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2024
report

Promoting innovation in technology and the natural sciences

The Werner Siemens Foundation supports groundbreaking projects in the natural sciences and technology. As a rule, the selected projects are conducted at universities and research institutions in Germany, Austria and Switzerland; key requirements include upholding the highest research 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

Science matters to society. It helps us to better understand our world, to solve critical problems, and to both simplify and enrich our lives. The Werner Siemens Foundation (WSS) demonstrates its commitment to advancing scientific progress by funding top-tier research in the life, natural and engineering sciences. All the projects selected by the Foundation are driven by a clear ambition: making a meaningful contribution to meeting the major challenges of our time.

One of the most pressing goals we face as a society is finding sustainable ways to manage our planet's resources. Achieving this calls for fresh and bold ideas from the scientific community—ideas like those of Chemistry Nobel laureate Benjamin List at the Max-Planck-Institut für Kohlenforschung in Mülheim an der Ruhr. In a newly funded WSS project, Professor List is pursuing what might be called the perfect chemical reaction. If successful, it could capture CO_2 from the atmosphere and help curb global warming (page 26).

Another key to combating climate change lies directly beneath our feet. The Earth's crust holds enough stored heat to more than cover the world's energy needs; it also contains layers and reservoirs that could serve as storage for fossil CO_2. At ETH Zurich, Professor Martin Saar is investigating both possibilities in his second project to receive WSS funding. His plan is to use 3D printing to recreate geological formations which he can then study with an MRI device of unique capabilities (page 36).

Also dedicated to sustainability is the catalaix WSS Research Centre in Aachen. As winner of the ideas competition held to mark the Foundation's centennial anniversary, the project officially launched last autumn. The inspired aim is to break down plastics into their core components using catalytic methods, paving the way for a multi-dimensional circular economy (page 82).

Meanwhile, the WSS Scientific Advisory Board has undergone a change. After twelve years at the helm, Gianni Operto was required by statutory age regulations to step down as Chair at the end of the year (see page 108). Taking up the role is Michael Hengartner, former President of the University of Zurich and now President of the ETH Board (page 114).

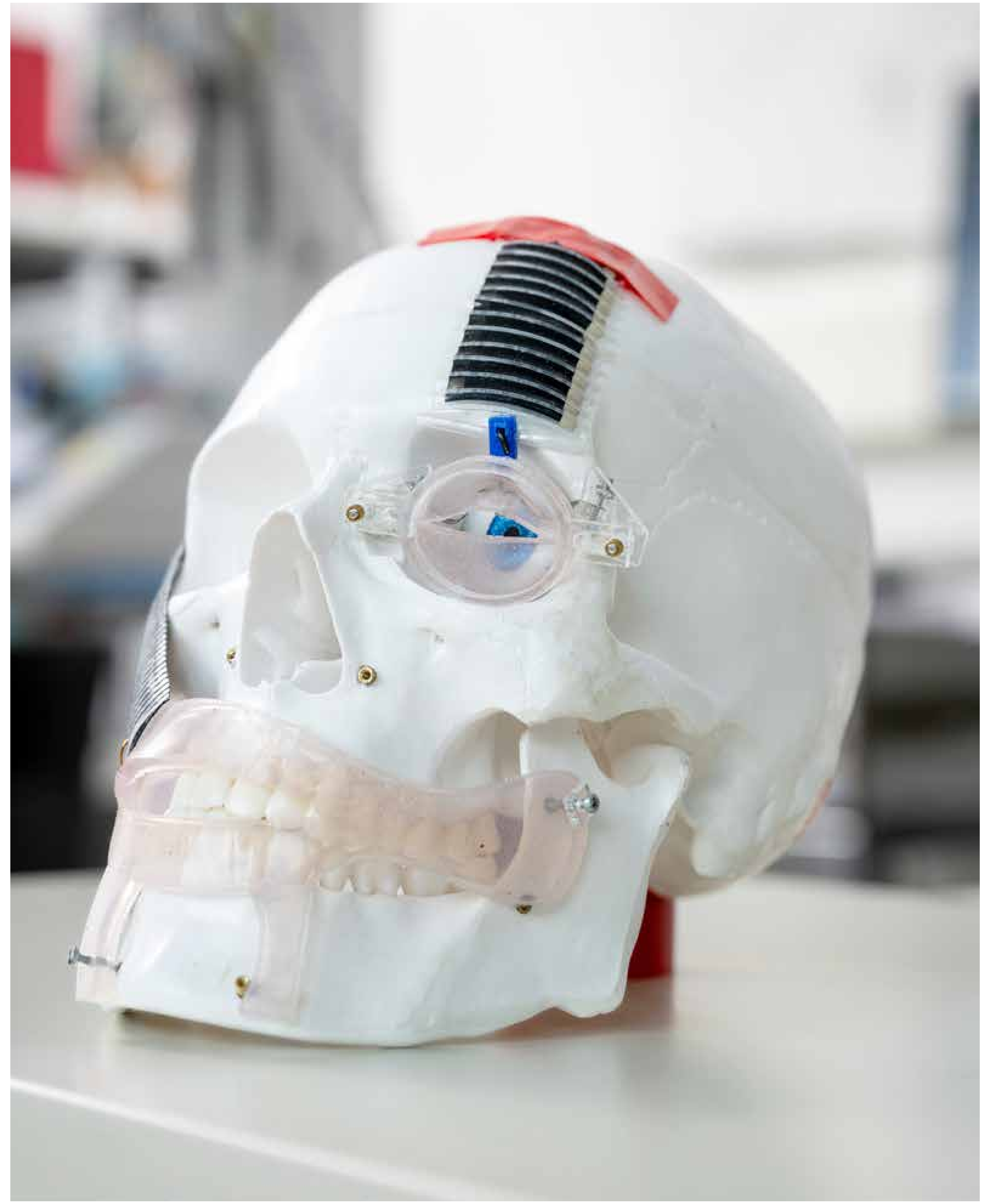
On behalf of the Foundation Board and the Family Advisory Board, I extend our heartfelt thanks to Gianni Operto for his exceptional dedication and invaluable service. At the same time, I wish Michael Hengartner every success in his endeavours—and am already looking forward to seeing what remarkable and ambitious ventures the Scientific Advisory Board will propose for funding under his leadership.

I hope you enjoy reading our report.

Hubert Keiber,
Chair of the Foundation Board of the Werner Siemens Foundation

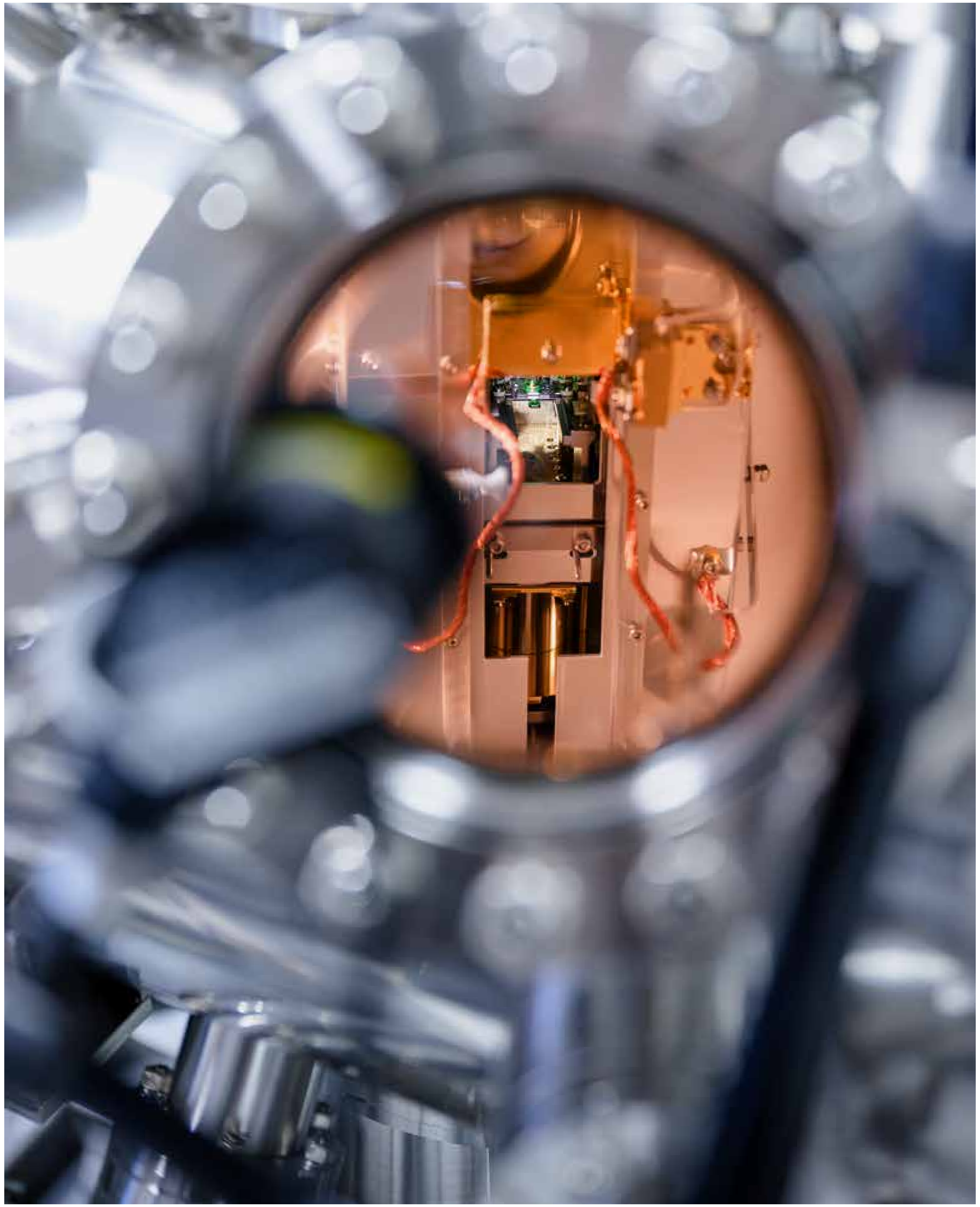
Contents

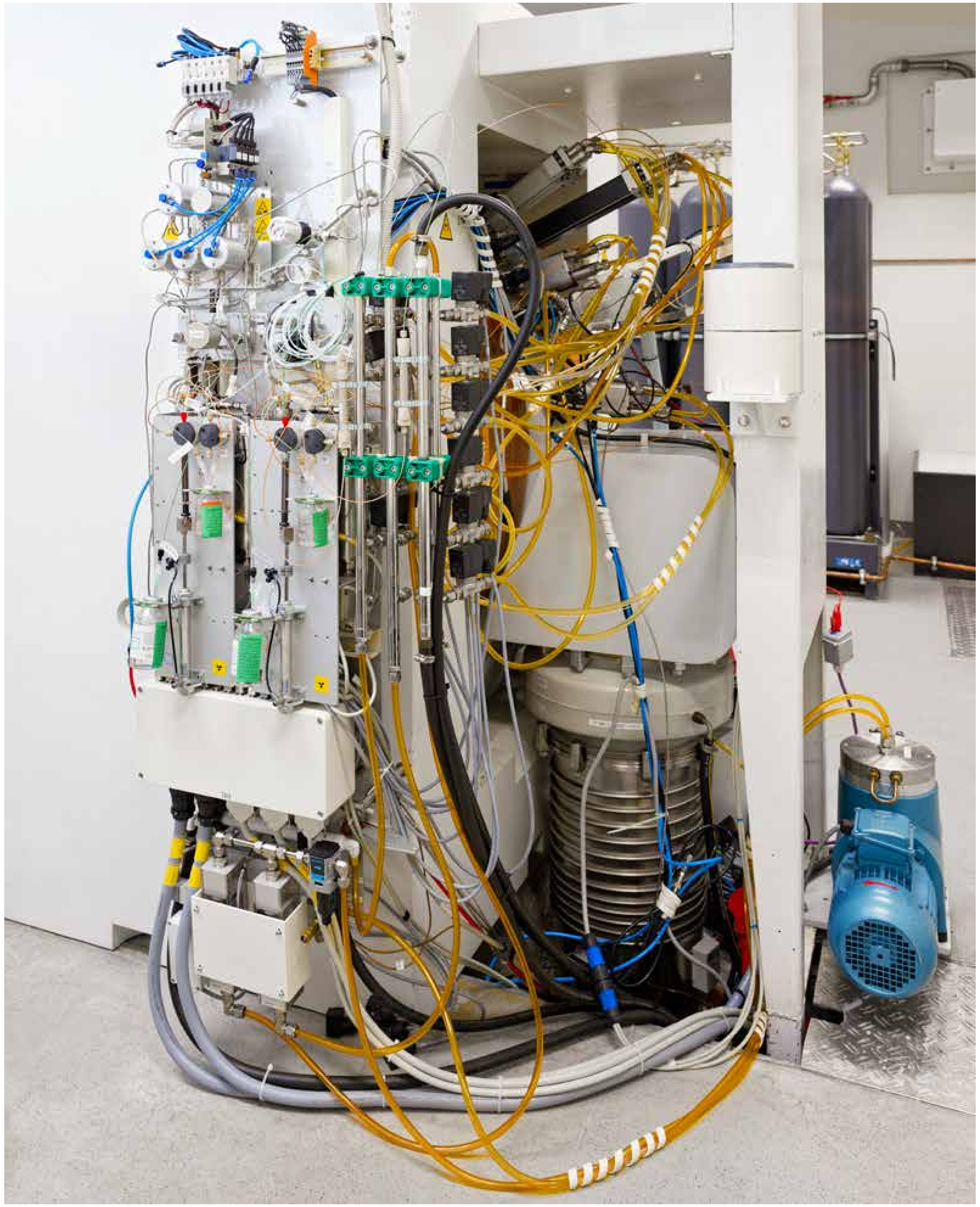
A researcher forms a test tube from molten glass at the WSS Thermoelectric Laboratory in Klosterneuburg near Vienna.



At the Center for Artificial Muscles in Neuchâtel, researchers are seeking ways to treat ailments in facial muscles.

Researchers at the Werner Siemens Imaging Center in Tübingen scan samples in their medical imaging devices to study diseases.


The scanning tunnelling microscope in the CarboQuant project at Empa provides insights into quantum electronics.


Operating complex equipment like that at the Werner Siemens Imaging Center means dealing with a jumble of wires.

An automation platform enables the palaeobiotechnology team to conduct high-speed tests on molecules found in ancient human dental plaque.

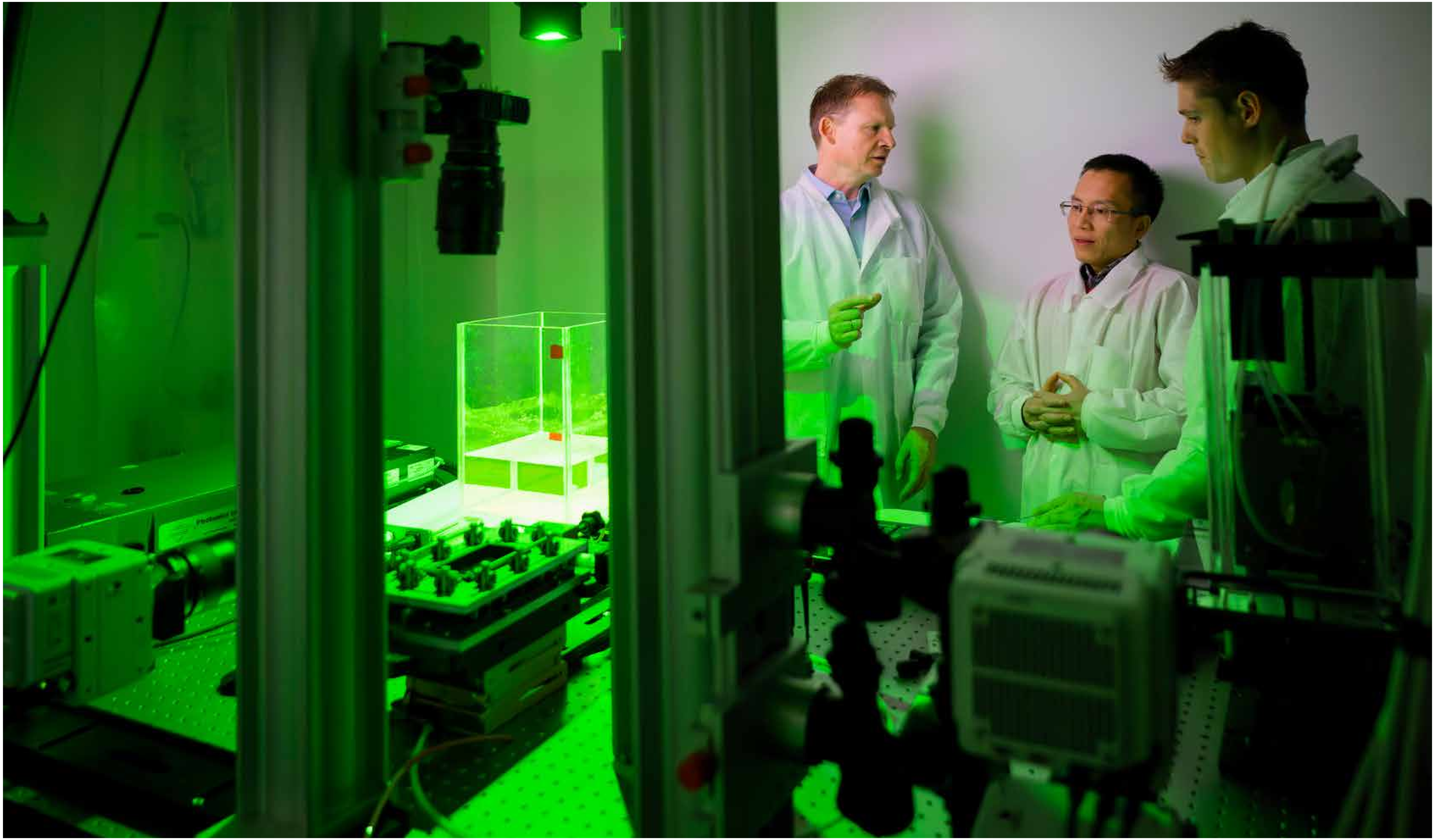
Last year, the crew on the sailing research vessel *Eugen Seibold* collected samples in the Pacific to study the climate phenomenon El Niño.

Researchers in the CERES project in Potsdam analyse copious quantities of climate policy data in their powerful data centre.

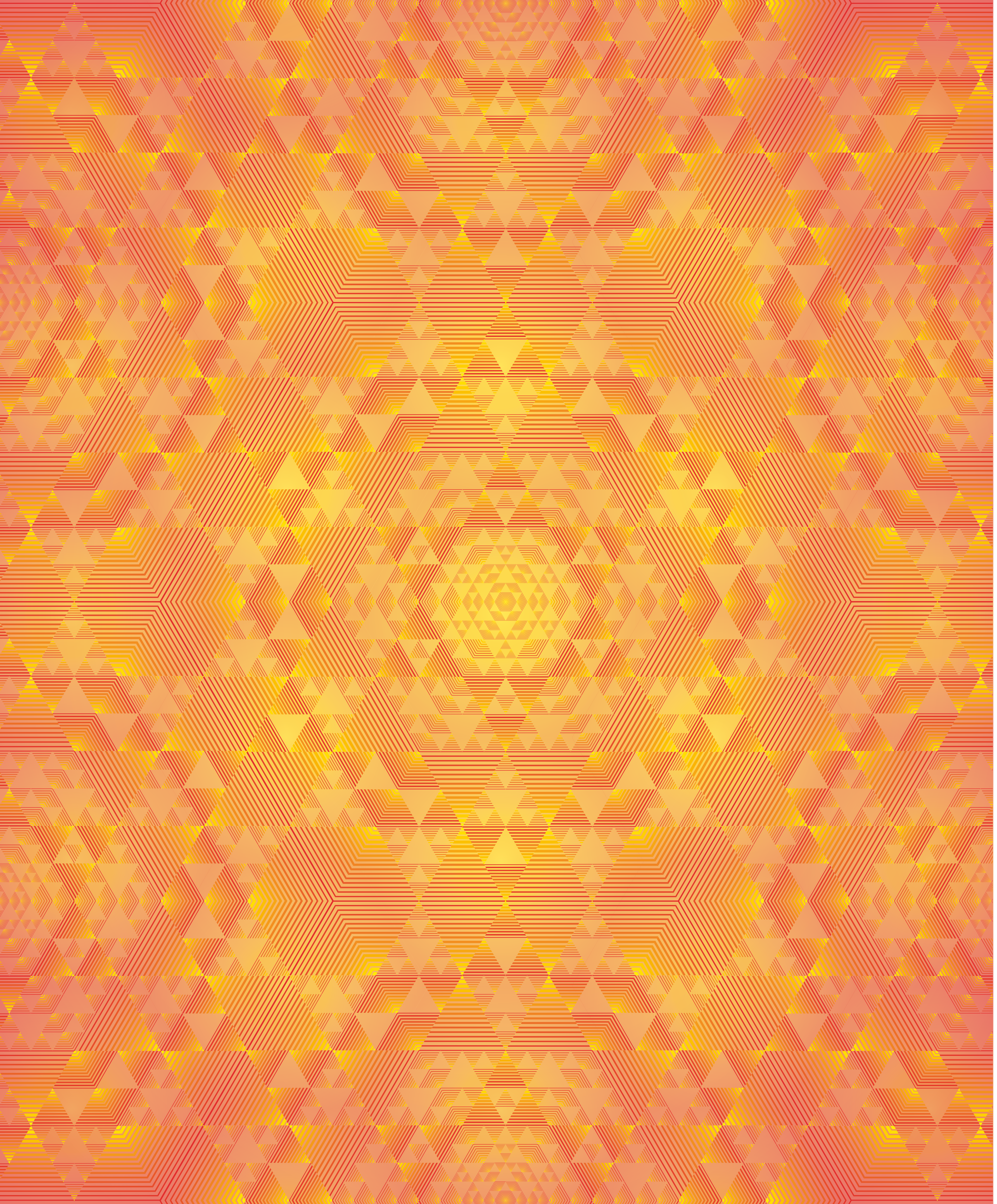
Researchers from the Innovation Center for Deep-Sea Environmental Monitoring in Bremen try out their underwater robots in a maritime testing pool.

