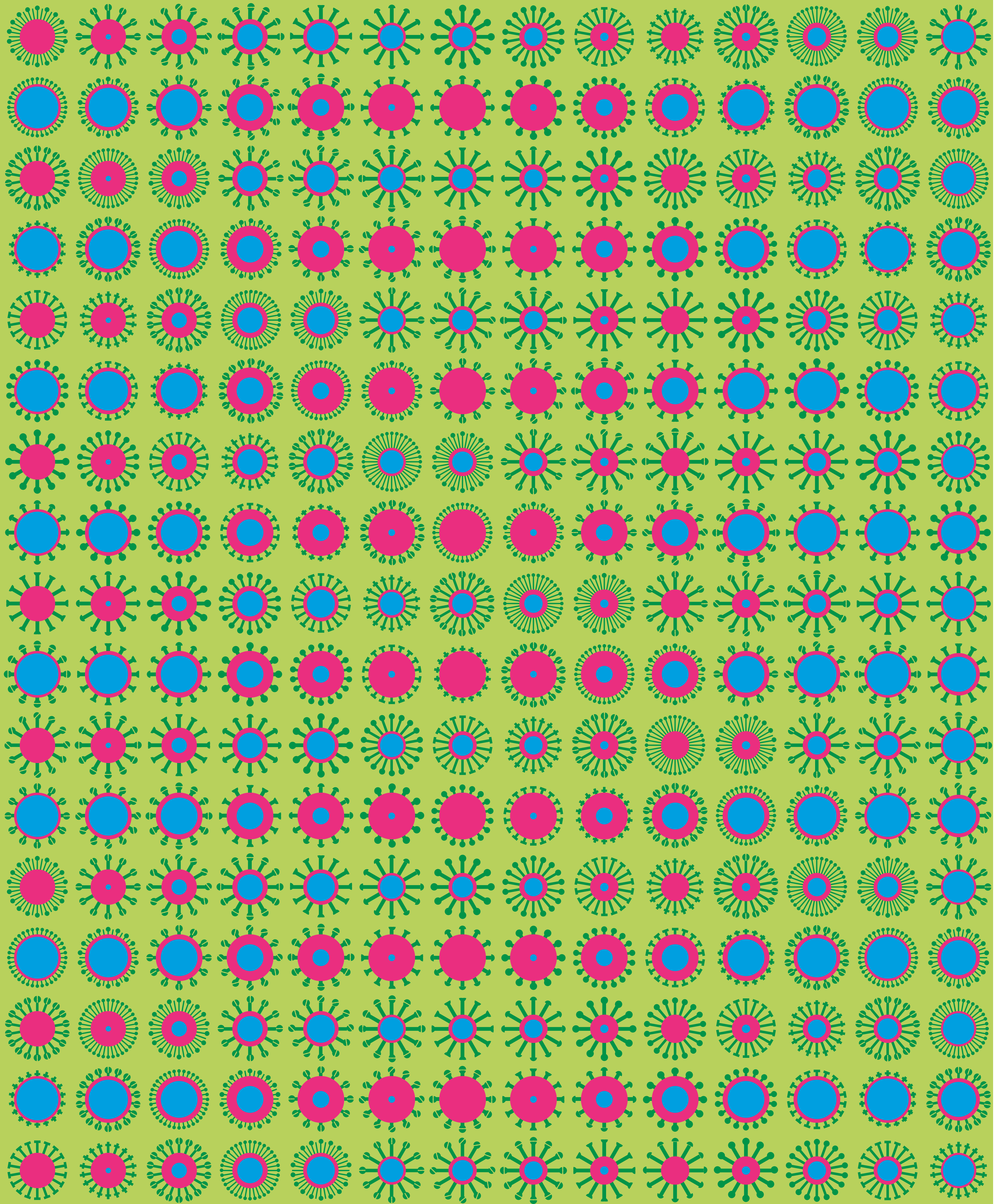


Taming the virus

Developing a broad-spectrum antiviral drug

Whether Covid-19, dengue fever or Ebola: a virus is often the root cause of devastating diseases. But medical science has not yet succeeded in developing an effective drug — akin to an antibiotic — that can be used to treat a wide range of viral infections. That may soon change.

Is an "antivirotic" on the horizon?

The "antivirotic" drug is the brainchild of materials scientist Francesco Stellacci, who has joined forces with medical specialists to realise his idea.

The dream of a broad-spectrum antiviral drug may soon become reality.

Francesco Stellacci would like to grant the world of medicine a long-cherished wish: a drug that can be used to combat a wide range of viruses—including the novel coronavirus. Thanks to funding from the Werner Siemens Foundation, the professor at the École Polytechnique Fédérale de Lausanne can take his search for an "antivirotic" to the next level.

The coronavirus caught the world of 2020 unawares—small wonder that the search to find effective therapies and a vaccine is correspondingly intense. If the efforts are successful, our world will again be a different place. But even better would be realising the age-old dream of a drug that is effective against not just one, but a whole range of viruses.

Experts estimate that our planet is home to thousands of different viruses, many of which can seriously impact the health of crops, livestock and humans. Roughly 50 viral infections are known to be responsible for the illness and death of millions of people a year around the globe. Vaccines have been developed for many of these diseases—smallpox, rubella, measles and hepatitis A and B—and effective therapies exist for several viral infections, including herpes, hepatitis B and HIV. Although this list is not exhaustive, it nevertheless remains modest in scope.

Spare the cell, harm the virus

What makes the development of antiviral drugs so difficult? Viruses have no metabolism of their own; instead, they reproduce by invading the cells of plants, animals and humans. We already know of so-called virocidal agents that are able to neutralise viruses—disinfectants, for example. But what works well on doorknobs, or even on the skin, can cause irreparable damage to cells inside the body.

The antiviral medications of today share this problem: they generally work by preventing a virus from multiplying inside a cell. This approach, however, can also damage the cell and result in serious side effects in the host. Preventing a virus from invading a human cell in the first place is a much safer approach, and corresponding drugs have already been developed. Unfortunately, they are unable to permanently damage the virus.

Clever and effective deception

Francesco Stellacci is exploring an approach that completely destroys viruses. A professor of materials science and head of the Supramolecular Nano-Materials and Interfaces Laboratory at the Institute of Materials at the École Polytechnique Fédérale de Lausanne (EPFL), Stellacci has been working on developing a broad-spectrum antiviral agent for the past ten years. To begin, he researched gold nanoparticles, later shifting his focus to modified cyclodextrins, a sugar molecule that is currently used as a food additive and being tested as a potential atherosclerosis drug. Now Stellacci envisions a huge breakthrough—an advancement on the scale of what Scottish bacteriologist Alexander Fleming achieved with his discovery of penicillin, the antibiotic effective against a large range of bacteria.

Similar to Fleming's achievement, Francesco Stellacci aims to develop an "antivirotic" and to treat viral infections with cyclodextrins. In his approach, cyclodextrins are modified with alkyl chains—made up of carbon and hydrogen atoms—that are end-capped with sulphonic acid groups. After being modified, the cyclodextrins can trick a virus into thinking they are receptor molecules on the surface of a human cell. Drawn to these pseudo-receptors, the virus binds with the decoy.

Bind and squeeze

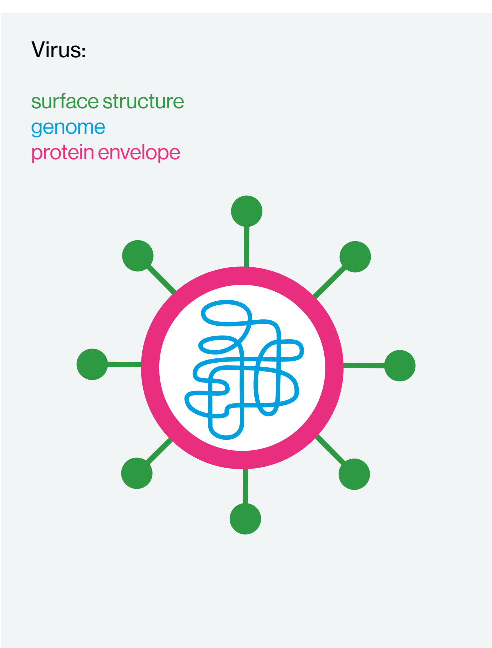
This basic idea of tricking a virus has been around since the 1930s, but deception alone fails to kill the virus. Stellacci has developed a two-pronged approach so that, after attracting the virus, the modified cyclodextrins can capture it with their long "arms" and literally squeeze the virus's outside layer, known as the viral envelope; the mechanical pressure is so strong that it bursts the viral envelope.

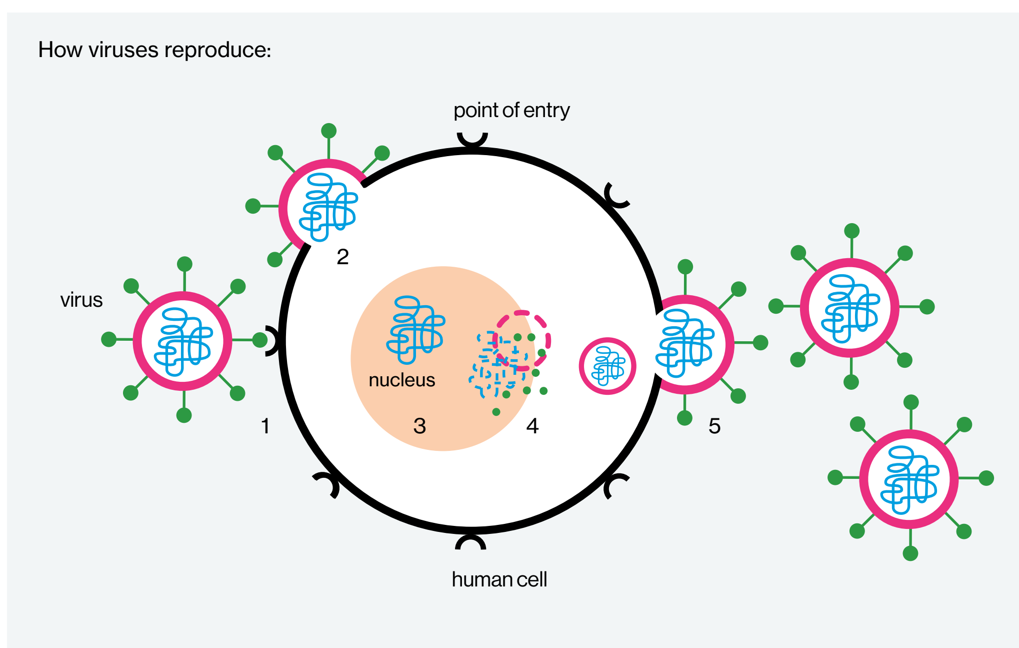
In contrast to current antiviral drugs, this process not only blocks a virus's capacity to replicate: it also effectively and permanently destroys the virus. Afterwards, the immune system takes over and processes the viral remains. The best part of this approach is that the cell itself remains unharmed, as the entire process is extracellular.

First choice in treatment

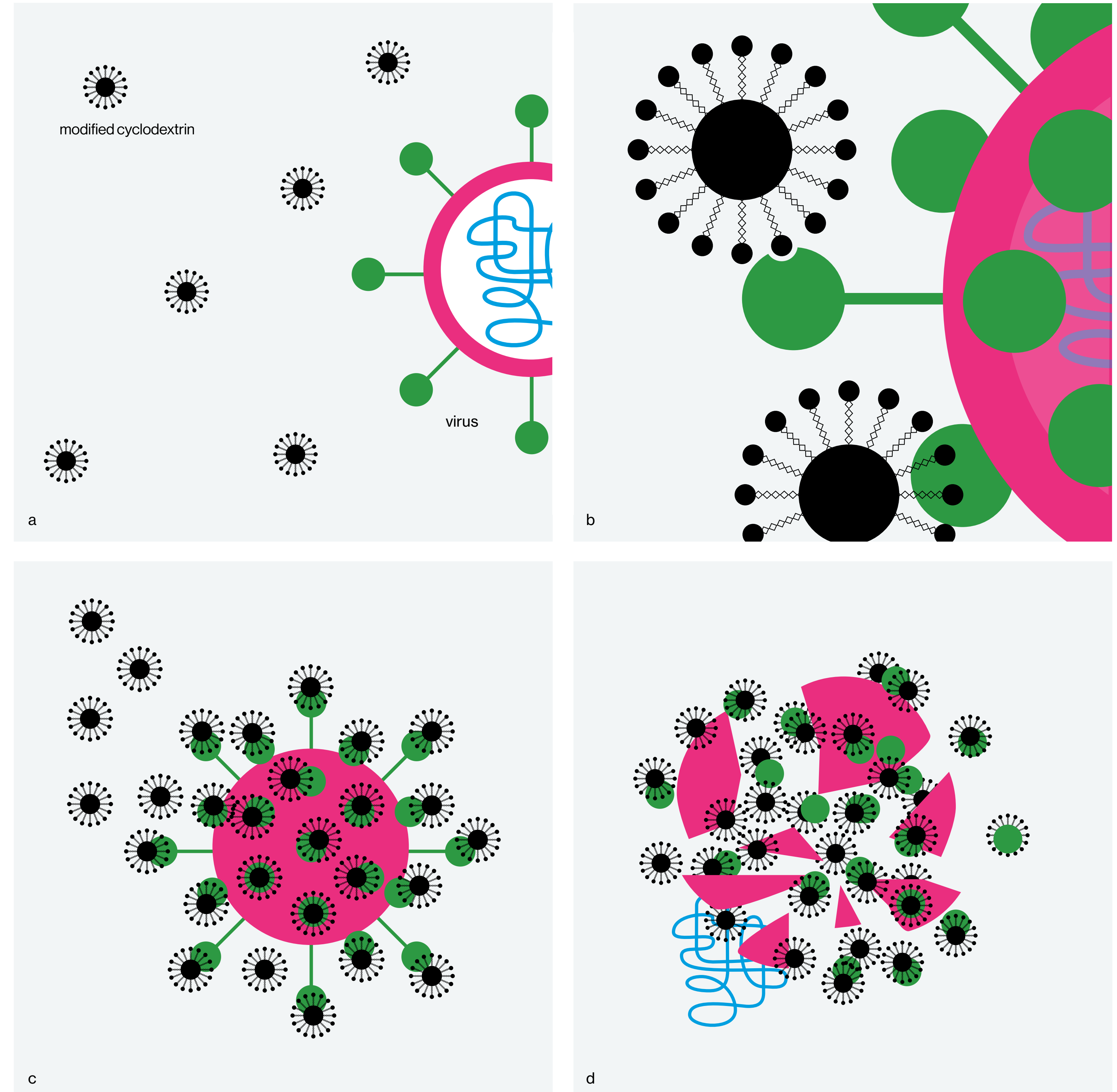
Intercepting viruses before they invade a cell and working with mechanical pressure rather than applying a chemical principle—Francesco Stellacci believes this unique approach is the best way to develop a widely applicable antiviral therapy. Nevertheless, he warns that we should remain clear-eyed about a future drug: "Just as there's no single antibiotic that can kill every kind of bacteria, there will probably never be a single substance that's effective against all viruses. They're just too diverse." For example, not all viruses are attracted to this type of sugar molecule.

That said, Stellacci estimates his agent could prove effective against 15 of the most serious diseases in humans caused by viruses. He is aiming for a drug that will be the first choice to treat viral infections, similar to penicillin,





How viruses reproduce in humans: the virus latches on to a human cell (1), penetrates the cell (2) and injects its genome into the nucleus of the cell (3). The human cell becomes a host to the virus: the genome and protein envelope of the virus are replicated in the cell's nucleus (4), the replications mature into new viruses (5) that exit the host cell and go on to replicate inside other cells in the body.



Francesco Stellacci's approach to neutralising viruses:
a The modified cyclodextrins (black) imitate receptor molecules on a human cell, attracting the virus
b The virus latches on to the cyclodextrin, and the cyclodextrin captures the virus with its "arms"
c The cyclodextrins apply a strong mechanical pressure on the virus
d The pressure destroys the viral envelope, neutralising the virus before it can enter a cell and replicate

The team in Francesco Stellacci's group at the Supramolecular Nano-Materials and Interfaces Laboratory are developing a broad-spectrum antiviral drug and …

which remains the first choice in treating many bacterial infections. But just as prudent use of antibiotics is essential, it is important to proceed with care when prescribing an "antivirotic", as viruses, too, can develop resistance to drugs. Nevertheless, Stellacci believes his approach reduces this danger in comparison to standard antiviral medications because the virus is attacked outside the cell.

Focus on respiratory infections

With the advent of the Covid-19 pandemic, Stellacci began focusing his research on the novel coronavirus and other viruses that affect the respiratory system or that are transmitted through the air. "These are the kinds of viruses that bear the highest risk, that are most likely to cause pandemics," says Stellacci.

In his research, Francesco Stellacci works with specialists from the fields of virology and infectious diseases at the University of Geneva and the Geneva University Hospitals. His approach has already been effective in laboratory experiments: after being injected with modified cyclodextrins, human cells were no longer vulnerable to a wide range of viruses—including the novel coronavirus. Experiments with lung tissue grown in the lab were also successful, as were tests using the approach on influenza and herpes viruses in mice. Particularly promising is that, in initial attempts, the method has also proven effective against viruses lacking a viral envelope—that instead are enclosed in a protein shell called a capsid. This expands the number and kind of viral infections that could be successfully treated.

Clinical trials scheduled

The strong results from these tests impressed the Werner Siemens Foundation, which is funding the next phase of the project. From the spring of 2020 to the end of March 2021, Francesco Stellacci is conducting additional toxicological studies and preparing drug manufacturing practices with external partners. The main goal, however, is to present the results of the first clinical trial by the spring of 2021. During this phase, the drug will undergo its first test for its safety on humans at the Geneva University Hospitals. Various versions of the drug will be tested, and a patent has been filed for all agents used in the trial.

If the results show the drug is safe, additional clinical trials will follow to test the efficacy of the approach on humans. "If all goes well and future funding can be secured, our agent should be available as a drug by 2025 at the latest. We expect it will be in the form of a throat spray," says Stellacci. An antivirotic throat spray—an elegantly simple solution to a serious global problem. One that has taken on new urgency in the wake of the novel coronavirus.

… testing it in the high-security EPFL lab, where the staff are required to wear protective clothing …

… and use fingerprint recognition to enter.

In the second airlock, a researcher wears a special biosafety suit
with a filtering device on the back (see image below).

The protective gear allows her to safely remove viral samples from the refrigerator
in the high-security lab and prepare them for a series of tests.

A final meal: before the cyclodextrin destroys them, a raspberry-coloured
culture medium is given to the lab-grown viruses.

“Research that makes a difference in the world”

A materials scientist with an ethical approach: project leader Francesco Stellacci wants to conduct research that also benefits people in poorer countries.

A materials scientist pursuing research into an antiviral drug? Obviously the sort of person who thinks outside the box. And a global thinker, too. Quite literally, as Francesco Stellacci, professor at EPFL, plans to make his research findings available to a worldwide audience—in order to encourage research groups from around the world to “seek even better solutions” to his innovative approach.

What motivated you, a specialist in materials science, to pursue medical research?

Francesco Stellacci: I want to conduct research that makes a difference in the world, both to people and the environment. I also believe it’s essential to find solutions for problems in poorer countries. And because health is at the heart of so many problems there, my focus has increasingly shifted to medical research. For example, I discovered additives that keep the temperature of vaccines stable for up to two months—without a refrigerator or other cooling methods. This can significantly lower the cost of vaccine programmes in developing countries, as up to 80 percent of all expenditures go towards keeping the vaccines cool enough. I intentionally didn’t have my discovery patented so that it can be used as widely as possible.

And now your goal is to develop a broad-spectrum antiviral drug?

Yes, it’s an absolute necessity. The problem with having drugs effective against only a single virus is that treatment becomes expensive and availability is limited. A broad-spectrum antiviral drug would be much more effective and would reduce costs in the healthcare sector, an essential factor for developing countries.

There’s hope that a vaccine against the novel coronavirus will be found before your drug is ready. Is it still worthwhile to focus on its efficacy in treating Covid-19?

I sincerely hope that we’ll have a Covid-19 vaccine very soon, but there’s no guarantee. In principle, it’s easier to find a drug to treat an entire class of diseases than it is to develop a vaccine for every single illness. And having a medication that’s effective in treating a wide range of viral infections can facilitate the development of a vaccine.

How so?

A vaccine offers preventive protection, but a drug cures illness. To prove the efficacy of a vaccine, people undergoing trials have to be willing to risk falling seriously ill. If the vaccine fails and no effective medication is available, we’re endangering the lives of the test subjects. Vaccine trials are much less risky if an effective way to treat a virus already exists. But again, it’s all the better if we soon have a Covid-19 vaccine. Of course, it’s also not certain that it will work perfectly for everyone, so a drug would be helpful in all scenarios. This is all the more true if the drug is effective against the kind of virus that could cause a future pandemic or against viruses like the influenza virus. Regarding the latter, it would be fantastic to see a real improvement in flu treatments.

You’re planning on making all your research findings openly accessible. What’s your reasoning behind this decision?

We want to motivate other research groups to seek even better methods of implementing the approach. Maybe someone will find a yet more elegant way to imitate our sugar molecules or to create pressure on the viral envelope. I want to show that the principle works. Then other researchers will be encouraged to apply the process, too. That’s how science works. And that’s exactly how it should be.

If this project is successful, what will your next goal be?

One issue that has preoccupied and also saddened me for several years now is that many children die of infectious diarrhoea, especially in poorer countries. It’s estimated that there are up to half a million deaths every year. As one of my next projects, I’d like to try to find a therapy to treat these kinds of diseases. Then, aside from medicine, I’m also interested in ecological issues. I’d like to help develop a sustainable form of plastic that doesn’t harm the environment. There are so many challenges in the world—I’m very much motivated to tackle some of them with my research.

Facts and figures

Project

Francesco Stellacci is developing a broad-spectrum antiviral drug that can be used to treat a wide range of viral infections. A particular focus is on Covid-19 and other respiratory diseases caused by viruses.

Support

The Werner Siemens Foundation is funding the project from April 2020 to March 2021. During the 12-month period, the agent is being tested on animals and in vitro, and good manufacturing practices (GMP) are being prepared. In addition, the first clinical trial will be held at the Geneva University Hospitals (HUG).