Correct labelling of chemical samples—as done here at the Max-Planck-Institut für Kohlenforschung in Mülheim an der Ruhr—is all-important.

A new tunnel is under construction in the ETH Zurich's BedrettoLab in Ticino, offering even better conditions for earthquake research.

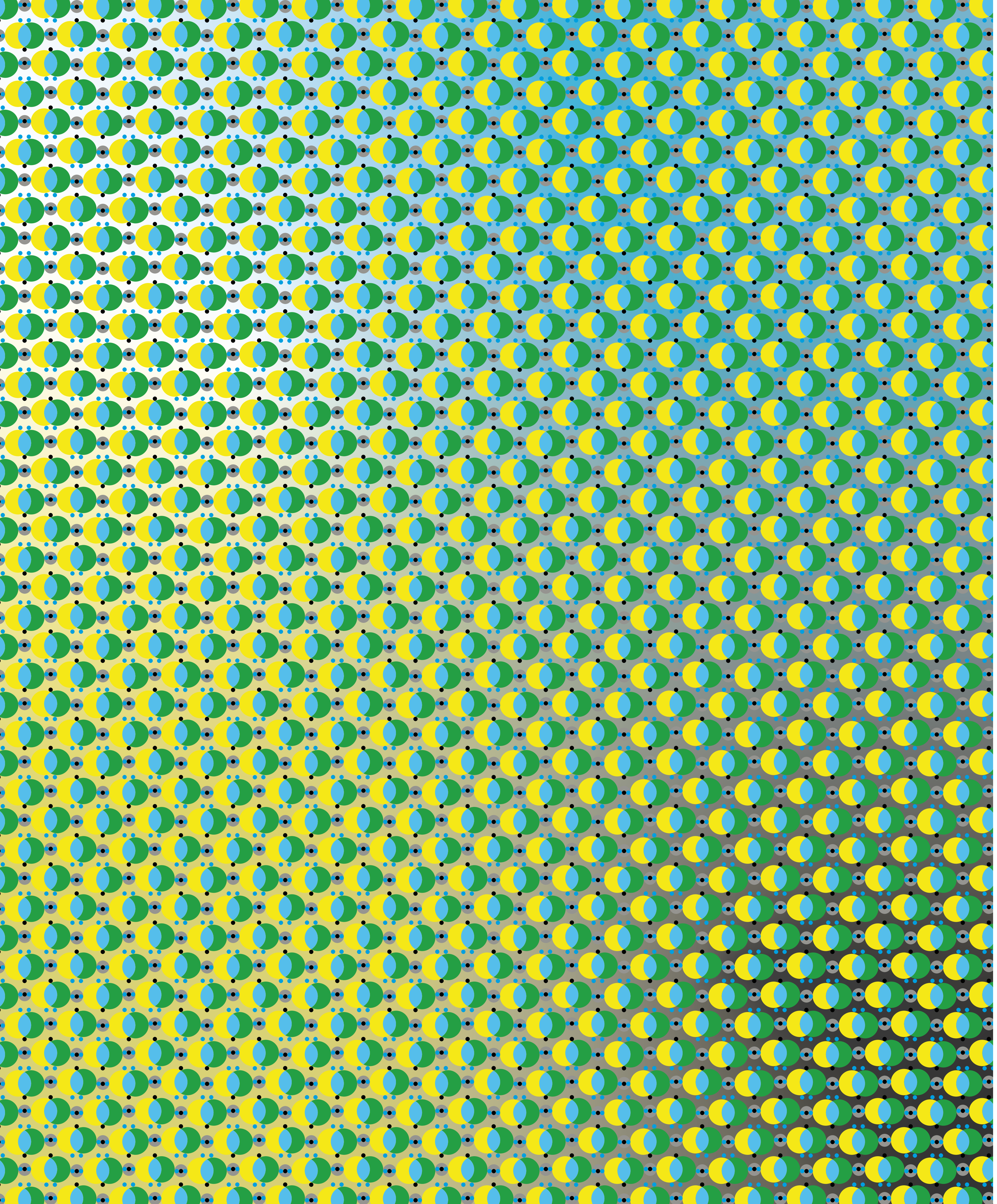


In their laser lab, the Geothermal Energy and Geofluids research group at ETH Zurich study the transport pathways of fluids and dissolved substances.



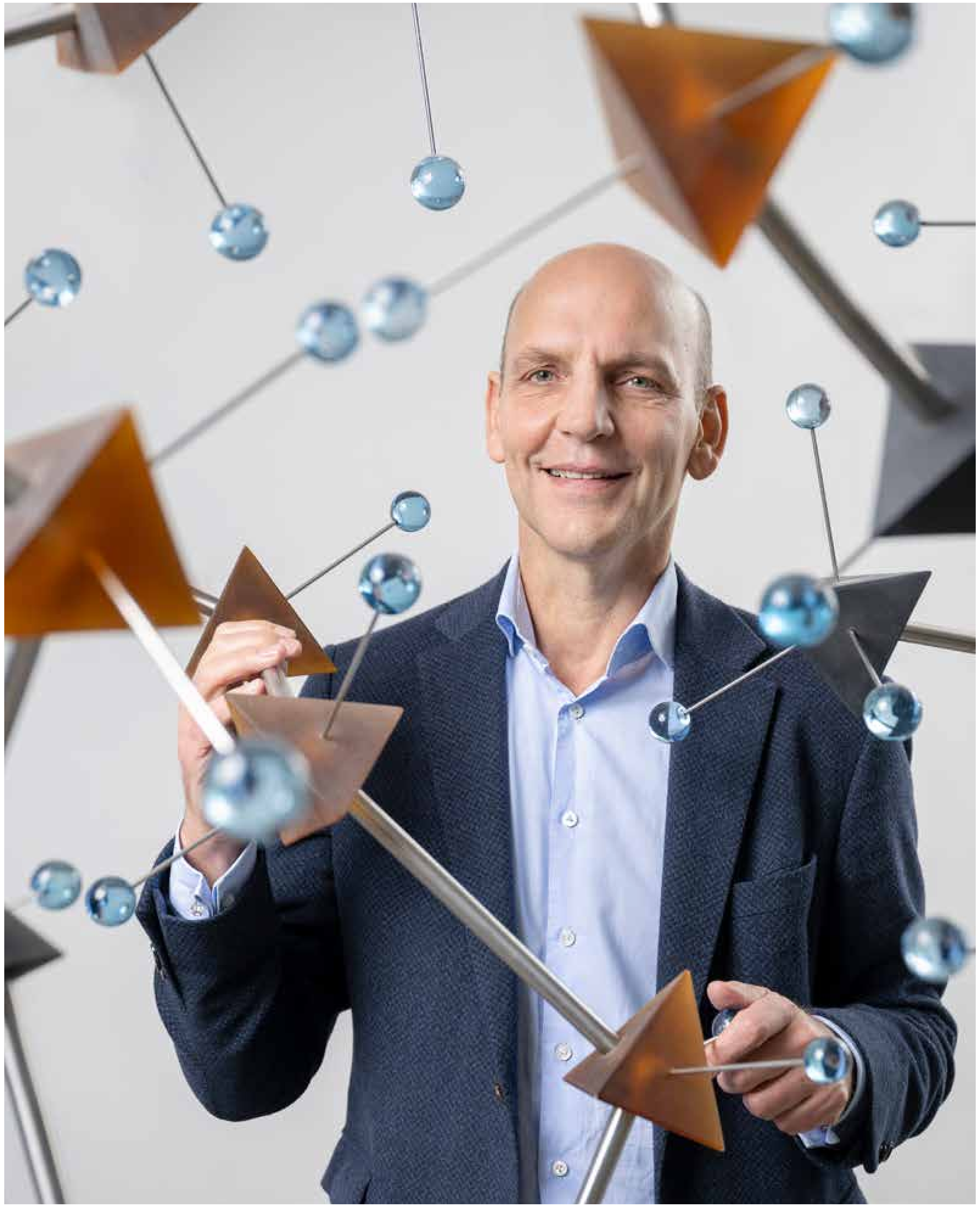
Exploring infinitesimally small worlds

In making their groundbreaking discoveries and inventions, researchers often enter realms that are hidden to the naked eye. State-of-the-art equipment is what enables their journey into these mini, micro—even nano—worlds. In our special focus on all things small, we show how scientists in the projects supported by the Werner Siemens Foundation study the tiniest of structures to help answer the big questions.



Making coal from air

New WSS project "Artificial photosynthesis"



“It would be the core of photosynthesis”

Plants have been removing carbon dioxide from the atmosphere for millions of years—and now, Nobel laureate Benjamin List, director at the Max-Planck-Institut für Kohlenforschung in Mülheim an der Ruhr, is aiming to develop an elegant chemical reaction that imitates the basic principle of photosynthesis. The potentially world-changing technology is the focus of a project that was recently awarded funding from the Werner Siemens Foundation.

Professor List, in your new project, which was recently awarded a ten-year grant from the Werner Siemens Foundation, you're seeking to develop a kind of artificial photosynthesis. What does this work entail?
Well, the project is in fact about imitating photosynthesis in plants. Plants convert carbon dioxide (CO_2) and water into carbohydrates—cellulose, for example—and oxygen is produced in the process. My original idea was to use a type of direct chemical photosynthesis to manufacture a synthesis gas consisting of carbon monoxide (CO) and hydrogen (H_2), which could be used to produce fuel. But then I realised there's a Swiss start-up that's already working on that exact process.

Synhelion?
Yes. They're using catalysts and sunlight to directly produce fuels from CO_2 and water. It's a great idea, and the company is collaborating with businesses like the airline SWISS to supply part of their jet fuel from sustainable sources. However, it's still an insignificant percentage, and what's really tragic is that even if the fuel for every car, plane and ship in the world were produced sustainably, we still wouldn't be able to stop climate change.

Why not?
Humans are emitting some fifty-two billion tons of carbon dioxide equivalents every year. But in the form of fuel, we only use roughly one billion metric tons. That means we ultimately have to remove much, much more CO_2 from the atmosphere.

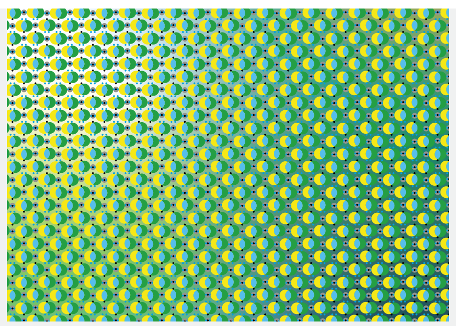
So you decided to develop a different approach?
That's right. Although I have to say that it's currently still more of an idea than an approach. But the general thrust is to remove the water molecules that are on either side of the chemical photosynthesis equation. Using light energy, carbon dioxide (CO_2) would then be transformed into pure carbon (C) and oxygen (O2). In other words, it would be the core of photosynthesis.

What advantages would the process have?
Should the idea work, the conversion into carbon would deliver the basis for making the chemical industry completely sustainable. All organic materials can be produced from carbon, we already have the necessary technology. We could use this solar coal to manufacture fuel by applying the Fischer-Tropsch process—which, incidentally, was developed here at the Max-Planck-Institut für Kohlenforschung one hundred years ago. Of course, this solar coal would also be burnt emission-free or used to generate electric power. And a last point is most important.

What would that be?
To capture enough carbon dioxide from the atmosphere, we need to produce much more solar coal than we can possibly use. And even if we used it to fabricate every single chemical product and all imaginable kinds of fuels, there would still be a great deal of surplus coal. However, it would be easy to bury the excess amount in the ground—here in Germany's Ruhr valley, for example. When I look out my office window, I see huge spoil tips from the coal industry. Beneath these massive mounds are enormous caverns where coal was excavated. Maintaining these underground caverns and old mining shafts costs a lot of money: they could sink or collapse, and it's important to ensure that no problems are caused by water flows and groundwater. Refilling the disused tunnels with coal would be an ideal solution.

"It would be easy to bury the coal in the ground."

Does that mean the underground storage of pure coal would be much easier than the carbon capture and storage methods most often proposed?
Yes! Transporting coal is simple. And



Artificial photosynthesis

If we want to get to grips with global warming, we need methods to remove carbon dioxide from the atmosphere—and that on a large scale. At the Max-Planck-Institut für Kohlenforschung, Nobel laureate Benjamin List is aiming to realise a photocatalytic CO_2 reduction to do just that. By using the right catalysts and sunlight, he aims to convert carbon dioxide (CO_2) into pure carbon (C) and oxygen (O_2). The "solar carbon" that results could be used to manufacture chemical products, produce sustainable fuels, generate electricity or build houses and roads. Another benefit is that surplus coal could be easily stored underground.

Funding from the Werner Siemens Foundation 10 million euros
Project duration 2025 to 2034
Project leader Prof. Dr Benjamin List, Max-Planck-Institut für Kohlenforschung, Mülheim an der Ruhr

Working with chemical samples requires much care and precision.

Cutting-edge equipment ensures that the composition of chemical samples can be identified quickly.

it's a solid—pressing a gas like CO_2 into the earth and storing it there is much more difficult.

Your approach sounds promising, but you yourself say that the reaction has yet to be realised. How extensively has the reaction pathway of CO_2 to carbon and oxygen been studied?
Basically not at all. There's hardly any information in the literature. Really, it seems that the idea has been more or less overlooked. Or—and this is what I think when I'm having a hard time sleeping—most chemists are smart enough to know that the reaction will never work. But things always look different in the morning, and I tell myself that revolutionary discoveries tend to stem from mad ideas.

What's so crazy about the idea?
We all know that coal burns well when oxygen is present. The planned reaction would take the opposite route—we want to reverse the process, as it were. Initially, that sounds pretty far out. But upon taking a closer look, it becomes apparent that, although the amounts of energy required are shockingly large—at some ninety-four kilocalories per mole—it's still less than what's consumed during photosynthesis. In other words, the plant process is more energy-intensive than our chemical reaction.

"I can give no guarantee that the reaction will work."

Does anything else make you feel confident about the project?
Yes, the fact that this reaction is already happening now, as we speak. In the atmosphere of Mars, for example, but also in the atmosphere of our own planet. After all, oxygen was already present in the atmosphere before the first photosynthetic organisms existed. Here the big question was where the oxygen came from. A few years ago an answer was found: experiments proved that CO_2 can be split into C and O_2 using very strong, high-energy UV light. The core part of my idea is to catalyse this reaction so that it needs less energy.

What ideas do you have for catalysing the reaction?
One thought is as follows: during the reaction, a solid—coal—is formed from the gas phase—carbon dioxide. If coal builds up on the surface of the catalyst, at some point the catalyst will be automatically deactivated. Such a deposition reaction also occurs when hydrogen is produced from methane. In that case, methane gas is conducted through hot, liquid tin. The hydrogen bubbles up at the top, while the coal is deposited on the tin. Then, a type of windscreen wiper is used to remove the coal from time to time.

Some of the chemical reactions are conducted under high pressure.


To help him realise his experimental idea, Benjamin List is seeking visionary and inventive minds.

And you could apply the same principle to your reaction?
Exactly. That's how we always proceed with ideas based in so-called heterogeneous catalysis. However, the details are complex. And, of course, secret for now.

Are there other ways to attain the desired reaction?
Another fascinating approach we're pursuing is biocatalysis. We're thinking about microorganism consortia in seawater that could transform CO_2 from air into coal. The resulting carbon may rise to the water's surface, where it could be skimmed off. I'm recruiting biologists for this part of the project.

What could go wrong during the project?
Quite a bit, I'm afraid. I communicated these aspects in the project proposal, and I also informed the Foundation—I can give no guarantee that the reaction will work. On the other hand, no one has yet presented me with a fundamental reason why it shouldn't. I'm an optimist and will do everything I can to make it happen. I also believe that the higher we aim, the more we achieve. Even if we don't quite reach our targets, we'll always learn something. Or we'll discover another interesting reaction.

What does it take for a research endeavour like this to succeed?
A good idea. But the people who work on the idea are at least as important. Thanks to the Werner Siemens Foundation, we're able to put together a superlative team: a group of five to ten people who will focus on the topic for the next ten years. My job is to find clever, creative and bold minds—and to hire them. Because trying to do something that's never been done before comes with a fundamental problem.

What would that be?
We humans tend towards living in herds. We like sitting at the same campfire, singing the same songs and drinking the same drink. That's our nature. In my research group, most team members are studying asymmetric organocatalysis; they celebrate their successes and publish excellent papers. But if someone comes along and works on a completely new topic, it can very quickly get very lonely. Researchers who do that need a robust kind of mentality.

Not all too long ago, asymmetric organocatalysis was completely new. You received the 2021 Nobel Prize in Chemistry for developing this process. When you first saw that small organic molecules like amino acids can be used as catalysts, were you aware that you had hit upon something big?
I still remember exactly how I did that experiment. It was about twenty-five years ago and I had just started an assistant professorship at Scripps Research Institute in Southern California. It worked fairly soon, and when I saw it, I thought: "Nice!" And

although I wasn't thinking about winning the Nobel Prize for it, I did hope it might lead to a permanent position. My wife and I had recently married, and soon afterwards our first child was on the way—so a permanent job was really an excellent prospect.

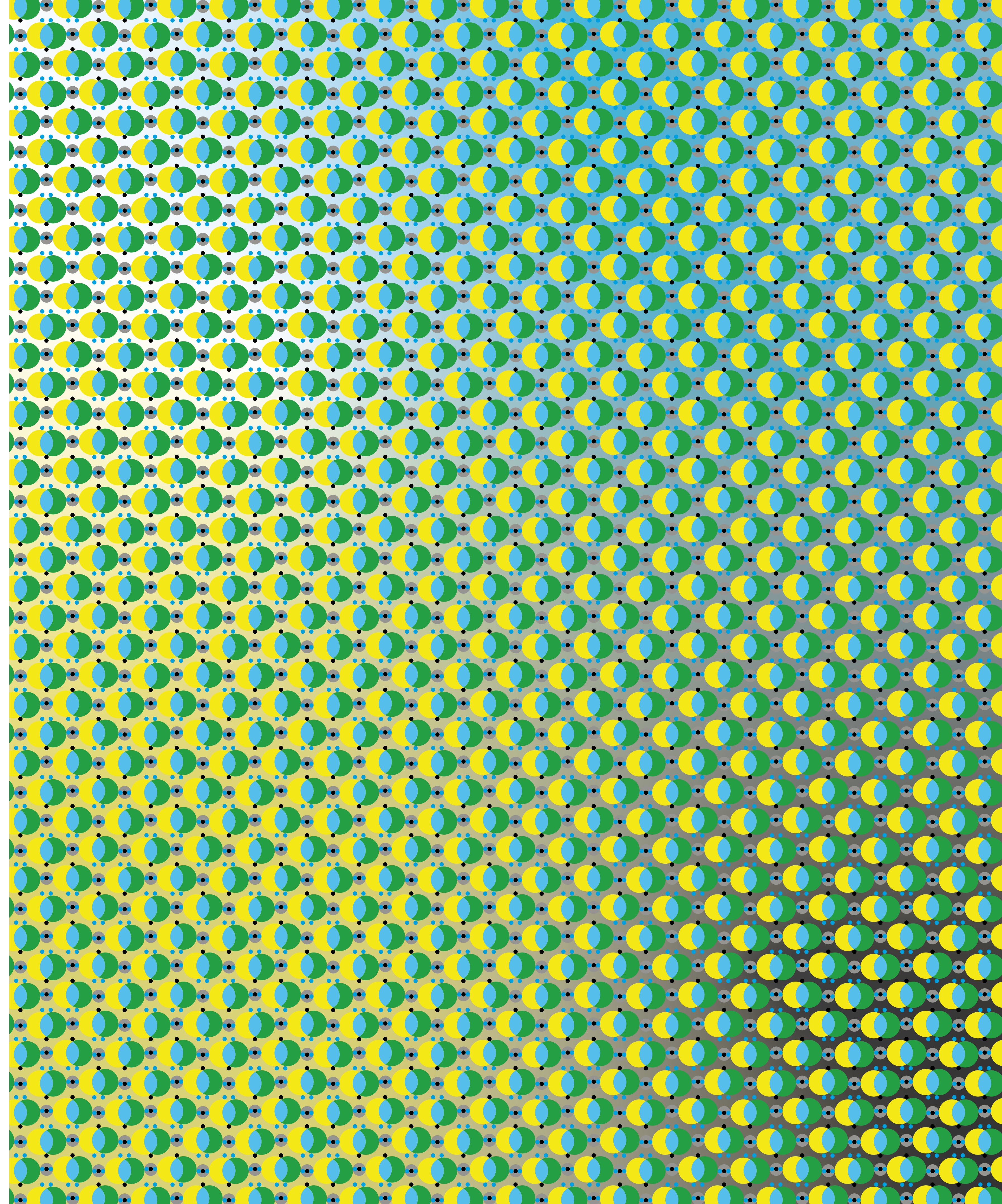
In the end, it brought about much more than a permanent position. Did winning the Nobel Prize change how you research?

2021 was an excellent year for me. We'd just discovered a new type of catalysts that were particularly reactive and selective. They signalled a breakthrough in organocatalysis and were what led to the almost blanket use of this technology in drug production, and even large-scale chemistry. When I was awarded the Nobel Prize, too, that was of course a huge surprise and absolutely wonderful. And I'll admit to briefly wondering what else I should do. But I also know that I love conducting research with my brilliant colleagues. So, I'm basically back to where I was before.

Does an honour like the Nobel Prize give you the freedom to try wild things like splitting CO_2? Or is it more of an inhibition, because you could risk your reputation as a successful chemist?

A certain sense of risk is there, a tingling sensation, a bit like with the discovery of organocatalysis. I also had the same thoughts—why am I the only one trying, and does every other chemist know it's a completely mad idea? In the past, I would have never spoken about it in public for fear of losing my reputation. But it's different today. This whole project has taken shape because I've been saying in talks for the past few years that the next generation of researchers should be exploring this kind of artificial photosynthesis. Thanks to the Werner Siemens Foundation, I'm now doing it myself. I may fail. But today, as a Nobel laureate, I'm more relaxed. I just think: I have to give it a try.

"I wasn't thinking about winning the Nobel Prize."

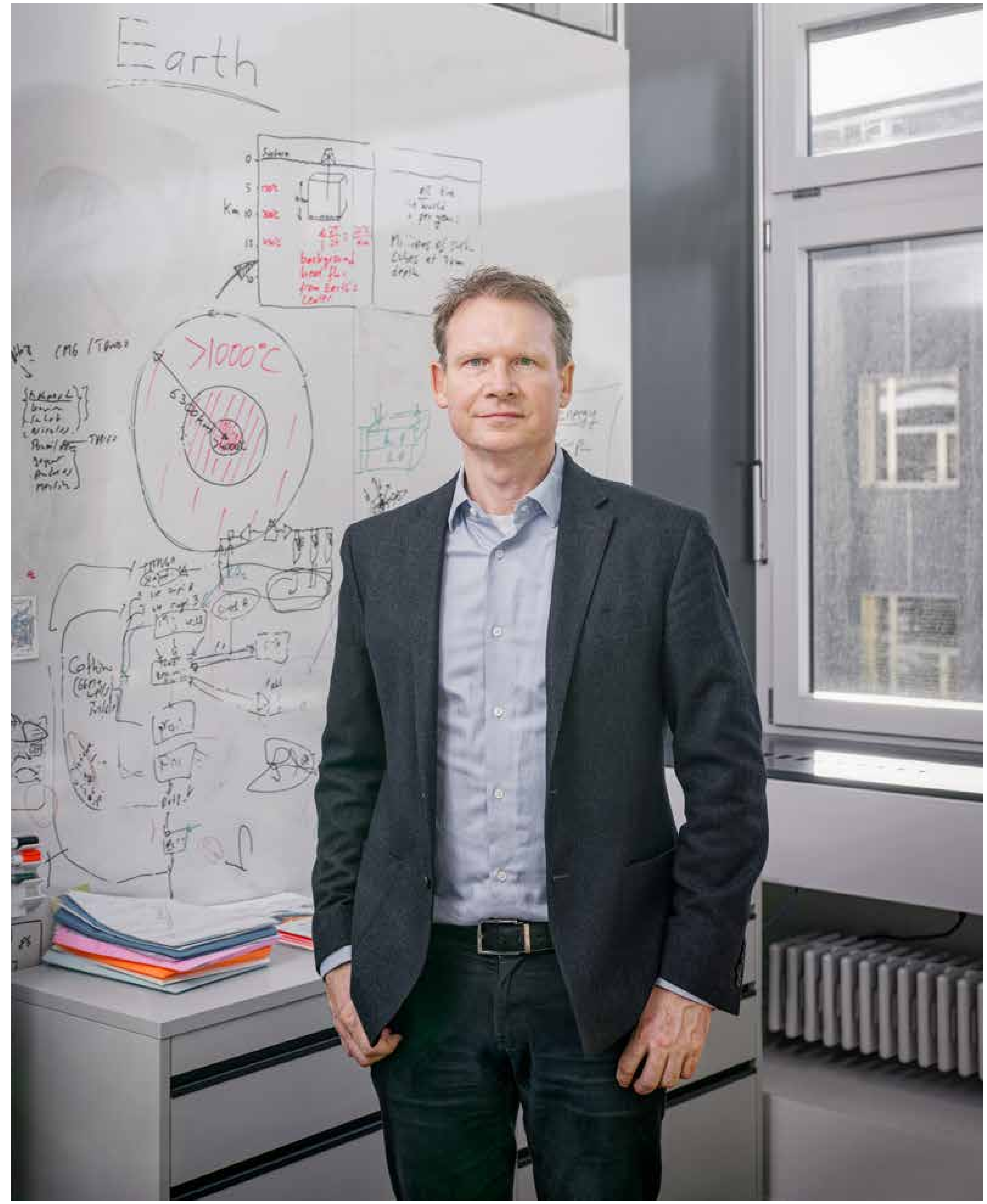


Sending the Earth's crust for an MRI

Follow-up WSS project "Deep geothermal energy"

Seeing inside rock layers

The Werner Siemens Foundation has supported Professor Martin Saar’s geothermal and geofluid research for the past ten years. During this time, several innovative developments have resulted in collaborations with industrial partners. Now, in a follow-up project funded by WSS, Saar is planning to study simulated geological formations in his ETH Zurich lab.



Researchers who want to study the Earth's interior need to get a little creative. After all, the Earth's crust is even harder to access than the deep sea or outer space, and diving into it—or flying there in a spaceship—are hardly viable options. That's why geophysicists like Martin Saar, Werner Siemens Foundation Endowed Chair of Geothermal Energy and Geofluids (GEG) at ETH Zurich, need to take recourse to other, often indirect and complex means in their endeavours to learn more about subsurface conditions and processes.

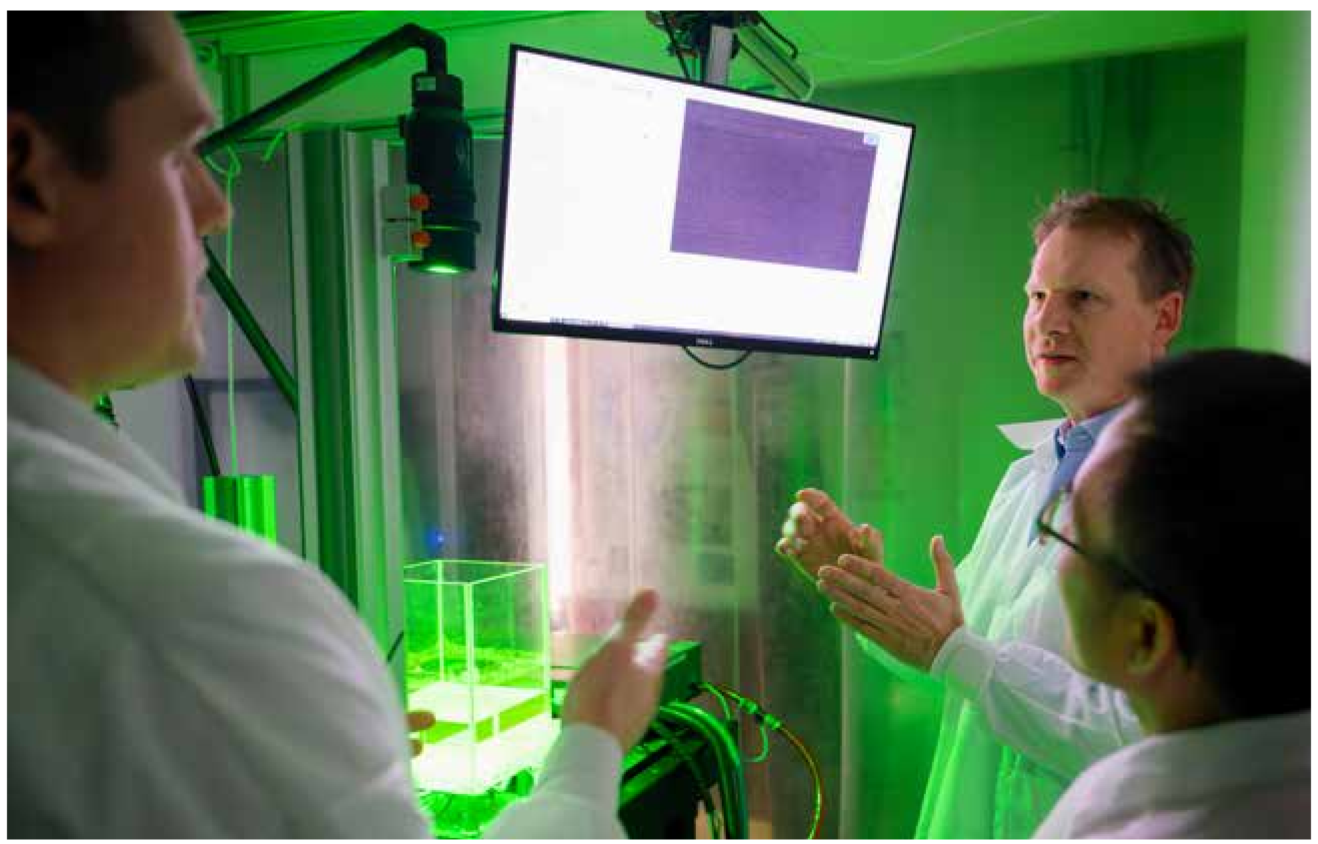
A tour of Saar's labs offers insight into this fascinating work. Several small cylindrical pieces of granite of roughly five centimetres in length are resting on top of a lab table. The researchers use these miniature specimens, called granite cores, to learn more about the processes occurring in deep rock layers. Martin Saar points to a nearby unit with various hoses and a steel cylinder. "We use it to heat the granite cores to up to two hundred degrees Celsius and expose them to pore water pressures of up to one thousand bar"—an environment that corresponds to the conditions found at a subsurface depth of roughly ten kilometres. The researchers inject fluids (liquids or gases) into the tiny pores, cracks or fissures in the granite core, and then measure flow velocities and any changes in the rock.

The 3D printers located near the windows in the lab represent another way to conduct measurements. The researchers use the printers to fabricate plastic elements replete with hairline cracks to simulate joints in the rock layers. They then introduce a fluid enriched with fluorescent particles into the elements and observe flow behaviours under various conditions.

Consultancy for geothermal projects

Some of the experiments can be classified as basic research, while others focus on real-world application. This is because Martin Saar's GEG group has set itself the goal of advancing deep geothermal energy, which has the potential to supply the world's population with sustainable energy sourced from the Earth's interior. However, tapping into geothermal reservoirs remains challenging. For one, the cost of drilling is exorbitant, as the energy is located several kilometres below the Earth's surface. And because the underground is so difficult to survey, trial drilling conducted by prospectors often hit unsuitable rock layers.

Despite—or possibly because of—the challenges, Martin Saar has observed a growing interest in scientific consulting in both the geothermal industry and the political sphere. In response to this demand, he's



In their laser lab, Martin Saar (centre) and his team discuss their experiments on the flow behaviours of liquids and gases.

A visualisation of the planned MRI lab: miniature models of geological reservoirs are printed in the 3D printer (right), prepared for the test on an experimental trolley (left) and then placed in the MRI (centre).

currently setting up a consortium for geothermal energy in Switzerland. The project will be led by Dieter Werthmüller, an experienced geophysicist whom Saar recently invited to Zurich. With the support of private companies and governmental offices, the consortium aims to lay the scientific foundations for geothermal projects in Switzerland—by mapping the geology of the underground, for example.

The consortium will also advise on specific projects. Saar says that several earlier projects in Switzerland have failed simply because the right rock layers couldn't be found. "Our project will help ensure that drilling in future geothermal projects will no longer be hit and miss."

To deliver on all these promises, the researchers must leave the lab and conduct field studies. Saar's GEG group is specialised in magnetotellurics, a key geophysical method used to determine the three-dimensional electrical conductivity of the subsurface by measuring secondary electromagnetic fields on the Earth's surface that are generated underground by the solar wind. Subsurface electrical conductivity is contingent on how permeable the subsurface is for fluids. "Magnetotellurics can aid us in locating potential sites for hydrothermal geothermal power plants and geological CO_2 storage, because a permeable reservoir deep in the subsurface is a prerequisite for these processes," Martin Saar explains, adding that project leader Dieter Werthmüller's expertise in the field of magnetotellurics will give this area of research in his group an even greater boost.

A consortium and a large-scale project

The two most common types of deep geothermal energy production are hydrothermal and petrothermal geothermal energy. The former capitalises on permeable rock layers in which water circulates naturally, generally at depths of up to five thousand metres. The latter, by contrast, taps into the earth's heat from compact, impermeable rock layers at depths of five to seven thousand metres. Aside from these processes, there are other, newer methods—to which Saar's research group has made major contributions. For instance, fifteen years ago, Saar co-invented the CPG method (CO_2 Plume Geothermal), which functions by injecting CO_2 into a suitable reservoir located 2.5 to 5 kilometres below the ground, where the greenhouse gas heats up to at least 100 degrees Celsius.

This heat can be exploited via a circuit: the heated CO_2 is brought to the land surface, where it's used in turbines to generate electricity—and then, after cooling, is channelled back into the underground storage facility so that the CO_2 injected at the start is permanently stored deep in the subsurface. Because CO_2 is less viscous than water and expands much more when heated, it has a

Xiang-Zhao Kong, senior researcher in Martin Saar's group, is specialised in converting findings from lab experiments into formats for computer simulations.

higher heat production rate, theoretically enabling more economical extraction of geothermal energy, and even the production of electricity, in less permeable rock layers at relatively low subsurface temperatures.

Two years ago, Martin Saar established the CPG Consortium, which is now conducting a feasibility study of the approach. The consortium is led by Jasper de Reus from Saar's GEG group, and its members include major companies like Shell, Petrobras, Holcim and Ad Terra Energy. And, as Saar relates, the Swiss Federal Office of Energy has recently become a sponsor. The initial phase is dedicated to gathering information about reservoirs across the globe to determine their potential for use. Following additional investigations, a large-scale demonstration project will be carried out.

Another more recently developed technology is called AGS (Advanced Geothermal Systems), which can be described as a type of heat exchanger that penetrates deep into the subsurface. A fluid circulates in a closed-loop circuit where it's heated by subsurface rocks. Saar and his team are testing the potential of this method in AEGIS-CH, a large-scale project financed by the Swiss Innovation Agency (innosuisse) in its flagship programme. In AGS, two boreholes are joined together by several U-shaped loops at a depth of five to ten kilometres below the Earth's surface; heat is then extracted from the rock using CO_2 as a circulation fluid. It's believed this kind of power plant could generate enough energy for five hundred to one thousand people—and it could be built in many different sites, as no particular geological conditions are required.

New drilling methods

The cost of drilling in the subsurface is one of the biggest problems encountered in deep geothermal projects. "You could say we're still using Stone Age methods to drill—the technology is based on abrasion," Saar says. Any geothermal undertaking that relies on conventional methods to break through kilometres of underground rock must reserve a good deal of time—and money—as the hard terrain takes a toll on the drill bits. In the interest of finding a better way, one of Saar's research priorities in the AEGIS-CH project is a method he helped develop: Plasma Pulse Geo Drilling (PPGD). Rather than mechanically breaking up the rock, PPGD functions with a type of electric shock: electric pulses blast through the rock, generating a plasma arc that fractures the rock from the inside out, much like scooping out ice cream. The technology consumes only around a quarter of the energy of conventional drilling methods, making it much more cost-effective.

Saar also has plans to research and further innovate another novel drilling method; this endeavour will be in collaboration with his ETH Zurich colleague Professor Alexander Barnes and Jasmin Schönzart, a postdoc in his GEG group. "Here, it's all about using microwaves," Saar explains. Specifically, a gyrotron—an extremely powerful microwave generator employed in nuclear fusion reactors—will send compact, high-power waves into the subsurface rock. "The temperatures in the rock layers rise to several thousand degrees Celsius, causing the rock to vaporise," Saar says.

Renewed funding

Saar has been able to pursue his many projects thanks in part to a ten-year grant from the Werner Siemens Foundation. Although the funding is set to expire at the end of 2024, Saar will be able to continue his pioneering research, as WSS has awarded him a new grant of fifteen million Swiss francs for the next ten years. With its unique, cutting-edge approach, the project has the potential to generate entirely new insights into the complex geological processes in the Earth's interior.

To explain this new line of research, Saar offers a tour of a second lab, which houses the group's inhouse computer tomography (CT) scanner used for conducting so-called reactive transport experiments—studying the chemical interactions between porous rock and the medium flowing through it. Rock samples like the granite cores are placed in the CT scanner, where they're exposed to geothermal pressures and temperatures, and a fluid is injected. The researchers can then observe in real time where the rock begins to weather, where minerals precipitate and how energy flow paths are blocked as a result.

The method has various applications and is used in the group led by senior researcher Maren Brehme to investigate how flow pathways affect operations at geothermal power plants over the course of time. Brehme is specialised in identifying—and solving—such problems. Saar relates how, in Indonesia, the group was able to clearly demonstrate how the production rate of geothermal plants can be increased.

However, CT scanners have one disadvantage: their functionality is based on X-rays, which are attenuated to varying degrees depending on the density of a structure. "That's why we can primarily observe how the rock changes," explains Saar. "Differences between gases and aqueous solutions, or their flow behavior, are hardly visible to us."

Custom-made MRI

During the next WSS funding period, the researchers are aiming to change this—with a custom-made magnetic resonance imaging (MRI) device that is likely the only one of its kind in the world. Unlike CT scanners, MRIs can render different fluid types visible. Put simply, the MRI excites the nuclei in certain atoms via a magnetic field, causing them to vibrate; the signals generated by these vibrations are processed, enabling distinctions to be made between different kinds of materials.

Most commonly, MRIs target hydrogen atoms (H-1), but some models can also measure several different elements such as carbon, fluorine, sodium and xenon isotopes. Saar has plans to design a multi-nuclide MRI device, which will be constructed by an external company. "The individual components we need have already been developed, but not yet in the combination necessary for our purposes," he explains.

He estimates it will take about two years to plan, procure and construct the device. By then, the second key component for the MRI experiments should also be ready: a 3D printer capable of producing ceramic replicas of rock layers—including underground deposits, reservoirs, faults and boreholes. The geological formations in miniature will be roughly the size of a brick, yet still contain all important geological features, thanks to modern 3D printing technology that can produce ultra-thin layers measuring no more than a hundredth of a millimetre.

Methane production with microbes

Saar will also use his new MRI to explore yet another idea: underground methane production. In his vision, sustainably produced "green" hydrogen and CO_2 are introduced into the subsurface together with microorganisms capable of utilising the Earth's heat to transform the hydrogen and CO_2 molecules—in a carbon-neutral process—into methane. When needed, the methane generated underground is then conveyed back to the ground surface and used as an energy resource in existing facilities.

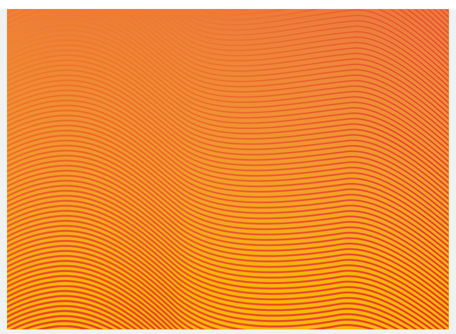
Conducting "methanogenesis" is, however, a highly complex undertaking, especially in the deep subsurface, which is why lab experiments must first be carried out. It's precisely for these kinds of simulations that the new MRI will be ideal, as Saar explains: "It will enable us to observe where the CO_2, hydrogen, microbes and methane produced go and where they accumulate. We can use this information to optimise the placement of injection and production wells."

The data gathered in these experiments will be incorporated into computer simulations, yet another indispensable tool in the GEG lab. Xiang-Zhao Kong, senior researcher in the team, is a specialist in the field. For his work, the data delivered by the MRI scans—3D temperature fields, pressure fields and velocity vectors of the various fluids and microbes—are invaluable.

Interdisciplinary interest

It should be noted that the significance of the new MRI system is even greater than Saar's groundbreaking geothermal experiments. One cross-disciplinary application is a planned collaboration with the ETH Zurich Centre for Origin and Prevalence (COPL) led by astronomer and Nobel laureate Didier Queloz. Researchers at COPL are interested in understanding where and how carbon and microbes accumulate in rock layers and how the latter multiply there; these environments can be simulated and observed in the novel MRI to uncover clues about the origin of life on Earth or other planets.