Funding from the Werner Siemens Foundation

5 million Swiss francs

Project duration

2020 to 2021

Project leader

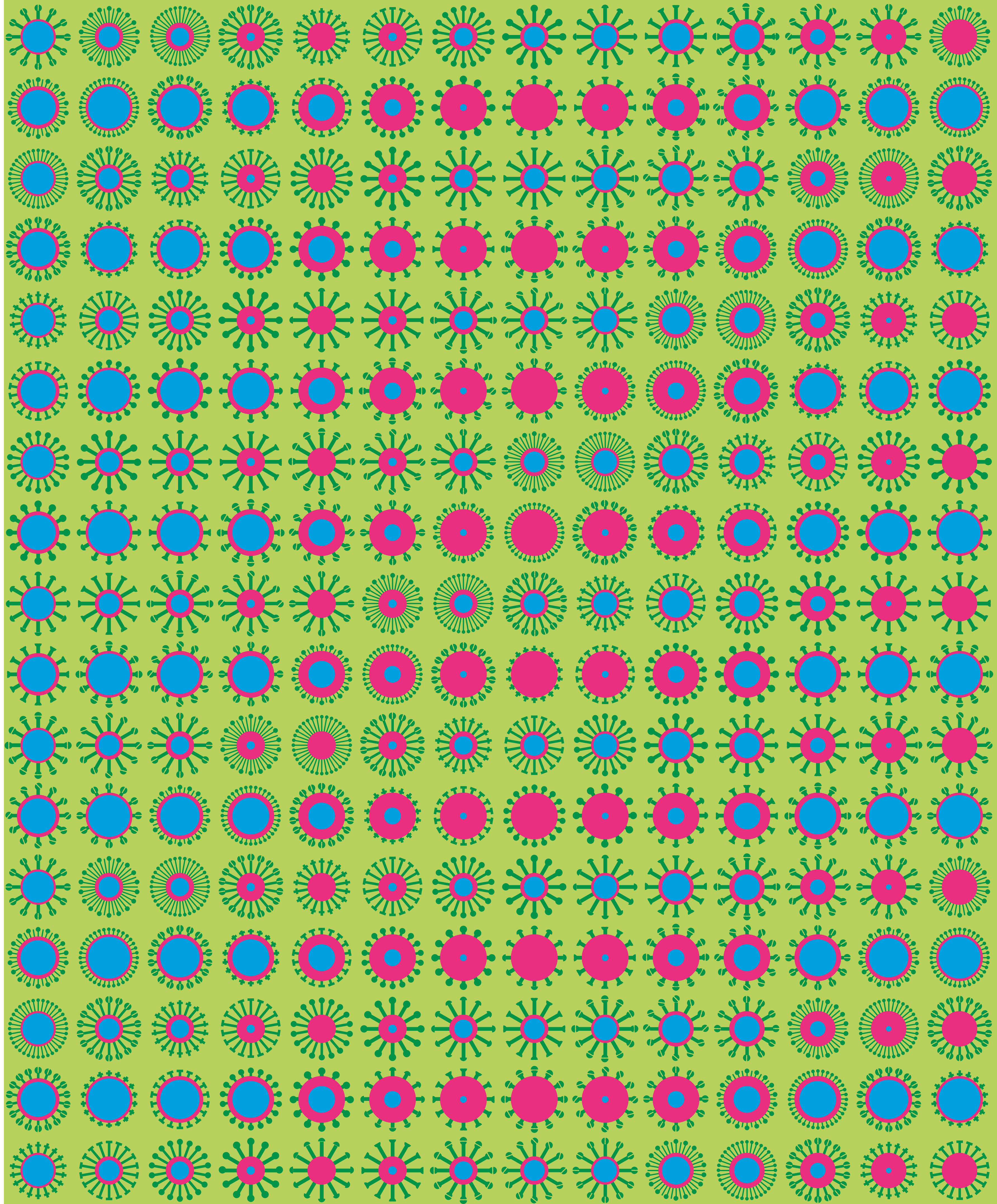
Prof. Dr Francesco Stellacci, Supramolecular Nano-Materials and Interfaces Laboratory, Institute of Materials, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

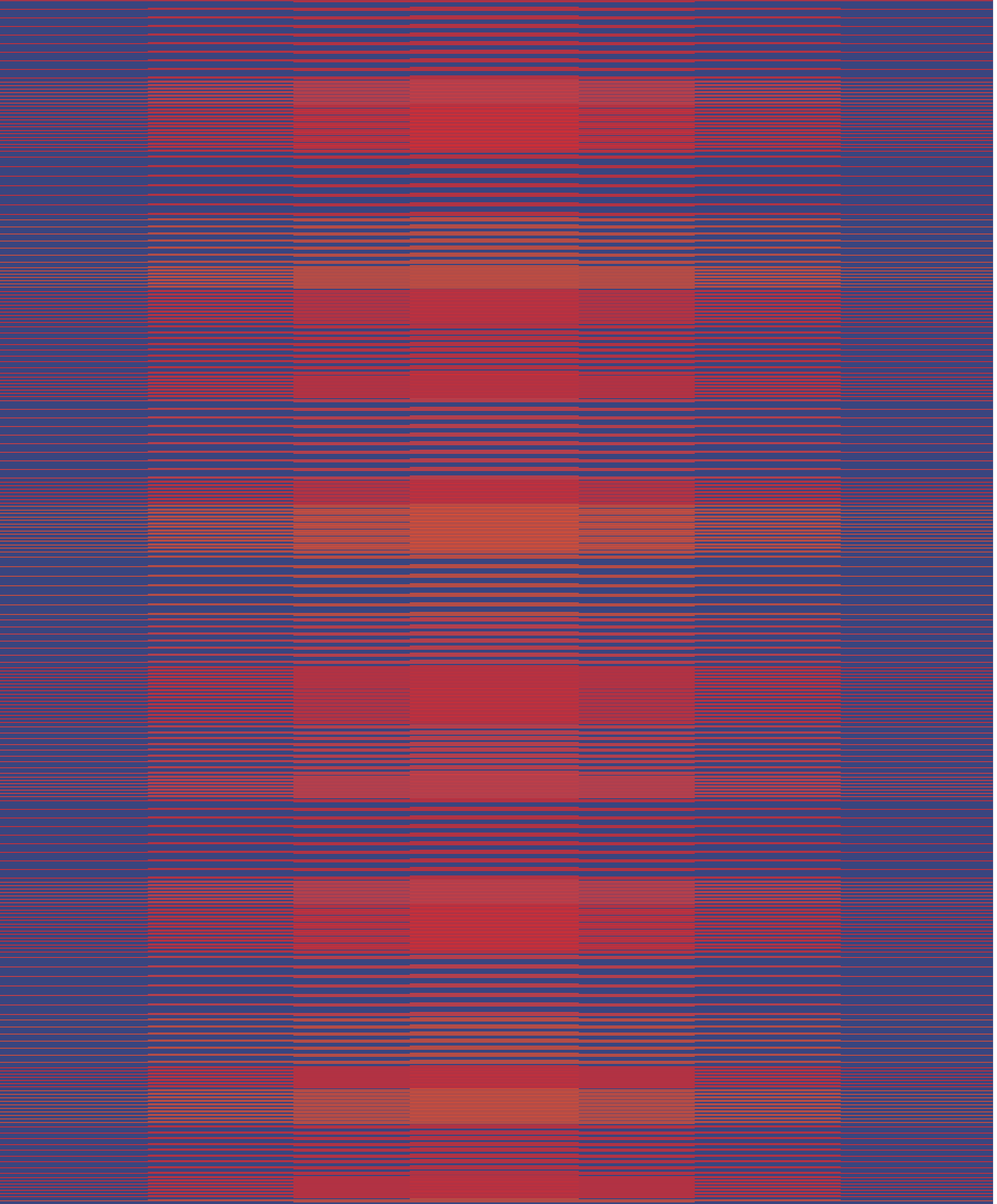
The research team has a "mascot": an orange virus model that breaks into pieces when placed under pressure.

broad-spectrum antiviral beneficial

Innovation

The Werner Siemens Foundation is supporting the development of an antiviral agent effective in treating a wide range of viral infections—because a broad-spectrum antiviral drug would be a major medical breakthrough that brings benefits to the whole of society.





Smart implants

Healing complex bone fractures

Far from being rigid or static, bones are in a state of flux, continually metabolising and growing weaker or stronger. Unfortunately, the outer shell of a bone gives no indication of its inner workings—a problem when treating complex bone fractures. Until now, patients have had no other option than to wait and see whether a fracture heals well—or not. In future, however, smart implants will correct course should the healing process veer off track.

Monitored healing

When treating fractured bones, doctors generally use standard implants. A plate is screwed into the bone to stabilise the fracture—regardless of whether the bone was twisted, bent or crushed. In 10 percent of cases, however, complications arise. To improve treatment, an interdisciplinary team at the Saarland University Medical Center is developing intelligent implants that not only stabilise the fractured bone but also detect and counteract incorrect weight bearing in individual patients. The project is now receiving funding from the Werner Siemens Foundation.

Where should the smart implant be fitted on the bone? Project initiator Tim Pohlemann (left) in discussion with project leader Marcel Orth.

The treatment of bone fractures has seen two major revolutions: in the 1960s, physicians began stabilising fractures with plates, relieving patients from long periods in heavy casts. The new procedure shortened rehabilitation time, prevented bone malalignment and allowed for greater mobility during the healing process. For many years, however, the only plates available were the few standardised models that had been developed to treat skiing injuries, and these were often unsuitable for the complex spiral and multiple fractures that commonly occur in traffic accidents. The second revolution, then, was the development of numerous new implants beginning in the 1980s.

A team of physicians at the Saarland University Medical Center are now aiming to start a third revolution: together with partners from the fields of applied mechanics, mechatronics and computer science, they want to develop smart implants that can monitor the healing of fractures and help to remedy incorrect weight bearing—autonomously, with no action required from either doctor or patient.

Personalised fracture treatment

Today, complications arise in around 10 percent of bone fractures; affected patients suffer pain and require further treatment. Aside from the personal trauma, this also places a burden on society, as the additional therapy increases healthcare costs and patients are unable to work. “Innovative technologies could make bone fracture treatment safer, more individual and more cost-effective,” says Dr Marcel Orth, who leads the project at the Saarland University Medical Center.

Adapting standard plates currently used to stabilise bone fractures is one approach to developing the novel implants; using external fixations, which have the advantage of protecting sensitive soft tissue, is another option. The idea is to apply a layer of “intelligent” materials—materials with sensoric and actuator (self-acting) characteristics (see interview pages 48 to 49)—to the standard plate or external fixation. Translating these new technologies from materials science to medical applications is the focus of the mechatronics engineers at the Center for Mechatronics and Automation Technology.

Intelligent implants

The aim is to create intelligent implants that can detect and respond to incorrect weight bearing on a fractured bone. For instance, if too much pressure or weight is placed on a fracture, the implant stiffens, relieving strain on the bone. By contrast, if a patient is too sedentary, the implant changes its shape and becomes more flexible, increasing the pressure on the bone. The implant can be monitored by an external device, such as a computer or smartphone, and is removed when healing is complete. The team plan to manufacture the components in a variety of shapes and sizes that can be combined to best treat the individual fracture. An additional benefit is that post-operative care is simplified.

But before they can design intelligent implants that aid healing processes, the researchers must identify which conditions are conducive to healing and which factors cause complications. “Today, no one knows exactly why compli-cations arise,” says Professor Tim Pohlemann, director of

Surgeon and clinic director Tim Pohlemann leads the interdisciplinary team developing smart implants.

the Department of Trauma, Hand and Reconstructive Surgery, at the Saarland University Medical Center. In current practice, patients receive instructions solely on how much weight they should put on the bone. “After that, physicians can only cross their fingers and hope,” says Pohlemann. Little is known about the effect of weight bearing on healing; moreover, findings from preliminary studies suggest that patients rarely follow the instructions of the physician. “We assume that in their day-to-day lives, patients have difficulty in putting the right amount of weight—for instance, half their body weight—on the bone,” explains Pohlemann.

Understanding the healing process

One of the most important and challenging steps in the project is gaining a clear understanding of the healing process, and the first studies are already in progress. Test persons with a lower-leg fracture wear an intelligent insole in their shoe; the insole has 16 pressure sensors that record 82 parameters per step taken, enabling the researchers to identify the forces acting on an affected bone. Using these data, experts from the Professorship for Engineering Mechanics at Saarland University conduct simulations and experiments to determine exactly what happens to bones when they are exposed to everyday pressure and strain.

The researchers plan to use artificial intelligence (machine learning) to distinguish between behaviours that promote healing and behaviours that tend to result in complications. Based on the test data, specialists at the German Research Center for Artificial Intelligence are developing algorithms that precisely predict which conditions are most likely to promote healing. To this end, the computer scientists define limit values for diverse parameters such as physical stress or strain; they also employ imaging techniques to enable healing prognoses on the basis of pictures.

The project team is aiming to build a prototype of an intelligent implant and to complete initial testing on animals by 2025. Nevertheless, it will probably take another two decades before the new technology can be used to treat fractures in humans, as approval procedures are very complex. But project leader Marcel Orth remains optimistic: “Smart applications are already standard in a variety of areas, such as automobile technology. There’s no reason why innovations from materials science can’t be of great benefit in medicine, too.”

The first step is understanding the basic principles: under normal conditions, which forces act on bones when a person walks?

The smart implant is being developed at the Center for Mechatronics and Automation Technology, where the interdisciplinary team are conducting a series of experiments to better understand how healthy and injured bones react to stress and pressure.

The benevolent breaking of bones

How are implants made intelligent? Two specialists from the research project on smart implants—mechatronics engineer Dr Paul Motzki from the Center for Mechatronics and Automation Technology in Saarbrücken and mathematician Dr Michael Roland from the Professorship for Engineering Mechanics at Saarland University—share their insights.

Have you ever broken a bone?

Paul Motzki: Yes, I once broke my femur in a sports accident. It was fixed with two rods in the side of my thigh—it looked pretty gruesome. Fortunately, the fracture healed well, but I know from other cases among my family and friends that difficulties can arise. My brother had problems for more than two years after breaking his collarbone, and a friend who broke his humerus in a moped accident in Thailand also needed additional treatment for quite some time. So I'm familiar with the fact that fractures don't always heal without complications.

Now you want to make intelligent implants that support the healing process. How are you developing these?

Michael Roland: First of all, we need data, data and more data, because it's crucial that we understand exactly which forces are acting on the bone. There has been research on animals in this area, but practically none involving humans. Right now, the physicians in our team are collecting data from test persons wearing shoes with smart insoles. We use this data to simulate the relevant forces and observe their effect in experiments. We've developed two machines for this. With the first device, we press and twist the bones until they break. Then we clamp them in the second unit, where we let the measured forces act on the bone. This enables us to see how the fracture and the bone are affected. The measurements help us to identify various factors, such as how stiff the bone still is, and we use a camera system to observe how the fracture moves. Then we pass on the test results to the mechatronic engineers.

What do the mechatronic engineers do with the results?

Motzki: We use the data to test the materials that we plan to use in producing, or rather modifying the implant to make it "smart". Right now, we're testing around the clock to observe the fatigue behaviour of the materials. In other words, we want to find out how the materials change when they're subjected to the wear and tear of millions of test cycles or when we change the ambient conditions such as temperature and humidity.

How do you go about making the implant intelligent?

Motzki: Our idea is to coat a standard plate with modular material layers that have sensoric properties, enabling precise measurement of the forces acting upon the fracture. In addition, the implant should also perform actuator functions—in other words, it must be able to directly steer the healing process by translating the signals from the sensors into a movement or change of form. We want to use novel materials to implement this function, too.

What exactly are these new intelligent materials?

Motzki: They're special metals that warp under thermal activation, but can "remember" their original state. They have very good sensoric properties. We're experimenting at the moment with a nickel-titanium combination, a so-called shape-memory alloy. Most people are familiar with these from flexible eyeglasses, orthodontic wires—or, in medicine, stents. The technology is well researched, and attempts have already been made to combine it with new materials to achieve a better actuator function. Our work builds on this research.

What are the greatest challenges in producing smart implants?

Roland: Although we're making good progress with the simulations, it will probably be most difficult to determine the key factors steering the healing of fractures. When does a break heal well? What causes complications to arise? For this, we need a great deal of data, also from patients who experience complications. These data are central: our simulations are based on them, as are the algorithms developed by our colleagues at the German Research Center for Artificial Intelligence.

Motzki: On the technical side, the actuator function presents the greatest challenge. But I'm fairly optimistic on this front, as the materials and the technology are in principle well known and available. Rather than creating a new material, we need to prepare existing materials for use in medical applications, and we have considerable expertise in this area. Another clear challenge is coordinating the various disciplines. We're dependent on one another because we need good data from our project partners. We also have to be sure that we're speaking the same language.

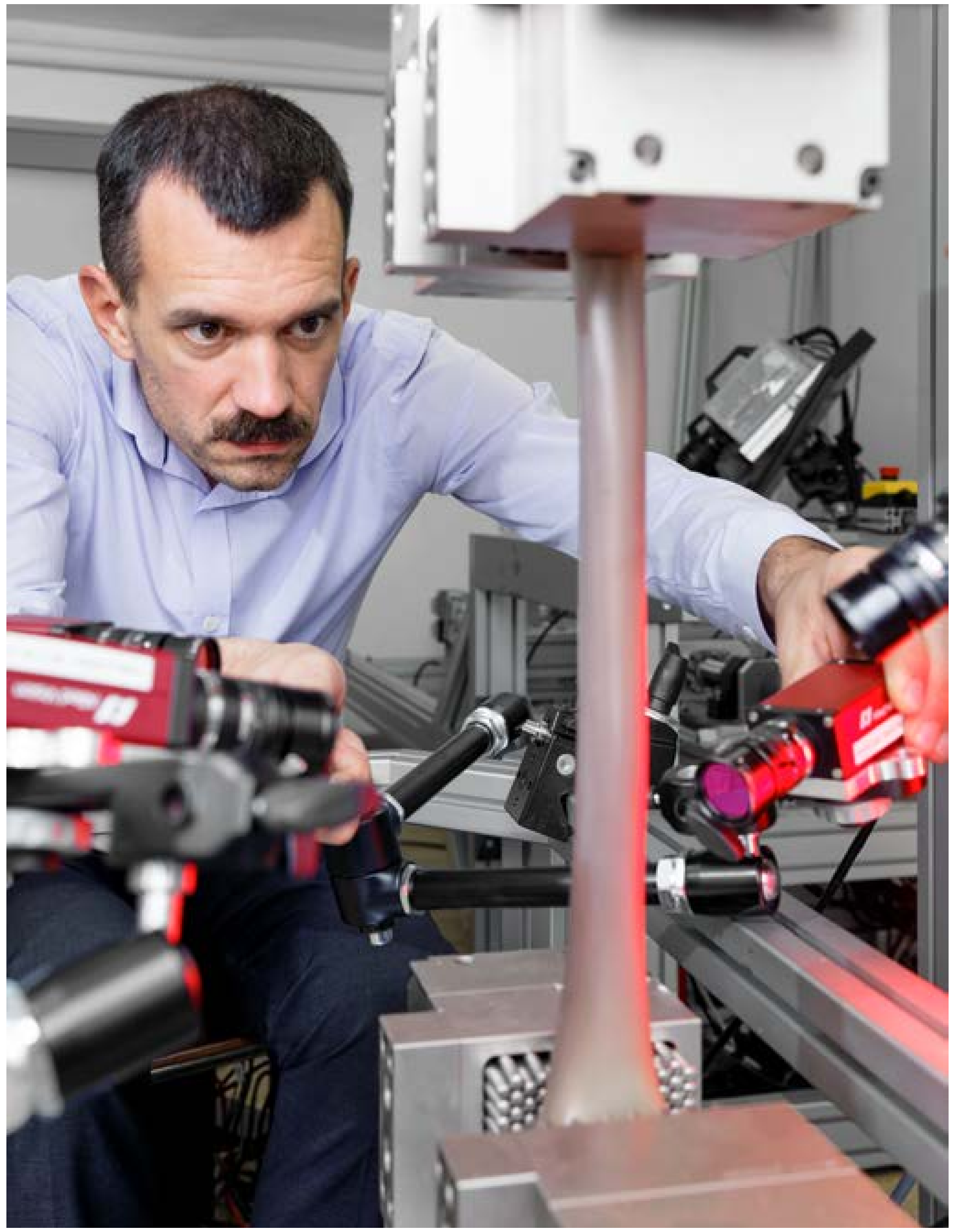
Can you give an example?

Motzki: Sometimes we use the same words to mean different things, which can lead to misunderstandings. For example, once the physicians were talking of "shearing movements". They were referring to movements of patients that are suboptimal for the healing process, as they can cause the fracture surface to shift sideways. We're familiar with the notion of "shear force" from engineering, but didn't know what that had to do with fractures. So for a while we were at cross purposes. The fact that our facilities in Saarland are close together and we can meet easily is certainly an advantage. Our communication is frequent and very productive.

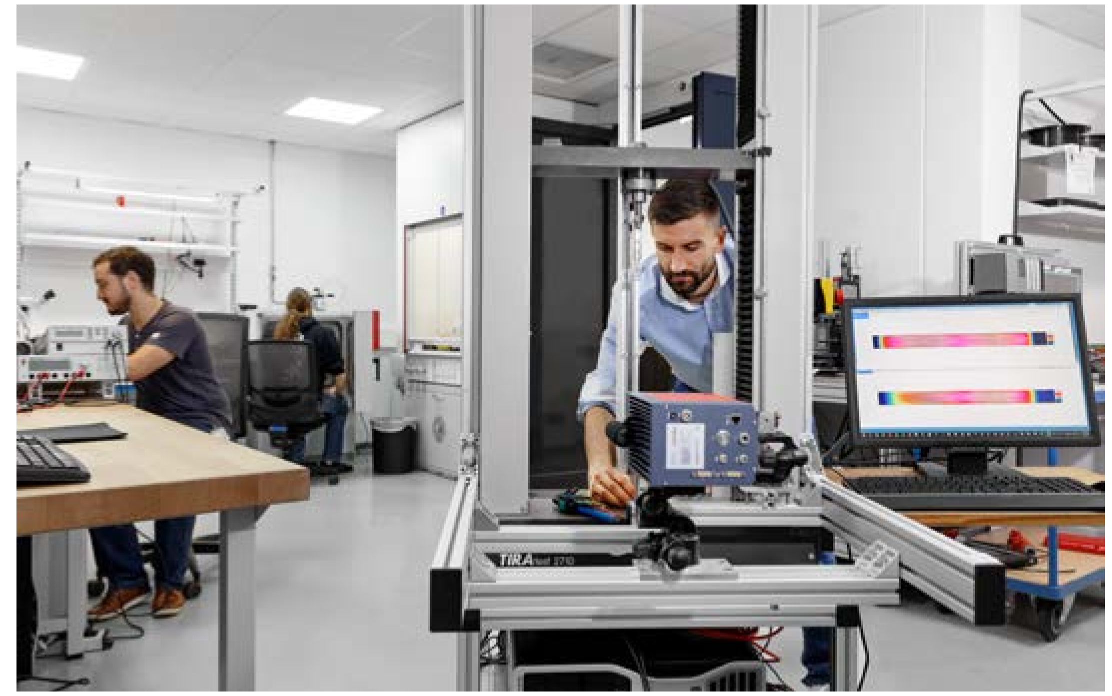
Are there also differences in mentality between researchers from the different fields?

Motzki: The disciplines are really very different. We engineers are trained for precision: every millimetre counts; we always seek ideal solutions and strive for innovation. Medicine, and surgery in particular, are more empirical disciplines, and physicians generally take a more conservative approach, as their priority is minimising patient risk. And sometimes on-the-spot decisions are necessary for the benefit of the patient.

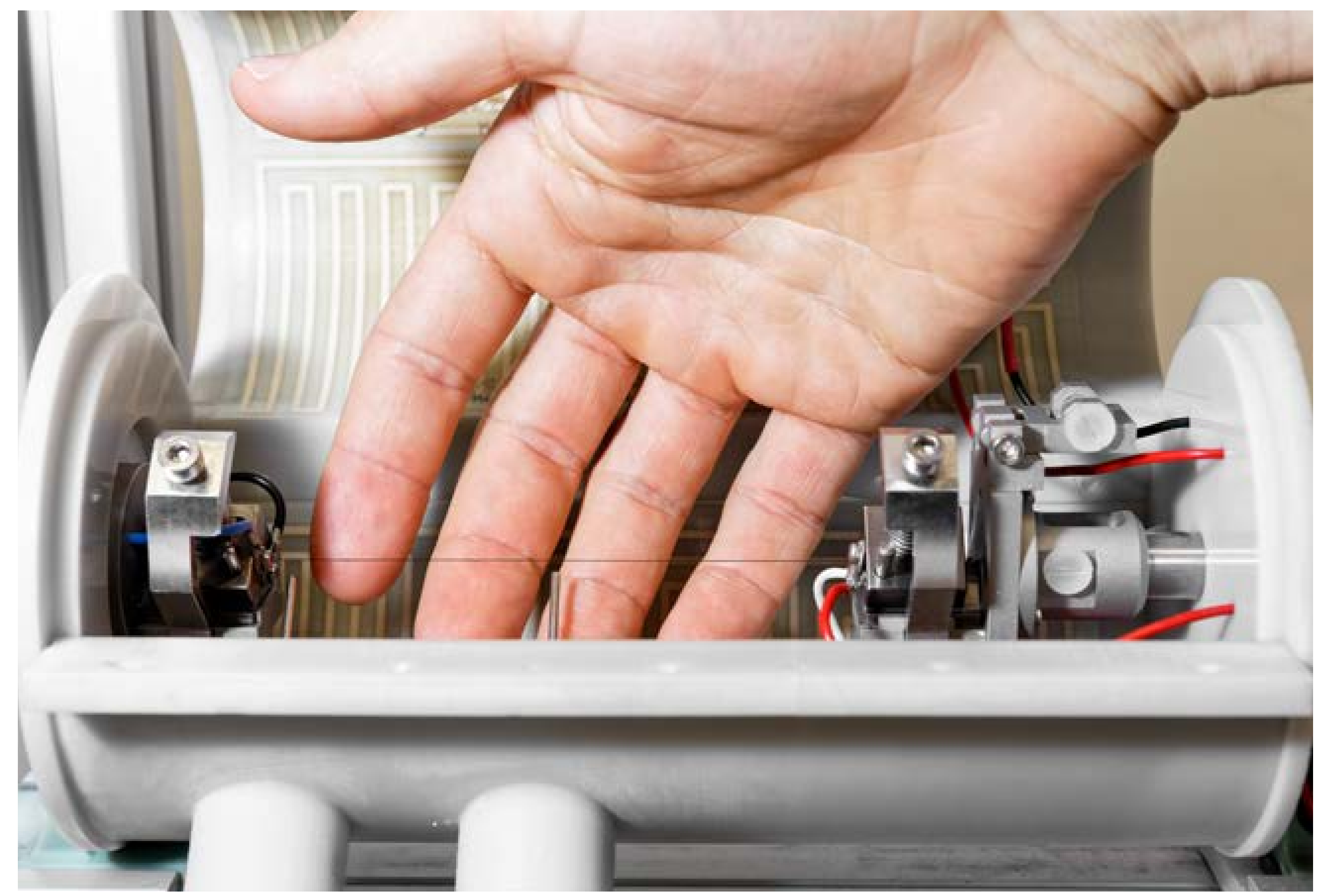
Roland: Physicians often don't have time to wait for the ideal solution, and patient health is dependent on a variety of factors. One thing I've learned is that it can be better to operate on a broken bone quickly rather than waiting and observing, because otherwise the risk of infection increases. In the end, it's the physician's responsibility to find a good solution for each patient. For me as a mathematician, the interdisciplinary teamwork has been greatly rewarding.



Mathematician Michael Roland from Saarland University monitors the measurement data delivered by pressure sensors worn by test persons. Using this information, he and his team then simulate the forces that act on a bone fracture.



Mechatronics engineer Paul Motzki at the Center for Mechatronics and Automation Technology, conducting a test using a promising component for the smart implant: ultra-fine wires.



The fine wires made of nickel-titanium have shape memory. The individual wires are grouped into cords, then combined into a thick strand. When an electric current is sent through the individual cords, the strand moves in the designated direction and is as flexible as an elephant's trunk. When no current is sent, the strand reassumes its original shape.

A part of the team developing the smart implants (left to right):
Aynur Gökten, research nurse at the Department of Trauma, Hand and Reconstructive Surgery, Saarland University Medical Center
Kerstin Wickert, Professorship for Engineering Mechanics, Saarland University
Prof. Dr Tim Pohlemann, project initiator and director of the Department of Trauma, Hand and Reconstructive Surgery, Saarland University Medical Center
Dr Tim Dahmen, German Research Center for Artificial Intelligence, Saarbrücken
PD Dr Marcel Orth, Department of Trauma, Hand and Reconstructive Surgery, Saarland University Medical Center
Annchristin Uhl, graduate student at the Professorship for Engineering Mechanics, Saarland University
Dr Michael Roland, Professorship for Engineering Mechanics, Saarland University

Facts and figures

Project

The team at the Saarland University Medical Center develop intelligent implants using novel technologies from materials science. The aim is to improve the treatment of complex bone fractures by monitoring and autonomously steering the healing process.

Support

The Werner Siemens Foundation is funding the planning stage, materials research and development of a prototype implant as well as animal testing in the validation phase.

Funding from the Werner Siemens Foundation

8 million euros over 6 years

Project duration

2019 to 2025

Project leadership

PD Dr Marcel Orth, Prof. Tim Pohlemann, Prof. Tina Histing, Dr Mika Rollmann, Dr Johannes Braun, Department of Trauma, Hand and Reconstructive Surgery, Saarland University Medical Center, Germany

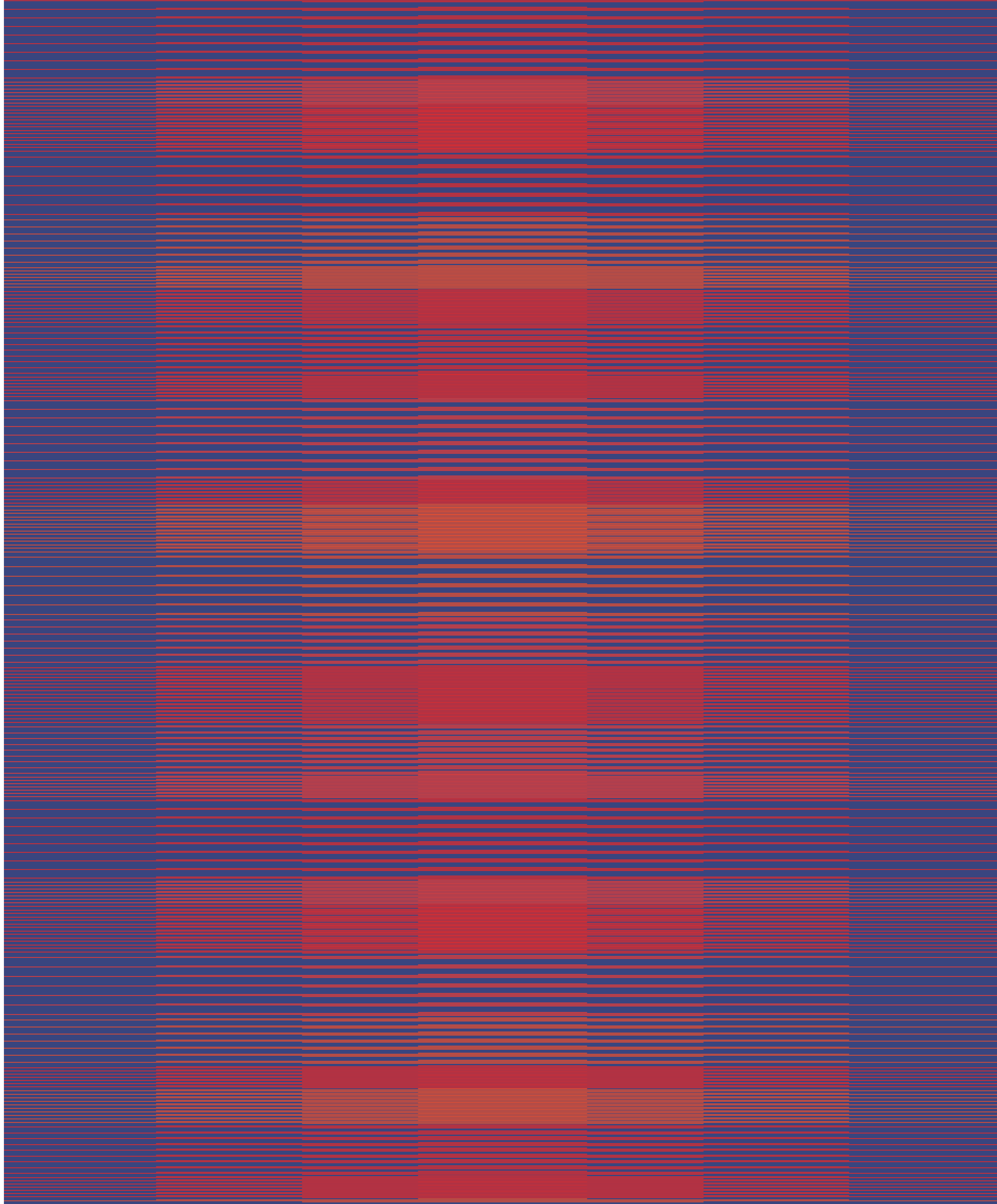
Project partners

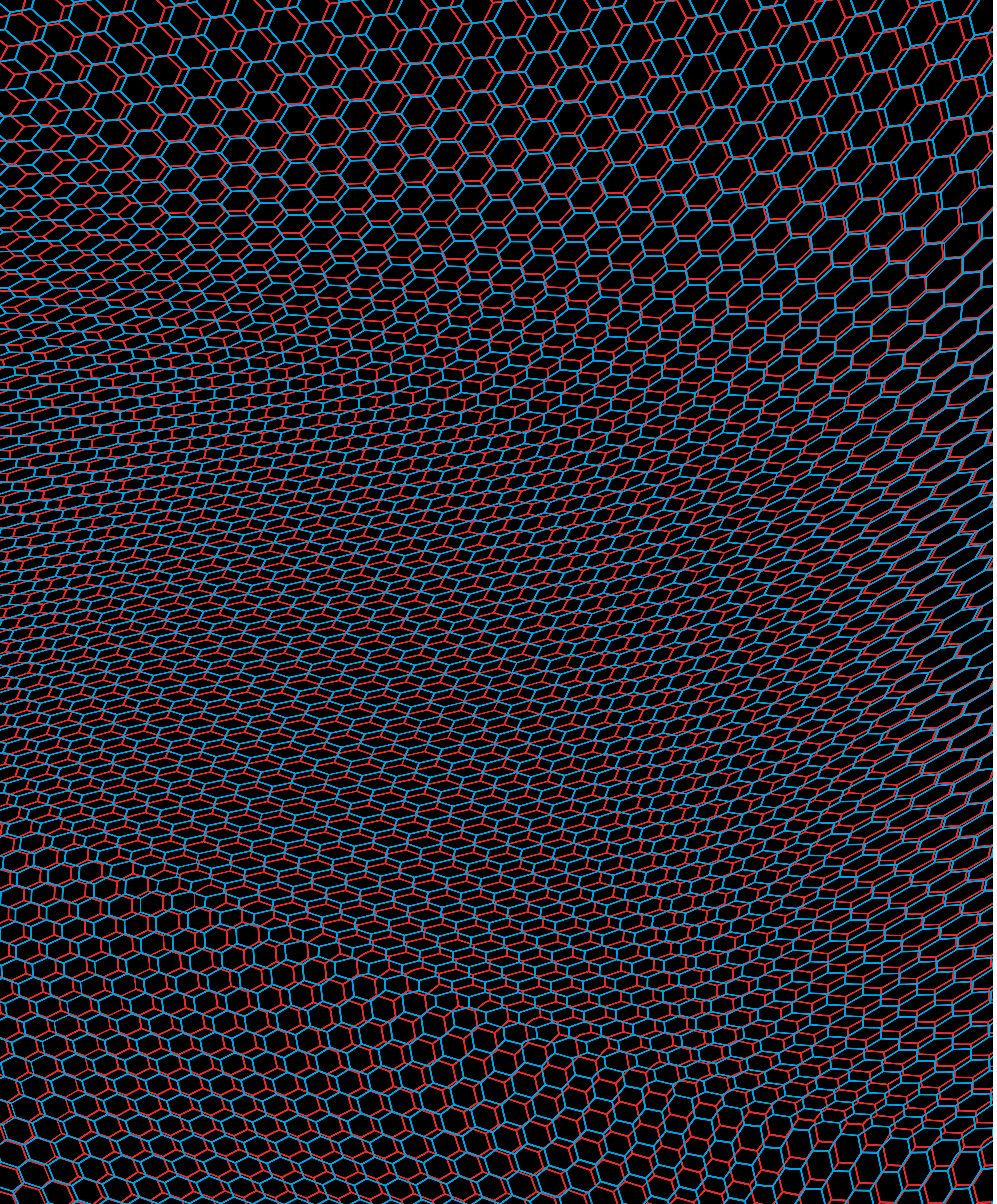
Prof. Stefan Diebels, Dr Michael Roland, Professorship for Engineering Mechanics, Saarland University, Germany
Prof. Stefan Seelecke, Dr Paul Motzki, Center for Mechatronics and Automation Technology (ZeMA), Saarbrücken, Germany
Prof. Philipp Slusalleck, Dr Tim Dahmen, German Research Center for Artificial Intelligence (DFKI), Saarbrücken, Germany

sensoric responsive individual

Innovation

The Werner Siemens Foundation is funding the development of smart implants that can monitor and aid the healing processes in broken bones—because the innovative implants promise to reduce the risk of complications while making the treatment of fractures safer, more individual and cost-effective.





Electrifying differences

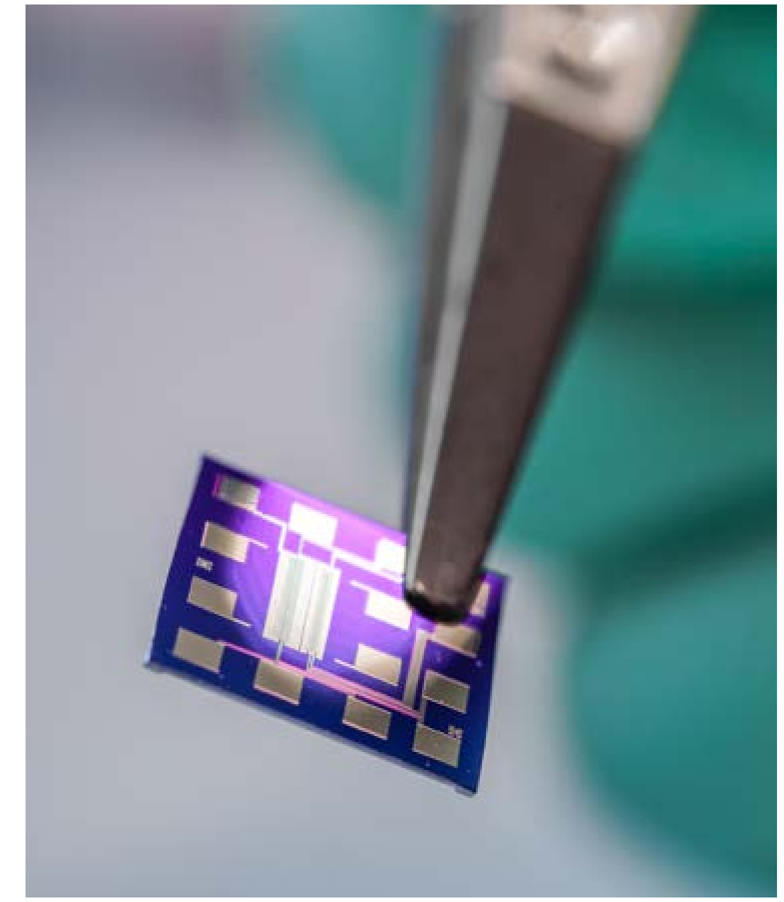
Seeking optimal thermoelectric materials at IST Austria

In days of yore, no one went to Gugging for pleasure. It would have been for a stay in the state “lunatic asylum”, founded in 1885. But times have changed. For the past 11 years, the historical site near Vienna has been home to a state-of-the-art research campus—the Institute of Science and Technology Austria, which has quickly developed into Austria’s premier research institution, attracting brilliant minds from all corners of the globe.

Striving for knowledge and innovation

The Institute of Science and Technology Austria (IST Austria) is young and pioneering—just like the professors who teach and research there. And while the application process for a position at IST Austria is long and arduous, those who succeed are guaranteed the support they need to conduct cutting-edge research. Among the chosen few is physicist Dr Maria Ibáñez, whose search for thermoelectric high-efficiency materials at IST Austria has been funded by the Werner Siemens Foundation since September 2020.

Having lunch together at IST Austria's modern cafeteria: research leader Maria Ibáñez and her team.



Ready for testing: newly developed nanomaterials with potentially interesting thermoelectric properties.

Catalonian physicist Maria Ibáñez is specialised in nanomaterials. Together with her team, she seeks new kinds of high-efficiency materials that can convert temperature differences into electricity. Her work draws on the phenomenon known as the thermoelectric effect: the build-up of electric voltage across a temperature gradient causes electricity to flow. Although it was first described nearly 200 years ago, no materials have been found that are able to utilise the phenomenon for high-efficiency, cost-effective power generation. Due to its low energy conversion efficiency, at just some six percent, thermoelectricity is simply not viable as an everyday source of power. Maria Ibáñez wants to change this: the physicist is going deep—down to the nanoscale—in her search for new, efficient and low-cost thermoelectric materials.

Research and family

For the past two years, assistant professor Maria Ibáñez has been teaching and researching at IST Austria, located north of Vienna, at a state-of-the-art campus built next to the renovated and repurposed former state asylum Gugging. Maria Ibáñez is, however, not just a dedicated scientist—she also has a family. After bringing her son to the IST campus day-care centre, she pursues her demanding, interdisciplinary research. At IST Austria no effort is spared to ensure that researchers can balance having a family and a career. At 5 pm, Maria Ibáñez picks up her son and embarks on the 30-minute bike ride home. Her evenings are spent enjoying family life with her husband and son.

Responsible and engaged

"I'm interested in how things work," says Maria Ibáñez. Over the past two years, this basic attitude has stood the PhD in physics in good stead: since taking up her position as assistant professor with her own research group at IST Austria, she has played an instrumental role in planning how the new chemistry lab at the campus is to be built and equipped. In addition to determining the technical instruments she needs for her research—including an X-ray diffractometer and an inductively coupled plasma optical emission spectrometer—she also worked closely with the construction manager to find the best solutions for the ventilation system, electricity supply and lighting as well as the pipelines for gases and water. Not exactly typical for the job of assistant professor. "The whole building phase was really intense," Ibáñez is ready to admit, "but the institute's commitment to the new lab and the responsibility I was given helped me develop deep ties to IST."

2021 will see the completion of "her" new chemistry lab, where Ibáñez's research group will share the generous space and lab infrastructure with other research groups. In her own, tailor-made section of the lab, she can focus her energies entirely on the search for new thermoelectric nanomaterials.

Thermoelectricity—from outer space into office space

Seeing the structure of promising thermoelectric materials—made possible by an X-ray diffractometer.

Physicist Maria Ibáñez is pursuing an ambitious goal: over the course of the next eight years, she plans to either find or develop new thermoelectric materials that are able to convert temperature differences into electric power much more efficiently than currently known materials.

The thermoelectric effect has been known as a physical phenomenon for quite some time. It works according to the following principle: if one side of a material is warm and the other cold, electrons will collect on the cold side, creating electric voltage. If the material is then connected to a circuit, the electrons can flow—and the flow of electrons is, by definition, electricity. Although the energy, called thermopower, created from thermoelectric materials can be used to power devices such as electric light bulbs, the voltage is very low, measuring only a few microvolts per kelvin temperature difference.

As such, the thermoelectric effect, even 200 years after German physicist Thomas Johann Seebeck first described it, is still not viable for large-scale power production. The thermoelectric materials used so far simply lack the required efficiency. To change this, Maria Ibáñez and her interdisciplinary team of researchers are seeking new thermoelectric materials that can generate maximum levels of electricity from minimal temperature differences. To do this, the team first connect molecular complexes and nanoparticles to form building blocks that can be used to construct novel thermoelectric materials; they then test the thermoelectric properties of the newly created materials.

From hot to cold

With thermoelectric materials, heat can theoretically be converted into electricity wherever and whenever temperature differences are present: car engines, windowpanes, water pipelines, the human body, laptops or charging devices. "If we had efficient and cost-effective thermoelectric materials, we could use all kinds of temperature gradients to generate electricity in many areas of life," says Ibáñez. But for optimal effect, a different kind of thermoelectric material will most likely be required for each different application. On clothing, for instance, we would need a thermoelectric material that works best at room temperature; in a car engine, by contrast, the material would have to prove its mettle at temperatures of around 500 degrees Celsius. "We're interested in all temperature ranges," says Maria Ibáñez.

Reliable and maintenance-free

Wherever electricity flows, large quantities of energy are lost as heat—a familiar-enough phenomenon when we think of how our computers, smartphones and chargers heat up when we use them. Moreover, large quantities of energy are lost when electricity is generated: over 60 percent of all power generated in Europe seeps into the environment in the form of waste heat. "If we could find a material that captures this waste heat and, via thermoelectric generators, transforms it back into electricity, we could generate power from almost anything," is how Ibáñez sees the potential of her research. "That's our big dream—but it's a little unrealistic. What's more realistic is using thermoelectricity to power smaller electrical components like remote controls or temperature regulators." In IT, for instance, thermoelectricity could be used to cool computers or other electronic devices. And Maria Ibáñez also sees potential applications in agriculture: farmers could use humidity sensors in the ground to know when a field requires irrigation. "The advantage of thermoelectricity is that it's extremely reliable and safe to operate. You don't need to charge anything, no sunlight or wind is required, there's no maintenance—you need nothing other than a difference in temperature," Ibáñez says and adds, "Although thermoelectric technologies are unable to deliver huge amounts of power, they can generate a constant flow of electricity—and that with absolutely no sound. What's more, it's 'reversible', meaning the selfsame device can be used to generate power and to cool."

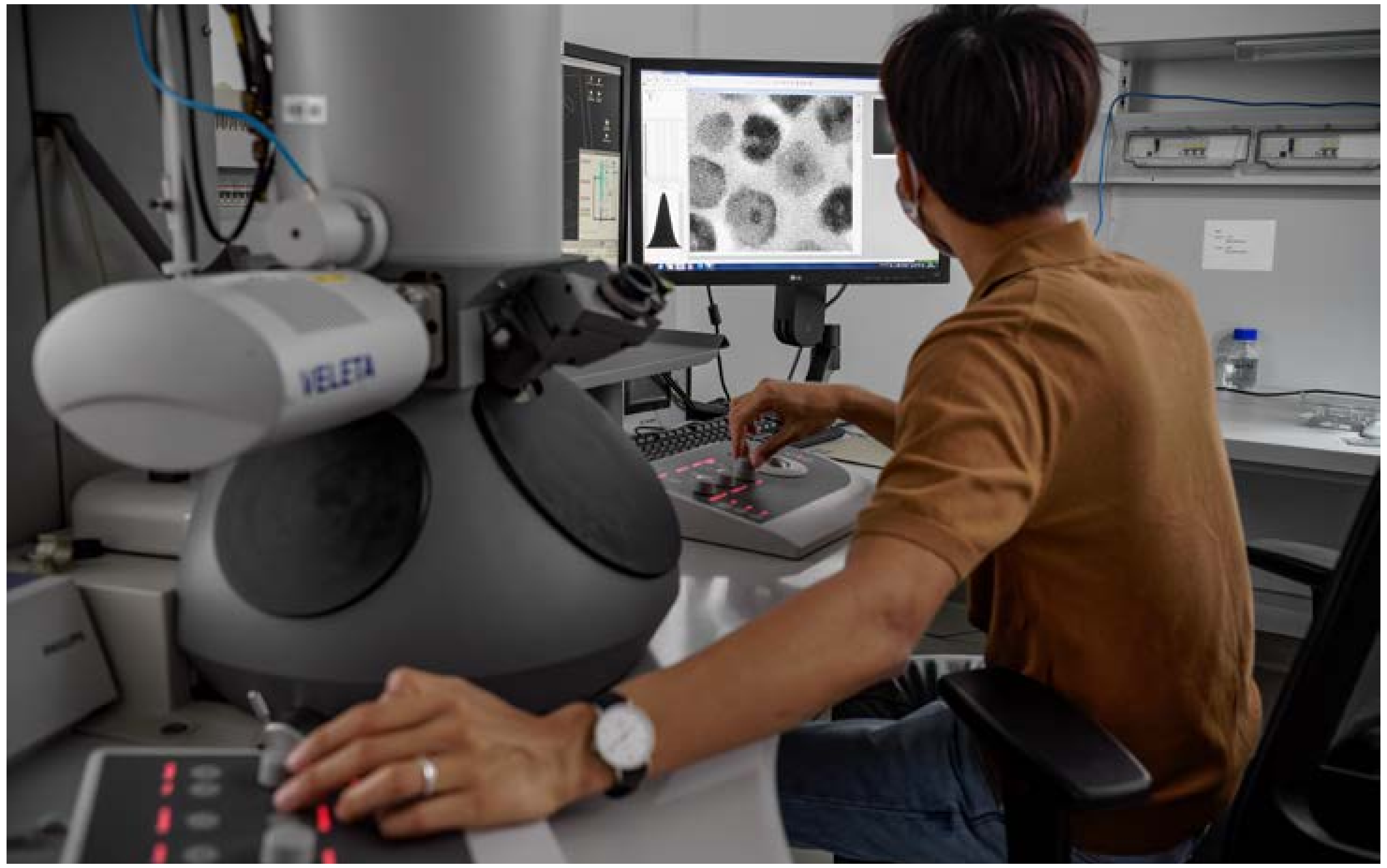
Thermoelectricity in outer space

Maria Ibáñez points to current applications in space travel for examples of how thermoelectricity has operated maintenance-free for many years. The space probes Voyager 1 and Voyager 2, which were launched in the mid-1970s and which have long since travelled beyond our solar system, continue to send data from their interstellar journey. The thermoelectric device used to generate power has been functioning for over 40 years, all with no maintenance or outside assistance.

Novel nanomaterials

Ibáñez is manufacturing the new, optimised thermoelectric materials from precursor materials at the nanoscale. One nanometre is equal to one billionth of a metre. As such, nanoparticles are unimaginably tiny—"about as small as a millionth of a strand of hair", is how Maria Ibáñez frames it. Nanoparticles occur naturally, for instance, after a volcano eruption or forest fires. For research, however,

To identify the thermoelectric properties in the new nanomaterials, researchers have to conduct painstaking analyses by hand. But soon, the high-throughput testing infrastructure in the new lab will speed up the process.



The electron microscope magnifies the nanoparticles into large shapes that the team can easily analyse.

Temperature test: how does a new nanomaterial behave when it is subjected to high or low temperatures?

nanoparticles are created in the lab—with extraordinary precision and under highly controlled conditions. Ibáñez and her team synthesise the particles from metals or semiconductors, or combinations of both. Size, surface, composition and numerous other factors can be modified, resulting in an entirely new kind of nanoparticle. "Their chemical and physical properties—for example, their chemical reactivity, electrical conductivity or their thermodynamic properties—change," says Ibáñez.

Nanoparticles made in the lab can be formed into larger crystals that often have entirely different properties than the original particles. "We use these nanocrystals as building blocks, like Lego, that can be combined and varied in innumerable ways," says Ibáñez. The team are employing a range of chemical and physical processes to gradually make their way towards new materials with the best-possible thermoelectric properties.

High-throughput analyses

What properties do these lab-made nanocrystals have? Can they be used as a thermoelectric material? Do they function better at high or low temperatures? The team is scrutinising the nanomaterials to achieve a precise categorisation of their properties. Until now, these analyses have been conducted by hand in the lab, a painstaking, time-consuming undertaking. "To speed up the process, we're now developing a high-throughput testing infrastructure," says Ibáñez. In the new lab, which will be ready to use in 2021, Ibáñez's research group will conduct what is called high-throughput experimentation (HTE). As such, they will belong to a small, select number of research groups in the world that use computer-assisted high-throughput technologies to identify high-efficiency thermoelectric materials.