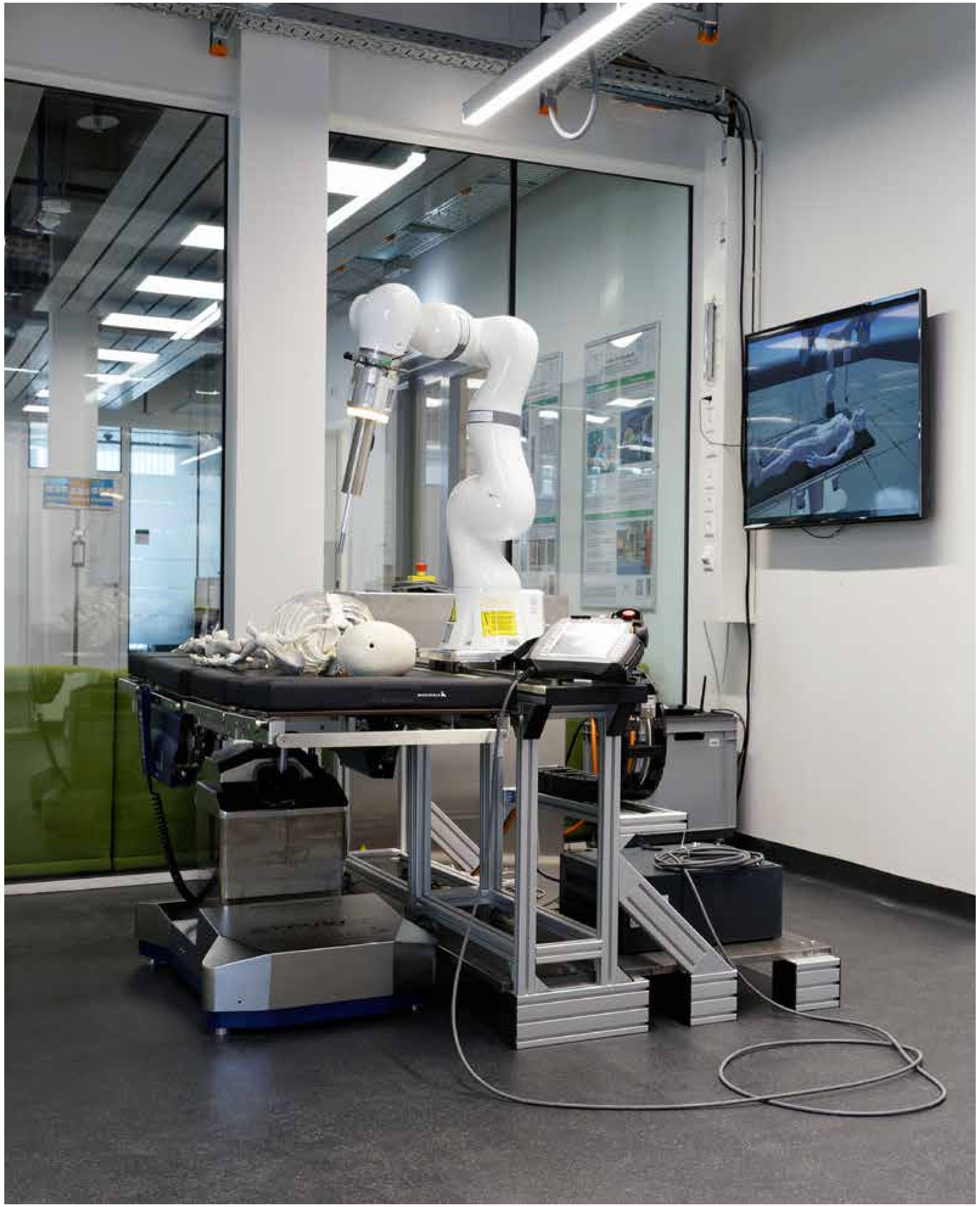
Last, but not least, specialists in the field of compressor and turbine development have expressed their interest in using the MRI for their experiments. Saar says that's exactly how it should be: "This kind of specialised, custom-made equipment is much too expensive to sit idle. It should be used practically round the clock." One way or another, Martin Saar is certain the investment will pay off—also for disciplines that go far beyond the geosciences.



Deep geothermal energy

The Earth's heat is one of the largest unused energy reserves on the planet, and Professor Martin Saar and his ETH Zurich team are seeking trailblazing ways to harness this heat on a large scale for direct use or power production. In collaboration with industry partners, Saar has developed a new drilling technology—and an innovative method for permanently sinking the greenhouse gas carbon dioxide into the Earth while simultaneously using it to generate geothermal electricity. Now, over the coming decade, his research priority is a one-of-a-kind MRI system that promises to deliver insights into the complex interrelationships between gases, liquids and rock layers.

Funding from the Werner Siemens Foundation
10 million Swiss francs (2015–2024)
15 million Swiss francs (2024–2034)
Project duration 2015 to 2034
Project leader Prof. Dr Martin O. Saar professor of geothermal energy and geofluids at ETH Zurich



Researchers in the MIRACLE II project in Basel are developing a laser robot with the aim of enabling precise, minimally invasive bone surgery.

Medical care of tomorrow

Medical interventions are continually becoming more precise, more sophisticated and less invasive. Three projects supported by the Werner Siemens Foundation are driving the developments in medical technology forward—each in its own way.

Getting it just right can be a question of life and death—especially in medical care. The more precisely a tumour can be removed or treated with radiation, the better a patient's chance of healing. The more effectively a drug can zero in on a pathogen, the lower the risk of side effects. And the higher the resolution of an X-ray or an MRI scan, the greater the likelihood of an early diagnosis.

In medical research, there are various approaches for making medical interventions and diagnostic examinations more accurate. One of the most important and promising of these methods is miniaturisation: because very small instruments have a much less disruptive impact on the body, patients experience fewer traumatic consequences. Nevertheless, building smaller, lighter and more versatile devices requires much more than medical knowledge. That's why the field of medical technology combines expertise from medical sciences with that from engineering, IT, electrotechnology, chemistry, biotechnology and other disciplines.

Minimally invasive laser scalpel

A prime example of this kind of interdisciplinary collaboration is found at the University of Basel Department of Biomedical Engineering, where the MIRACLE II team are shaping the future of bone surgery. The research groups led by Philippe Cattin, Georg Rauter and Florian Thieringer are creating a robot-guided laser scalpel to enable minimally invasive, high-precision surgical interventions—that are planned and monitored using an innovative virtual and augmented reality system.

"The technology we need for our dream device has yet to be developed," says Philippe Cattin, professor of image-guided therapy. "That's why we're exploring miniaturisation in all areas of our research. We're trying to push the boundaries of the possible, whether with our robotics platform or in laser optics." This is critical because the team's novel surgical robot will only make the leap from lab to clinic if each and every aspect of the project can overcome existing limitations.

Development of the robot itself is the remit of Georg Rauter, professor of surgical robotics. The basic idea is to create an instrument that functions much like a human hand: the "arm" will be positioned in the operating theatre, outside the patient's body, and surgeons will use it to guide the finger-shaped, jointed appendage at the tip—the endoscopic mini-robot.

Benefitting from Swiss precision

Rauter's team are seeking to miniaturise both parts of the system. The "arm" is currently quite bulky and takes up too much space in the operating theatre. "Our goal is to have a hand-held system that can be mounted on the operating table," Rauter says. By contrast, the foremost, finger-like appendage of the robotic system is already incredibly tiny, with a diameter of just eight millimetres. Nevertheless, there are still size-related challenges: currently, the "finger" is made of aluminium but, to be safe for use in the body, it must be built from materials like titanium or stainless steel. "And it's almost impossible to fabricate something this small with those materials," Rauter says.

Fortunately, the Swiss watch industry is specialised in the construction of high-precision components made of stainless steel and titanium. Rauter has now asked a mechanical workshop active in the watch industry to manufacture the parts for their robot. He says it may sound simple to have a component built using a different material. "But," he adds, "in reality it's a big step."

In another part of the project, a laser for cutting bone is being integrated into the tiny robot. This task has been assigned to Ferda Canbaz, head of the Center for Intelligent Optics. "Up to now, we've been using a bundle of optical fibres with a diameter of roughly three millimetres to supply the tip of the endoscope with enough power," Ferda Canbaz says. "Now, we're aiming to channel the laser energy through a single optical fibre." One of the ideas they're pursuing is converting the optical fibre itself into a laser medium. "To do this, you shoot a laser at the optical fibre, whereupon the laser light is generated in the optical fibre itself," Canbaz explains.

Different means, same end

Philippe Cattin's group has developed two techniques for continually monitoring the endoscope's location in the body. The first utilises optical interference in the optical fibres: "We interpret the interference and reflected light to determine the bending of the optical fibres—and thus where in the body the robot is located." The second technique is based on minuscule angle measurement sensors that are just one cubic millimetre; these tiny devices are used to determine the robot's position by means of the joint angle. Cattin is pleased: "The sensors are a really nice accomplishment. Not only are they much smaller than anything on the market, they're also up to fifty times more accurate."

It's not unusual for researchers to seek several solutions for the same problem. After all, it's impossible to know in advance whether a concept will work, and whether it can at some point be made marketable. Another example of multiple approaches to solve a single problem are the ideas being developed to prevent the smart laser from cutting into the wrong tissue. Ferda Canbaz and her team are applying a spectroscopic method that uses plasma light to determine what kind of tissue is being cut; at the same time, they're also investigating an optical system that measures the depth and shape of an incision as well as the temperature at the site of the cut.

Meanwhile, Georg Rauter's robotics team are tackling the problem from yet another angle. They've developed a technology that uses springs instead of a cable drive to connect the joints of the endoscope robot to the motors. "When the endoscope bumps into something, the spring reacts immediately, without the robot knowing about it," Rauter explains. This means shocks that would otherwise damage tissue in the body are absorbed.

An implant that heals

As in the MIRACLE II project, bone injuries are the focus of the "Smart implants" project at Saarland University, Saarland University Medical Center, the Center for Mechatronics and Automation Technology and the German Research Center for Artificial Intelligence. The team led by Professor Bergita Ganse and Professor Tim Pohlemann are aiming to develop an implant that not only monitors the healing process of complex fractures but that also promotes healing through its autonomous, activating movements.

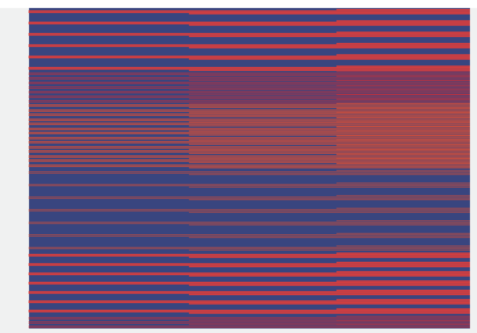
To realise their multi-tasking implant, the researchers are integrating a wire made of nickel and titanium—so-called shape-memory alloys, which are materials that can assume two different states, depending on the temperature. The alloys can be moved back and forth, like an artificial muscle, and they're able to transfer large amounts of energy in a small space.

In a recently published study, the Saarland researchers used simulations to show for the first time how powerful one of the implant's "micro-massages" should be to support healing. The results showed that, depending on the type of fracture and healing phase, the implant's range of motion would have to be restricted to between 0.1 and 0.5 millimetres. "In this micro-movement, very large forces are transferred, up to several hundred kilogrammes," as Tim Pohlemann explains. Indeed, one of the project's major challenges lies in managing this area of tension between micro-movements and macro-forces.

MIRACLE II

Gentle, minimally invasive, robot-guided and highly precise bone surgery—this is the aim of the MIRACLE II project at the University of Basel. The team are developing an endoscopic laser robot capable of making ultra-exact incisions in bones, while miniature sensors and a 3D software program are used to promote patient safety during surgery. In the hospital's inhouse 3D-printing lab, made-to-measure implants will be fabricated to fit into the pre-cut bones. All of which means that bones can heal faster after an intervention.

Funding from the Werner Siemens Foundation 12 million Swiss francs
Project duration 2022 to 2027
Project leaders
Prof. Dr Philippe Cattin, Department of Biomedical Engineering (DBE), University of Basel
Prof. Dr mult. Florian M. Thieringer, DBE, University of Basel and University Hospital Basel
Prof. Dr Georg Rauter, DBE, University of Basel



Smart implants

In future, intelligent implants fitted in a bone will be able to directly monitor how well a lower-leg fracture is healing. In addition to stabilising the broken bone, the implants will provide information on the healing progress and detect incorrect weight-bearing. If a bone isn't healing well, the implant will react and, if necessary, trigger targeted movements to actively stimulate healing at the site of the fracture. The Smart implants project is conducted by a research team at Saarland University Medical Center.

Funding from the Werner Siemens Foundation 8 million euros
Project duration 2019 to 2025
Project leaders
Prof. Dr Tim Pohlemann, Prof. Dr Bergita Ganse, Saarland University Medical Center

The team in the Smart implants project use a demonstrator to show how their clever implant works.

Data in the soles of their shoes

Another difficulty the team face is determining which patients need a micro-massage—and when. For this, the implant must have access to precise data on stress and strain in the fracture gap. These data are gathered through the sensors in the smart implants themselves, but also from insoles fitted with sensors that patients wear in their shoes. “The conventional approach would be to collect relevant data, analyse the information and then send it all back to the implant,” Bergita Ganse says. “But our vision is to create automated, AI-controlled data interpretation—that way, the implant can function autonomously.”

The researchers have already compiled data in profusion in their specialised gait lab, where the insole-sensors record patient data on strain, acceleration and weight-bearing. “We’ve learned a lot about how these parameters change in patients who are healing well—and also how they change when healing is sub-optimal,” Bergita Ganse says. “And we’re now able to use the gait and movement data to assess early on whether or not a fracture will heal well.”

The team have also made progress in another crucial part of the project. “We asked ourselves how we’ll be able to prove that it’s actually the implant that impacts healing,” Ganse says. Their solution is to measure blood flow in the fracture tissue. By doing so, the researchers were able to demonstrate that circulation and oxygen saturation change during a favourable healing process. In future, this knowledge will enable them to measure whether massaging the site of a fracture will—as they believe—improve these parameters.

Immense potential

At present, the smart implant has a long way to go before it’s ready for market entry, as Tim Pohlemann says. Currently, they have a demonstrator, but before they can use it to build a prototype, they must first make several advances. In short, it will take years before a highly complex, auto-regulating implant that’s safe for use in the human body will be approved for medical care. “We have to plan many steps in advance—but also streamline the project wherever possible,” Pohlemann explains.

One potential simplification involves controlling how the implant should move in the body. “At first, we were thinking the implant would need complete freedom to move in all directions,” Tim Pohlemann explains. “But, when dealing with the kinds of forces that are involved in the motions, it’s almost impossible to control mechanically.” To solve the problem, the researchers are exploring variations with a somewhat limited range of movement that are much easier to manufacture. “We probably don’t need to have the device moving in every single direction.”

Tim Pohlemann and Bergita Ganse are convinced that the Saarland smart implant model can do far more than treat bone fractures. “After all,” Pohlemann says, “we virtually look through skin and can influence body processes from the outside. The approach has immense potential.” One possible application would be treating osteoporosis or bone tumours that cause bones to disintegrate over time. In such cases, a minimally invasive implant could increase bone stability while simultaneously serving as a sensor: should the implant detect a decrease in stability, a surgeon can operate to prevent more serious damage.

Regenerating damaged cartilage

The TriggerINK project at DWI – Leibniz Institute for Interactive Materials in Aachen is also focusing on influencing healing processes from outside the body. Researchers in the teams of Laura De Laporte, Stefan Hecht, Andreas Herrmann and Matthias Wessling are developing a novel strategy for regenerating damaged cartilage—in cases of osteoarthritis, for example. Put simply, their vision is to form a supportive hydrogel scaffold made of a gelatinous substance—starting from a bio-ink—into a damaged joint. Once the structure is in place, innovative techniques and materials designed by the researchers will trigger a process of cartilage regeneration along the scaffold.

TriggerINK is emblematic of an important paradigm shift in the field of medicine. “For the past several decades now, there’s been a movement away from conventional surgical interventions towards minimally invasive or even regenerative strategies,” says Laura De Laporte, professor of Macromolecular Materials for Medicine at RWTH Aachen University and member of the DWI scientific board.

Initially, the regenerative approach consisted mainly of cultivating replacement tissue in the lab and then implanting it in the body. “Unfortunately, this procedure often failed because the cultivated tissue integrated poorly into the surrounding body tissue,” De Laporte explains. And when the attempt was made to grow tissue directly inside the body, a serious problem arose: the method utilises proteins and other signals that are instrumental for embryonic development and wound healing—but that also play a role in tumour growth.

“It’s absolutely essential to ensure that these techniques don’t trigger unwanted growth,” De Laporte stresses. That’s why researchers have turned to a new tactic which involves programming materials with functions that can be steered and set in motion. “This is our goal at TriggerINK,” De Laporte says. The researchers work with tools such as magnetic fields, photochemistry, ultrasound and the emerging field of mechanobiology.

Molecular switch with visible light

Photochemistry is the domain of Stefan Hecht, Einstein Professor at Humboldt-Universität zu Berlin and associated researcher at DWI Aachen. His team is developing an innovative method to enable the polymer molecules in the bio-ink to link with each other and form a lattice-like gelatinous hydrogel structure. Specifically, they want to form this hydrogel directly in the wound by irradiating the polymer solution. The light stimulates the molecules in the bio-ink so that they begin to crosslink at certain points. Over time, they form the structured scaffold that supports growth of the cartilage tissue.

The crosslinking already works when the bio-ink is exposed to UV rays. “But our aim is to use visible light that’s gentler on the cells,” Stefan Hecht explains. This is easier said than done, as using a different wavelength calls for intense, complex research. “We’ve designed a whole array of different molecules, but the first of these didn’t deliver the desired results.” Recently, however, his team scored a success and proved that the principle of a molecular photoswitch based on visible light is indeed feasible.

They’ve also already identified optimal parameters for the hydrogel—how stiff it should be, for example—to best enable fast tissue regeneration. The researchers are also taking steps to ensure that the tissue grows in the right direction. This is achieved by means of rod-shaped microparticles in the bio-ink that are aligned via a magnetic field. Initial findings have shown that stem cells inside scaffolds with this kind of orientation differentiate into cartilage cells more effectively.

Targeted release of molecules

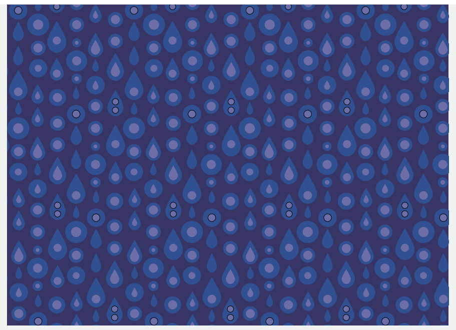
Nevertheless, even if the hydrogel parameters and alignment are perfect, the stem cells still need some assistance to differentiate and regenerate the tissue. To ensure the cells get the help they need, the researchers are integrating biologically active, cell-growth promoting molecules into the bio-ink. Andreas Herrmann’s group is working on ways to release these molecules by means of external ultrasound signals—that are sent at the right time and right place, deep within the regenerated tissue.

Last year, the researchers used an immunostimulatory molecule in living animals to show for the first time that a local release triggered by ultrasound is possible. In their experiment, they injected the compound into the tail vein of mice and waited until the substance spread via the blood vessels through the entire body. The researchers then activated the molecule via ultrasound—targeting only the liver of the animals, and this with pinpoint precision.

Like their WSS colleagues in the Smart implants project, the TriggerINK team also seek ways to promote healing via external stimulation, although their project functions on an even smaller scale. Instead of using an autonomous implant, the Aachen researchers are working with microgels in combination with gold nano particles. The nanoparticles are activated externally with safe infrared light that penetrates into the printed construct. The pulsing light causes the microgels to contract at regular intervals—every second, for example—and then expand again.

“We’ve taken a big step here, too,” Laura De Laporte says. “Initial tests have shown that the microgels we synthesised and set in motion do indeed activate the cells.” With this achievement, the team have met the first requirement: they’ve demonstrated that stimulation can influence the growth and regeneration properties of cartilage tissue.

It’s fair to say that the three micro-medical projects supported by the Werner Siemens Foundation are well underway. And despite their differences, they all pursue a common goal: improving medical care by making it less invasive, less traumatic and more patient-friendly.



TriggerINK

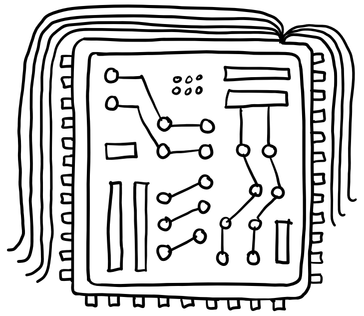
Regrowing damaged cartilage using a scaffold made of bio-ink: this is the aim of researchers in the TriggerINK project at DWI – Leibniz Institute for Interactive Materials in Aachen. First, a 3D printer injects the bio-ink into a wound, where it is infused with light and aligned via a magnetic field. Then, ultrasound is applied to activate or release the agents and growth factors contained in the bio-ink at set times. If their method works, it promises to revolutionise cartilage regeneration therapies.

Funding from the Werner Siemens Foundation 10 million euros
Project duration 2022 to 2026
Project leaders
Prof. Dr-Ing. Laura De Laporte, DWI – Leibniz Institute for Interactive Materials and RWTH Aachen University
Prof. Dr Stefan Hecht, Humboldt-Universität zu Berlin, associated researcher at DWI Aachen
Prof. Dr Andreas Hermann, DWI and RWTH Aachen University
Prof. Dr Matthias Wessling, DWI and RWTH Aachen University

At present, the bio-ink used in the TriggerINK project is still tested on a slide. In the future, it could help stimulate cartilage healing in knee joints.

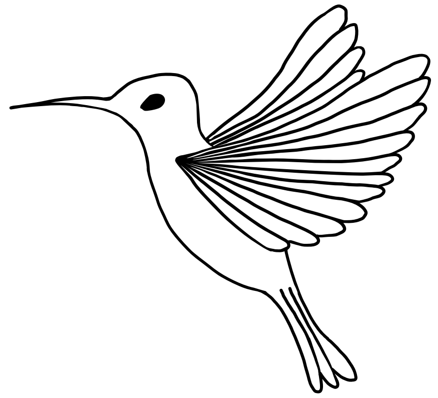
Twelve surprising little things

From microorganisms to microchips: the world of infinitesimally small things can teach us a thing or two about efficiency—while never ceasing to amaze.



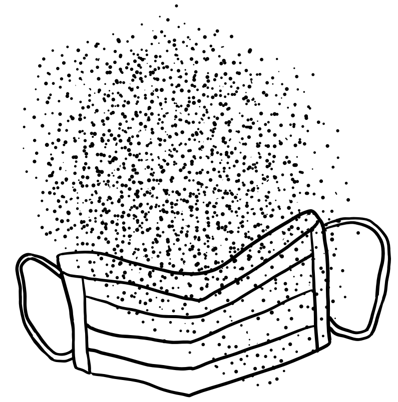
Minuscule microchips

The miniaturisation trend in computer technology continues unabated. The distance between data lanes on modern microchips is now a mere twelve nanometres—five thousand times finer than a human hair. If today's technology were used to reconstruct the very first commercial computer, the original twenty-seven metric ton colossus would be invisible to the naked eye.



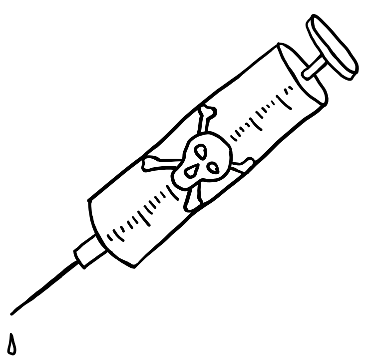
Hungry hummingbirds

The world's smallest bird is the bee hummingbird, a species native to Cuba. Males are just five centimetres long and weigh two grams, while the females are slightly larger. Their little hearts beat eight, their wings eighty times per second. But to survive, these tiny birds need to consume half their body weight in nectar every day.