With HTE, the researchers can simultaneously test large amounts of starting material for different parameters. "This will markedly accelerate the production of a very wide range of nanomaterials in different states," says Ibáñez. In the coming six months, she will be recruiting an engineer with whom she can design the HTE system. Further evidence that Maria Ibáñez's research, as is standard at IST Austria, thrives in an interdisciplinary setting.

My success is your success

Luck had little to do with the fact that, in 2018, Maria Ibáñez was selected from a pool of 1481 applicants and appointed to an assistant professorship at the Institute of Science and Technology Austria. She was chosen because she embodies the hallmarks of the young, yet already successful institution: multidisciplinary, state-of-the-art research combined with a respectful, cooperative, ethical and responsible approach.

Collaboration beats competition – a wall of framed scientific papers is testimony to the successful research collaboration at IST Austria.

Physicist Maria Ibáñez is head of the Werner Siemens Laboratory for Research on Thermoelectric Materials at IST Austria.

Maria Ibáñez is not afraid of leaving her comfort zone. While still a physics student at the University of Barcelona, she ventured out to attend the Institute for Nanoscience and Cryogenics in France, and during her doctoral studies, she was a visiting PhD student at a different American university every year: the University of Chicago in Illinois, Caltech in Pasadena, California, Cornell University in Ithaca, New York, and Northwestern University in Evanston, Illinois.

To begin, solar cells were the focus of her doctoral thesis, but when she started working with a materials group that also explored thermoelectricity, her interests gradually shifted in this direction. In 2013, she completed her dissertation on the synthesis of new nanomaterials produced from nanocrystals, for which she received the Extraordinary Award, the highest accolade of the University of Barcelona. Afterwards she researched at the Catalonia Institute for Energy Research in Barcelona and, in 2014, took on a position at ETH Zurich in Switzerland to explore the surface chemistry of nanocrystals. Indeed, it is precisely the surface of nanoparticles that has proven highly important in the search for thermoelectric materials.

At the end of 2016, Maria Ibáñez applied for a position at the Institute of Science and Technology Austria, submitting a research proposal on the fundamental transport properties of electrons and phonons in nanomaterials—expertise that is instrumental in designing novel thermoelectric materials. Her project stood out amongst the other 1481 applications. Maria Ibáñez successfully completed a complex application process—including a two-day assessment interview—and was awarded a tenure-track assistant professorship at the end of 2018. That same year, she moved with her family from Zurich to Klosterneuburg, which is a 30-minute bike ride away from her new employer. “I grew up in a small village in Catalonia and would never have wanted to live in Vienna,” the physicist says.

Collaboration beats competition

In her role as assistant professor, Maria Ibáñez is one of 57 group leaders at IST Austria. If her work proves successful over the coming years, a tenured professorship will be the reward. But, as opposed to the situation at “ordinary” universities, she has no need to compete with her physics colleagues for one of the rare job openings. Indeed, the Institute of Science and Technology Austria promotes collaboration, not competition. The search committee selected Maria Ibáñez for the position of assistant professor because they believe in her work and her qualifications—and because they believe she will meet with success. To prevent her from being bogged down with other work, IST Austria has organised a team of specialists to assist Ibáñez in administrative tasks, including finances, procurements, recruiting and reporting. Everything has been arranged to ensure that the assistant professor can conduct her research and move on to a full professorship.

IST Austria’s general approach to supporting their staff has the positive effect of fostering open collaboration among the various research groups. “It’s really true that colleagues at IST are also friends, and that we support one another by reading each other’s scientific papers and funding applications and by giving constructive feedback,” says Ibáñez.

Where their project will take off in 2021: Maria Ibáñez and her team at the future IST Austria lab.

Barbara Abraham, deputy managing director at IST Austria, confirms this: “Our assistant professors aren’t in competition with their colleagues at IST—they measure themselves against the international scientific community.” When IST researchers publish their research findings in renowned scholarly journals such as *Nature* and make a name for themselves in their area of expertise, it also enhances the reputation of IST Austria.

The individual before the discipline

IST Austria plans to continue growing. The exact area in which this happens—whether in physics, mathematics, informatics or life sciences—is of lesser importance. Because the new research institution is not entrenched in traditional, hierarchical structures, it is free to pursue its own growth strategy, which emphasises the individual over the discipline. IST Austria fosters forward-looking researchers who embody the institution’s values, and whose thinking and approach to research is interdisciplinary, constructive and egalitarian. As such, IST Austria was mainly interested in hiring Maria Ibáñez, the outstanding physicist. A positive side effect is that her cutting-edge research provides the opportunity to establish the field of thermoelectricity at the institute.

International recognition

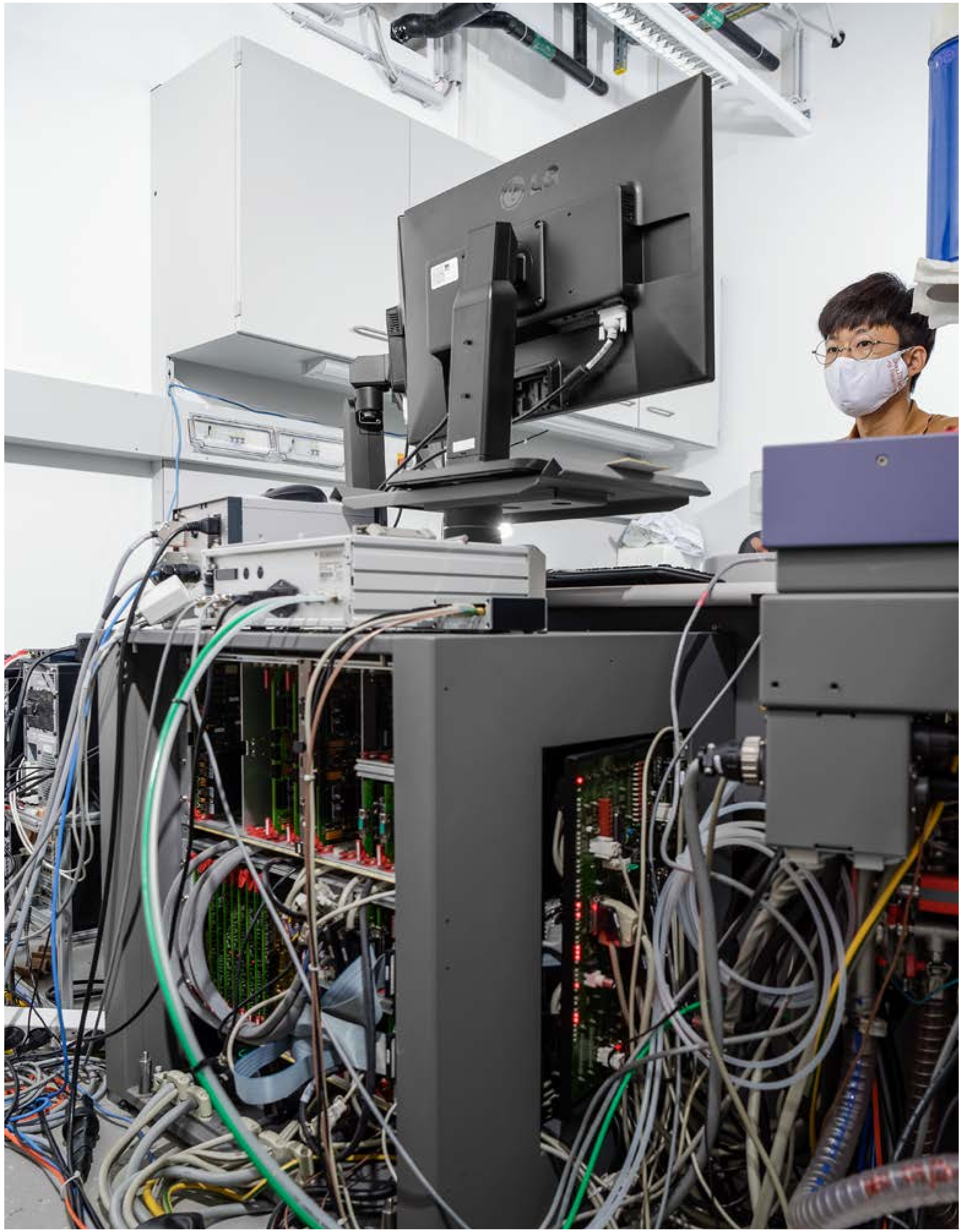
IST Austria is meeting with success. The European Research Council (ERC) has assigned the Austrian research institution a success rate of nearly 50 percent, which translates as a top position in the international ranking; moreover, IST has already acquired nearly 80 million euros in ERC grants. How has the comparatively small institution garnered this recognition? Barbara Abraham explains it as follows: “IST Austria and the European Research Council were founded at roughly the same time and have similar ideas about how to best recruit successful researchers.”

Since its establishment 11 years ago, IST Austria has acquired third-party funds amounting to nearly 160 million euros. In addition to the increase in financial contributions, research quality at IST Austria is also reaching new heights. In scaled rankings of the highly respected journal *Nature*, IST Austria achieved the stellar ranking of third place. This means that IST Austria, in relation to its size, published the third-highest number of scholarly papers in major scientific journals. As such, it ranked ahead of the venerable ETH Zurich and the world-famous Massachusetts Institute of Technology.

“I’m no fan of rankings,” says Maria Ibáñez, “but this third place is very important for IST Austria. For a long time, the institute was nearly unknown in the global scientific community. This ranking has made it visible.”

Young and successful: the research groups at IST Austria—like physicist Maria Ibáñez and her team—play in the premier league.

The historical buildings from 1885 reflected in the modern glass façades at the IST Austria campus.



Keeping sight of the bigger picture: a view from behind the electron microscope.

Facts and figures

Project

At IST Austria, physicist Maria Ibáñez and her research group are seeking high-efficiency, cost-effective thermoelectric materials to convert temperature differences into electricity. The overall aim is a broad application of thermoelectricity in, for instance, generators and cooling devices.

Funding from the Werner Siemens Foundation

The Werner Siemens Foundation is financing the Werner Siemens Laboratory for Research on Thermoelectric Materials at IST Austria. The search for suitable thermoelectric materials is to be accelerated by using high-throughput material screening, machine learning, data mining and atomistic simulation.

Amount

8 million euros, distributed over 8 years

Project duration

July 2020 to June 2028

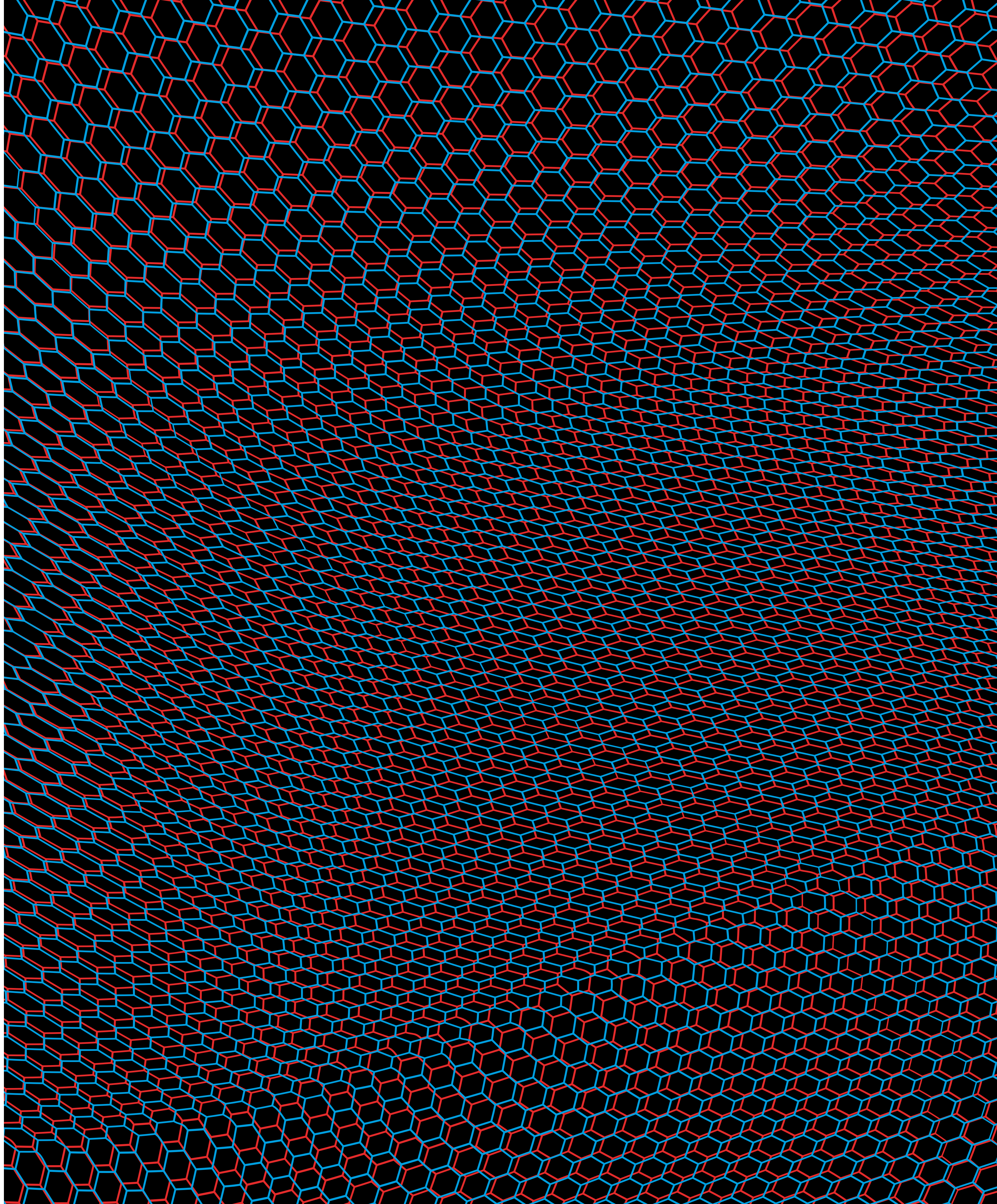
Project leader

Prof. Dr Maria Ibáñez, Institute of Science and Technology (IST Austria), Austria

phenomenal
reliable
accessible

Innovation

The Werner Siemens Foundation is supporting the search for high-efficiency, cost-effective thermoelectric materials—because these materials have the potential to make existing energy available for numerous applications in our daily lives, from cooling down electronic devices to powering sensors.



Deana Mohr, biologist and MedTechEntrepreneur Fellow at the University of Zurich, says the Werner Siemens Foundation programme has prepared her well for her new role as CEO of MUVON Therapeutics..

Researcher in the executive suite

Update: MedTechEntrepreneur Fellowships funding programme at the University of Zurich

With its MedTechEntrepreneur Fellowships, the University of Zurich helps junior researchers to establish a company—so that medical innovations can be translated into clinical care as quickly as possible. One example is a new way to treat incontinence.

Dr Deana Mohr has changed sides: she swapped the laboratory for the executive suite. And the biologist has no regrets: "I'm discovering a whole new world. I've developed a real passion for entrepreneurship." In September 2020, Mohr officially became a CEO when she founded her company, MUVON Therapeutics, with Dr Jenny Ann Prange, Dr Steve Kappenthuler and Professor Daniel Eberli. The company's mission is to provide a novel treatment for stress incontinence, a form of urinary incontinence in which people lose small amounts of urine when they sneeze, laugh or otherwise put pressure on their bladders. In Switzerland alone, the problem affects an estimated 400 000 people, mainly women after giving birth or experiencing hormonal changes. The cause is a weakened urethral sphincter, and MUVON Therapeutics wants to help affected persons by implanting muscle stem cells that develop into muscle fibres able to fully close the bladder. The first clinical study started at the University Hospital Zurich at the beginning of 2020.

For Deana Mohr, who coordinates the entire project, the novel treatment already represents nine years of hard work. While working on her PhD thesis, she demonstrated that the procedure functions properly and safely in the lab and in animal testing. Following this success, her research group at the University of Zurich received an EU grant of six million euros, "but it became quickly clear that patients would never benefit from the technology unless we established a company and found investors", says Mohr. The next clinical study alone is expected to cost between 15 and 20 million Swiss francs.

Perfect mix

To prepare herself for the business world, Deana Mohr began learning about founding a company and attended courses on entrepreneurship. Then, in 2018, when the University of Zurich (UZH) launched its MedTech-Entrepreneur Fellowship programme with funding from the Werner Siemens Foundation, Deana Mohr applied. She was awarded one of the 18-month fellowships, which has given her the opportunity to expand her expertise and skill set in courses and in dialogue with other fellowship holders. This includes learning how to communicate with investors, develop a business plan and build a supportive professional network for the project. "What fascinates me most is the range of issues that I can deal with—be it seeking staff, leading teams or addressing regulatory matters," says Mohr. Through the fellowship, she and her team also have access to the UZH Incubator Lab, which has been equipped specifically for budding biotech and medtech spin-offs—and which also receives funding from the Werner Siemens Foundation.

As part of the fellowship award, the selected projects receive funding of 150 000 francs, an amount that has enabled Deana Mohr's team to employ an additional person. "Financial support plus knowledge sharing: this mix offered by the UZH MedTech-Entrepreneur Fellowship is perfect. And a rare find," says Deana Mohr.

Female applicants gaining ground

The MedTechEntrepreneur Fellowships are awarded twice a year by a jury of experts from academia and industry. 23 applications have been received since the programme was launched in 2018; Deana Mohr is one of 11 researchers selected as a MedTech Fellow for the period ending in mid-2020. "It's particularly pleasing to see that more and more women are submitting applications," says Michael Schaepman, who initiated the fellowship programme and was recently elected President of the University of Zurich.

The quality of the submitted projects has also increased—partly due to the feedback the jury gives on projects that show potential but that need a more polished approach. "With this jury feedback, applicants can substantially improve their applications before making a new submission," says Michael Schaepman. One indicator of the high quality of the selected projects is that they have gone on to attract some one million Swiss francs in additional third-party funding. Moreover, four of the projects supported to date have led to the establishment of a spin-off company. "For many of the junior researchers, our fellowships have been the decisive factor in launching their entrepreneurial career," says Schaepman.

Well prepared for the executive suite

Deana Mohr has carefully planned her career shift: "I feel well prepared for my role as CEO of our company," she says. And she knows her project is socially relevant: "Around 150 million women worldwide suffer from stress incontinence. And the number of unreported cases is probably very high, because the condition is often a taboo." If all goes according to plan, the clinical studies on stem-cell therapy will be complete in the course of 2026. In the meantime, the aim is to ensure that MUVON Therapeutics is established and ready for market entry.

Funding from the Werner Siemens Foundation

10.67 million Swiss francs over a period of 10 years

Project leader

Prof. Dr Michael Schaepman, President of the University of Zurich (UZH), Switzerland

Project duration

2018 to 2027

Goddess of the waves

Update: *Eugen Seibold*, the sailing research lab

No other research vessel tests the waters with as much elegance and ecological integrity as the *Eugen Seibold*—small wonder that people fall in love with the sailing yacht whenever they catch a glimpse. That said, we at the Werner Siemens Foundation nearly let the ship sail right out of this year's report, as our financing was scheduled to end in 2019, with the completion of the maiden research voyage. But, the attentive reader may have guessed: our collaboration has been extended and the Werner Siemens Foundation is pleased to be funding the operating costs for the *Eugen Seibold* over the next ten years.

Refurbished energy equipment and secured financing: the sailing research vessel *Eugen Seibold*.

The crew of the *Eugen Seibold* had planned to collect samples across the entire Atlantic Ocean, from the tropical south to the subarctic north, already in the summer of 2019. But the following September, after their expeditions to the subtropical regions of the Atlantic around Lanzarote, Madeira and the Azores, and then in the eastern zones of the Northern Atlantic, the team realised that additional precautionary measures would be necessary to protect the vessel's sophisticated electrical infrastructure on board against the rough waters of the Northern Atlantic.

In particular, the main battery used to power the vessel's technical equipment was pushed to its limits. Should the battery completely fail in a storm, the crew would have recourse to only a single portable backup generator. "It just wasn't safe enough," says Professor Gerald Haug, the mastermind behind the *Eugen Seibold* and director of the Department of Climate Geochemistry at the Max Planck Institute for Chemistry in Mainz. "Storms in the Northern Atlantic can be harrowing."

High operating costs

There were also other unexpected developments. Only the best, most modern measurement instruments were installed on the *Eugen Seibold*, "which all worked beautifully", Gerald Haug is careful to stress. "But, with the rough conditions of the high sea, it's to be expected that one or the other is always breaking down." As a result, the technical devices and installations all needed to be modified, optimised and recalibrated.

After the first year, it also became clear that the budget for operating costs was too optimistic. "A single repair job can easily run to 20 000 euros," says Haug. In 2019, the Max Planck Institute for Chemistry in Mainz was obliged to spend some three million euros on new instruments and on adapting electric and electronic devices for the research voyages; operating the *Eugen Seibold* in the coming years will likely generate similar costs.

To ensure future operations, the owner of the *Eugen Seibold* (the private foundation Forschungsschiff S/Y *Eugen Seibold*) applied to the Werner Siemens Foundation for a credit of three million euros. In addition to covering basic operating costs and foreseeable expenses over the next ten years, funds will be reserved for unexpected expenditures.

A different kind of emergency

A general overhaul of the *Eugen Seibold* was conducted from September 2019 to February 2020, at shipyards in Bremerhaven and Kiel. The research vessel now has three electrical supply options and is fully capable of sailing home should any unexpected problems arise along the north-south Atlantic research transect.

No one, however, was reckoning with a global pandemic. Starting in March 2020, the novel coronavirus forced the world to take a break. International harbours closed, and the *Eugen Seibold* had little choice other than to drop anchor until the end of June 2020. Only then could the crew and researchers on board—after testing negative for Covid-19—embark on the scheduled transect from the subarctic Northern Atlantic to the equatorial Atlantic Ocean. After leaving

Bremerhaven, the crew steered the *Eugene Seibold* through the North Sea up to the Faroe Islands, on to Iceland, then to the edge of the Arctic Ocean.

In addition to project leader and geologist Ralf Schiebel, the oceanographers Hedy Aardema and Maria Calleja, marine chemist Hans Slagter and atmospheric scientists Antonis Dragoneas and Isabella Hrabe de Angelis were essential to the expedition's success. The team worked in shifts and, for each section of the transect, collected water and air samples, which they then analysed in detail on board the *Eugen Seibold*. They used two mass spectrometers and a flow cytometer to measure key environmental parameters of the water samples, including temperature, salinity, chlorophyll levels, nutrients, oxygen levels, carbon and nitrogen levels, carbon dioxide, trace metals and pH values. The air samples were analysed for their carbon dioxide levels, aerosols and other particles. The team also sampled the plankton living in the upper water column of the ocean.

Well-measured success

The daily measurements generated a colossal quantity of data, which were stored on hard disks aboard the yacht. A custom-made router then integrated the data won from the measurement instruments, the navigation system and the logbook into a uniform protocol. The router is an absolute innovation—a world's first—that already during the expedition simplified data processing and linked the data to the correct geographic location.

The crew then sent the massive data sets to servers at the Max Planck Institute for Chemistry in Mainz, where they are currently undergoing detailed analysis in research groups specialised in micropalaeontology, geochemistry, organic isotope geochemistry, palaeoclimatology, aerosol analysis and microscopy as well as aerosol and air quality.

At the end of July 2020, and before the first icebergs north of Iceland came into view, the experienced skippers reversed course and embarked on the next leg of the journey, southwards to the equator.

The crew managed to collect samples from the northern transect of the Atlantic down to Madeira, weathering storms and heavy seas—and dealing with unpredictable quarantine regulations in the harbours. The research work on the normally less demanding southern leg of the voyage down to the Tropical Atlantic was then constrained by restrictions related to the novel coronavirus.

Riding a wave of popularity

The sailing research lab has become something of a celebrity in Germany. Gerald Haug says, "People are fascinated by the *Eugen Seibold*, and the yacht is quite well known in Germany. Federal ministers and even the German President are quite taken by our mission. And when I tell them how straightforward it was to realise our vision of the world's greenest research vessel with funding from the Werner Siemens Foundation—that, in our meticulously regulated world, a single handshake was all it took to seal the agreement—well, they're quite frankly amazed and think it's wonderful." That the Werner Siemens Foundation

While the *Eugen Seibold* sails northwards on the Atlantic, the experienced crew systematically collect water and air samples.

At the rainbow's end: in August 2020, the researchers completed the first comprehensive profile of the Northern Atlantic.

approved an unconditional grant of 3.5 million euros to construct a sailing research vessel has met with widespread approval and praise. Gerald Haug says, "The story of the *Eugen Seibold* proves that philanthropists can take a bold and unconventional approach and that a project promising to benefit all society can be realised without a drawn-out legal effort."

Complete profile of the Atlantic Ocean

The end of August 2020 saw a major goal of the project achieved: the completion of the first comprehensive profile of the Northern Atlantic. Gerald Haug says, "We have now documented the current biological, chemical and physical state of the Atlantic Ocean, from the icy seas of the Arctic to the tropical water masses at the equator. This has never been done before."

Although definitive conclusions would be premature, the data gained during the first major research voyage corroborate several theories. For instance, plankton appears to migrate towards the poles—a phenomenon possibly caused by shifts in the ocean currents or due to temperature-related values such as oxygen levels in the water. As a result, the marine food chain is gradually changing, which will ultimately also adversely affect fish populations—and thus a major source of food for much of the world.

How will ocean waters change as the climate continues to warm? Providing a detailed answer to this question is the mission of the *Eugen Seibold's* next expeditions—made possible for the next ten years thanks to funding from the Werner Siemens Foundation.

Funding from the Werner Siemens Foundation

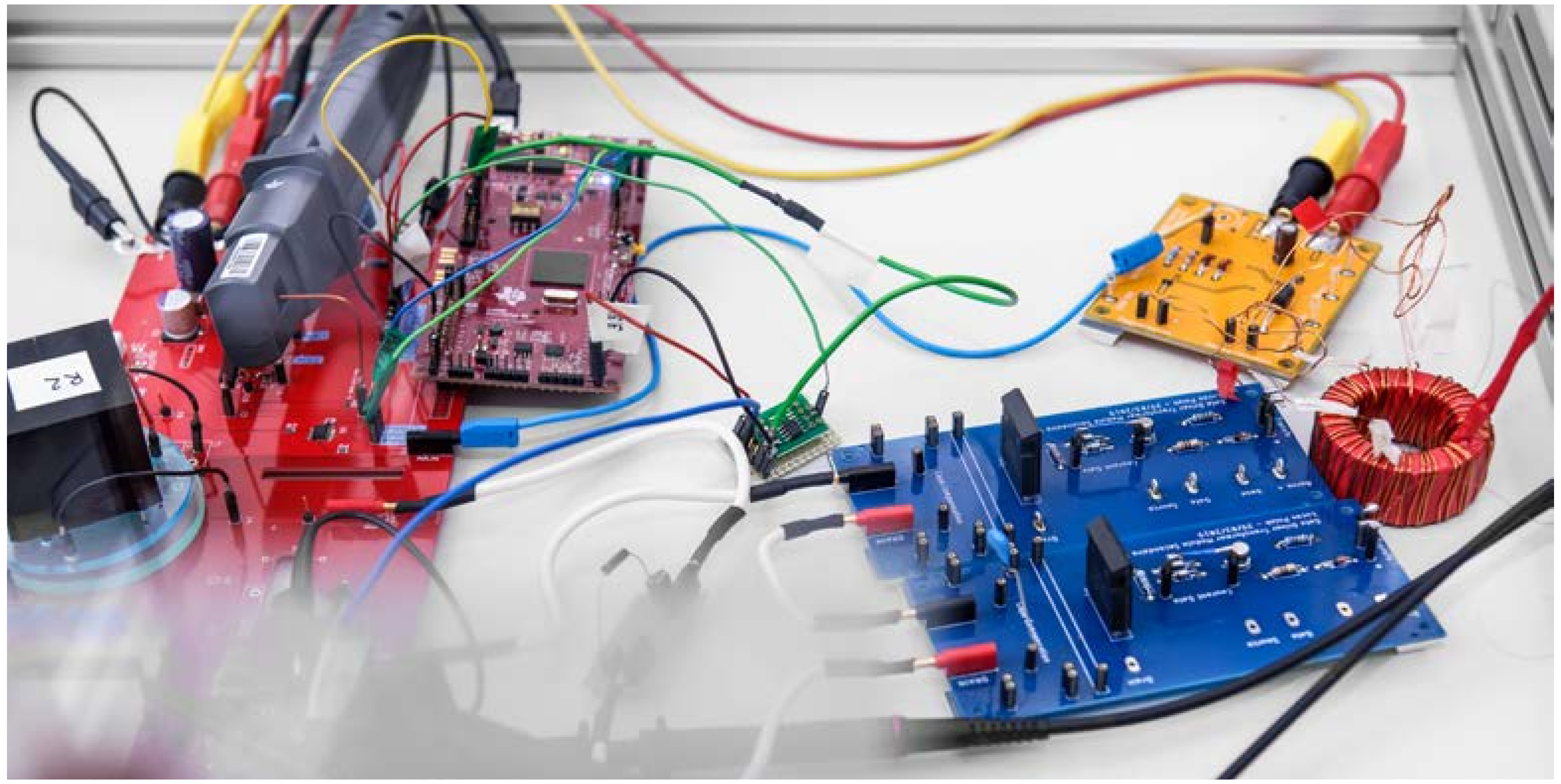
3.5 million euros for construction, technical installations and testing of the *Eugen Seibold* (2015 – 2019)
3 million euros for operating the *Eugen Seibold* (2020 – 2030)

Project leader

Prof. Dr Gerald Haug, Director of the Department of Climate Geochemistry at the Max Planck Institute for Chemistry in Mainz, Germany, and Professor at ETH Zurich, Switzerland
Dr Ralf Schiebel, Head of Micropaleontology at the Max Planck Institute for Chemistry in Mainz, Germany

Project duration

2015 to 2030



The ring-shaped artificial muscle that fits around the aorta can now deliver 5000 volts of power to give weak hearts a boost.

The tension mounts

Update: Center for Artificial Muscles in Neuchâtel

The Werner Siemens Foundation is financing the Center for Artificial Muscles in Neuchâtel, Switzerland—and with it an innovative team of researchers, who are developing a novel approach to treating cardiac insufficiency: placing a ring-shaped artificial muscle around the aorta to give weak hearts a boost. The first preclinical studies have been scheduled.

Every day, the human heart pumps over 7000 litres of blood through the body. An impressive feat. Over the course of a lifetime, however, many people develop cardiac insufficiency. Till now, doctors have treated the condition by prescribing medication or inserting ventricular pumps—but neither therapy is free from risk. As an alternative, Professor Yves Perriard and his team at the Center for Artificial Muscles, an institute at the École Polytechnique Fédérale de Lausanne, are working to create a ring-shaped artificial muscle made of an elastic membrane that can be wrapped around the aorta. Electrical impulses from a battery cause the membrane to expand; when the voltage is switched off, the membrane assumes its original shape. The resulting pressure on the aorta helps the heart pump blood through the body.

Greater pumping capacity

For the past three years, the Werner Siemens Foundation has been funding the multidisciplinary team made up of micro engineers, materials scientists, biomedicine specialists and surgeons. In 2020, the researchers made key advances in the most challenging area of the project: attaining the necessary pumping capacity—and this with a membrane that is biocompatible to prevent tissue rejection.

As a rule, our hearts require one watt of electrical power to function properly. In patients suffering from severe cardiac insufficiency, the artificial muscle would have to perform 30 to 50 percent of the work. But ideally, the aorta ring will also be used in less severe cases, where an additional 5 to 10 percent would be enough to attain normal pumping capacity. Researchers hope the extra boost could even help weak hearts to recover and function on their own again. The team has already developed an aorta ring that supplies this lower power level. “Right now, our membrane can generate about 10 percent of the heart’s pumping capacity,” says project leader Yves Perriard. But the work continues: 20 percent capacity is the next goal.

To meet the target, the researchers are seeking solutions for the main elements of the artificial muscle: the right material, the number of layers required and the best power supply for the aorta ring.

Optimised membrane

The team started their search for the right material with Elastosil®, an ultra-thin silicone rubber film. In tests, the material has proven highly promising, as it can bear a sufficiently large load of electricity without growing brittle. The researchers have conducted various experiments with the silicone rubber, including experiments in their custom-made testing unit that simulates blood circulation in the body. Now, the first preclinical studies on animals to assess the functionality of the aorta ring are scheduled for 2021.

At the same time, the team are widening their search for an even better material for the membrane and have already developed a prototype of a custom-made product. Another crucial factor is the number of layers needed for the ring. To connect the layers, the researchers have invented a novel type of glue—and filed a patent for their invention.

Up to 7000 volts

The team have made great advances in designing the power supply for the aorta ring, which takes the shape of a 12-volt battery for patients to wear on a belt. The 5000 volts of electricity required to power the artificial muscle are generated via magnetic induction; should the material ultimately selected require a higher voltage, the system could even supply up to 7000 volts. Nevertheless, the mantra is: as much as necessary, as little as possible.

At the start of 2021, the individual components of the power supply will be ready to be connected to the aorta ring. Then the system’s efficiency will be tested. The researchers are particularly interested in recovering the energy stored in the aorta ring and then channelling it back into the electric circuit.

During the preclinical phase and the subsequent clinical phase, Perriard and his Neuchâtel team will work with specialists from the University of Bern and the University Hospital Zurich. Starting in 2025, renowned cardiac surgeon Thierry Carrel plans to begin testing the aorta ring in clinical trials.

The artificial muscle created in Neuchâtel could also help patients other than those with weak hearts. The researchers hope to use it as an artificial sphincter in cases of urinary incontinence. In addition, the technology has the potential to restore chewing function and facial expressions to accident and burn victims. In 2020, the research team began preparatory work on an artificial sphincter and have already been granted two patents for their innovations.

Funding from the Werner Siemens Foundation

12 million Swiss francs

Project leader

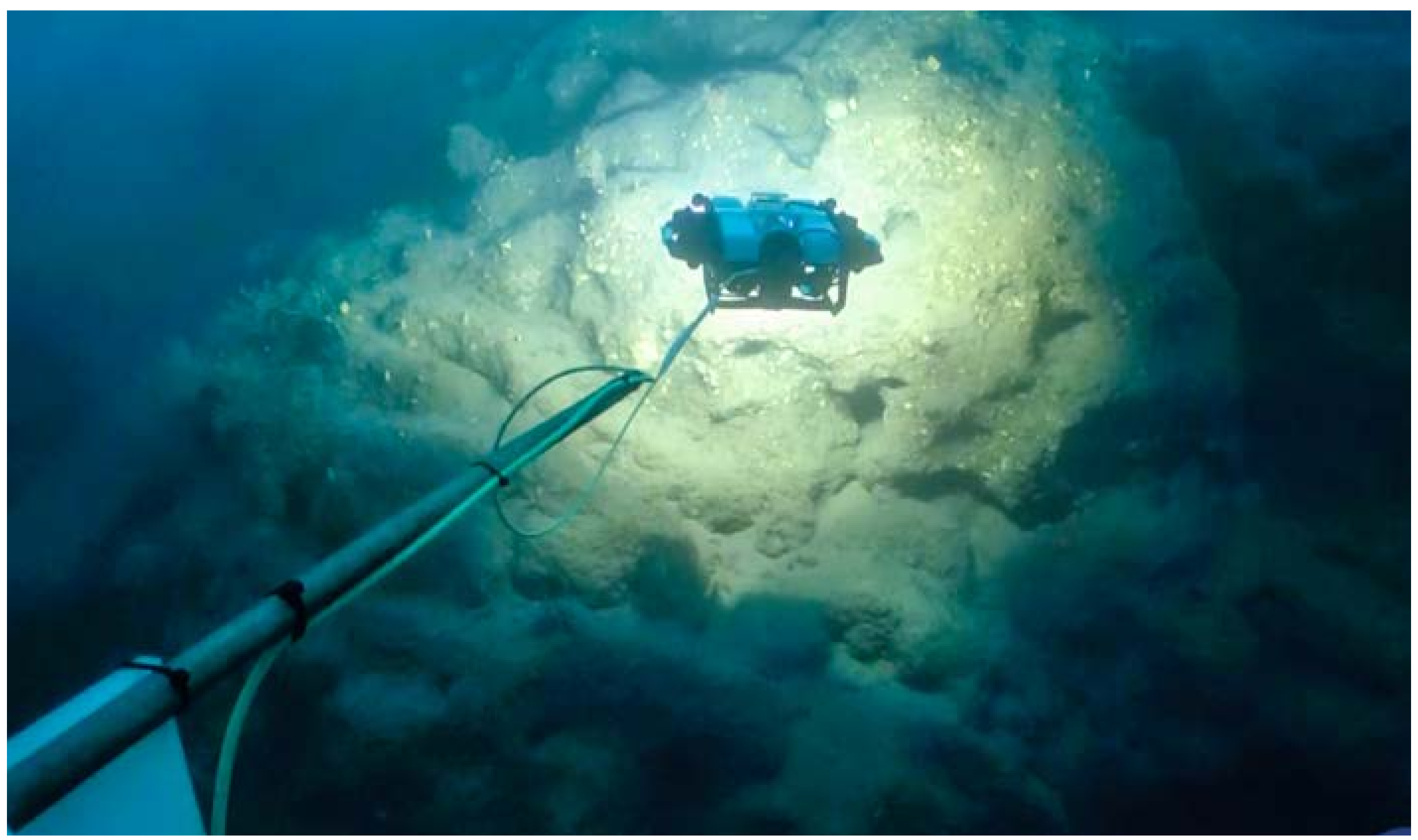
Prof. Dr Yves Perriard, Director of the Center for Artificial Muscles and the Integrated Actuators Laboratory, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Project duration

2018 to 2029

Stress tests

Update: Innovation Center for Deep-Sea Environmental Monitoring at MARUM, University of Bremen



The first step in protecting the deep sea is charting its mysterious depths. But the best mapping strategy is worthless without on-site testing. The first equipment tests were run in the Mediterranean in February 2020—before the coronavirus pandemic sent the researchers back to their desks.

In March 2020, just as they were due to begin intensive testing of key components in their deep-sea monitoring system, the Covid-19 pandemic banished Ralf Bachmayer and his team at the Innovation Center for Deep-Sea Environmental Monitoring to their desks.

The year had begun so well. At the end of February 2020, Professor Ralf Bachmayer from the Innovation Center for Deep-Sea Environmental Monitoring and two of his colleagues were ready to test the main technical components in their deep-sea monitoring system: the deep-water robot operated via remote control (ROV, or remotely operated vehicle), the latest model of their customised autonomous underwater vehicle (AUV for short), an optic modem, a low-light camera and—the newest component—the “Bodenknoten”, an autonomous stationary camera system. These instruments are the fruit of two years of research, and this was the first time they would be tested in the ocean.

The ROV and AUV are at the centre of the researchers’ strategy to chart the deep sea. The movements of the vehicles must be as gentle as possible to avoid disrupting—and in the worst case permanently damaging—the underwater environs. To ensure eco-friendly operations, Ralf Bachmayer is taking a multipronged approach. Firstly, the small agile AUV records images as it slowly glides over the seabed. It then transmits the image data to the larger ROV located above the AUV at a greater distance from the seabed. The ROV sends this information to the MARUM team aboard a research vessel, providing them with an overall impression of the seabed and the AUV’s location and enabling them to maintain overall control and coordination of the ROV and AUV.

The precious deep sea

The ecosystems in the deep sea are so sensitive that recovery is almost impossible once they have been disrupted. Starting at an ocean depth of 200 metres, all aspects of life—motion, reproduction and regeneration—occur at a very, very slow pace. This means that the plans held by many countries and businesses to mine the seabed for valuable resources (gold, silver, cobalt, manganese and rare earth elements) are nothing short of devastating. Indeed, earlier mining attempts caused serious damage to the highly sensitive deep sea, damage that remains visible decades later.

Bachmayer is developing methods and systems to monitor the fragile deep-sea ecosystems—because only when the International Seabed Authority ISA has gathered more exact knowledge of the ecologically valuable areas will it be able to protect these regions and forbid mining operations in them.

Tests in the Mediterranean

In February 2020, Ralf Bachmayer and his team were in the starting blocks. Stationed in the Mediterranean, the anticipation mounted as they sat in the control room of the research vessel *Alkor* and tracked the progress of their underwater robots on a monitor. “We switched on the ROV’s light, and the low-light camera on the AUV captured images of roughly 70 square metres of the seabed—with no glitches in the ROV,” says Bachmayer. “The communication between the vehicles worked as we had envisioned it. We were thrilled.”

Testing out the Bodenknoten—the autonomous, stationary camera system—was also successful. “We positioned the Bodenknoten on the sea floor of the Mediterranean,” says Ralf Bachmayer. “The system looked around and autonomously detected the light source—from the ROV in this case—and then took pictures despite poor visibility, just as we had planned. The system sent the images via the wireless optic modem up to the ROV.” In future, the Bodenknoten will be used to take measurements and capture images of the seabed, either individual photographs or as a series. The data recorded can be retrieved via the wireless optic modem.

The final station before the lockdown was an observatory off the Spanish coast. These observatories are stationary measuring stations, used to gauge various parameters, including pressure or the temperature profile of the sea floor. Observatories can also store data, including image data, which can be retrieved wirelessly; as such, researchers can use the observatory as temporary storage for image data while charting the seabed.

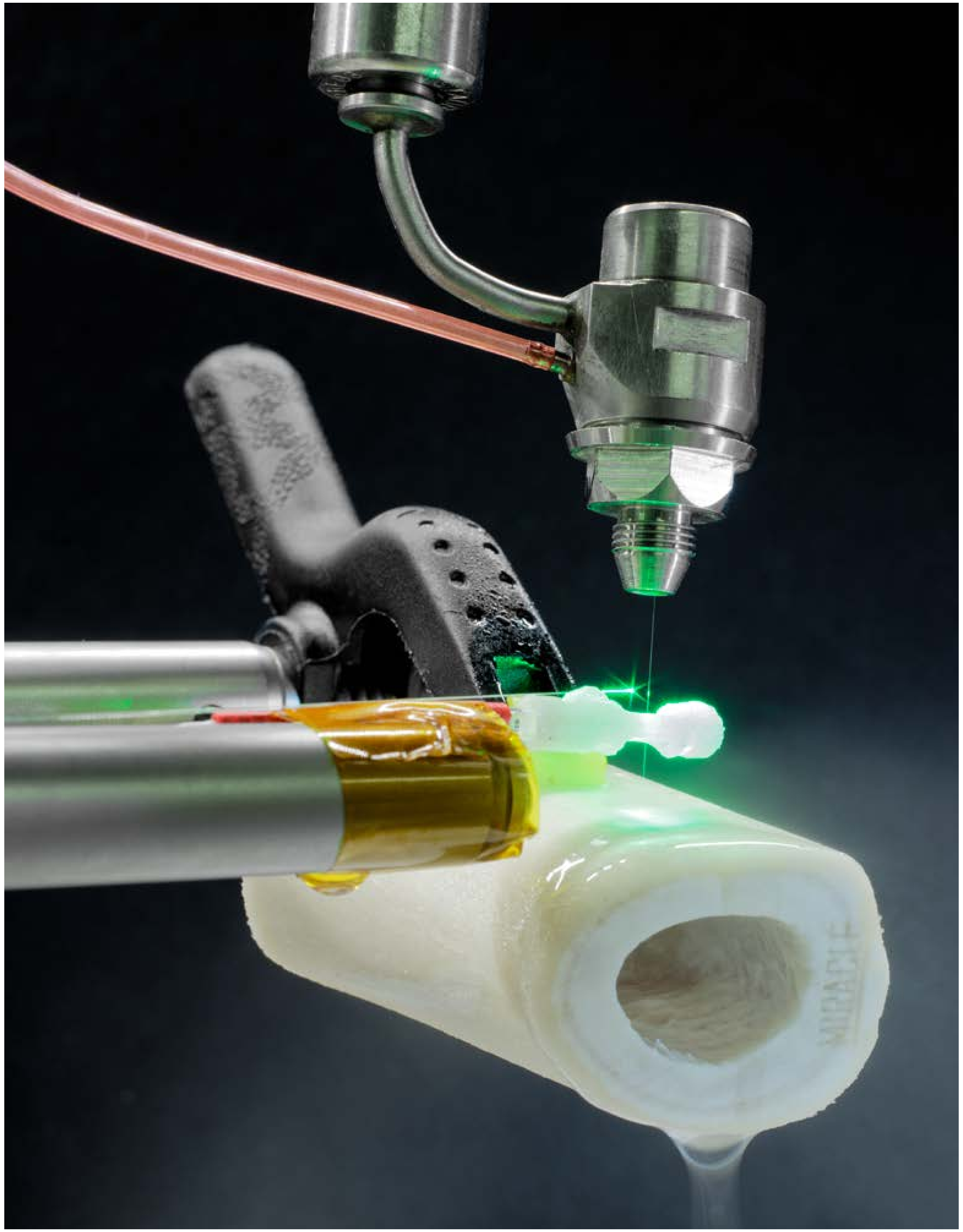
A rude interruption

The coronavirus pandemic arose just as the tests on equipment in the Mediterranean were drawing to a close, thwarting any chances of quickly developing the components any further. “In a worst-case scenario, we can test our components in bodies of water that are close to Bremen—the Weser or the North Sea, for instance,” Bachmayer said during the summer, after the lockdown restrictions had been lifted. “The North Sea is only 40 metres deep compared to the 200 metres in the deep sea, but we could at least test the AUV’s navigation system in conditions of poor visibility.” Ralf Bachmayer would naturally like to realise all the plans he had laid for 2020. “The pressure is on, but we researchers are setting the fast pace, not our employers,” he says, adding, “which can sometimes make it harder.” Can the team overcome the additional obstacles created by the novel coronavirus in addition to mastering the challenges posed by the deep sea itself? “We’ll get it done,” says Bachmayer. “But it’s essential that we take a step-by-step approach to realising our deep-sea monitoring strategy. The many technical and scientific challenges might otherwise be overwhelming.”

Funding from the Werner Siemens Foundation
4.975 million euros

Project leader
Prof. Dr Michael Schulz, Director of MARUM – Center for Marine Environmental Sciences at the University of Bremen, Germany

Project duration
2018 to 2028



Smart laser scalpel

Update: MIRACLE—making minimally invasive bone surgery a reality

Forget the bone cutter—get ready for the laser scalpel: researchers from the MIRACLE project are working to make minimally invasive bone surgery a reality. Their robot-guided laser system makes fine, precise incisions and—thanks to newly developed sensors—can monitor its own incisions and ensure patient safety.

The new photoacoustic sensor makes it possible for the laser scalpel to recognise tissue type during an operation. Because the cutting laser beam is invisible to the naked eye, a green light was incorporated to show surgeons where they are moving the scalpel, allowing them to make precise incisions.

Today, abdominal and joint surgery is routinely performed using minimally invasive procedures. Rather than making large incisions through skin and tissue, surgeons access the operation site by inserting endoscopes into the body through tiny incisions. These procedures are much less traumatic for the patient: wounds heal more quickly and recovery time is faster. That is why the MIRACLE project team, led by professors Philippe Cattin and Hans-Florian Zeilhofer at the University of Basel, want to make minimally invasive surgery possible on bones, too—using a robot-guided laser beam. Their "laser scalpel" makes extremely fine and precise incisions in bones, and is able to cut in straight, curved and S-shaped lines. Broken bones can be fitted together again like three-dimensional puzzle pieces, allowing them to knit faster.

Smaller size, greater control

The research team in Basel are moving ever closer to their goal of developing a laser scalpel for minimally invasive bone surgery. They are currently working on two fronts: first, the laser components developed to date must be made smaller to fit into the endoscope tip; second, miniaturised sensors must be placed at the endoscope tip in order to continually measure the exact location of the laser scalpel during an intervention. "During endoscopic procedures, surgeons can't directly see what's happening in the body, so we need technologies that aid navigation," says Philippe Cattin.

To this end, the researchers have developed new optical sensors to be inserted into the flexible, robot-guided joints of the laser endoscope tip; the sensors record the angle of the joint and thus the movements of the endoscope. Cattin holds up an approximately one-centimetre large sensor and explains: "Electric components and tiny mirrors are positioned inside the sensor so that they can make extremely precise measurements of angles. It already functions in principle. Now we have to make the sensors just a little smaller so that they fit into the joints of the laser endoscope tip."

Tiny and reliable

Professor Georg Rauter, head of the project's robotics group, shows how the laser scalpel is situated at the endoscope tip—the actual heart of the system is a bona fide robot in miniature. On its sides are two "arms" that can latch on to the bone for stability and precision; recent tests have demonstrated that the tiny robot can perform precise movements down to at least the quarter millimetre.

But the laser can do more than cut—the MIRACLE laser physicists have created a true multitalent. Using Optical Coherence Tomography (OCT), the laser scalpel simultaneously measures the depth of an incision while cutting. The system can also characterise tissue: depending on the type of tissue, the laser light produces different light emissions and acoustic signals that are then measured by the system to determine whether the laser is cutting through bone, nervous tissue, healthy tissue or a tumour. Combined with the OCT method, which also delivers information on tissue type, the technology works already shortly before the laser starts cutting. "This way, we can convert a laser beam that, in principle, would cut indiscriminately through anything and everything into a smart and safe system that only severs the targeted tissue," says Professor Azhar Zam, head of the Biomedical Laser and Optics Group.

One challenge lies in integrating the laser light at the endoscope tip, as standard laser sources are far too large to fit into an endoscope. As such, the considerable laser energy required to cut through bone must be generated either by a much smaller source or externally via a thin glass-fibre cable inserted in the endoscope tip. The various approaches under consideration by the laser physicists are now being further developed and tested in order to determine the best method.