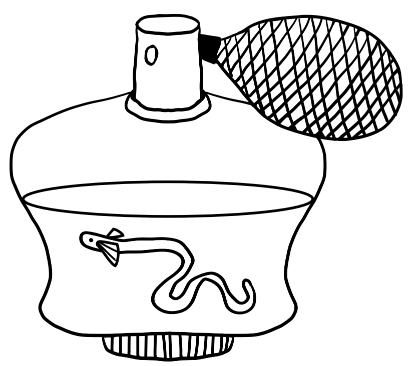
Perfidious particulates

The finest particulates—minute particles that even the best filters can't remove from the air—are the most detrimental to our health. Because they're so tiny, they can penetrate particularly deep into our lungs—and even our brains. Prolonged exposure causes respiratory tract infections and can lead to diminished mental capacities.



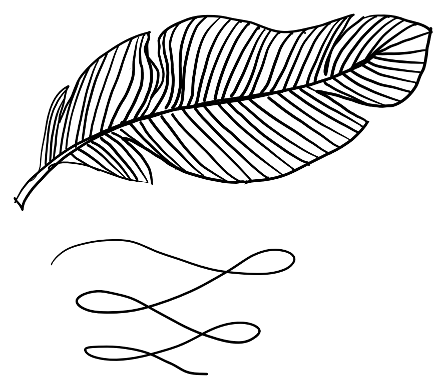
Potent poison

The deadliest of all known substances is botulinum toxin, or "botox". As little as one ten-millionth of a gram is enough to kill a human being. Paradoxically, however, the poison is also used as a medication to treat muscle spasms—and as a cosmetic procedure to remove wrinkles.



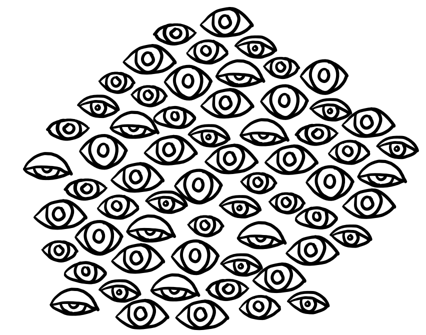
Fine-nosed fish

It's believed the European eel has the best nose in the animal kingdom. It can even smell substances at a concentration of just one thousand seven hundred and seventy molecules per gram of water—that's the same as a drop of perfume in a body of water three times the size of Lake Constance.



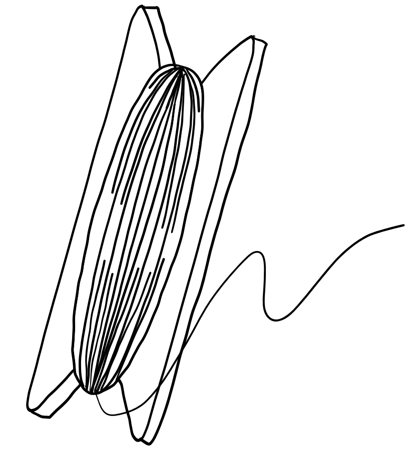
Paltry pull

Although gravity governs our everyday lives, in physical terms it's absurdly weak—electromagnetic force is one sextillion (a number with thirty-six zeros!) times stronger than gravity. That's why a small magnet can hold a note on the fridge although the whole Earth is pulling it downwards.



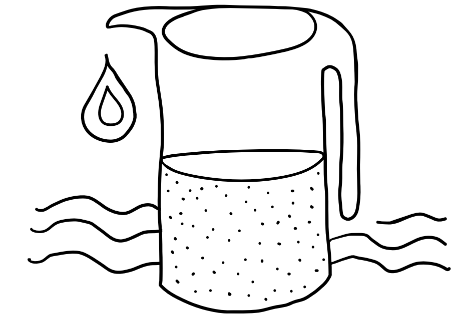
Eye spy

Cyanobacteria have the smallest eyes in the world. Or rather: they are the smallest eyes in the world. Each one of these round, single-celled organisms acts as a tiny eyeball. Light is refracted on the cell's surface and collected on the cell wall opposite. This way, cyanobacteria can sense where light is coming from and move towards it.



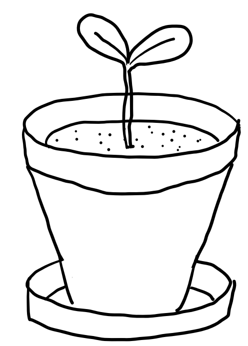
Malleable metal

Gold is the most flexible of all metals. Theoretically, one single gram could be stretched into a super-fine thread measuring twenty-four kilometres. That's a thousand times thinner than a sheet of paper.



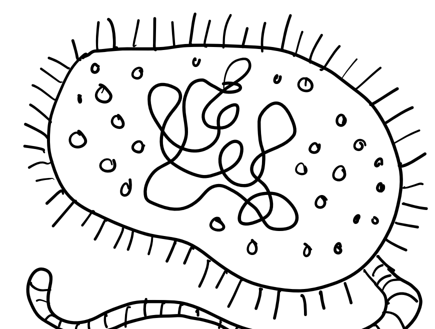
Rhine riddles

Any given sample of the Rhine near Basel contains two to three thousand organic substances, most in very small concentrations. The vast majority are unknown—it's not even clear if they're micropollutants or if they occur naturally.



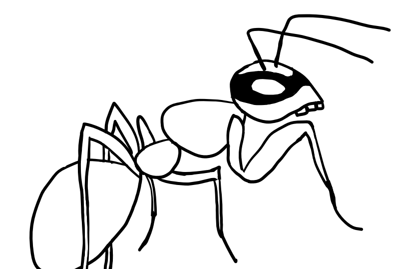
Gargantuan growth

The giant sequoia known as "General Sherman" is believed to be the largest living tree on Earth. It's estimated to weigh almost two thousand metric tons—making it some four hundred billion times heavier than the seed from which it sprang.



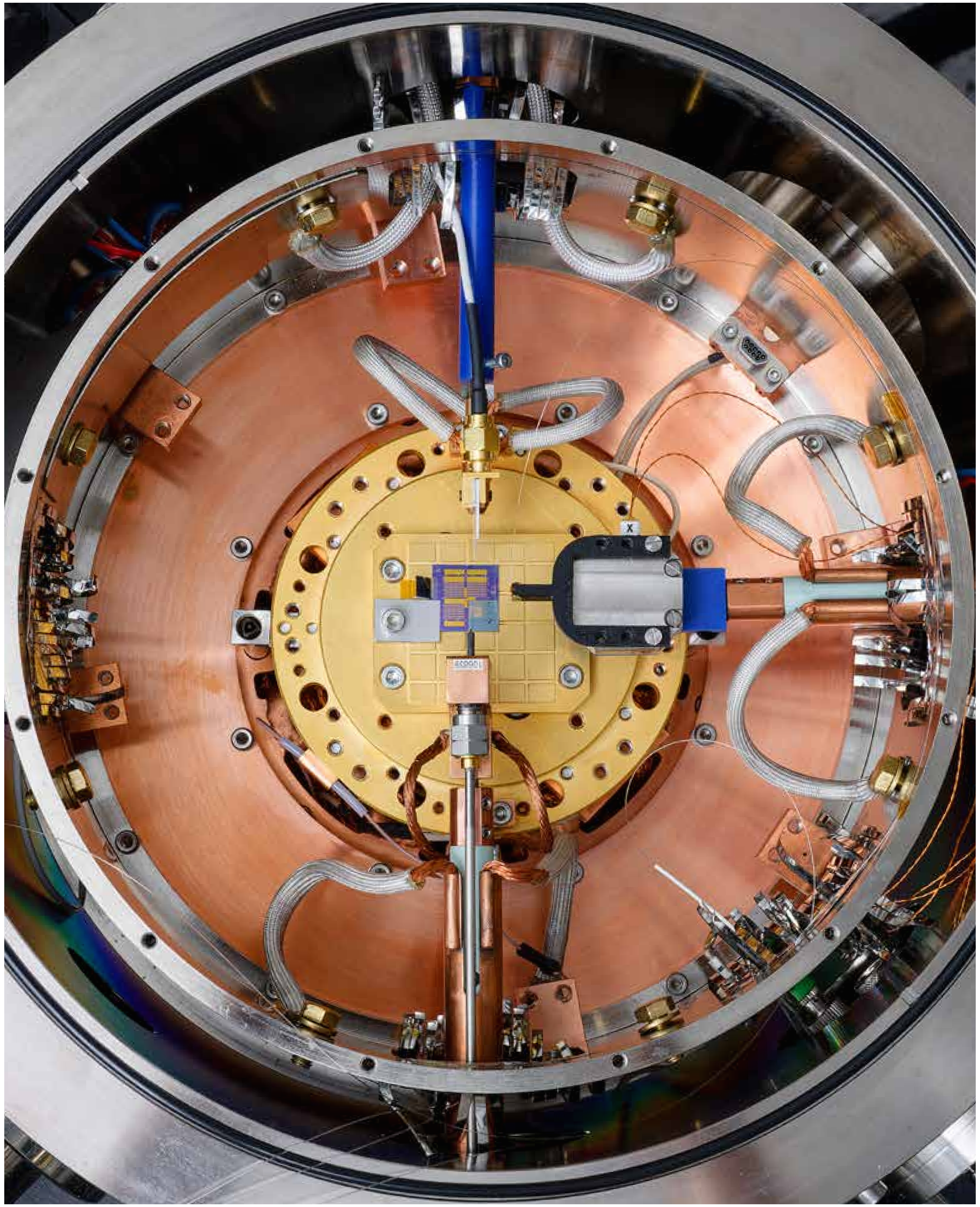
Oodles of organisms

The most common organism in the world is the *Pelagibacter ubique*, a bacteria measuring not quite two hundred nanometres that floats en masse in the ocean waters. However, despite their smallness, there are so many of them that their combined biomass is believed to be a billion metric tons—which is twice as much as the combined weight of all humans.



Biting brigade

Ants, when they join forces, can make the mighty elephant take flight—even though, one-to-one, the mammal is two million times heavier. Ants do it by biting the elephants in their hypersensitive trunks. Elephants are also afraid of bees: they make tracks if they so much as hear a swarm buzzing.



Today's electronic components are ever-smaller—and ever-more powerful.

The electronics of the future

Developments made in electronic devices over the past several decades are nothing short of astonishing. And now, it's said that fundamentally new computing technologies are in sight—an assessment shared by Jürg Leuthold, from the single-atom switch project, as well as Roman Fasel and Oliver Gröning, from the CarboQuant project. A conversation about tiny components, formidable challenges and costly microscopes.

Roman Fasel, Jürg Leuthold and Oliver Gröning (left to right) watching an experiment at Jürg Leuthold's Center for Single Atom Electronics and Photonics at ETH Zurich.

Jürg Leuthold, Roman Fasel and Oliver Gröning, you're all endeavouring to make electronic components even smaller and more powerful. What will our smartphones, laptops and PCs be able to do in twenty or thirty years' time?

Jürg Leuthold: We're on the cusp of a revolution. The CMOS semiconductor technology used in today's laptops dates back roughly seventy years to the very first transistors made. But now we're exploring entirely new approaches. At present, no one knows which of the solutions we're currently investigating will prevail or exactly what the new technology will look like. But we know for certain that it will have superior capabilities.

Oliver Gröning, Roman Fasel, do you agree?

Oliver Gröning: What Jürg Leuthold says is correct. CMOS technology depends on our ability to make things smaller and more compact. Sometimes this is done via new technologies, but its basic functioning has never really changed. Now, however, we're working on new functions, new ways of generating signals in electronic components—ultimately how these components run their calculations.

Roman Fasel: To answer your question more directly: it's precisely because we're on the verge of creating computing technologies that function in a fundamentally new way that I'm not convinced our laptops and smartphones will be significantly faster in twenty or thirty years. In terms of miniaturisation and performance, these new developments must first achieve what CMOS can do today. That will take time. But one way or another, the new technologies will be much more energy efficient.

What do the new approaches look like?

Leuthold: Some are in the field of quantum computing, others explore two-dimensional, novel materials. Still others—and this is what my research group and I are focusing on—deal with so-called memristive neuromorphic systems. The idea here is to imitate natural neural networks. In the past, we in electronics pushed electrons around, as it were. But in the human brain, it's ions—electrically charged atoms or molecules—that are being pushed around. And that's the basic concept behind our single-atom switch project: one single atom should suffice to completely change a switching state.

How does that work?

Leuthold: So, I take two metals, and I bring them together in such close proximity that only one atom fits between them. If I can render this construct conductive, I can skip five or six orders of magnitude of electrical resistance to turn a switch on and off. All I need to do is move a single atom, and have an on-off switch. That's similar to the principle at work in our brains.

Turning to the CarboQuant project: Roman Fasel, Oliver Gröning, you're working with quantum effects. How does that work?

Gröning: We're trying to create molecular structures that will allow us to take advantage of quantum effects—with the aim of implementing new optical, electronic or magnetic functions. As Jürg Leuthold was saying, these are non-linear processes. Electric resistance, by contrast, is linear: if the voltage is doubled, you get twice as much electric current. But we're not interested in that. The single-atom switch is designed to require just a tiny input to move an atom and nonetheless attain a huge effect: with a minute energy input the current increases by six orders of magnitude. Put differently, that's a scale of one to a million. Our project has a related approach in that we define extremely precise electronic energy levels through which an electric current can flow. If we bring these levels into alignment, something happens that's similar to the single-atom switch, although we don't move any atoms. Rather, we create a major change in the electric current by making a minor change to the voltage.

What other effects are you studying?

Gröning: Our goal is to use a single electron charge, or a charge quantum, to make a transistor switch. We can also capitalise on magnetic moments: instead of generating an information signal with a current of one hundred million electrons, we reverse a single magnetic moment. We're working on an entirely different energy scale because we use individual quanta—the spin in the case of a magnetic moment, or a photon in that of a quantum of light. It's also pushing against the boundaries of what can still be described as information in physical terms. We design materials with these kinds of properties, and we're working on integrating them into device components.

Building such tiny structures can't be easy.

Gröning: We wouldn't mind working with larger objects, but it's a simple fact that the quantum effects we use are manifested only at the atomic or molecular scale. Our materials typically measure one nanometre. It would certainly make our lives easier if they were ten nanometres.

Jürg Leuthold, in your project, you're also pushing against the boundaries of the possible in terms of size. How is this work advancing?

Leuthold: We're getting better and better. We've now managed to transfer processes that occur in the brain to semiconductor technology. And in the meantime, we've also been able to group several components together and build the first functional blocks—the first switches that imitate the functions we see in the brain. We've even constructed a small network based on our switches. It's still small, but we can already see that it will outperform conventional technologies.

How exactly does it work?

Leuthold: It's a transmission network of a transmitter consisting of a laser and a modulator, and a receiver. There are billions of these in each and every data network. The signal transmitted is distorted when it arrives, and our job is to make the information readable. For fifty years, electronic communications theory has said we need to attach a processor that comprises various possible computing techniques—a processor that would require roughly ten thousand computing steps to rectify the signal in our small network. Now, let's compare that system to our neural network—and transfer it to an optical neural network that requires absolutely no computing steps. The latter option beats them all.

What does that mean?

Leuthold: It means that our latest development requires around two orders of magnitude less computing power to render the signal readable. That said, there is one caveat: the result is based on components we've actually built and characterised, but the network itself is simulated on the basis of data. Our next step is to

Revolutionary single-atom switch

From espresso machines to huge mainframe computers, microchips are found in almost every electronic device we use. In recent years, researchers have succeeded in making microchips smaller and faster, but the push to get even more minuscule has now hit a wall, and the amount of energy the chips consume has become problematic. That's why researchers at the Center for Single Atom Electronics and Photonics at ETH Zurich and at the Karlsruhe Institute of Technology (KIT) are seeking to create a completely novel microchip—one that functions at the atomic level.

Funding from the Werner Siemens Foundation 12 million Swiss francs
Project duration 2017 to 2025
Project leader
Prof. Dr Jürg Leuthold, head of the Institute of Electromagnetic Fields, ETH Zurich

optimise the system and place it onto a chip. But the most important message is that the potential is huge. And I'm convinced that, in the next five to ten years, every electronic component currently used in electronic devices will have to be replaced. Because you can't justify calculating ten thousand times more information.

"We're working with such minuscule structures that we haven't yet mastered the technology to the degree we'd like."

Will the new components be ready so soon?

Leuthold: Some of them will see practical application much sooner than many might think. I take a positive view of the future, despite all the talk you hear in the world. For example, it's often said that neural networks and machine learning will cause energy consumption to spiral out of control. Of course we now have more ways to apply these technologies, which does indeed increase energy consumption. But if I look just at our results, boosting energy efficiency by a factor of one thousand is very feasible. If we continue on this route, the future isn't as bleak as some see it. Quite the contrary—there's a lot of hope.

Are people really that pessimistic?

Gröning: Well, we're consuming more digital services, and that uses considerably more energy. But the developments—also regarding neural networks—have huge potential. However, I don't think it's so much that people are pessimistic and underestimating the potential as much as I think they're very aware of the problems that go along with these new technologies.

Leuthold: When talking about energy in general, there's certainly a tendency towards pessimism. But if we get things right, energy consumption doesn't necessarily need to increase.

Fasel: Perhaps it depends on how you look at it. Right now, we're using computers to simulate neural networks. But let's assume that, in ten years' time, I can buy a chip with an atomic switch from you, Jürg, that itself is a neural network. Then we'd no longer need the massive computing power for the simulation. There's potential for an incredible amount of energy savings right there. Nevertheless, we're not there yet. In future, we most likely won't have an energy problem but, at present, we do. As an example: not too long ago I read about a company that wants to build small nuclear power reactors to supply energy for the computer centres it uses to train AI models.

Roman Fasel says research into more energy-efficient technologies is needed to compensate for the higher energy consumption in data centres.

Oliver Gröning relates how researchers in the CarboQuant project succeeded in producing entire spin chains in which individual spins can be turned on and off with precision.

Leuthold: It will probably even out. There will be clear progress in hardware, but the advances will be neutralised by the rise in consumption.

These rebound effects are part of being human.

Fasel: That's why we do research! And that's why we need energy-efficient technology. But it's not yet market ready.

Roman Fasel and Oliver Gröning, your CarboQuant project is not as close to market entry as the single-atom switch and neural networks. What progress have you recently made?

Gröning: We're now able to design and fabricate so-called spin chains, and to turn the individual magnetic moments—the spins—on and off with precision. It's a huge step forwards. For example, we create a chain with four spins and turn all of them on. Then we turn one of the spins off and observe how the system reacts.

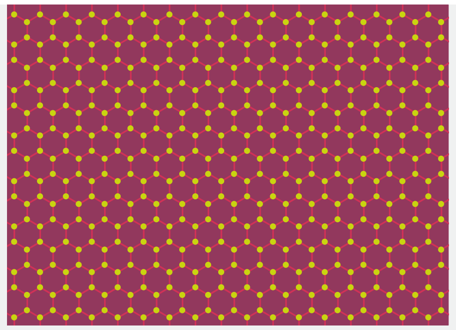
Fasel: Quantum physicists work with various kinds of one-dimensional spin models, each of which has slightly different properties. Over the past two years, we've succeeded in realising and characterising in detail the three most fundamental models with carbon atoms—now with up to fifty spins. It's so complex that it can no longer be calculated using conventional methods. And that's just the beginning.

"We're dealing with single atoms. When one singer in a trio is off-key, you're going to hear it."

Gröning: We can think of these models as equations. Normally, researchers look for materials that would depict these equations by chance, in nature for example. But in our work, we're looking at the equation itself, its elements and the connections between spins. Then we go to the drawing board to design a structure with these exact connections. We fabricate them and take measurements to control whether our theoretical prediction is valid. It's my dream to use these kinds of quantum simulations to move from a one-dimensional chain to a two-dimensional network. One that has various interconnected layers. That would be an astounding leap.

How do you study the magnetic moments?

Gröning: We use scanning tunnelling microscopy, but our options with the instruments we currently have are very limited. That's why we're building a new lab for diving even deeper into quantum magnetism and further developing the field. In this lab, we're setting up two new scanning tunnelling microscopes that work with radio



CarboQuant

The CarboQuant team at the Swiss Federal Laboratories for Materials Science and Technology (Empa) in Dübendorf, Switzerland, is aiming to develop extremely small quantum electronic components that will ideally function at room temperature, making them suitable for use in everyday devices.

Funding from the Werner Siemens Foundation 15 million Swiss francs
Project duration 2022 to 2032
Project leaders
Prof. Dr Roman Fasel, head of nanotech@surfaces Laboratory, Empa, Dübendorf
Dr Oliver Gröning, deputy head of nanotech@surfaces Laboratory, Empa, Dübendorf

frequency and a strong magnetic field, enabling us to analyse and measure magnetic properties in time resolution on the atomic scale.

Fasel: We needed completely new labs for these instruments. It involved a huge investment. In terms of resources, it's probably the biggest development we're working on at the moment.

Were the microscopes custom-made according to your specifications?

Gröning: Yes. Complex and expensive equipment like this can't be ordered from a catalogue. The basic system is there, but we had to adapt it to our own specific needs—we want to synthesise our materials in a vacuum, for example. From the design phase to final delivery, each of the microscopes took more than two years to construct.

Fasel: And the most important point is that we need people capable of operating this kind of equipment. There aren't too many of these specialists—maybe just a few research groups worldwide have the necessary experience. We're fortunate in that we found a first-rate researcher: Yujeong Bae from South Korea.

What else do you need to make these quantum effects applicable?

Gröning: We have to place our elements on a chip and connect them with electrical contacts. But we encounter an uncertainty factor in this transfer—we don't know exactly where our spin chains come to rest. That's why we also can't say whether a specific property stems from our system, from the specific type of contact or from the interaction with the component. We have to find a solution here.