Better surgery planning

The researchers have also further developed SpectoVR, their successful virtual reality software that aids doctors in planning operations. The system transforms CT or MRI scans into virtual, three-dimensional images that can be explored using data goggles. "It makes surgical planning simpler and more intuitive," says Cattin, "and the feedback from doctors already using SpectoVR is very positive." But the team have still greater ambitions: the next goal is to integrate haptic rendering capabilities into the system, enabling doctors not only to see in 3D, but also to touch virtual objects in the simulated environment. The prototype, which has already been constructed in Georg Rauter's robotics lab, is now being further developed.

Progress is well underway: users can already use a stylus to "feel" a backbone in the virtual environment. Using haptic technology, the software renders the original CT images, generating the right amount of resistance for each point touched—so that the virtual copy feels like a real vertebra. The system is a global first and extremely useful: in addition to allowing surgeons to plan operations even more precisely, the haptic experience is designed to improve surgical training. "We envision future surgeons using a virtual 3D model to practise precise drilling techniques on bones," says robotics engineer Georg Rauter.

Based on its considerable successes, the MIRACLE project will receive a grant from the Werner Siemens Foundation for a second phase starting in 2022.

Funding from the Werner Siemens Foundation

15.2 million Swiss francs (2014–2021)
12 million Swiss francs (2022–2027)

Project leaders

Prof. Dr Philippe Cattin, Professor of Image-Guided Therapy and Head of the Department of Biomedical Engineering, University of Basel, Switzerland
Prof. Dr Hans-Florian Zeilhofer, Associate Vice President Innovation, University of Basel; former Head of the Clinic of Oral and Maxillofacial Surgery, University Hospital Basel, Switzerland

Project duration

2014 to 2027

Grasp and understand: the researchers have added a haptic dimension to their successful virtual reality software SpectoVR.

MIRACLE takes shape: the main components needed for minimally invasive, robot-guided, computer-assisted laser bone surgery are ready.

Flexible keys

Update: Centre for Cyber Trust at ETH Zurich

Every key in its own place—in future, a link to a physical space will make the internet safer.

Compared with the relative safety we enjoy in the physical world, security problems abound in the digital world. To remedy this, researchers at the Centre for Cyber Trust at ETH Zurich are working on an internet technology that is rock solid and safe from attacks—one using virtual "keys" that are linked to a physical or geographic proof.

Imagine this: a couple has booked a stay at a charming mountain inn. Upon their arrival, the receptionist welcomes them and hands them the key to their room. Even when they return the key while out on their daily hikes, the couple know the belongings left behind in their room are safe—because they trust the hotel staff to guard the key.

In the digital world, however, equally trustworthy services are much more difficult to set up. To be sure, the internet also uses "keys" to protect property—or data—in a process called public key authentication. These virtual keys consist of a long sequence of numbers and characters that encrypt the data being transferred and thus prevent unauthorised persons from reading them.

The standard public key infrastructure used to implement authentication processes is, however, not fail-safe. Fraudulent websites are sometimes so convincing that even experts can be fooled. "Not nearly enough is being done to ensure that ordinary citizens can safely use the internet. Our project wants to remedy that," says Professor Adrian Perrig, who leads the Centre for Cyber Trust at ETH Zurich with his colleagues Professor David Basin, Professor Peter Müller and Professor Matthew Smith. Their aim is to make the internet completely safe.

Proof in the physical world

Last year, the team developed their concept for a novel public key infrastructure (PKI)—the flexible PKI—bringing them one step closer to achieving their goal. The concept is based on a certification system that relies on a physical or geographic proof to make it readily clear whether or not a sender is trustworthy. The electronic key would be linked to the physical location—much like the key to a hotel room remains safely at the reception desk while guests are out on adventures. "We believe the physical aspect makes the idea very transparent. With flexible PKI, users can recognise whether an email was sent by a specific individual or from a bank," is how Adrian Perrig explains the concept.

The flexible PKI would allow every individual, company or other entity to decide whom to trust, just as in the physical world. The innovation is also designed to prevent hackers from compromising digital certification authorities and the public keys these authorities issue—which in turn limits the damage caused by hackers. Adrian Perrig says, "The most forceful attacks would no longer be like a machine gun assault. More like a fight with a water gun."

Perrig explains that every single user of a flexible PKI would also receive a guideline (called a policy) that is valid for the key. The policy—stored separately in a manipulation-proof area—is what governs the generation of keys. Although creating and storing these policies is highly complex, they could be used to create new and update old keys. Nevertheless, several problems remain to be solved, including whether the designated physical location actually belongs to an entity and what happens to a key when the owner of a location changes.

Software verification

The flexible PKI concept involves other aspects as well. Parallel to the work in Zurich, research partner Matthew Smith is conducting studies to discover whether new technical solutions alone are enough to increase user trust in the digital world.

In addition, David Basin and his team have the task of verifying the functioning of the flexible PKI and testing its correctness; to do so, they are designing a customised software program. Once the software design has been verified, Peter Müller and his group will apply a mathematical proof to determine whether the software implementation functions correctly and reliably. "We'll be working on this for a while," says Peter Müller of this separate verification. "Our experience from past projects has taught us that verifying software takes five times as long as writing the program." For this reason, Müller and his team are also seeking ways to increase the efficiency of verification methods.

Harmonising the two verification steps represents yet another major challenge. A kind of "glue" is needed to link the software design (what should be programmed) with the programming code (what is programmed). David Basin gave their innovative solution a clever name: Igloo—pronounced "I glue". This novel verification method is a breakthrough for the researchers at the Centre for Cyber Trust. Peter Müller compares Igloo's role with that of a building inspection: "In the end, the purchaser wants to know if the building was constructed the way it should have been, in accordance with all the plans. As a mathematical proof, Igloo likewise shows how well design and implementation correspond." The planned software verification would close all software loopholes that hackers currently exploit for their attacks.

Funding from the Werner Siemens Foundation

9.83 million Swiss francs

Project leaders

Prof. Dr David Basin, Department of Computer Science, Information Security, ETH Zurich, Switzerland
Prof. Dr Peter Müller, Department of Computer Science, Programming Methodology, ETH Zurich, Switzerland
Prof. Dr Adrian Perrig, Department of Computer Science, System and Network Security, ETH Zurich, Switzerland

Academic partner

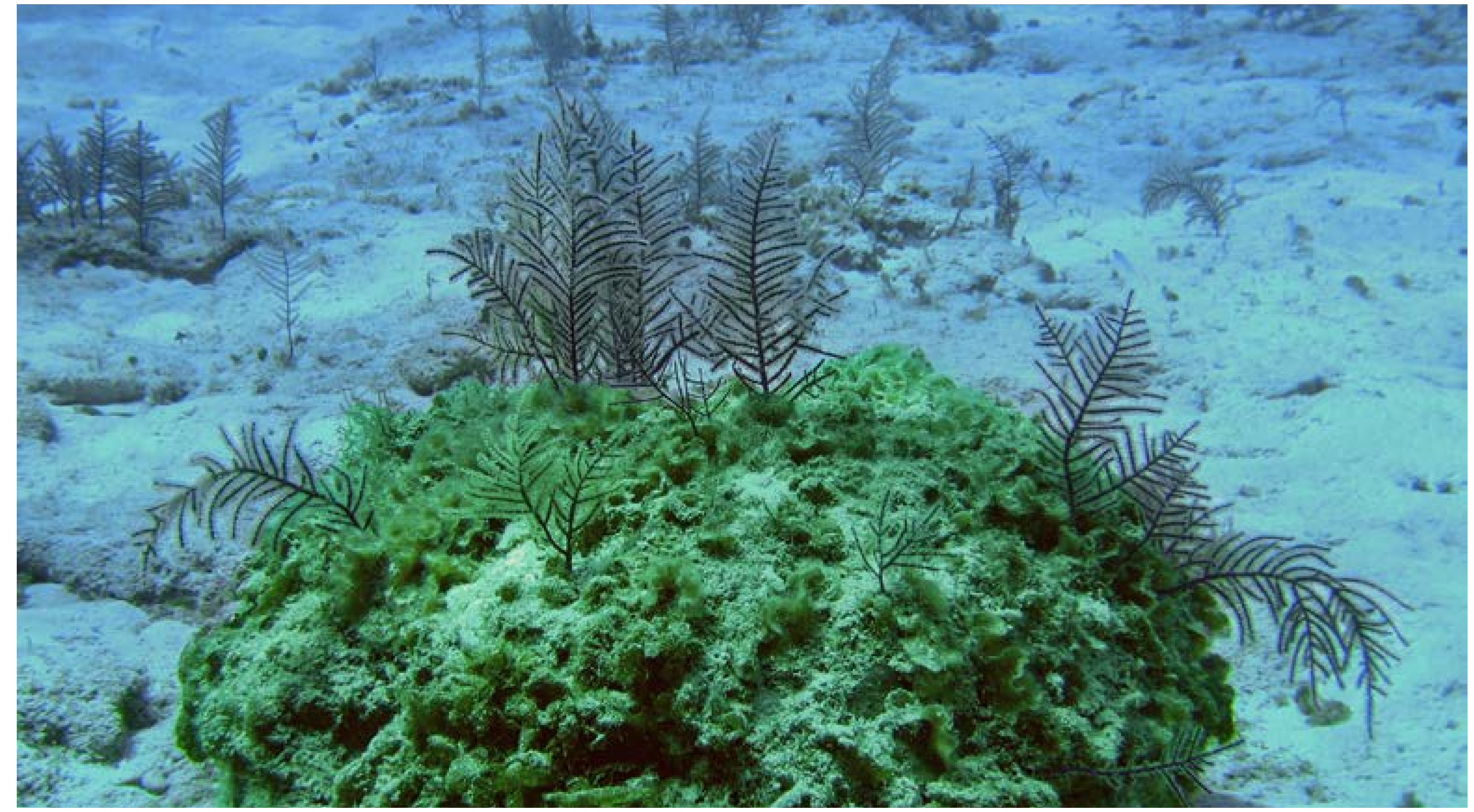
Prof. Dr Matthew Smith, Institute of Computer Science, University of Bonn

Project duration

2019 to 2027

Copying nature

Update: Synthetic Biotechnology at the Technical University of Munich



The protected Caribbean horn coral produces a valuable antibiotic substance—one that researchers at Synthetic Biotechnology now can reproduce in the lab using genetically optimised coliform bacteria.

Novel anti-inflammatory agents, a new antibiotic, "green" carbon fibres, a palm oil alternative, algae as fuel—these are just a few of the projects currently pursued by the Synthetic Biotechnology team at the Technical University of Munich. But Werner Siemens Foundation Endowed Chair Thomas Brück remains modest, saying his researchers "can do a lot, but not everything". Where necessary, Brück seeks reinforcement and collaborates with partners from industry and research. He also envisions regular meetings with the leaders of other projects supported by the Werner Siemens Foundation.

"The Werner Siemens Foundation promotes cutting-edge research. We should take advantage of the synergies that arise." Biochemistry professor Thomas Brück spares no praise when it comes to his fellow researchers whose projects receive funding from the Werner Siemens Foundation. To benefit from one another's expertise, he would like to "meet them and ask: what are you working on?" He could easily imagine that joint, third-party-funded projects would be the result. He can also envision creating a larger network of Werner Siemens Foundation Endowed Chairs.

New partnership in Israel

Brück has mastered the art of collaboration. The most important new partnership established in 2020 is a collaboration with the renowned Weizmann Institute of Science and with Bar-Ilan University in Israel, a high-tech project launched to produce novel anti-inflammatory agents. Brück's favourite candidate is cyclooctatin. For the past six years, Brück's team has already been able to manufacture small amounts of cyclooctatin using the techniques of biotechnology. Now, the partnership with the Israeli researchers will help them to produce larger amounts. "Our Israeli bioinformatics colleagues have designed new algorithms to calculate how we can improve the surface structure and the active centre of a key enzyme—which leads to increased efficiency and stability throughout the entire process," says Brück. "Our team didn't have this knowledge, but our colleagues in Israel are international leaders in this highly specialised area of bioinformatics."

Fighting inflammation

Back at the Werner Siemens Synthetic Biotechnology (WSSB) lab in Munich, Brück plans to use the data and results delivered by the Israeli bioinformatics specialists to improve "his" enzymes that produce cyclooctatin. "With this technology, we can create a completely new anti-inflammatory drug that potentially has fewer side effects than standard products on the market," says Brück. His goal is to test the new agent in clinical trials. "For that, we need to produce it by the kilo," he explains. Thanks to the know-how of the Israeli elite researchers, he can now make production of cyclooctatin more stable and higher-yielding.

Inspirational corals

In mid-2020, Thomas Brück's team also developed a production process for an agent that is effective against bacteria, specifically: against multiresistant tuberculosis bacteria. For this, his team reconstructed erogorgiaene, a naturally occurring antibiotic. In nature, erogorgiaene is produced by the Caribbean horn coral. But coral reefs are ecologically too valuable to be sacrificed for harvesting erogorgiaene. Moreover, the horn corals produce only small amounts of the agent—and they are listed as an endangered species. Thomas Brück and his PhD student Marion Ringel, together with colleagues from Berlin, Canada and Australia, succeeded in producing the antibiotic agent in the lab—without sacrificing a single coral. The main function in the process is taken on by genetically optimised coliform bacteria. After being fed with glycerine (a by-product of biodiesel production), they produce a molecule that can be transformed into erogorgiaene using enzymes. The entire process produces no waste, as all by-products are reused in a closed-loop cycle. Through the innovative procedure, larger amounts of erogorgiaene can be produced at a lower cost; a patent has been filed for the new technique.

Green carbon

Green carbon, the "invention" made by Thomas Brück and his team in 2019, has become highly sought-after in the past 12 months. Several industrial companies have expressed interest in the carbon-neutral production of carbon fibres using algae, including large international producers of sporting equipment that would like to manufacture high-performance sports gear and clothing from green carbon. "This is an application for the material that I had certainly never imagined," Thomas Brück says.

Applications in construction, however, were definitely part of the plan. Last year, his team worked with German partner company TechnoCarbon Technologies to build

Algae oil as a kerosene replacement would be possible ... if an algae production plant could be made large enough. If Thomas Brück gets his way, one will soon be built in sunny Italy.

a prototype for a six-metre T-beam for a Finnish construction company that wants to use the carbon-stone composite in its building projects.

Integrating ecology and construction

"The combination of ecological carbon fibres and stone is a perfect alternative to steel in the building sector," says Brück, adding that the material can be used to realise even large, complex constructions like bridges. Brück's team produced a reinforcement bar to strengthen concrete girders from the inside. Normally, reinforcement bars are made of steel, but steel loses its elasticity over time and begins to rust, which can cause cracking. By contrast, the carbon-stone composite is rust-proof, weighs only half as much as steel—and is equally stable. Independent tests have confirmed as much. "The results of the stress tests by the German Institute for Standardization are truly surprising—even for us," Brück says.

The new composite material is also a viable alternative to concrete, as it is suitable for constructing very thin yet strong supporting walls and floors. Prefabricated module systems that get by without cement would be particularly "green". "This would reduce the CO_2 output in construction—because cement production is currently responsible for roughly five percent of the world's carbon-dioxide emissions," says Brück. A further advantage is that the carbon-stone composite material is manufactured on the basis of algae, which absorb carbon dioxide. "Our production process using algae absorbs more CO_2 than it emits," says Brück. "Green carbon has the potential to revolutionise the construction industry."

Value chains

Brück has already been contacted by Composite United e.V., the German association of carbon fibre manufacturers and buyers, various federal ministries in Germany and major chemical companies who are interested in preparing the technology for producing ecological carbon fibres for market—and in doing so, creating a permanent carbon sink.

The next task for Brück is designing a manufacturing process suited for cooler regions, as the production of algae-based carbon fibres is dependent on heat and solar power. One possibility is gas fermentation, which has two major advantages: "For one, gas fermentation could be combined with our oleaginous yeast refinery," the biotechnology professor explains. "The oil created by our yeast could be used very efficiently for carbon-fibre production. Second, it would be possible to couple the procedure with manufacturing 'green' hydrogen."

Ecological hydrogen

Brück explains his rather sudden reference to hydrogen by saying that the element is currently seen as the most promising alternative to fossil fuels. He envisions manufacturing hydrogen in a closed-circuit, value-adding biochemical cycle. In layperson's terms, the cycle would be as follows: wind and solar power are used to split water molecules into hydrogen and pure oxygen. Brück then wants to channel the pure oxygen into his biorefinery: yeast love pure oxygen and it helps them to produce larger amounts of biomass and oil. Moreover, the hydrogen and the carbon dioxide that also arise through splitting the molecules would be used for gas fermentation and converted into acetic acid. The acetic acid is mixed with carbohydrates from biogenic residual material (for example, straw) and then fed to the oleaginous yeast; the latter are able to produce an abundance of oil in a short time—WSSB was granted a patent in 2019 for the procedure. Using techniques of biotechnology and sustainable chemical processes, the resulting oil can be converted into a wide range of basic substances—the latest being a palm oil alternative.

Palm oil replacement

Palm oil is a widely used resource, but its cultivation destroys the world's rainforests. "We now have a complete replacement for palm oil," Brück says with evident satisfaction. The new spin-off company Global Sustainable Transformation is responsible for bringing the palm oil replacement to market. An agreement has already been concluded with a US food company, which has the rights to produce the palm oil alternative.

Fuel from algae

The Covid-19 pandemic and ensuing lockdown brought the lab experiments at WSSB to a halt. "But the three-month waiting period also gave several firms time to see that they have to get more serious about sustainability if they want to maintain a market presence in the long term," says Brück. One such company is airline manufacturer Airbus, which is currently focusing on solutions for sustainable air travel. The company's strategy team is made up of diverse suppliers—and Thomas Brück, who is working with industrial partners to identify potential locations and methods for accelerating the production of the sustainable fuel. Brück has his eye on an algae production site measuring 100 hectares in Italy. Why Italy? "Because Airbus has operations in Italy," says Brück, "and because Italy is a major player in the food industry." Food industry? "Yes, the food industry. I would love to create really good pasta made of algae."

Funding from the Werner Siemens Foundation
11.5 million euros

Project leader
Prof. Dr Thomas Brück, Werner Siemens Foundation Endowed Chair for Synthetic Biotechnology at the Technical University of Munich (TUM), Germany

Project duration
2016 to 2021

From one world record to the next: even the developers of the single-atom switch are surprised by its energy efficiency.

The power of a single atom

Update: Center for Single Atom Electronics and Photonics at ETH Zurich

Computers, USB sticks, smartphones: every electronic device contains millions of energy-hungry components. The team at the Center for Single Atom Electronics and Photonics are developing highly energy-efficient components using a principle based on the switch function of a single atom. Now, the team has once again topped their own world record in energy efficiency.

“Imagine we had a microchip that was a thousand times more efficient than today’s computer chips,” says Professor Jürg Leuthold, director of the Center for Single Atom Electronics and Photonics at ETH Zurich. Developing precisely this kind of chip is the goal he is pursuing with his project partners, Professor Mathieu Luisier of ETH Zurich and Professor Thomas Schimmel of the Karlsruhe Institute of Technology. A novel principle is at the root of their approach: instead of utilising the flow of electrons as is common in standard electronics, their components are based on the switch function of a single atom. The idea is to place metallic contacts (electrodes) close together—so close that the space between them is the size of a single atom. When an atom is shunted back and forth across this miniscule gap, an electric current either flows or is disconnected.

A certain degree of activation energy is required for each individual switch. When applying the single-atom principle, however, this amount is negligible: the latest version of the single-atom transistor constructed by Thomas Schimmel and his team consumes a mere three millivolts of activation energy—a world record—and the previous model was already hyper-efficient, requiring only six millivolts. “We attained these significantly better values last year by optimising the construction of the electrode microstructures,” says Schimmel. As a comparison: standard transistors used in devices like smartphones consume nearly a volt of electricity—300 times more than the single-atom transistor. “Once the system is ready for market, we expect energy efficiency to be as much as 1 000 times better,” says project leader Jürg Leuthold.

From gel to glass

To date, the clever principle functions only under laboratory conditions in a system that uses a gel electrolyte as a charge carrier. Because gel electrolytes are difficult to realise in CMOS devices, Jürg Leuthold’s research group is exploring ways to apply the single-atom switch function in a system made of solid materials. The researchers recently took a major step towards this goal by constructing a single-atom component with platinum and silver electrodes and using glass as a charge carrier in place of the gel electrolyte.

The researchers then connected the single-atom component to an inverter, a key building block in common electronic devices. This led to a surprising discovery: with this combination, what is known as “dark current” is 100 times lower. Dark current is the amount of electricity that electronic components consume even when they are switched off and that collects in electronic devices in the form of standby power, also called “vampire power”. In addition, Leuthold’s combined set-up reduces power consumption by a respectable factor of 10 when the component is switched on.

Handy computer simulations

At the same time, the team are seeking the best materials for constructing the electrodes. In the gel system, silver proved most advantageous—due to its electronic properties and because the malleable material proves ideal in forming the minute electrode structures. To further optimise their system, the researchers have begun working with computer simulations. “It would be impossible to test all the different materials in lab experiments,” says Leuthold. The reason is that an extremely wide range of materials could theoretically be used as a charge carrier for the electrodes (including gel, glass, titanium oxide or aluminium oxide) and because the potential production processes are equally numerous. This is where the group of Mathieu Luisier enter in: they developed a computer program modelled on the physical laws and properties of atoms to simulate how a material would perform in the single-atom system. Last year, the researchers further developed and validated their algorithm on the basis of the current single-atom transistor with the tin electrodes. “In future, we can use the simulations to examine different materials and to keep learning more,” says Leuthold.

Funding from the Werner Siemens Foundation

12 million Swiss francs

Project leader

Prof. Dr Jürg Leuthold, Head of the Institute of Electromagnetic Fields, ETH Zurich, Switzerland

Project duration

2017 to 2025

Magnetic resonance imaging and hyperpolarised medical imaging make it possible to recognise cells with disrupted metabolic processes—cancer cells, for instance—already at an early stage.

Peering into the human cell

Update: medical imaging techniques at the Werner Siemens Imaging Center in Tübingen

The researchers at the Werner Siemens Imaging Center in Tübingen are making excellent progress: they combine different medical imaging techniques to create new technologies that deliver a nuanced picture of a disease. These innovations mean it will soon be possible to better predict and steer how successful a given therapy will be for a specific individual. A decisive step towards personalised medicine.

Diseases are individual, and factors beyond genetic disposition and lifestyle play a role in whether a person is susceptible to developing an illness. In addition, not all patients respond equally well to the same therapy, nor is the severity of side effects experienced uniform. This holds particularly true for cancer patients. “Every tumour and every patient is different, and each metastasis has its specific traits,” says Bernd Pichler, head of the Werner Siemens Imaging Center (WSIC). Pichler and his WSIC colleagues create detailed images to make visible what these differences consist of and how they can be utilised in choosing a medical treatment.

In addition to developing advanced medical imaging diagnostics, the team of roughly 60 researchers at WSIC also explore ways to combine the various imaging techniques. “These new and combined procedures deliver a more comprehensive picture of a disease, and this helps us to better understand how we can treat it,” says Pichler. The team conduct experiments on mice to investigate cancers as well as cardio-vascular diseases and inflammation.

To translate these findings into clinical care and ensure that patients quickly benefit from the medical advances, the WSIC researchers collaborate with the Tübingen University Hospital.

Insight into metabolic processes

In 2019, Dr André Martins, WSIC group leader, began using a novel method: hyperpolarised imaging, which renders the metabolic processes of cells visible in magnetic resonance imaging (MRI); it is precisely this type of cellular activity that is disrupted in numerous diseases. The most astounding part of the technology? It alters the magnetic state of a metabolic molecule, making it 10 000 times more visible in an MRI. As a result, recognising even low numbers of such molecules becomes much easier, and measurements that previously took nearly four days to complete can be made in ten seconds.

This, however, is easier said than done, as preparing molecules for imaging is a complex procedure. In a specially designed instrument, the molecules are first cooled to minus 270 degrees Celsius, then heated to 180 degrees Celsius before being brought back to body temperature. The researchers then have just two minutes to take the MRI measurements before the magnetic effect disappears.

André Martins and his team use this elaborate but effective method to observe various processes, for instance, how pyruvate, a metabolic molecule, converts into lactic acid. Initial findings from animal studies indicate that rats with a comparatively high risk of stroke produce more lactic acid in the vulnerable regions of the brain than those with a lower risk; in future, these observations may help to assess an individual's risk of suffering a stroke. The team use a similar technique to render images that reveal which of the malignant cells in a cancer tumour have a high metabolic rate and are more aggressive. In 2020, André Martins received the prestigious Sofja Kovalevskaja Award, worth 1.65 million euros, for this work.

More effective immunotherapies

The most intense area of work for the WSIC research team is determining the efficacy of immunotherapies, which for the past several years have been regarded as the most promising way to treat cancer. The procedure involves stimulating an individual's own (endogenous) immune cells, called T cells, to attack tumour cells. Group leader Bettina Weigelin explains the process as follows: "The T cells have a complex task: they have to reach the cancerous organ, penetrate the tissue and assess every single cell." With some cancers and in some patients, immunotherapy works well—in other cases, only poorly or not at all. "We're trying to understand why that's the case and how we can destroy resistant tumour cells."