Fasel: We're developing a materials platform that we hope will eventually be available for quantum applications. There's much work to be done here, as each material has to be integrated, linked and addressed. On top of that, there's all the hierarchical systems. As big as the WSS project is, and as much as we're doing, it's important to put it in the proper perspective.

Jürg Leuthold, your project is at a more advanced stage.

Leuthold: We have individual components that function. Now, our job is to bring them all together. However, we're working with such minuscule structures that we haven't yet mastered the technology to the degree we'd like. Conventional electron-beam lithography can fabricate structures of down to around ten nanometres. Now, we're endeavouring to boost precision by using atomic force lithography. Our biggest challenge is the precision placement of individual atoms.

Is the challenge similar to placing spin chains?

Gröning: That's right. It's a fundamental problem in our work. Miniaturisation is approaching the atomic scale, and a silicon semiconductor measuring five to ten nanometres contains tens of thousands of atoms. But in both our projects, we're dealing with single atoms. A choir is a good analogy: if two of ten thousand singers hit the wrong note, it's no big deal. But when one singer in a trio is off-key, you're going to hear it.

Can your two groups learn from each other?

Leuthold: We're already benefiting from the synergies. Some of my team work at Empa because they have the equipment they need there. And our approaches complement each other. As I said earlier, it's unclear which technology will win the race. And maybe we'll need all of them: plasmonic particles, memristors and quantum components. I'm convinced that the computers of the future will take the best from every new technology.

Gröning: The areas that overlap in our project are concrete. Professor Mathieu Luisier, who researches in the single-atom switch project, is an absolute expert in the theoretical calculation of electron currents in such small systems. This aspect is important in our project, too, and we're also working with him. Our projects are more closely related than may seem apparent at first sight.

Jürg Leuthold is convinced that new technologies will increase energy efficiency in electronic components by a factor of one thousand.

Is the physical proximity an advantage for this collaboration?

Fasel: Certainly. We use some of the same infrastructure. Jürg Leuthold needs a clean room, we need a clean room. Not every lab houses equipment for structuring or etching materials. That's why Zurich is a good research location.

Leuthold: My vision is to create a new clean room for electronics and nanotechnology on the site of the former Dübendorf airfield. The more we move into the atomic scale, the more expensive the machines. If we—ETH Zurich, the University of Zurich, PSI, Empa and private companies—work together, the Zurich region will become a real powerhouse in the field.

Can you say what new applications will be possible if you succeed in miniaturising electronic components to the nth degree?

Gröning: It's really difficult to predict what new needs will arise. However, disruptive concepts like quantum computing can be used to calculate things like complex biological systems. It would make quantum chemistry or highly interconnected climate simulations possible.

Leuthold: I've already seen the potential in some smaller outcomes. For example at Sleepiz, one of our institute's start-ups, where a device was developed that uses electromagnetic waves to monitor the body during sleep—tracking information like how the chest moves and the heart beats. By processing the data gathered, it can send a warning signal two weeks before a heart attack is likely to happen. The device was created using findings from our research into optical communication systems.

That's something you wouldn't expect.

Leuthold: True. And you don't even need a giant supercomputer for it. Our developments are simple, but spectacular.

Gröning: That's a very good point. New technologies often run in the background, and we use them without really noticing them. Every day, I commute from Solothurn to Zurich with two thousand other people, maybe five hundred of whom are watching a film in real time on their smartphones. Every now and then, it would be good to stop and think about the technical developments of the past ten years that have enabled this kind of data transmission.

In a new full-body scanner, combined PET/CT images can be made of large sections of the body in a single session.

The see-through body

Medical imaging techniques are used in almost every area of medicine. And researchers are continually discovering new ways of rendering the most minuscule structures in our bodies visible—as seen in a recent visit to the Werner Siemens Imaging Center in Tübingen

The researchers need powerful computers to interpret the abundance of data produced by the full-body scanner.

A more fitting address for the Werner Siemens Imaging Center (WSIC) would be hard to imagine: Röntgenweg, a street the city of Tübingen named in 1956 in honour of Wilhelm Conrad Röntgen, the discoverer of X-rays. Röntgen is widely regarded as the founder of medical imaging, and it was his groundbreaking work in 1895 that first enabled doctors to look inside the human body without needing to cut it open.

In the meantime, numerous other non-invasive imaging techniques have been developed—also at WSIC, which opened its doors here in 2014. Today, under the leadership of Professor Bernd Pichler, fifteen research groups with a total of some one hundred and forty employees are currently working on—and further developing—many of these modern medical imaging methods. "Our innovative work is only possible thanks to the long-term funding provided by the Werner Siemens Foundation," Bernd Pichler says. "Without WSS, our centre would have remained a small lab with five researchers."

The Foundation's support, which has recently been extended for another ten-year funding period, is instrumental in enabling the WSIC team to create the conditions for their cutting-edge research. And only institutions that generate first-rate findings have a chance of securing additional funding—and of growing. In this regard, WSIC researchers have achieved outstanding success: over the past twenty years, the group has raised more than one hundred million euros in funding. Indeed, in terms of financing, WSIC is looking at a pivotal year in 2025, when its renewal application for the German Research Foundation's iFIT Cluster of Excellence is due. iFIT stands for "Image-guided and Functionally Instructed Tumor Therapies", and WSIC is a leader in the cluster that will hopefully be funded with approximately eighty million euros over another seven-year period. "It's also the only cluster of excellence for oncology in the whole of Germany," Pichler says. "And most crucially, iFIT is of great strategic importance for us."

Sleeper cells

Oncology is one of the research priorities at WSIC. Modern medical imaging devices are used in oncology to render tumours visible in a variety of ways. One of the most important areas here—which Bernd Pichler and his group have significantly shaped in recent decades—is the development of so-called tracers: substances with very low levels of radioactivity that are introduced into the body and take part in metabolic processes or bind to structures on the cell surface. Due to their radio-active labelling, the tracers—which are safe—can be detected using nuclear medicine techniques, including positron emission tomography (PET).

PET scans enable the researchers to differentiate between tissue phenotypes or metabolic processes in organs and cell phases. Regarding the latter, many tumour cells exist in what is known as a senescent state: although they no longer divide, these cells are still alive and can trigger the growth of other tumour cells. Pichler says, cancer therapies for treating solid tumours have been known to cause cells to enter a senescent state: "This is a double-edged sword—on the one hand they don't proliferate anymore but cause non-senescent cells to trigger tumour growth even more. That's why detecting these cells and finding the right moment to administer drugs that destroy them is critical."

Pichler and his team have developed promising tracers to identify these senescent tumour cells: a phase I clinical trial has already been completed and the tracer selected for the study has proven to be safe for use in patients. A phase II trial is now underway and, as Pichler says, "it looks very good". The researchers have submitted a related article to a top-tier scientific journal. But they aren't stopping there—Pichler says his team have already developed senescence tracers that are three to five times more accurate than the version currently being tested in the trials.

Chemistry and pharmacy

Also working on the development of PET tracers is Professor Anna Junker, the most recent addition to the Tübingen team and group leader at WSIC. Junker began her work as professor of radiochemistry and the development of medical imaging probes at the University of Tübingen at the start of 2024. WSIC director Bernd Pichler is pleased with the added value she brings to the team: "She contributes exciting new approaches, fresh ideas and new input."

No wonder, considering her extensive knowledge and experience in two core areas of tracer-based medical imaging: chemistry and pharmacy. The ping-pong game between the two subjects began before she'd even had a chance to start her studies. Although she ended up studying pharmacy in Münster—as was her original plan—this happened only in her second attempt, as she relates with a laugh. Due to an administrative error when she applied to the pharmacy programme in Münster, she was admitted to the university in Halle. "But I didn't want to go to Halle," she says. And so she decided to enrol in chemistry at Münster, as there were still places available.

Her intention was to switch to the pharmacy degree programme after the first semester, which she did, albeit with certain misgivings: "I had enjoyed chemistry so much that it was a little hard to change programmes." Yet, despite her reservations, she's never regretted the decision, especially as her third semester would bring about yet another crucial change of course. She says she remembers the day very well: "I was sitting in Professor Bernhard Wünsch's chemistry lecture and was totally

Anna Junker, recently appointed professor of radiochemistry and the development of medical imaging probes at the University of Tübingen, is the latest addition to the WSIC team.

New ideas, new endeavours: WSIC director Bernd Pichler (left) in discussion with two team members.

engrossed in what he was saying. I told the person sitting next to me that I wanted to do what he does."

Bernhard Wünsch develops ligands—chemical compounds that can activate or block receptors in cell membranes. Anna Junker wrote her PhD thesis under the supervision of Wünsch—with a detour to Japan—and developed her first radiofluorinated tracer molecules. "I had a real 'aha' moment when my PET tracer was tested in a mouse," she says. "It was the first time I had ever seen one of my molecules in a living organism."

Acquiring and consolidating knowledge

Although Anna Junker was fascinated by organic chemistry, she knew that medical-pharmaceutical applications were an even greater passion. Nevertheless, it took still a few more years before she found her precise calling. After earning her PhD, she held a position as a postdoc in Professor Christa Müller's group at the University of Bonn, where her research involved working closely with a pharmaceutical company. After this role, she received a one-year research grant to go to the US and work for Professor Kenneth Jacobson at the National Institutes of Health (NIH) in Bethesda, Maryland. Jacobson is a pioneer in research on adenosine receptors—the protein-coupled receptors present in a wide range of diseases. "But this was medical chemistry, not imaging," Junker says.

Her next station saw her return to Münster, where she participated in a postdoc programme and had the opportunity to conduct independent research on the receptors involved in prostate cancer. At that time, she also applied for—and received—funding from the German Research Foundation's Emmy Noether Programme. Junker was awarded a six-year grant of 1.3 million euros. She says the funding was a game-changer for her career: "It's what enabled me to set up my own research group, and—for the first time—I could relax a little and focus on long-term research questions."

An exciting discovery

Her appointment as professor in Tübingen bears witness to the success she achieved in her group, with a particularly striking example being her most promising discovery to date: a PET tracer for the enzyme CD73. Junker developed the tracer while in Münster, and the University of Tübingen has taken over the patent. CD73 naturally converts adenosine monophosphate (AMP) stemming from adenosine triphosphate (ATP) into adenosine. As the universal energy carrier in cells, ATP is one of the most important molecules in living organisms.

"But ATP also enters extracellular spaces, where it functions as a signalling molecule to alert the immune system to danger or to indicate that inflammation is present," Anna Junker explains. Adenosine, by contrast, sends the exact opposite message: if this compound is present, the body knows all is well and that it doesn't have to activate immune cells. The problem is that, in the extracellular spaces, ATP breaks down very quickly into AMP, which is converted to adenosine by CD73, a reaction that many cancer cells take advantage of. "All solid tumours produce increased amounts of CD73," Junker says. "This means they literally wrap themselves in an adenosine cloud that holds the body's immune system at bay."

Her idea is to use a radiolabelled CD73 ligand to render cancer cells visible—or to fight them if the ligand can prevent AMP from breaking down into adenosine. The researchers have already delivered evidence of the first point for pancreatic and breast cancer. "Our tracer enables us to depict these tumours in animal models much more precisely than with the tracer that was previously the gold standard," Junker explains.

Although it will take some time before the new development finds clinical application, Anna Junker is optimistic: "The infrastructure here in Tübingen is ideal for translating basic research to patient care. There are very few places in Germany that have these capacities."

Managing data overload

Just a brief tour of the centre and its labs provides ample evidence of the depth, breadth and excellence of the interdisciplinary research conducted at WSIC. There are chemistry and microbiology labs, analytical devices for reaction controls and labs for designing tracers.

The premium—and most sensitive—devices are located behind closed doors: large, costly microscopes and, of course, the PET scanners in the imaging labs used to observe the tracers in tissues or lab animals. In all the facilities, it's critical to avoid even the most minuscule impurities, and researchers must first undergo a complex cleansing procedure before they're permitted to enter.

One rather nondescript little room houses a key component in the research conducted at WSIC: powerful computer stations used for analysing data gathered in the experiments. Despite their many differences, all imaging techniques generate massive amounts of data, and researchers must rely on specialised software programs, memory cards and large computers in order to come to terms with the abundance of information. "Dealing with all the data is one of our biggest challenges," Bernd Pichler says. "Because the key issue in future is that we'll no longer be simply working with multi-modal systems—we'll be working on multiple scales."

In practice, this means not just combining techniques like PET, MRI and CT, but merging microscopic and macroscopic studies: for example, scanning the entire body for metastases—at a high-spatial resolution.

WSS competition for doctoral students

Conducting independent research is no easy task, especially at the outset of a research career. To help PhD students get off to a good start in their projects, the Werner Siemens Imaging Center (WSIC) organised a competition with funding from the Werner Siemens Foundation. During a week-long retreat, doctoral students had the opportunity to work in small groups to develop and present their ideas, including a financial plan. The winning team—Daniel Bleher, Eden Laing and Laura Kübler—received a grant of fifty thousand euros to pursue their proposal. "It's fantastic to have the chance to plan a project from scratch," Daniel Bleher says with evident satisfaction.

The trio convinced the jury with their clever idea of developing a tracer that indicates *Porphyromonas gingivalis* infections. *P. gingivalis* is a key bacterium in cases of gum inflammation and chronic periodontitis. "In Germany, thirty to forty percent of all people will experience this kind of infection at least once in their lives," Daniel Bleher explains. The bacteria's impact, however, goes far beyond our mouths and oral health. Studies have linked *P. gingivalis* to chronic inflammation in the body as well as to neurological conditions and to poor prognoses for cancer patients.

"Our group is a dream team," says Bleher, who is a PhD student in Professor Kristina Herfert's group, where he develops tracers that detect structures in the brains of patients with Parkinson's or related diseases. Eden Laing, who belongs to the group of Privatdocent Nicolas Bézière, is working on her dissertation in the area of infection imaging. And Laura Kübler, who is now a postdoc in Professor André Martins's group, contributes her experience in tumour imaging.

The three are working on their joint project alongside their day-to-day research. "It demands an extra effort from all of us," Daniel Bleher says. "But when given a chance like this, there's no question that we'll be putting in the work." The junior researchers have already met with success: they've synthesised several compounds that have potential in radioactive labelling. "We're also cultivating the inflammatory bacteria for the study, which is actually quite difficult because they only grow in an oxygen-free environment." Their aim is to test the radiolabelled compounds in the bacteria and then later in diseased tissue. "If all goes well," Daniel Bleher says, "the findings may result in an initial publication and the possibility to continue pursuing the idea in a larger project."

He believes the WSIC competition for PhD students is unique, adding that it was certainly the first one he had ever heard of, and that PhD students responded to the event with huge interest. "It would be fantastic if something similar could be held again."

The equipment at WSIC is extremely sensitive – it's critical to exclude even the smallest possibility of contamination in the experiments.

In addition to the sheer volume of data generated, the information is incredibly complex and comes in a wide spectrum of formats.

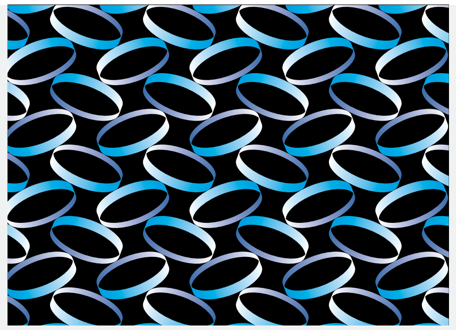
Tracers with faster tissue distribution

Pichler is convinced that this ability to establish connections across various body organs will play an ever-greater role in examinations and diagnoses. "We've repeatedly seen that immunotherapies are effective only in some patients," Pichler says. "By studying key organs and tissues of the immune system—the spleen or bone marrow, for example—we can help uncover the links."

On top of this, the team will also continue their efforts to drive innovation in individual medical imaging techniques. For instance, the Tübingen researchers are currently working on nanobodies—PET tracers created on the basis of antibody fragments so tiny that they can distribute better and faster throughout the body, where they can be used for medical imaging.

"We've been studying these nanobodies for around five years—as one of just a few research groups in the world," Bernd Pichler says. And that with very satisfying results. Recently, WSIC saw the foundation of its first spin-off company, immunAdvice, where researchers are using nanobody tracers to visualise immune cells in the body with the aim of assessing an immunotherapy's success.

This example demonstrates two points. First, the imaging experts in Tübingen are in no danger of running out of ideas. Second, their research is consistently geared towards bringing tangible benefits to patients as swiftly as possible.



Werner Siemens Imaging Center

The Werner Siemens Imaging Center in Tübingen plays in the world's premier league of research on medical imaging techniques, and the Center's work on personalised tumour therapies forms part of Germany's national Excellence Strategy. The new, combined medical imaging techniques developed at WSIC make it possible to study tissues and molecules in greater detail. The innovative technologies are also instrumental in identifying which patients will benefit most from which therapies.

Funding from the Werner Siemens Foundation
18.4 million euros (2024–2033)
15.6 million euros (2016–2023)
12.3 million euros (2007–2016)
Project duration 2007 to 2033
Project leader Prof. Dr Bernd Pichler, Werner Siemens Foundation Endowed Chair and Director of the Werner Siemens Imaging Center at the University of Tübingen

“Foundations can take greater risks”

In the realm of space exploration, researchers develop highly sophisticated methods and instruments to answer humankind’s biggest questions. In the following interview, Thomas Zurbuchen, ETH Zurich professor and former Head of Science at NASA, discusses the existence of extraterrestrial life, what to do when missions go wrong, intelligent ways of fostering innovation and the art of miniaturisation.

Thomas Zurbuchen, the phrase “aim high” features prominently on your personal website. Are there any such high aims, or rather any unsolved research questions that you would love to answer?
My whole life, I’ve wondered whether there’s intelligent life elsewhere in the universe. It’s one of those very basic questions that people have asked throughout history. And over the course of my research career, the context for this question has changed quite fundamentally.

How so?
We’ve made enormous advances. When I was an astrophysics student, we hadn’t yet observed planets outside

our solar system, but now, in the meantime, more than seven thousand exoplanets have been discovered. We also know that each star is orbited by at least one planet and that water could potentially be found on some twenty percent of these exoplanets. Also: we used to believe that complex molecules arise late in the evolution of a planet, but today we know that the most primitive building blocks of a solar system already contain molecules like amino acids—the building blocks of the proteins needed for life to emerge. And so on.

How does one go about looking for extraterrestrial life?
The Drake equation formulated by US researcher Frank Drake summarises the necessary conditions for a planet to host intelligent life. We already have answers to the first three parts of the equation, which I mentioned before: how many planets there are, how many of them could contain water and how many could host complex molecules. As yet, we don't have an answer to the next question: the number of planets with a physico-chemical environment theoretically able to support life that will actually develop life. The question concerning intelligent life, then, comes later—and whether we can receive signals sent from an intelligent civilisation.

How can we detect molecules or signals from worlds that are unfathomably distant?
No matter where we look, the universe is made up of the same components. That's why one approach is to look for CO_2 or ozone molecules that accumulate in our atmosphere only because there's life on our planet. Or we can use telescopes to detect signs of intelligent communications. Here the question is: if I look at Earth from a star, how would I know intelligent beings live there? One answer is that I'd see radar or light signals that don't occur naturally. And that's what we look for with other planets.

You look for what can't be explained?
For things that have no natural explanation. It's an incredibly difficult line of evidence. The other approach is to say that if life is common, it's possible that there's life on Mars. So we go there and dig. They're both very different methods, but both are instrumental in seeking life.

What do you think? Is there life beyond our own planet?
That's my assumption, but we've yet to prove it and uncertainties abound. Most researchers think there are many other civilisations—common estimates are that a galaxy like ours with four hundred billion stars could host maybe ten thousand intelligent civilisations. But then, it's possible there's only one, which, if true, would mean intelligent life is much rarer than we think.

"Every NASA mission is difficult, impossible really."

Even in the absence of an answer to this big question, you've achieved extraordinary goals in your career. From 2016 to 2022 you were Associate Administrator for the Science Mission Directorate at NASA—arguably the biggest job in space exploration. How did you first discover astrophysics and then make your way to NASA?
I was interested in the skies already as a child. I grew up in alpine Bernese Oberland where the nights were dark. That really shaped me. The night sky in the mountains is very different to skies where there's artificial light: you can see the Milky Way—our galaxy—and the colours of stars and planets. You can see the difference between stars and nebulae. Later, I began studying physics at the University of Bern and then switched to astrophysics. I had the opportunity to work in a satellite project and even built part of a satellite.

That was used in a NASA mission.
Yes. I not only did the analyses for the instrument: I built it. I had help from an outstanding technician in Bern who trained me and made sure I did everything correctly. And the instrument was still part of the inventory of the missions I was in charge of when I joined NASA.

After graduating, you went to the US, where you were appointed professor at the University of Michigan. How did you move to the leadership role at NASA?
I made my name in the US through the successful satellite experiments I conducted there, and also because I built up innovation systems. For example, at Michigan, I initiated one of the most important start-up systems in the US. Then, several people from NASA management called me to say the position in the Science Mission Directorate was open and that I should consider applying. Which I did.

So it was the combination of research excellence and entrepreneurial thinking that convinced NASA?
Exactly. The second quality is also very relevant. The people at NASA said they needed someone who understands both—and they had the feeling there weren't too many viable candidates in the world of science.

You led one hundred and thirty missions at NASA. Which were the most interesting?
I launched thirty-seven new missions into space, one of which was the James Webb Space Telescope, the most complex and expensive mission ever. It caused enormous problems—it was one of those missions that started out difficult and that came close to being discontinued several times. Others had already saved it before, I saved it a third time. And then the telescope went into outer space. Ever since, it's been writing science history week for week: whether it's identifying new exoplanets or gaining new insights into stars or black holes.

What made the mission so difficult?
Every NASA mission is incredibly difficult, impossible really, and they all have their challenges. In essence, two things need to work: the technology and people as a team. We generally get the technology up and running, but the human component is more challenging—eighty percent of the problems stem from people. It's about leadership, culture, people's willingness to give their all to achieve a goal. That was the problem with the James Webb Space Telescope: team members were unmotivated and made unbelievable mistakes. Once, a thousand screws fell out during a test.

In other words, a key part of your work was motivating staff.
Absolutely. Missions will only ever succeed when everyone understands what they have to do, why they're doing it, and under what constraints and conditions. And when everyone says they're part of a team.

You mentioned that technical problems can generally be solved. Space research is renowned for bringing about technical wonders—for example, for miniaturising highly complex instruments and systems so that they can actually fit on a spaceship. How does this happen?
In space research, the goal is to find an easy way to do complex things. A lab like the one here at ETH Zurich would have to be transformed into an instrument that a single person could carry. That means you have to reinvent the whole thing. Miniaturisation doesn't mean that each component is made smaller—an entirely new approach is needed.

Do you have an example from your time at NASA?
At NASA, my first step was to start initiatives building small satellites in every research area. A satellite that was the size of a bus had to be made to fit on a table, or even be as small as a loaf of bread. There are two advantages. First, small satellites are much less expensive. And second, you can use a hundred small satellites to view the Earth in high resolution round the clock—as soon as one satellite disappears behind the horizon, the next is coming. A single geostationary satellite can't do that.

Did this also call for a new technical approach?
It did. A lot of scientists underestimate miniaturisation's role in innovation, but making things smaller usually means they have to be simpler. You can't conceal as many sins, as it were. For example, if a large satellite's thermal system isn't working at one-hundred-percent efficiency, a common solution is to simply add on a heater that weighs five kilos. You can't do that with a small system, everything has to be just so from the very start. And we often need smaller systems when the aim is mass production, something innovators understand. These constraints mean we have to start rethinking everything, which makes room for completely new ideas to emerge.

"In the field of innovation, it's vital that we try crazy things."

Ideas and innovations are also at the heart of your work at ETH Zurich, where you've led the ETH Zurich Space initiative since 2023 and you're Head of a National Innovation Initiative in the area of space research. What does this work entail?
We want to build three main pillars in the area of space research. The first pillar is a new master's degree programme for space systems that focuses on data, constructing innovative systems and sustainability. ETH Zurich is a university where students are the most important people. After all, patents aren't the best drivers of innovation. People are. Research projects are the second pillar. ETH Zurich has already been involved in past space missions, but we want to be even more active in future.

And the third pillar?
That would be innovation initiatives. We want to collaborate with yet more established companies. And we want to support the growth of start-ups with the aim of sharing Swiss technology and entrepreneurship to benefit society.

Thomas Zurbuchen
Thomas Zurbuchen is Professor of Space Science and Technology at ETH Zurich and heads the ETH Zurich Space initiative. Zurbuchen, aged fifty-six, grew up in Switzerland's Bernese Oberland. After studying physics, he was appointed professor at the University of Michigan in the US. His scientific research covers the fields of solar and heliospheric physics, experimental space research, and space systems; he is also highly respected for his achievements in the areas of innovation and entrepreneurship. From 2016 to 2022, he was Associate Administrator for the Science Mission Directorate at US space agency NASA, where he was responsible for one hundred and thirty space missions, thirty-seven of which were launches into outer space.

What elements are necessary to bring about major innovations?
Essentially three things: good ideas, smart and ambitious people—and funds.

What about being open to new ideas—and being lucky? Key developments at NASA have been used for many purposes other than space research. Just one example would be the NASA image sensors that make our smartphone cameras possible.
That's the great advantage of basic research: new findings give rise to things that can find quite different applications. For the James Webb Space Telescope, we developed a technology that uses distributed optics to automatically and autonomously concentrate light on one spot. In the meantime, the system has been adapted for use in eye surgery. And luck is always important. While there's a lot that can be planned—there's a lot that can't. In the field of innovation, it's vital that we try crazy things. Not crazy in the negative sense of the word, but crazy hard, crazy ambitious. It's this sort of environment that gives rise to findings that make things like the Internet possible. Multi-billion-dollar industries almost exclusively emerge from these kinds of research settings.

What can Switzerland and Central Europe do better in the area of promoting innovation?
Innovation is inextricably linked with the practical question of what happens when a project fails to bring about the desired outcome. If we have to stop after the first attempt, we won't be innovative. That's why it worries me to hear that researchers have to go to the US after attaining disappointing results—because they're not given a second chance here. If I had a lot of money, I would invest in people in Switzerland who need a second chance. Or a third.

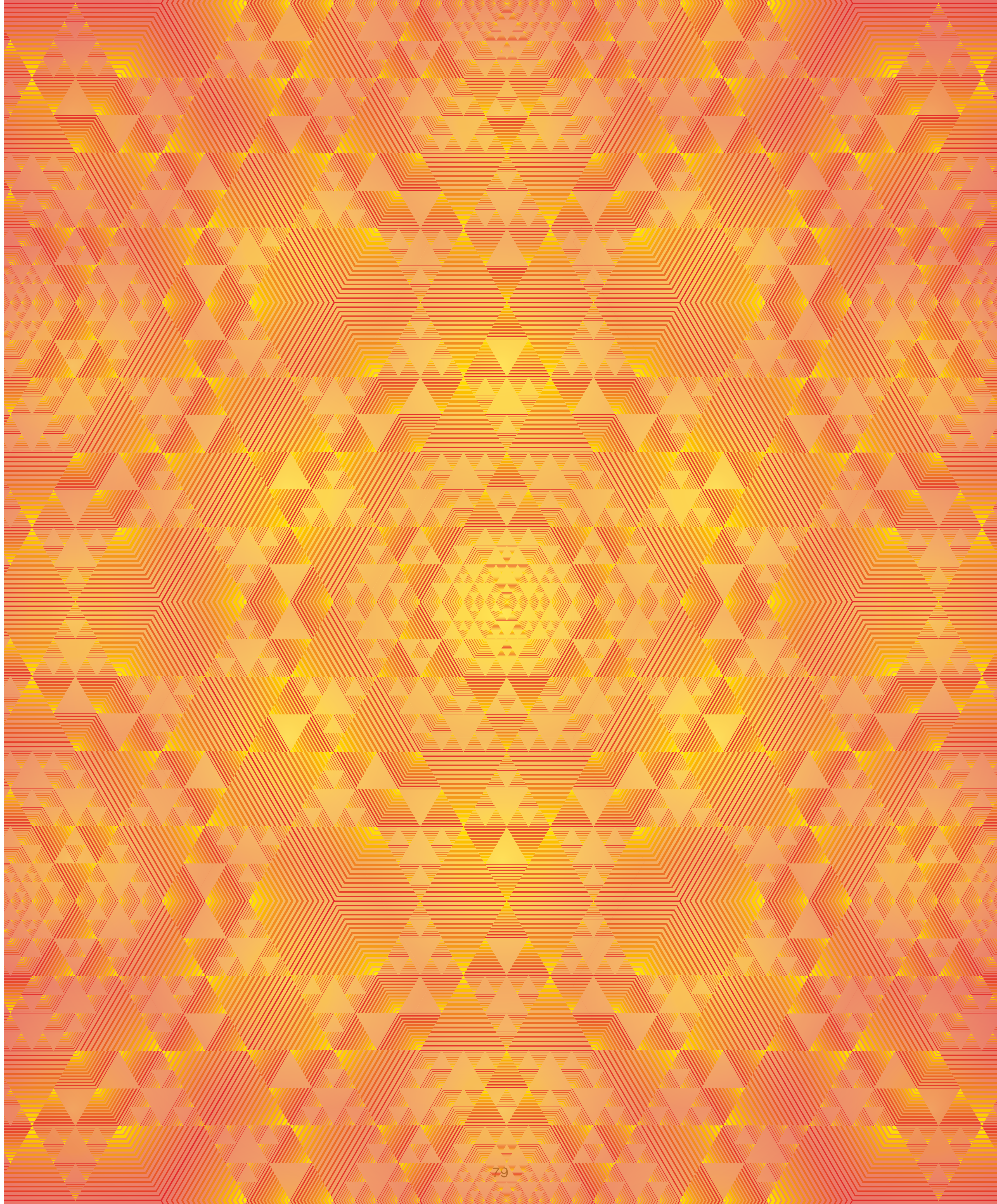
Do you have other concerns about innovation in Central Europe?
I'm also concerned that productivity is in decline. Whoever is trying to develop innovative, world-changing ideas is in competition with teams from across the globe. If they work twice as hard, they'll have twice as many chances. Because I don't think it's the geniuses who win: it's the people who work hard and stick to it. That's something I learned growing up in the mountains. And the same holds true for Silicon Valley, Zurich, Berlin and everywhere else in between.

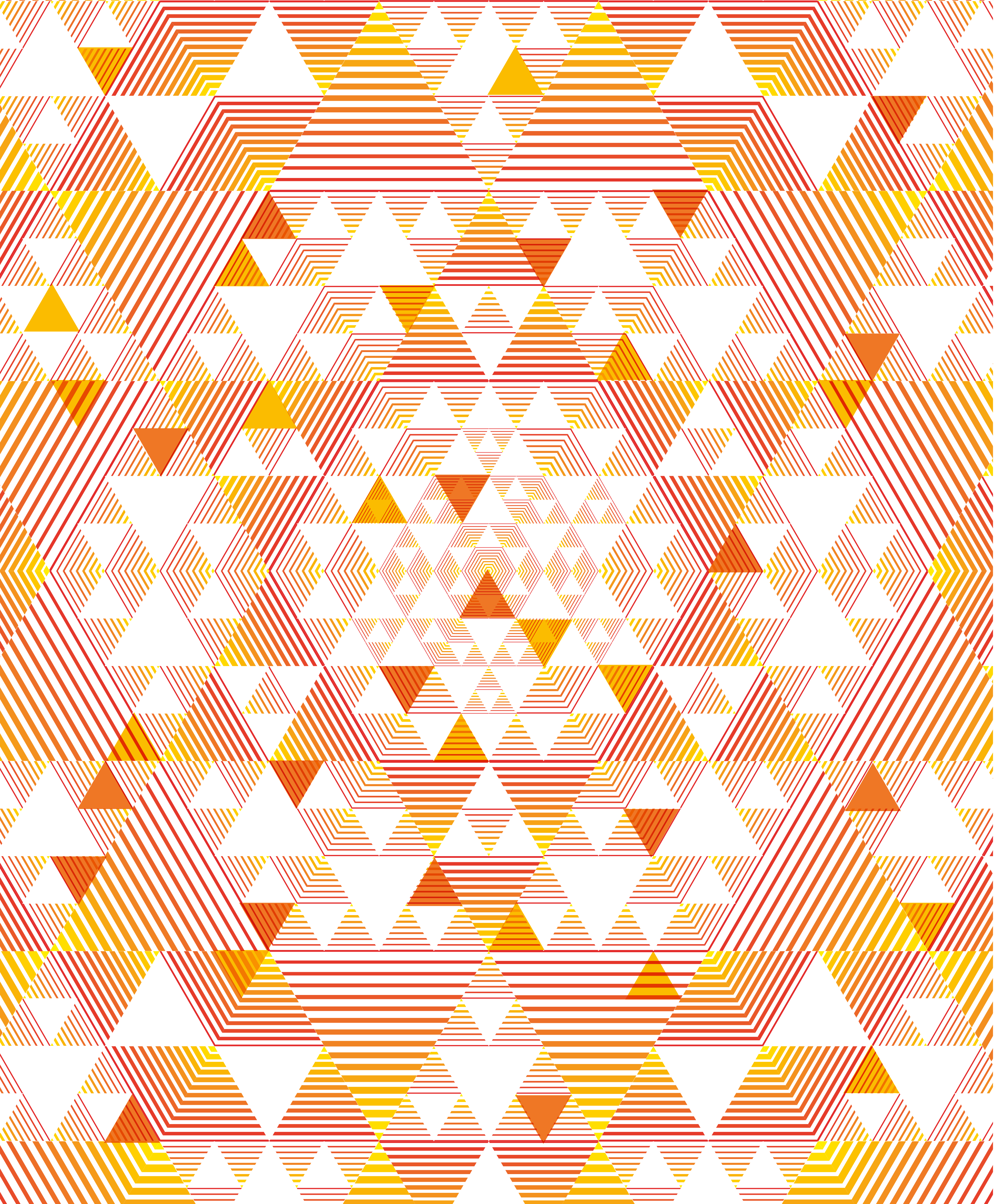
What part can foundations play in supporting vital research and innovation?
Foundations are incredibly instrumental in this area. They can take greater risks than state organisations. There's a great deal of evidence that foundations invest more wisely than governments—and that their funding generates new, groundbreaking fields of research. That family foundations invested in the first telescopes used for observing space is just one example. The way we think about ourselves today is the result of these investments.

Space missions are typically long-term projects, while many funding instruments run for just a few years. Does this cause problems in space research?
There's short- and long-term research, and both are important. But basic, transformational research takes time. A major project like the James Webb Space Telescope is only possible if full funding is secured for twenty years. The advances made in the process lead to Nobel Prizes and so on. I think a mixture of patience and impatience is a good innovation strategy.

As a last question, let's return to "high aims": what's the best advice you have for young researchers?
Eighty percent of the time that goals aren't met is because researchers didn't try—not because they did something wrong. That's why I tell young people: "You have a chance to do great things. Try doing something that will make the world a better place."

"I think a mixture of patience and impatience is a good innovation strategy."





Projects

Deep-sea monitoring, thermoelectrics, reinforced concrete structures — the extraordinary endeavours financed by the Werner Siemens Foundation stem from a wide spectrum of research domains. Over the following pages, readers can learn about the progress made in the projects not discussed in our special focus.

A festive event to launch the catalaix project: the researchers with guest speakers and representatives of the Werner Siemens Foundation.

The project of the century has begun

The catalaix project at the WSS Research Centre has officially commenced its mission. At a festive event to launch the project, researchers demonstrated how they plan to break down plastics into their individual components—and lay the foundation for a multidimensional circular economy

The team led by RWTH Aachen University professors Regina Palkovits and Jürgen Klankermayer have set themselves an ambitious goal. Indeed, their aim is nothing less than revolutionising the chemical industry. Today, industrial chemists employ a series of complex, sophisticated processes to manufacture a wide range of products from petroleum-based raw materials. At the end of their life cycle, most of these products are simply thrown away.

The Aachen researchers want to change this by using tailor-made catalysts that are capable of breaking down these products into their molecular building blocks—which can then be fed into a multidimensional circular economy. In this context, the researchers will focus first on the plastics industry. Last year, they began realising their ambitious endeavour in the WSS project of the century: their research proposal was selected as winner of the Werner Siemens Foundation's ideas competition held to celebrate the Foundation's centennial, and their catalaix project was awarded a grant of one hundred million Swiss francs.

Congratulations, talks, prognoses

At the end of September, some two hundred guests from the worlds of politics, industry and academia were invited to celebrate the launch of the new catalaix WSS Research Centre in Aachen. At the festive—and scientifically substantial—event, Siemens Family Advisory Board Member Christina Ezrahi congratulated the researchers on behalf of the Foundation, while Sibylle Keupen, mayor of Aachen, and Ulrich Rüdiger, rector of RWTH Aachen University, spoke of the significance the new research centre will have for the city of Aachen and its university.

In a series of discussions and presentations, experts then placed the project in a wider context. Steffen Knodt, board member of the German Association for Marine Technology and the UN Ocean decade, described the negative impact of plastic waste in the oceans on the marine ecosystem, saying that, by 2050, there will be about as much plastic waste in the ocean as there are fish. In his talk, André Bardow, professor of energy and process systems engineering at ETH Zurich, outlined the challenges inherent in creating a climate-neutral plastics industry. In addition to attaining a recycling rate of at least seventy-five percent, he said using large quantities of biomass and renewable energies is essential. Bert Weckhuysen, professor of inorganic chemistry and catalysis at Utrecht University, then described the refineries of the future where chemical products will be created from plastic waste and renewable energies rather than from petroleum.

Cleaving chemical bonds

Regina Palkovits and Jürgen Klankermayer introduced the core idea behind catalaix and outlined their initial priorities at the new research centre. Catalysis—the process in which a chemical reaction is accelerated or made possible in the first place—is the sum and substance of their project. To date, catalysis has been used mainly to form bonds, Klankermayer explained—and then got straight to the point: "But now, we're also looking to cleave chemical bonds." Specifically, they want to break down bonds in plastic materials to yield high-value molecular building blocks that can be utilised in various production chains—to utilise plastic waste as a raw material.

Regina Palkovits pointed out that tailor-made catalysts alone won't bring about the desired shift towards a sustainable chemical industry. Developing scalable processes that maintain efficacy even at high production volumes is crucial. To meet this challenge, the make-up of the catalaix team is decidedly interdisciplinary, with researchers in seventeen different research groups covering each step of the complex process—whether in the lab, the pilot plant, or regarding the value chains for the resulting products.

Plenty of ideas, initial results

The work is already progressing rapidly. Jürgen Klankermayer demonstrated how plastic polyethylene can be converted into biodegradable polylactic acid, and he presented a polymer adhesive developed by his research group whose bonds are broken down via an electrical power source.

Several catalaix group leaders also reported the initial results of their approaches in short talks and on posters. For example, Ulrich Schwaneberg, who is developing customised material-binding peptides that adhere to various plastics, a development that could play a decisive role in separating mixed plastics. His colleague Lars Blank is focusing on microorganisms that split plastic compounds; indeed, Blank's team has genetically modified the *Pseudonomas putida* bacterium so that it can simultaneously break down different plastic building blocks.

It will be interesting to see how the "catalaix" project will influence the plastics and chemical industry in the coming years.

WSS 100

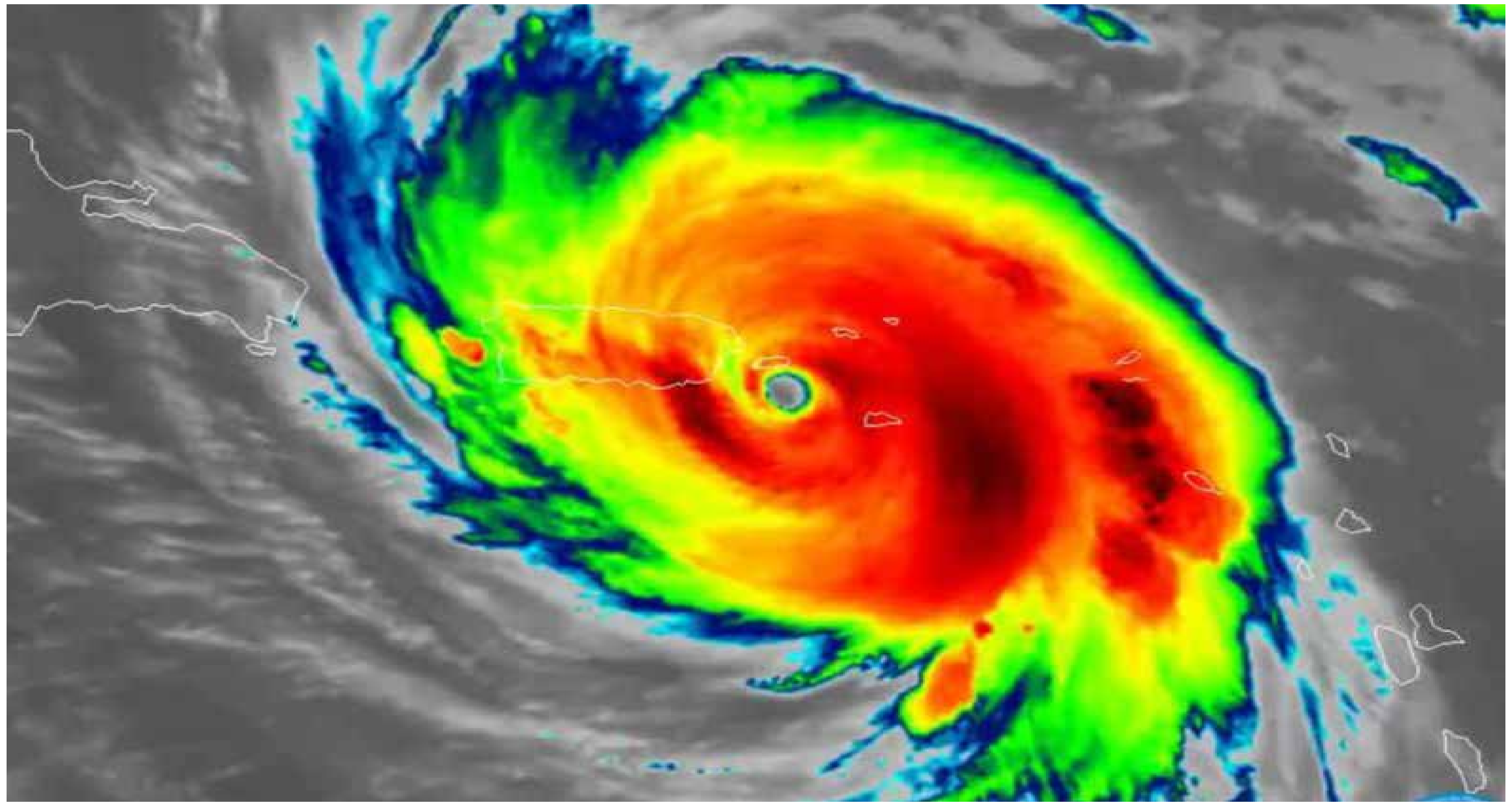
catalaix

Most chemically manufactured products are thrown away at the end of their life cycle. The research team led by Regina Palkovits and Jürgen Klankermayer at RWTH Aachen University want to change this—with the help of catalysts that accelerate chemical reactions or make them possible in the first place. Their primary goal is using novel catalysts to break down plastic materials and mixed plastic waste into versatile building blocks. In the process, they plan to develop a modular system that will pave the way for a multidimensional circular economy in the chemical industry.