To realise this goal, Bettina Weigelin began building a unique microscopy infrastructure in 2019; already in operation is the fluorescence microscope for cell cultures that she and her team use to follow the battle between immune cells and tumour cells in real time. Through these studies, the researchers have observed that highly aggressive tumour cells, which infiltrate the tissue to a larger degree, are generally the only cell types that the immune cells effectively attack. Weigelin expects to gain more detailed

WSIC group head André Martins (standing) and his team discuss the images rendered by the hyperpolarised imaging technology.

Gaining a glimpse into a cell's metabolic processes requires nimble action: the researchers must take the MRI measurements within two minutes.

findings once the new microscopy system—which will take up an entire room at WSIC—is completed at the start of 2021. With this intravital microscopy, researchers can make images of immunotherapies in vitro. The team will also work with infrared lasers that penetrate deep tissue layers and reveal a larger section of a tumour. With the information gained, they can better identify how immune cells reach affected organs and tissues and which parts of a tumour they most effectively combat.

A revealing combination

The two methods described above—hyperpolarised imaging and fluorescence microscopy—deliver even more information when they are combined. The fluorescence microscope provides information on the processes in different tissues—skin, muscles, blood vessels—and on how individual cells react to a therapy. The hyperpolarised imaging contributes to better understanding anatomical aspects and molecular metabolic processes within an entire organism. "In a way, it works like Google Maps," says André Martins. "Using both techniques allows us to see the processes from different perspectives and on different scales."

Personalised cancer therapies

In the past, the WSIC researchers had already combined positron emission tomography (PET) with magnetic resonance imaging (MRI) and gained valuable evidence for improving medical treatment. Their overarching goal is to predict which therapy will be most effective in an individual patient. Recently, the team applied their findings in a clinical study to chart the precise characteristics of breast cancer—with success. A therapy for colorectal cancer is also being researched, Bernd Pichler says, adding that "this work, too, is looking very promising".

Funding from the Werner Siemens Foundation

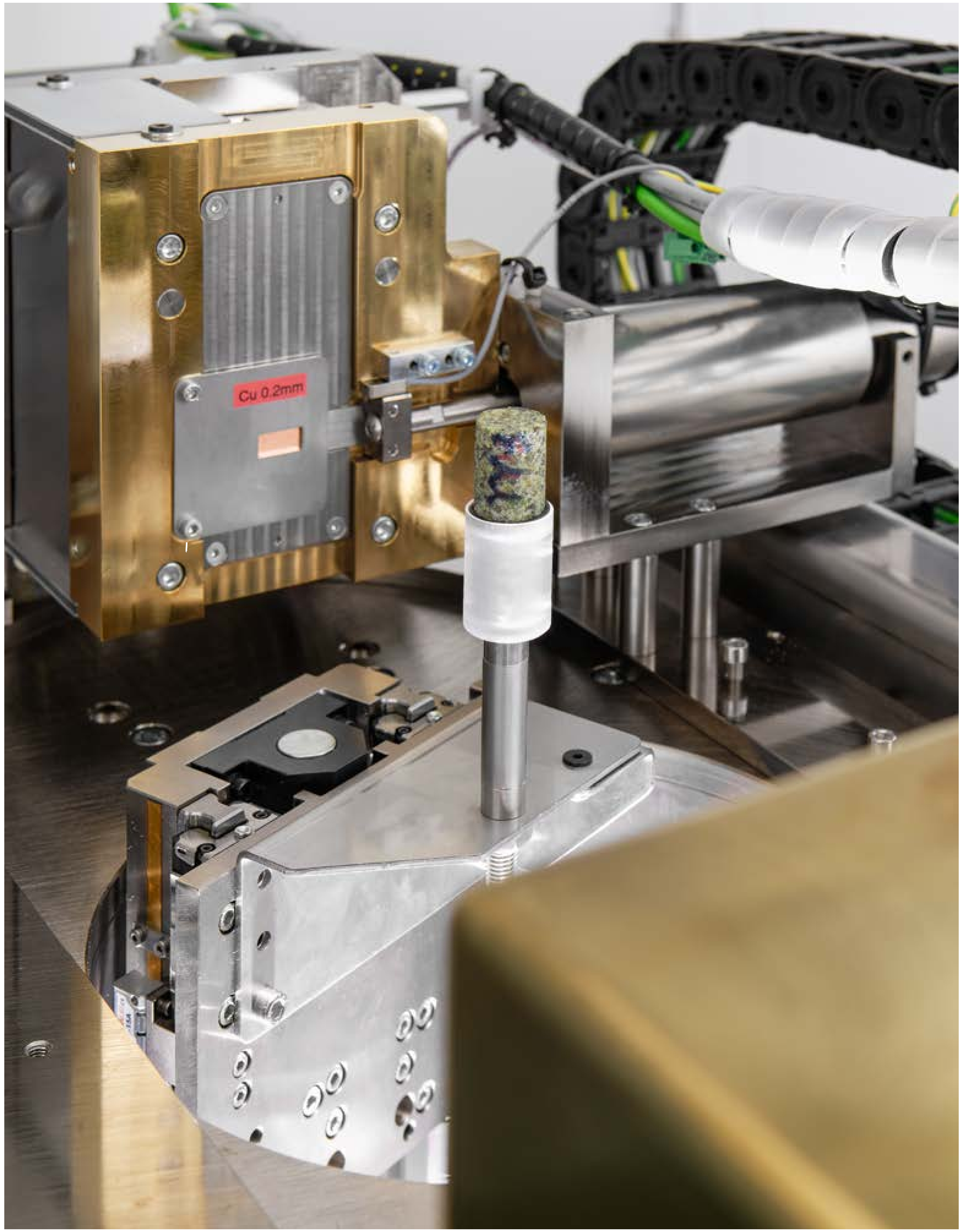
12.3 million euros (2007 – 2016)
15.6 million euros (2016 – 2023)

Project leader

Prof. Dr Bernd Pichler, Werner Siemens Foundation Endowed Chair and Director of the Werner Siemens Imaging Center (WSIC), Germany

Project duration

2007 to 2023



Underground hotspots

Update: Werner Siemens Endowed Chair of Geothermal Energy and Geofluids at ETH Zurich

The interior of the earth harbours massive amounts of energy. But harnessing it is complex: deep drilling is expensive, rock layers are unstable or impermeable, while the lucrative hot fluid streams flow too deep to access or their location is a mystery. Geophysicist Martin O. Saar has now developed an innovative method to tap into the energy in the earth's crust—and capture the greenhouse gas carbon dioxide at the same time.

How dense or porous is the rock sample (centre)?
A newly developed X-ray device renders the interior of the rock visible.

The cylindrical piece of rock, a drilled sample measuring just a few centimetres, is wrapped in a thick, insulating outer shell. Leading into the cylinder are several thin metallic tubes that conduct pressure, heat or fluids into the rock. The aim is to place a sustained stress on the rock for days, effectively simulating the conditions at 10 kilometres below the surface of the earth; a computer then records in minute detail how the fluids and the rock react.

The testing unit is called a "reactive transport press" and is one of three units in the lab run by Professor Martin O. Saar, Werner Siemens Foundation Endowed Chair and head of Geothermal Energy and Geofluids, a group of nearly 30 researchers at ETH Zurich. After five years of preparation, the lab with the descriptive name Geosystem Reactive Transport (GREAT) Visualization Lab is now fully equipped. Indeed, the research findings from the lab have already generated doctoral theses and many of the 29 scientific papers that Saar's group has published in leading journals over the past nine months.

Studying water flows

Although the earth's crust consists mainly of hard rock, the deep geothermal energy experiments at the lab are focused on fluids and flows—indeed, it is flow resistance in rock that poses the greatest challenge to Saar and his team. To learn more, the researchers simulate and calculate in the lab what normally occurs deep down in the darkness below the earth's surface. For instance, they use a 3D printer to create transparent, highly accurate models of the fracture patterns in the rock. A fluid—saltwater, for instance, with special markers added—is then pressed through the cracks; the markers are designed to glow in laser light, enabling them to be photographed by the three high-resolution cameras that capture up to 2 000 images per second. Because the cameras work simultaneously, the researchers can map a vector field of the fluid's flow velocity and then calculate it on their supercomputer.

3D visualisations

Lead-clad walls shield the newest part of the lab where Saar's team conduct their reactive transport experiments with machines normally used to scan human bodies: using X-ray computer tomography, they create 3D visualisations of rock weathering and mineral precipitation as they are commonly encountered when tapping into deep geothermal energy. The 3D printer can also print the visualisations created by the CT scans; the resulting models are then used in the laser-light experiments. "Thanks to the GREAT Visualization Lab, we can create detailed models of the reactive transport of geofluids. It's unique in the world," says Martin O. Saar. To create the models, the researchers develop customised computer programs; they also have the capability to test the computer simulations and recalibrate them to the scale of actual geological reservoirs. Saar says this would be out of the question in a standard lab experiment.

First study in Switzerland

One part of the research team conducts field experiments—more precisely: underground experiments—to explore the conditions. To date, explorations have been conducted in Ethiopia and Mongolia and are currently ongoing in the Swiss canton of Aargau, where literal hotspots have been discovered: areas in the earth's crust where hot water flows relatively close to the earth's surface—roughly one to two kilometres underground. There, the researchers use an electromagnetic geophysical method known as magnetotellurics to measure underground electric currents. This delivers information on how well the porous cavities in the rock are connected, what kind of fluid is flowing underground and where zones with good conductivity are located. "The first study in Aargau is promising. But it isn't easy to interpret the electromagnetic waves in heavily populated areas," admits Saar. For their measurements, the team use electromagnetic fields that arise through solar winds or lightning during massive thunderstorms at the equator—phenomena so strong that they can be measured in Switzerland. On the downside, electric mains in populated areas often interfere with the measurements. Here, too, Saar and his team have found an innovative solution: in collaboration with another ETH research group, they developed a new software program that calculates and partially eliminates electromagnetic noise in the atmosphere.

Carbon dioxide sinks

Martin O. Saar and his team aim to go beyond researching basic principles: they want to discover efficient and ecological applications for their findings. One such application is the subject of Saar's largest project that explores using CO_2 as both a geofluid and a conduit. In a closed-loop cycle, carbon dioxide is channelled underground and used to transport heat back up to the surface. Ten years of research have been invested in the project, three in collaboration with the Siemens Group. Now, the chance of running the first practical test is a real possibility. "Reducing CO_2 emissions is one of the world's most important climate goals," says Saar. Currently, the researchers are negotiating with the managers of a carbon dioxide reservoir in Canada where 350 000 tons of carbon dioxide emitted from a coal-fired power plant have already been stored at a depth of 3.2 kilometres. The reservoir would be suitable as the first testing site for Saar's new technology. In comparison to water, Saar believes using CO_2 as a geofluid could double the efficiency of geothermal power plants. Moreover, the method would be ecological, as the carbon dioxide would remain trapped underground. Saar is convinced: "We'll need to use these technologies in future if we want to stop global warming yet continue to produce electricity."

Funding from the Werner Siemens Foundation

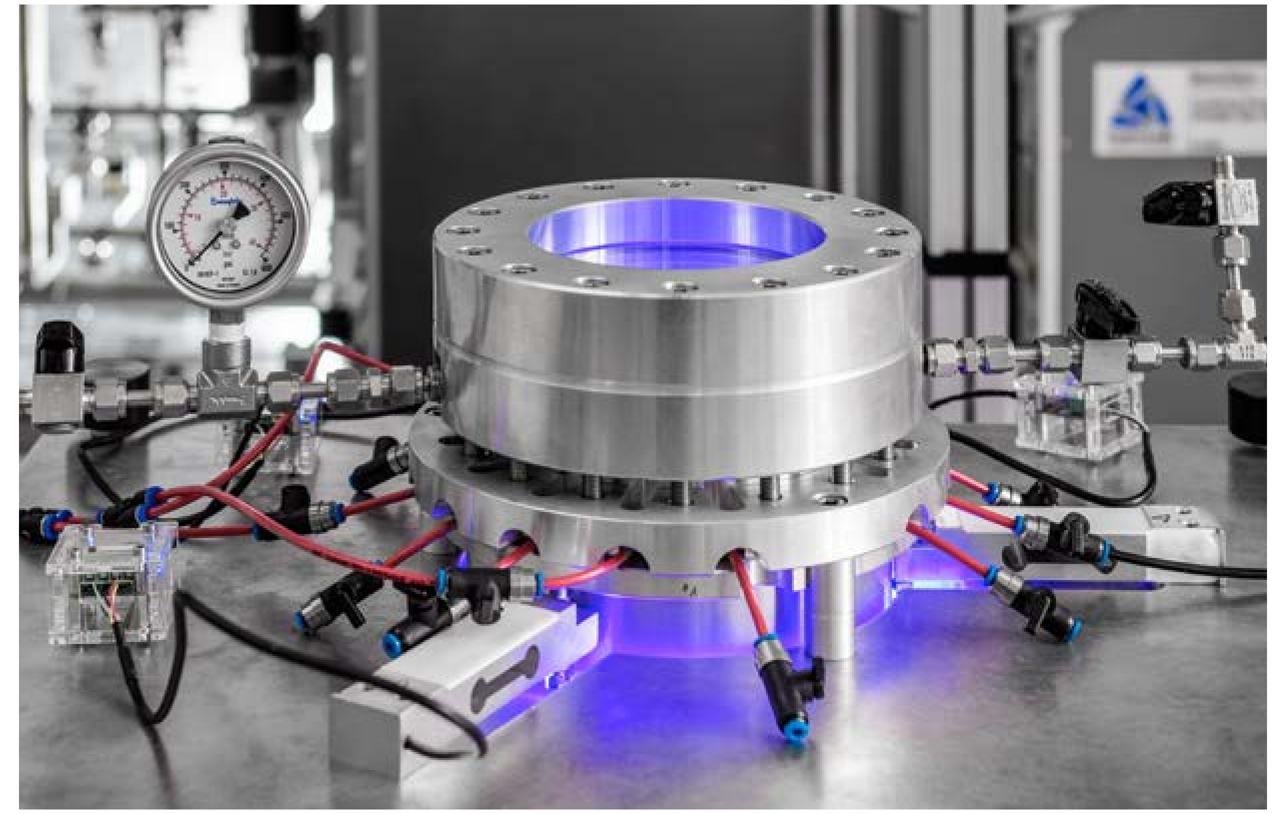
10 million Swiss francs

Project leader

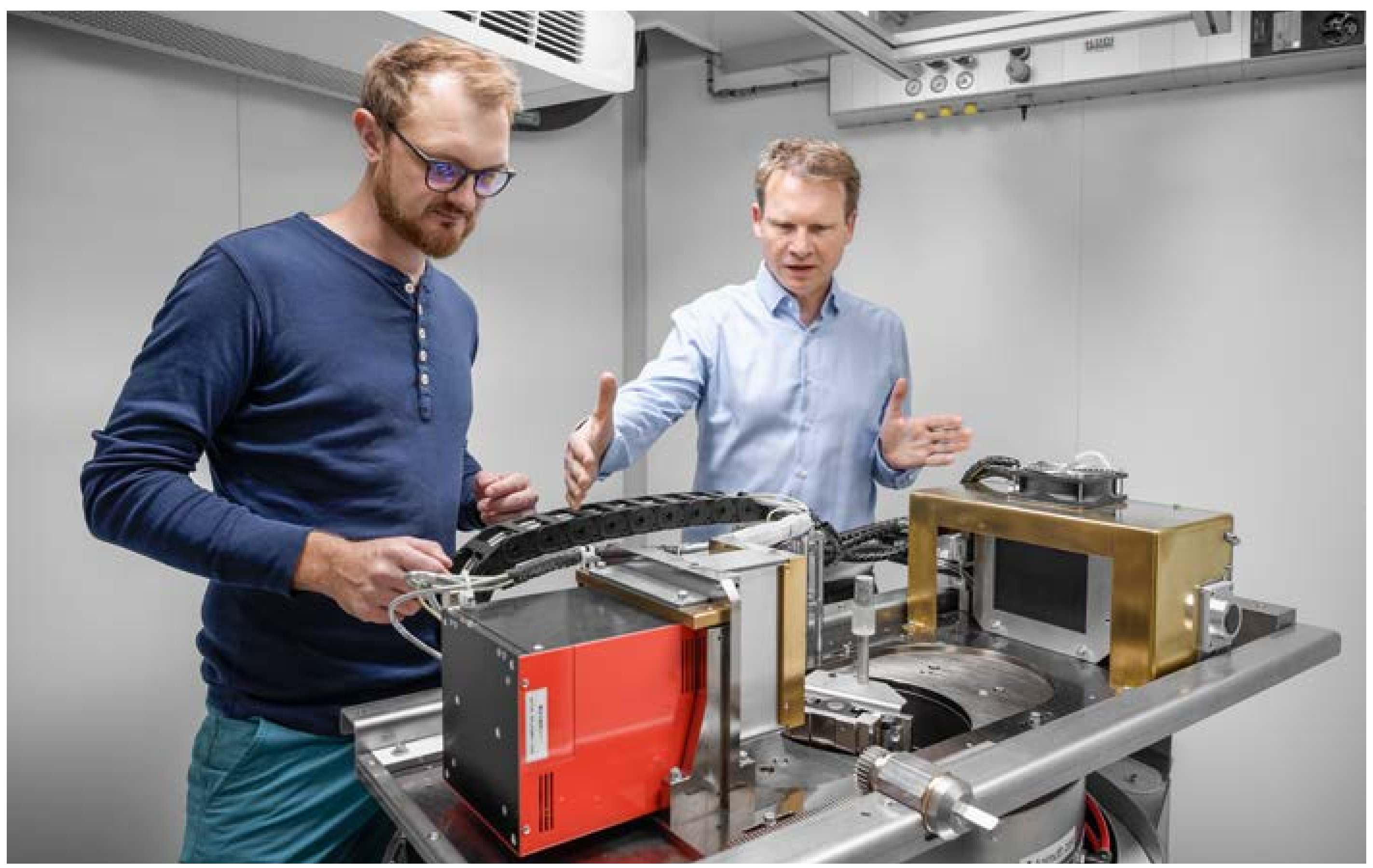
Prof. Dr Martin O. Saar,
Werner Siemens Foundation Endowed Chair of Geothermal Energy and Geofluids, ETH Zurich, Switzerland

Project duration

2014 to 2021



How porous are the fissures (called "joints") in the rock? The latest in-house innovation by Saar's team can now deliver precise answers to this all-important question in geothermal energy.



To attain optimal images of the rock's interior, the sample is securely mounted and the X-ray machine circles around it. The technical head of the lab, Nils Knornschild, (left) and project leader Martin O. Saar worked with SCANCO Medical to develop the X-ray tomography device.

Drilling deep

Update: deep geothermal energy in the Bedretto Underground lab, located in the Swiss Alps

The Bedretto Underground Lab was completed in 2020—in spite of the coronavirus pandemic.
Now, international research groups can conduct experiments on deep geothermal energy in the innovative lab.

The preparations for the Bedretto Underground Lab took just over a year. But what might sound quick and easy was in reality an immense feat for both man and machine. Now, however, the lab infrastructure is set up and the deep geothermal energy experiments can begin.

"There were a few surprises," says Dr Marian Hertrich, manager of the Bedretto Underground Lab. The biggest surprise came right at the start of the project. "We drilled 150 metres into the granite without hitting a single vein of water. Solid granite all the way."

This posed a fundamental problem, as tapping into deep geothermal energy is impossible in solid granite. To generate electricity from the heat in the earth's interior, the rock layers must have fault zones with cracks and fissures—called joints—for water to flow through.

One year on, the main boreholes in the lab have been completed: the construction workers eventually discovered zones with joints, and Marian Hertrich is now convinced that the geological conditions in the Bedretto Underground Lab are the "perfect playing field" for experiments on deep geothermal energy. Indeed, the boreholes penetrate several different geological states of granite: solid granite, fissured rock, pulverised granite. This diversity provides an ideal basis for the researchers to conduct experiments on all granite types found in Switzerland.

Boreholes for experiments

Two large boreholes were planned for the experiments. Each is 20 centimetres wide, one descending 350 metres, the other 400 metres. "400 metres is even deeper than planned," says Domenico Giardini, project leader and professor of seismology and geodynamics at ETH Zurich. The team drilled four control boreholes around the two main boreholes; hundreds of sensors were then installed in the control boreholes to measure any changes in conditions during the experiments in the main boreholes—including seismic movement in the rock, sound waves, pressure, temperature and water flow. "Thanks to the sensors, we know what's happening inside the rock," says Domenico Giardini. Two additional control boreholes are planned for the winter.

To create the control boreholes, the team used the "Wassara", a new down-the-hole percussion hammer. Wassara was tested as part of the international technology project ZoDrEx (Zonal Isolation, Drilling and Exploitation), which was set up to assess the best drilling systems for deep geothermal energy. Wassara uses a water-powered hammer that breaks the rock with targeted blows rather than using a conventional rotating drill bit. "Once Wassara is set up, it works relatively quickly," says lab manager Marian Hertrich, adding that the percussion hammer can drill several decimetres per hour.

After the four control boreholes with sensors were completed, they were filled with cement, creating a compact, 400-metre-deep volume of rock with properties similar to the surrounding granite with regard to hardness, hydraulic conductivity, stiffness and porosity. "Now the rock doesn't 'realise' it's been drilled and equipped with sensors, and it reacts to the tests as if it were intact," explains Giardini.

The lab is ready

"Officially, the first 'real' experiments on deep geothermal energy are slated to begin in October 2020," announced Domenico Giardini in August. "Some 30 experts from Switzerland and abroad will participate, either in the tunnel or from one of the many monitoring screens. After the instruments and network have been checked, we'll stimulate the granite by injecting water at high pressure into the rock and afterwards measuring how the fissures and cracks form."

A moderate depth

The goal of the first experiments is to establish whether the rock at a depth of 1 400 metres reacts to stimulation the same way as at a lesser depth. The reason for this approach is that tapping into heat at a depth of 5 000 metres is no longer viewed as a requirement for deep geothermal power plants in Switzerland: to convert heat into electricity, reservoirs at a more moderate depth of 1 500 metres are now considered more viable. During the warm summer months when surplus energy is available, water can be pumped into the underground reservoirs where it is heated for use in winter when buildings and homes require warmth. "Municipalities in the cantons of Bern and Geneva already have plans for this kind of energy reservoir," says Domenico Giardini. "Reservoirs at a more moderate depth have the advantage that we don't need to drill to the 5 000-metre zone, where earth tremors naturally occur and where the situation is difficult to control." Giardini adds that over 50 percent of Switzerland's energy consumption is in the form of heat, mainly through heating systems. "This means we don't need to transform the heat into electricity first—we can use it directly. It's the way of the future."

Funding from the Werner Siemens Foundation
12 million Swiss francs

Project leader
Prof. Dr Domenico Giardini, Professor of Seismology and Geodynamics, ETH Zurich, Switzerland

Project duration
2018 to 2024

Dental plaque from down under

Update: palaeobiotechnology research in Jena – harvesting prehistoric natural products that have antibacterial properties

Is it a scrap of prehistoric dental plaque with valuable DNA, or just a speck of dirt from the find spot? A new software program promises to provide reliable answers to this question.

Since beginning their work in the new research discipline of palaeobiotechnology last year, the research team in Jena have gone far. Quite literally: their search for ancient substances with the potential to combat today's resistant bacteria extended all the way to Oceania.

Pierre Stallforth and Christina Warinner are working together to establish palaeobiotechnology—an entirely new research discipline. The biotechnologist and archaeologist are leaders in their respective fields: Dr Christina Warinner is professor at the Max Planck Institute for the Science of Human History and at Harvard University and is specialised in the analysis of ancient DNA, while Dr Pierre Stallforth leads a research group at the Leibniz Institute for Natural Product Research and Infection Biology, where he focuses on the analysis and synthesis of natural products. With their joint project in Jena, the two researchers want to help solve an urgent problem in human medicine: resistance to antibiotics.

Palaeobiotechnology offers an entirely new approach to this challenge. The researchers are delving deep into early human history in their search for substances able to combat present-day bacteria that have grown resistant to standard antibiotics. The idea in a nutshell? Warinner and Stallforth want to surprise pathogens with agents that no longer occur in nature—because today's bacteria have had no opportunity to develop defence mechanisms against them.

Ancient DNA

The most unusual aspect of the project is that these prehistoric agents are found in the dental residue of early humans. Indeed, ancient teeth have proven a veritable gold mine for well-preserved genetic material, as both food scraps and the remains of countless bacteria are conserved in dental plaque. Because bacteria have always produced antibiotic substances—to ward off other food competitors, for example—DNA sequences responsible for producing these kinds of agents can be found in the genetic material of prehistoric bacteria. The researchers aim to identify these DNA sequences and, under laboratory conditions, insert them into the genetic material of modern bacteria. For their work, the team in Jena can draw on the thousands of archaeological specimens stored at the Max Planck Institute for the Science of Human History.

Interdisciplinary understanding

The Werner Siemens Foundation is supporting the innovative project with funding in the form of a ten-year grant. During the first year of the project, the research team managed to hold their inaugural retreat just before the coronavirus lockdown began. The aim was for the scientists in the two teams to better understand each other's research and approach. How does an archaeologist conduct research? What does the work of a biotechnologist involve? Afterwards, the teams participated in numerous video conferences to deepen their appreciation for the "other" discipline. Project leader Pierre Stallforth says, "This work was essential in further establishing palaeobiotechnology as a new discipline."

Sophisticated software

That the labs at the Jena research institutions were closed for two months during the coronavirus lockdown had little impact on the project's progress. The focus for 2020 was on bioinformatics, and the researchers set to work improving existing software programs with the aim of optimising their analysis of the DNA sequences in ancient dental plaque. One of the software's tasks is to clearly identify whether the genetic material is indeed prehistoric and not a modern-day dust speck from the excavation site. Moreover, bioinformatic data provide indications as to which snippets of genetic material from the DNA are responsible for coding antibiotic agents. The goal is to have all software tools ready by the start of 2021; that the field of bioinformatics is currently making rapid leaps thanks to artificial intelligence is of great benefit to the new discipline.

Dental plaque from around the globe

Over the course of the project's first year, the team obtained more than 200 new dental specimens from museums and archaeological projects located in all corners of the globe. "In some cases, the genetic material is even better preserved than we had hoped," says Christina Warinner. Specimens from Europe and Asia were already well represented in the collection, and numerous samples from Oceania were added this past year. "It's important to have a broad range of specimens from all over the world in order to achieve maximum diversity in the bacterial DNA," the archaeologist explains. The team's analysis of ancient DNA also generated several publications in 2020, including a paper on the evolution of the oral microbiome over the past 100 000 years.

Grow and test

As the project progresses, the research team will identify the most promising candidates among the agents found in the dental plaque specimens. Afterwards, the next step will be to use biotechnological methodologies to insert the corresponding DNA sequences into modern-day laboratory bacteria and then grow them in a fermentation process. The antibiotic agents harvested can subsequently be tested for their effectiveness against the most common multiresistant bacteria. By 2029, the researchers aim to present interesting agents to pharmaceutical companies for the development of novel antibiotics.

Funding from the Werner Siemens Foundation
10 million euros

Project leader
Dr Pierre Stallforth, Head of Palaeobiotechnology at the Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute in Jena, Germany

Project duration
2020 to 2029

Who we are

A woman of the world

The founders and benefactors of the Werner Siemens Foundation:
Charlotte and Marie—Anna and Hertha—*Nora*

Nora (white dress) was close to the Siemens family, even after the death of her first husband, Werner Hermann. On her visits, she came to know—and love—Werner Ferdinand von Siemens (top left).

Born in 1874, Nora Füssli—well educated, well bred and devoted to music—charmed the menfolk with her beauty and captivating ways. Of her four husbands, two shared her passion for music—both of whom were members of the Siemens dynasty. Shortly before her death in 1941, Nora von Siemens, née Füssli, bequeathed her considerable assets to the Werner Siemens Foundation, firmly establishing her legacy as a major benefactor.

Nora's father, Wilhelm Heinrich Füssli, was born into an old Zurich family whose origins can be traced back to the 13th century. Over several generations, the Füsslis had established themselves as an affluent family in the artillery casting industry. But Wilhelm Heinrich chose to leave the austerity of Protestant Zurich behind to pursue a career as portrait painter.[1]

Nora's mother, Emma von Möllenbeck, came from a very different background. Raised a Catholic, she was descended from a long line of German nobility on her mother's side. Before her marriage, Emma relished her life as lady-in-waiting to the Grand Duchess Maria Maximilianovna, also known as her Imperial Highness Princess William after her husband, Prince William.

Artist father, courtly mother

Nora's parents met in the spring of 1869. Although both were past the first blush of youth, they fell passionately in love and married that same year. Five years later, they had their first and only child, Anna Eleonora, whom everyone simply called Nora.

But having a child exacerbated the couple's differences. Nora's father avoided family life in Karlsruhe and pursued his work as a portrait painter wherever it led him. Nora's mother felt abandoned with her young child, and she yearned for her earlier life at court. In 1890, Emma and Wilhelm Heinrich separated, although they never divorced. Nora was 16 years old at the time. From then on, she lived with her mother in Karlsruhe and Baden-Baden, where they often attended social events: dinners, tea parties and the opera. Emma was hoping to make a good match for Nora, now just shy of 20, something that seemed highly likely, as Nora "always made a strong impression, especially on the gentlemen"[2]. At a soirée, Nora met Werner Hermann von Siemens, who led a quiet life following his divorce from an unhappy marriage. The two quickly discovered their shared love of music, playing together already at their second meeting: "Werner Hermann played his Stradivarius and Nora was his animated accompanist" [3] on the grand piano. For Werner Hermann von Siemens, it was apparently love at first sight, and Nora soon returned his interest.[4] They married in 1895, just a few weeks after first meeting. Nora Füssli was 21 years old.

Marriage to Werner Hermann von Siemens

Werner Hermann was the son of Carl von Siemens and a nephew of Siemens founder Werner von Siemens. At the wedding, Carl gave Werner Hermann a life annuity of 25 000 marks, while Nora received 6 000 a year from her own father—guaranteeing the couple a carefree life. The matters of estate were also agreed upon the marriage: should Werner Hermann precede Nora in death, the widow would receive unconditional, lifelong usage rights to his estate.

Nora and Werner Hermann spent their summers in the regal Palais Biron with its expansive park in Baden-Baden, and their winters in St Petersburg. They had a large music room built, where they held many a house concert. In 1896, the couple had a son, whom they named Werner Wilhelm Carl. The parents were overjoyed, and grandfather Carl von Siemens was delighted to have a young namesake. Sadly, the happiness was short-lived. The boy died at the age of two, and more tragedy was to follow. Just two years later, Werner Hermann died suddenly of appendicitis, aged just 44. In a letter, Nora's mother asserted that had he fallen ill in Germany, Werner Hermann would most likely have undergone an operation and would have been saved.[5]

Charlotte, Marie and Nora

After Werner Hermann's death, Nora left Germany and moved to Rome, but remained in close contact with her father-in-law, Carl von Siemens, and her sisters-in-law, Charlotte von Buxhoeveden and Marie von Graevenitz. (Some 20 years later, the two sisters established the Werner Siemens Foundation.)

Nora's health suffered after her tragic losses. To regain her strength, she spent the spring of 1904 in the mild climes of San Remo, where she met Freydoun Malcom Khan, a Persian prince and an acquaintance of Carl von Siemens who was in attendance at all official gatherings.

The charming prince

Nora had a weakness for all things Middle Eastern, and she soon fell for the charms of handsome Freydoun. The wedding was held in Berlin, in 1905. After their civil wedding service, the couple headed directly to the notary public to conclude an agreement on marital property. Because Nora had a life annuity of over 80 000 francs from the Siemens family fund, yet the prince commanded only 3 000 francs yearly, the couple agreed to a complete separation of property. The newlyweds then relocated to Rome, where they moved in the beau monde. But Nora never found happiness with her prince: he spent her money with little compunction, and the couple divorced in 1908.

Nora von Siemens (centre) ca 1898, with her first husband, Werner Hermann von Siemens, and her sister-in-law Marie Baroness of Graevenitz, née Siemens, who together with her sister Charlotte would establish the Werner Siemens Foundation in 1923.

Accusations of spying

After her divorce, Nora again used the name "von Siemens". She discovered new happiness and began holding a salon in her residence, welcoming dignitaries from the Quirinal Palace and the Vatican, government officials and high-ranking military men—many of whom actively courted Nora. But Nora's social triumphs attracted ill will: in a series of unfortunate events, she was accused of spying. Turf battles broke out: some gentlemen incited harsh accusations against Nora, others defended her innocence. Some disputes even made their way to the Italian parliament, where ugly scenes ensued, ranging from personal insults to physical assaults. Then, in 1910, a fateful duel took place: General Luigi Fecia di Cossato took up his sword to defend Nora's virtue—and lost. Nora rushed to his side to nurse him back to health—and to marry him. Despite the 33-year age difference, the marriage was happy and lasted 11 years, until the general's death in 1921 at the age of 80.

Ties to the Siemens family

Nora, aged 47 and widowed a second time, again found solace with the Siemens family. In addition to Carl von Siemens and his daughters Charlotte and Marie, Nora was also close to the sons of Werner von Siemens, Arnold and Wilhelm, and to their families. On her visits, she often came into contact with Wilhelm's son, Werner Ferdinand von Siemens, the grandson of Werner von Siemens, founder of the Siemens firm.

Werner Ferdinand was 11 years younger than Nora. He had studied electrotechnology and took up employment in the Siemens & Halske company when he was 25. When he met Nora, Werner Ferdinand already had two unhappy marriages behind him.

Happy years

At the start of the 1920s, Werner Ferdinand and Nora began meeting frequently. At 49, Nora was a beautiful, vivacious woman who shared her love of music with Werner Ferdinand—an excellent pianist with a passion for conducting symphony orchestras; in 1923 he even led a concert of the Berlin Philharmonic. Just a few weeks after the performance, Werner Ferdinand hired an estate at Lake Lugano, and Nora had her furniture sent to the new residence where the two soon married. But society in Lugano was a rather drab affair, and the couple returned in 1925 to the Correns estate in Berlin, a manor with expansive grounds and a tennis court. The Berlin of the time was a thriving metropolis with countless opportunities to encounter intellectuals, artists, diplomats and other illustrious personalities.

High life in the roaring twenties

Nora enjoyed Berlin society in the roaring twenties—but music remained the focus of her life with Werner Ferdinand. Because Werner Ferdinand had excellent relations with Berlin's musicians, he was able to pursue his passion for conducting. In 1928, the couple invited over 400 guests to a reception with an orchestra. Nora was responsible for planning and catering to the guests, and Werner Ferdinand conducted the orchestra. After the concert, there was a grand buffet and a dance—a night of imbibing in French champagne and caviar. One guest wrote approvingly, "Finally, after years of drought, a party of the superlative."[6] And still, Werner Ferdinand felt the rooms at the estate were not up to standard ... and with no further ado had a concert hall built. In 1929, the opening of the new hall was celebrated, with notable personalities from the whole of Europe.

Nora and Werner Ferdinand also adored going to the theatre and the cinema; the latter was a fairly new invention at the time. The silent films were accompanied by live music, often featuring theatre organs. Indeed, those organs came to fascinate Werner Ferdinand. The Siemens company had grown to a major company generating millions in revenue and employing thousands—so why not splurge on a theatre organ? Werner Ferdinand purchased a Wurlitzer for his private concert hall—and framed his prized possession with four concert grands. At the party to celebrate the Wurlitzer, Werner Ferdinand conducted the overture from Wagner's *Meistersinger* and treated his guests to dance music and jazz as well—the event, with prominent guests from Germany and abroad, was a smashing success.

Fast cars, family matters

From 1919 to 1927, Werner Ferdinand was an official representative of Protos-Automobil, a car manufacturer temporarily owned by Siemens. Werner Ferdinand had a passion for cars—not even his collision with a beer lorry diminished his enthusiasm. In his red Maybach, he and Nora motored to Bayreuth to attend the Bayreuth Festival, to Baden-Baden to visit the spa and gamble at the casino, and even to Monte Carlo, where the first Grand Prix was held in 1929. In reality, Werner Ferdinand should have been attending to the family firm, a local reporter admonished in 1932, adding that the scion of company founder Werner Siemens apparently had no mind for practical matters—that Werner Ferdinand was interested only in Wagner and Brahms. And cars of all kind.[7]

Werner Ferdinand's three children from his first marriage were by now coming of age: son Peter entered Siemens & Halske in 1934, his daughter Irene married the business magnate Oskar R. Henschel (locomotives, lorries, omnibuses, aircraft) and son Carl Wilhelm studied economics. In May of 1937, Werner Ferdinand and Nora visited his first grandchild. He then died in July of the same year, of a tumour in an advanced stage. He was 52.

Final years

Nora was happily married to Werner Ferdinand for 14 years. After his death she led a quiet, secluded life. She was 65 years old at the time and suffered ill health. On 19 July 1939, she wrote her last will and testament, bequeathing her entire estate to the Werner Siemens Foundation in Switzerland. Nora's last years were spent in Munich hotels, together with two loyal servants. On 19 February 1941, Nora von Siemens, née Füssli, closed her eyes for the final time—retaining her sense of luxury and style to the very end: according to family legend, she wore jewels in her final hour.

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1 Yvonne Gross and Ludwig Scheidegger, *Nora Füssli*, Thomas Helms Verlag, Schwerin, 2018. p. 16.
2 Gross/Scheidegger, p. 62.
3 Gross/Scheidegger, p. 76.
4 Gross/Scheidegger, p. 77.
5 Gross/Scheidegger, p. 84.
6 Gross/Scheidegger, p. 146.
7 Gross/Scheidegger, p. 152.

Governing bodies

Siemens Family Advisory Board

Descendants of Werner von Siemens and his brother Carl von Siemens sit on the Siemens Family Advisory Board. The Siemens Family Advisory Board supports the work of the Foundation Board and holds important veto rights.

Gerd von Brandenstein
Chair
Berlin, Germany

Oliver von Seidel
Member
Düsseldorf, Germany

Dr Christina Ezrahi
Member
Tel Aviv, Israel

Foundation Board

The Foundation Board manages the ongoing activities of the Werner Siemens Foundation.

Dr Hubert Keiber
Chair
Lucerne, Switzerland

Prof. Dr Peter Athanas
Member
Baden, Switzerland

Beat Voegeli
Member
Rotkreuz, Switzerland

Scientific Advisory Board

The Scientific Advisory Board of the Werner Siemens Foundation is an independent body that supports the Foundation Board in identifying suitable projects. Board members are responsible for reviewing the quality of proposals submitted to the Foundation, and they seek new projects of outstanding merit that meet the funding criteria of the Werner Siemens Foundation. When necessary, the members consult with external experts to better assess the potential of an innovative new project. If the assessment is positive, the Scientific Advisory Board issues a recommendation to the Foundation Board in favour of the project.

The members of the Scientific Advisory Board are introduced on the following pages.

The Scientific Advisory Board of the Werner Siemens Foundation: (left to right) Prof. Dr Peter Seitz, Prof. Dr Bernd Pichler, Prof. Dr Gerald Haug, Prof. Dr.-Ing. Dr h. c. Matthias Kleiner, Gianni Operto, chair.

Members of the Scientific Advisory Board

Gianni Operto

Chair

President of AEE SUISSE, the Swiss umbrella organisation of the economy for renewable energies and energy efficiency; owner of Operto AG for clean-energy consulting, Ebmatingen, Switzerland

Gianni Operto is an expert in innovative technologies for renewable energies and their translation to market applications; he also advises on company establishment in this area. Following his studies in mechanical engineering at ETH Zurich, he then completed a management course at the London Business School. At the start of his career, he worked for ABB in numerous countries. After taking up employment at the City of Zurich electric supply company, he introduced a business strategy in the mid-1990s that prioritised renewable energies. He then shifted his interests to finance. He co-founded Nextech Venture AG, a company that supported start-up companies in the area of energy and environmental technologies with capital and expertise, he helped set up SAM Private Equity, and at Good Energies, he took on responsibility for the “future technologies” investment area. In 2011, he established Cleantech, his own energy consulting company. Gianni Operto is a member of several management and advisory boards, including the steering committee of the Swiss Competence Center for Energy Research and the start-ups greenTEG and NexWafe.

Prof. Dr Gerald Haug

Member

President of Leopoldina, the German National Academy of Sciences, Halle (Saale); director of the Max Planck Institute for Chemistry in Mainz, Germany; professor at ETH Zurich, Switzerland

Gerald Haug is palaeoclimatologist, palaeoceanographer and marine geologist. His research interests include the development of the earth’s climate over the past thousands to millions of years; causes of climate changes; dynamics of climate systems; and interactions between climate and advanced civilisations of the past. In 2020, Gerald Haug was named president of Leopoldina, the German National Academy of Sciences, where he has been a member since 2012. Leopoldina unites 1 600 leading researchers from over 30 countries. In 2007, Gerald Haug was appointed full professor for climate geochemistry at the Department of Earth Sciences at ETH Zurich, where he also earned his professional qualification. Since 2015, he has also been director of the Department of Climate Geochemistry at the Max Planck Institute for Chemistry in Mainz, Germany, and Scientific Member of the Max Planck Society. He is chair or member of various governing bodies, including the Alfred Wegener Institute/Helmholtz Centre for Polar and Marine Research, the Potsdam Institute for Climate Impact Research and the Swiss Polar Institute. Gerald Haug has received numerous distinctions for his work.

Prof. Dr.-Ing. Dr h.c. Matthias Kleiner

Member

President of the Leibniz Association, an organisation that connects 96 independent research institutions, Berlin, Germany

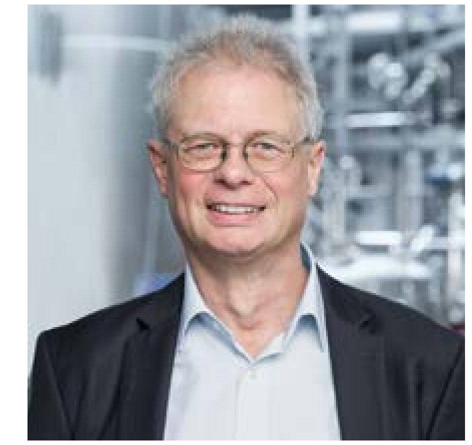
Matthias Kleiner holds a doctorate and the professorial title in mechanical engineering; he is specialised in lightweight construction and forming technology, including their digital methodologies. In 1994, he established the professorial chair for construction and manufacturing at Brandenburg University of Technology Cottbus, where he served as vice president. He was awarded the Leibniz Prize of the German Research Foundation in 1997. In 1998, he moved to TU Dortmund University, where he established the Institute of Forming Technology and Lightweight Construction and was dean of the Faculty of Mechanical Engineering. In 2007, he was elected president of the German Research Foundation. He co-founded Science Europe and the Global Research Council and was member of the European Research Council’s Scientific Council. In 2011, he chaired the ethics commission for safe energy supply in Germany. He is member of numerous national as well as international academies and serves on scientific and management bodies and boards; in addition, he is a juror and expert for research programmes and bi- and multilateral collaborations. He has served as full-time president of the Leibniz Association since 2014.

Prof. Dr Bernd Pichler

Member

Dean of the Faculty of Medicine, Eberhard Karls University of Tübingen, Germany; Member of Leopoldina, the German National Academy of Sciences, Halle (Saale), Germany

Bernd Pichler, electrotechnical engineer with a specialisation in biomedicine, investigates multimodal imaging techniques and detector physics; he also conducts pure research in biomedicine, specifically in oncology, neurology, immunology, infectious diseases and radiochemistry. In 2008, he was named director of the Werner Siemens Imaging Center and the Department of Preclinical Imaging and Radiopharmacy at the University of Tübingen, where he combined the medical imaging techniques of PET and MR to facilitate precise diagnostics and individual therapeutics, especially for patients with tumours. Bernd Pichler has received numerous awards and grants. He is a member of the most important associations and bodies in his field, including the Council of the European Society for Molecular Imaging. He has been a member of Leopoldina, the German National Academy of Sciences, since 2017. In 2020, Bernd Pichler was elected dean of the Faculty of Medicine of the University of Tübingen.



Prof. Dr Peter Seitz

Member

Vice president of the Swiss Academy of Engineering Sciences; Senior Technologist Europe at Hamamatsu Photonics, Japan; professor at EPFL, Switzerland

Peter Seitz is a physicist specialised in semiconductors; he earned his doctorate at ETH Zurich in the area of biomedical technology. He conducted research at the David Sarnoff Research Center in Princeton, NJ, USA, and during a ten-year period, he established the area of semiconductor image sensors and optical measurement systems at the Paul Scherrer Institute. Afterwards, he took on various roles as head of research at the Swiss Center for Electronics and Microtechnology (CSEM), including the position of vice president of photonics and vice president of nanomedicine; he also was instrumental in establishing the CSEM branch in Silicon Valley. During this time, Peter Seitz was also associate professor for optoelectronics at the University of Neuchâtel; he has held the same position at EPFL since 1997. In 2012, he began establishing the Innovation & Entrepreneurship Lab at ETH Zurich. Peter Seitz is author or co-author of over 200 scientific publications, is owner or co-owner of over 70 patents on inventions and co-founder of 6 high-tech start-ups. He and his teams have received 22 international awards and honours.

Presenting Gianni Operto

Gianni Operto, an experienced energy specialist and promoter of innovation, has been championing renewable energy sources for decades. His knowledge and expertise also benefit the Werner Siemens Foundation: since 2012, he has been chair of the Foundation's Scientific Advisory Board.

Gianni Operto, chair of the Scientific Advisory Board of the Werner Siemens Foundation, promotes sustainable energy technologies that can help to restore our planet's health while also securing energy supplies for future generations.

You studied mechanical engineering and worked for ABB before becoming director of the City of Zurich electricity works; after that, you focused your energies on the promotion and financing of renewable energy projects. Since 2012, you've also been chair of the Scientific Advisory Board for the Werner Siemens Foundation. How did you come to take on this role?

Ludwig Scheidegger, who preceded Hubert Keiber as president of the Board of Trustees, initially approached me. We've known each other since the 1990s, and it was probably my expertise and interest in the fields of energy, telecommunications and medical technology that made him consider me for the role. In addition, my experience in sourcing venture capital for start-ups in renewable energy has honed my skills in distinguishing between less promising projects and those with high potential.

Speaking of "selecting high-potential projects"—how does the Werner Siemens Foundation differ from other organisations in this regard?

It's the role of the Scientific Advisory Board to recommend projects for funding to the Foundation Board. Our members are all well networked, and through our connections we often hear of unconventional and bold ideas that require seed funding to proceed. When an idea sounds promising, we encourage the researchers to submit a funding application. At the same time, the Werner Siemens Foundation is becoming increasingly well known, so people also approach us directly. Many researchers, however, are reluctant to request large sums of money. They're used to receiving small contributions and they evidently believe that requesting low amounts of funding is the best guarantee for receiving any funding at all. But the Werner Siemens Foundation doesn't work that way. We support cutting-edge research into radically new approaches to solving the most urgent problems facing our world today. We also want our project funding to enable rapid and effective progress. That's why we select a small number of projects, but award considerable amounts of funding, sometimes for long periods of time. This approach to research funding is unique to the Werner Siemens Foundation.

Does this approach of "fewer projects, greater funding" work?

Yes, our experience has shown that it's very effective: all projects selected to date are fully on track. Our portfolio of projects is also evidence that the Foundation is prepared to take action on the most urgent issues of our times. Take, for instance, the single-atom switch project at ETH Zurich, which plans to revolutionise telecommunications. Or the medical projects that aim to enable precise diagnoses and novel treatments for a wide range of diseases. And, of course, the Werner Siemens Foundation is heavily invested in the issue of climate change—for instance, our funding for deep geothermal energy and synthetic biotechnology projects that seek alternatives to fossil fuels. Given my professional background, the topic of renewable energy is naturally close to my heart. Fossil fuels have made our lives comfortable and convenient for a long time, but at a high cost. Now it's essential to secure energy supplies yet also leave future generations with a healthy planet. The Werner Siemens Foundation is committed to being part of that transformation.

Selection process

Selection criteria

Every year, the Werner Siemens Foundation finances up to three new groundbreaking projects in the fields of technology and the natural sciences. The projects are generally conducted at higher education institutions in Germany, Austria and Switzerland. Requirements include upholding the highest standards and contributing to solving key problems of our time.

As a rule, each project is awarded generous funding of 5 to 15 million euros or Swiss francs. Projects are selected in a multistep procedure by the Scientific Advisory Board, the Foundation Board and the Family Advisory Board of the Werner Siemens Foundation.

In addition to projects, the Werner Siemens Foundation funds exceptional programmes in education and in the promotion of young talent in STEM subjects.

The Foundation does not support activities in the arts, culture, sports, leisure, politics, disaster relief, nor does it support permanent projects, commercially-oriented projects, project co-sponsoring with other foundations, individual scholarships, costs of studying or doctoral theses.

Project application

Project proposals must be submitted in writing to the Werner Siemens Foundation. The selection process is as follows:

1. Project proposal is appraised for compliance with the Foundation's funding criteria
2. The Scientific Advisory Board evaluates the project
3. The Scientific Advisory Board presents its recommendation to the Foundation Board and the Siemens Family Advisory Board
4. The Foundation Board and the Siemens Family Advisory Board consider the project for approval
5. Final decision
6. Contract

The selection process takes approximately six months.

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Where mandatory mask-wearing requirements were in force at the time photographs were taken, pictured persons in groups removed their masks briefly only for the actual photograph. Social distancing was observed at all times possible and in accordance with the prevailing measures.