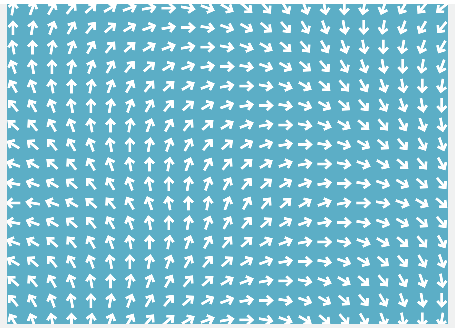
Funding from the Werner Siemens Foundation 100 million Swiss francs
Project duration 2024 to 2034
Project leader Prof. Dr Jürgen Klankermayer, Chair of Translational Molecular Catalysis, RWTH Aachen University
Prof. Dr Regina Palkovits, Chair of Heterogeneous Catalysis and Technical Chemistry, RWTH Aachen University

All about El Niño

It's often a question of being at the right place at the right time. That was the case last year for the team aboard the research yacht *Eugen Seibold*: while collecting samples from the Pacific, they were also able to gather comprehensive data on the global climate phenomena El Niño and La Niña—a world first.



The conditions created by climate phenomenon El Niño can also promote hurricane formation.



Research vessel *Eugen Seibold*

Since 2020, the team on the research yacht have been sailing the world's seas to study the water and atmosphere. The first stage was dedicated to gathering samples across the entire Atlantic Ocean. Currently they're collecting detailed data on the global climate phenomena El Niño and La Niña.

Funding from the Werner Siemens Foundation 3.5 million euros (2015–2019 construction, technical installations)
3 million euros (2020–2030 operating costs)
Project duration 2015 to 2030
Project leader Prof. Dr Gerald Haug, Director of the Department of Climate Geochemistry, Max Planck Institute for Chemistry, Mainz and Professor at ETH Zurich
Dr Ralf Schiebel, group leader of micropaleontology, Max Planck Institute for Chemistry, Mainz

It's not only baby Jesus who makes an appearance around the end of December. Every two to seven years, the climate phenomenon El Niño also arrives, and it comes bearing a gift that nobody really wants: heat. Water and land temperatures at the equator rise significantly and, for about six months, the air and ocean currents between South America and Southeast Asia are altered, preventing cold deep-water in the eastern Pacific from rising. El Niño has devastating effects across the globe, causing drought, flooding, hurricanes and species extinction.

Although hot El Niño and his cold counterpart La Niña are recurring natural weather phenomena that have been documented for at least four hundred and fifty years, scientists know very little about what exactly happens in the Pacific during these major oceanic-atmospheric events. But now, thanks to the data collected by the team on the WSS-funded research yacht *Eugen Seibold*, El Niño and La Niña can be studied in detail for the first time.

In spring 2023, the *Eugen Seibold* relocated to the harbour in Panama City and the research team began sampling the eastern Pacific in their neutral pre-El-Niño state. Then, at the end of 2023, El Niño arrived in full force. "When we were at sea in December, the water was so warm that the *Seibold's* air conditioning system for cooling the samples nearly broke down," says Gerald Haug, climate geochemist and "father" of the sailing research vessel. Despite the difficulties, the team managed to sample the critical equatorial marine regions between Panama and the Galapagos Islands.

In addition to measuring the rise in water temperature, the researchers also spent months continuously monitoring the key physical, chemical and biological parameters, including the concentration of CO_2, phosphate, nitrate, chlorophyll and their interactions. "We want to understand El Niño in its entire complexity: in the water, in the atmosphere and at the water surface, the interface where the gas exchange takes place," Haug explains.

During El Niño's peak, water temperatures in the eastern Pacific approached record highs. At the same time, the Amazon basin and northern Brazil experienced a severe drought while regions in India saw the thermostat rise to fifty-two degrees Celsius. During the summer El Niño subsided, as expected, and the water temperatures in the tropical eastern Pacific plummeted by nearly ten degrees Celsius in some places. Ralf Schiebel—head of research on the Seibold and group leader at the Department of Climate Geochemistry led by Gerald Haug at the Max Planck Institute for Chemistry in Mainz—emphasises that this is indeed a huge temperature difference.

For the first time, complete datasets on the oscillation between El Niño and La Niña have now been collected. Director Gerald Haug is very satisfied with the work, saying, "We have all the data we wanted."

Have they already identified any trends? Both Haug and Schiebel demur. "It takes three to four years to analyse a complete dataset," as Schiebel says. The measurement data must first be cleansed and quality controls conducted. In addition, the data gathered in the air and water samples have to be correlated. This step is critical, as there are numerous interactions, feedback loops and interdependencies between the ocean, the Earth's crust and the atmosphere. As an example, Schiebel refers to CO_2 measurements, saying, "the Galapagos Islands have active volcanoes, and natural outgassing can lead to locally higher CO_2 concentrations. We have to factor this out of the high CO_2 values we measured."

The researchers must also always adjust for temperature, salinity and air pressure when interpreting CO_2 levels. More CO_2 is dissolved in the ocean's surface water when the water is colder and less salty, and when the atmosphere's CO_2 pressure is higher. "That's why calculating CO_2 measurements without data on temperature makes no sense," Schiebel says.

The researchers measure the water temperatures with an accuracy in the thousandths—because it's normally only the upper water layers that are warmed by the sun and air, whereas at depths of about two hundred metres and lower, the water temperature should remain consistently cold. Schiebel explains that, if deeper water in the Pacific is just a few hundredths of a degree Celsius warmer, it means "a whole lot of energy was involved". This energy is apparently being pumped into the system by human-caused global warming, and Schiebel shares an uncomfortable truth: "The ocean is now already significantly warmer at depths of two thousand metres."

More energy in the system has various effects, including an increasing likelihood of tropical storms. High winds, for their part, accelerate other processes in the world's oceans. "This generates feedback loops that are difficult to fully grasp," Gerald Haug says. The researchers believe the comprehensive data collected in the coming years will lay the basis for a deeper understanding of the world's oceans in the age of global warming.

Dealing all kinds of viruses a deadly blow: Francesco Stellacci's vision of a broad-spectrum antiviral drug is beginning to bear fruit.

Crushing the viral envelope

Francesco Stellacci's quest for a broad-spectrum antiviral is progressing at a brisk pace. At the École polytechnique fédérale de Lausanne (EPFL), he and his team have now added a whole new range of highly promising preparations to their already impressive repertoire of antiviral agents.

Although viruses were discovered more than one hundred years ago, their secrets have yet to be fully understood. And although we have very effective vaccinations to prevent several viral diseases, medications for treating viral infections are still rare. In particular, there are no drugs that—akin to broad-spectrum antibiotics—can be used to treat a wide range of viral infections.

Francesco Stellacci and his group at the EPFL Supramolecular Nano-Materials and Interfaces Laboratory in Lausanne have resolved to change this: they're developing broad-spectrum antivirals whose active substances attack the viruses already before they have the chance to enter a cell and replicate. To create their virucidal molecules, the researchers modify cyclodextrins (a type of sugar molecule) by attaching several water-repellent chains of carbon and hydrogen atoms.

Crushing the viral envelope

Due to their chemical end groups, the finger-like protrusions of these carbon-hydrogen chains attract viruses, bind them, and then exert such strong mechanical pressure on them that the viral envelope is destroyed. In contrast to conventional antiviral drugs, the new approach not only prevents viruses from replicating: it also effectively and irreversibly neutralises them—the viral remains are then disposed of by the immune system. And because all the action is extracellular, the human cells themselves remain entirely unaffected.

Stellacci and his team have already developed a promising cyclodextrin-based drug that is successful in combating influenza and other viruses. "We demonstrated its efficacy both in cell cultures and in animal tests with ferrets," Francesco Stellacci says. "And we've advanced so far as to now have an inhalable powder that's easy to administer." He says he's currently seeking funding for developing the substance into a marketable drug. "That's a major, and expensive, step," Stellacci says.

New bases for active agents

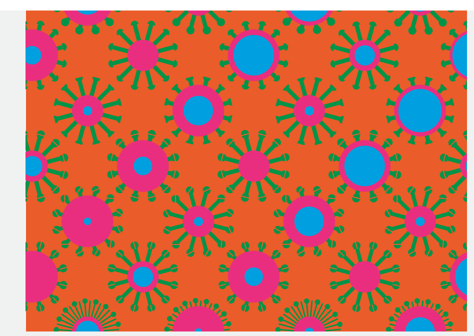
At the same time, the researchers also expanded their repertoire of antiviral agents—a step made necessary because, for unknown reasons, the original cyclodextrin-based antivirals proved to have limited efficacy against the SARS-CoV-2 coronavirus. After testing a range of new compounds in drug cores, the most promising alternatives for attaching the virus-binding carbon-hydrogen chains proved to be so-called benzenes—ring-shaped molecules made up of six carbon and six hydrogen atoms in their basic form.

The researchers then developed a benzene-based molecule that, in animal experiments, was at least as effective as the approved preparation currently recommended for early treatment of at-risk patients. But the Lausanne drug has other advantages when it comes to healing serious lung infections: in addition to treating SARS-CoV-2, it's also effective against viruses like influenza, RSV, herpes, hepatitis, HIV or the Epstein-Barr virus.

Medications plus immunisations

Stellacci and his group have also succeeded in increasing the number of functions in their antiviral agents. A study they published last year presents a substance that takes on a dual function when fighting influenza viruses: it acts as a drug by first preventing the viruses from entering a cell and then destroying them, while also stimulating the immune system, hence acting like a vaccine.

At present, Stellacci is seeking other, possibly even more effective benzene-based substances. And he believes the finger-like protrusions of his molecules—the virus-binding carbon-hydrogen chains—hold yet more potential. "We've already attained good results with Respiratory syncytial virus (RSV) and Herpes simplex viruses (HSV)" he says. It's certainly no stretch of the imagination to say more discoveries will soon follow.



Antiviral drugs

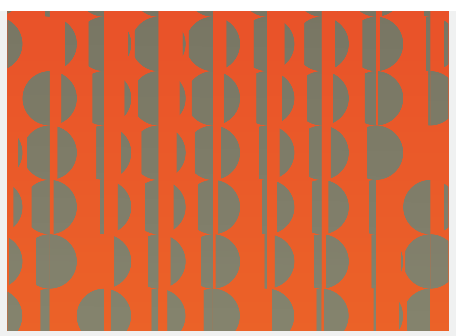
Materials scientist Francesco Stellacci and his team are developing artificial molecules that use hydrophobic pressure to destroy viruses before they can enter a human cell. The researchers are aiming to develop broad-spectrum antivirals to treat various kinds of viral infections as well as drugs that target specific viruses.

Funding from the Werner Siemens Foundation
5 million Swiss francs (2020–2021)
4.5 million Swiss francs (2021–2023)
Project duration 2020 to 2023
Project leader Prof. Dr Francesco Stellacci, Supramolecular Nano-Materials and Interfaces Laboratory (SuNMIL), Institute of Materials, École polytechnique fédérale de Lausanne (EPFL)

Fresh wind in the underground lab

The Bedretto Underground Lab is ready for the future: more research projects have commenced, new international collaborations are planned — and one innovative idea envisions a borehole of up to two kilometres beneath the tunnel ground that would significantly increase measurement capacities.

The BedrettoLab is full of pumps, sensors, cables and tubing for the many and various experiments conducted below the ground.



Bedretto Underground Lab

The Werner Siemens Foundation financed the construction of a unique underground research facility located below the Saint-Gotthard Massif and is funding the innovative research projects conducted there. In the near-authentic conditions of the Bedretto-Lab, ETH Zurich researchers and their partners from Switzerland and abroad have an ideal environment for studying the physics of earthquakes and testing methods for the safe use and storage of geothermal energy.

Funding from the Werner Siemens Foundation 12 million Swiss francs
Project duration 2018 to 2024
Project leaders Prof. Dr Domenico Giardini, Professor of Seismology and Geodynamics, ETH Zurich

Located deep below the Saint-Gotthard Massif, the BedrettoLab—built with funding from the Werner Siemens Foundation—is an inexhaustible wellspring for ideas. The team in the underground facility for studying earthquakes and geothermal energy are currently working on several new approaches and technologies. As research leader Domenico Giardini from ETH Zurich says, "Thanks to the lab's unique infrastructure, we're constantly coming up with new ideas."

Because all the experiments are conducted deep in the underground, safety is a critical feature at the BedrettoLab—and one of the team's goals is to automate as many processes as possible. "That way, we can steer them from outside and no one has to be working in the tunnel," Giardini explains. The project is on track: sensors, pumps and much more are now monitored and adjusted remotely.

New projects

This new capability will pay off in the recently launched BEACH project (Bedretto Energy Storage and Circulation of Geothermal Energy) that aims to realise underground energy storage: in summer, water is heated with excess solar power and injected into the subsurface rock, warming the surrounding layers, and in winter, energy from this heat reservoir is then available for use. To discover how well this principle works under different conditions in crystalline rock, the researchers are injecting various amounts of water at diverse pressures and temperatures. Using their new automation technology, they can monitor the parameters from outside the tunnel.

The same automation capacity is also an important element in the FEAR project (Fault Activation and Earthquake Rupture) which is currently in full operation. At present, a specialised firm is drilling a side tunnel of roughly one hundred and thirty metres along a large fault that will enable the researchers to generate controlled earthquakes in the fault zone and study the seismic activity at close range using a network of sensors. They've already triggered tens of thousands of microearthquakes with magnitudes ranging from minus five to zero and plan to induce more quakes with magnitudes from zero to one.

Observing earthquakes from below

An entirely new idea concerns the ability to measure seismic activity in the rock layers. "Till now, we've only been able to measure what happens directly around or above the boreholes," Giardini explains. However, to get the big picture, the researchers also need to know what occurs below the borehole in the deeper regions. "That's why we want to drill a borehole for measurement sensors that extends a distance of up to two kilometres below the tunnel ground," he says.

However, the new borehole—that would angle down at a diagonal from the tunnel entrance—comes with a major drawback: its high price tag. The researchers are now compiling the calculations they need to submit a funding application. "If we can realise this project, we'll be able to monitor and conduct experiments at depths of up to roughly three and a half kilometers below the surface." Giardini explains. "It would be the first time this has ever been done."

It's a long-term project that would take several years, but the time is ripe: ETH Zurich is currently in talks with the Matterhorn-Gotthard Railway to secure permission to operate the underground lab for another ten years. "When that's settled, the continued research and development in the tunnel is ensured for the years to come." Giardini says.

International projects

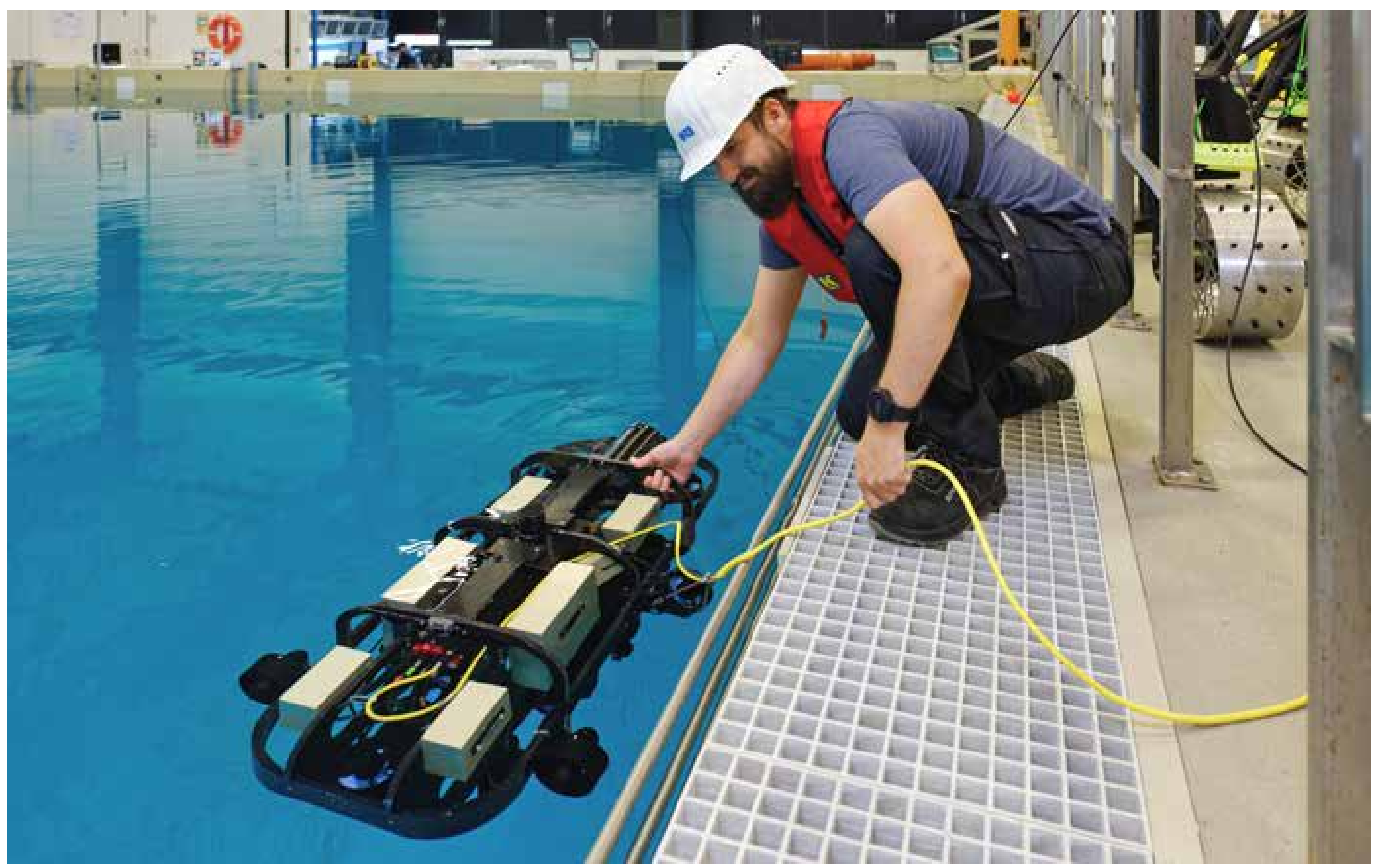
Permission to use the tunnel is also critical for international collaborations, many of which are currently in progress—a sign of how great the interest in the lab is. Giardini relates that a ten-person delegation from China visited last summer, explaining that hundreds of kilometres of tunnels are being built for new train connections in the country's western regions. "They're drilling in large fault zones, where strong earthquakes can naturally occur—and China wants to use the opportunity to study earthquakes at the same time."

The final project mentioned here is an official collaboration between ETH Zurich and the Helmholtz Association of German Research Centres, which is financing the construction of an underground lab in Germany—akin to the BedrettoLab—with a grant of several dozen million euros. "But unlike the Bedretto, which is located in an existing railway tunnel, this lab has to be built from scratch. It will take at least ten years," Giardini says, adding that the collaboration will enable the German researchers to conduct experiments in the BedrettoLab beforehand.

"But it's a win-win partnership that benefits our project, too," Giardini says with evident satisfaction. "We'll be able to confirm our tests with experiments conducted under other geological conditions in Germany. Or we can plan joint experiments, which lowers costs—and consolidates brain power." There's no doubt about it: a fresh breeze is blowing through the tunnel lab deep in the mountain.

Monitoring node in the deep sea

Last year, the team at the Innovation Center for Deep-Sea Environmental Monitoring in Bremen took a great leap forward, with major improvements made in navigation, data transmission and energy supply of their underwater robots. Their new monitoring node—which can be deployed systematically on the ocean floor—functions simultaneously as a power supply and a secure data storage system for an underwater vehicle.



And down we go! SPIRULA being tested in the Maritime Exploration Hall for Deep-Sea Robots in Bremen.

Ralf Bachmayer and his research team at the Innovation Center for Deep-Sea Environmental Monitoring have added a multifunctional component to their monitoring system: a monitoring node that functions as an underwater charging station, computing node and data storage device for data collected by the underwater vehicle. The node, which is made of steel, can be placed more or less at any interesting location on the seabed—and it's so heavy that even strong currents can't displace it.

Bachmayer says the team came up with the idea to link the underwater vehicle with a monitoring node last year when they tested their original Autonomous Underwater Vehicle (AUV) concept in the North Sea. The researchers hoped to detect and sample naturally occurring gas seeps—succeeding despite having to contend with forces of nature. “Strong currents and tides, poor visibility—you name it, we had it,” Bachmayer recalls. “It was so bad that we had to ask ourselves whether it's even possible to leave an AUV unattended in such an inhospitable environment for a longer period of time—and still be sure that we'll find it there when we come back.” The answer was clear: a more robust system with greater technical reliability was needed.

In the team's revised deep-sea monitoring concept, the underwater vehicle is now connected to the base station via a cable during its exploratory missions. The vehicle unwinds along the cable and begins spiralling in concentric circles around the base station, reliably collecting data as it goes. The researchers christened their new system SPIRULA, after the small squid that lives in a spiral-shaped shell; strictly speaking, however, SPIRULA stands for “SPiraling Intelligent Robotic Underwater monitoring pLAtform”.

Large-scale monitoring

The expected maximum radius of the spiral is around twenty metres, which comes to a good twelve hundred square metres of contiguous area that can be explored, as Bachmayer explains. “This capacity to repeatedly study an area of that size—and to precisely position the vehicle—is a big step forward,” says Michael Schulz, former director of MARUM in Bremen, where Bachmayer's innovation centre is based. Previously, the researchers were limited to taking isolated or single point measurements that lacked immediate environmental context, which greatly curtailed their ability to study the deep sea. “But with SPIRULA, we're now able to analyse a large swath of the seabed under many various conditions over time and space,” Schulz says, while also pointing out that this major advance was made possible by funding from the Werner Siemens Foundation.

As the vehicle glides gently above the seabed on its cable, the camera on its “belly” takes brief, overlapping flash photos, which are later used to construct 3D images of the ocean floor. The underwater vehicle also has a sonar fitting at its front for sensing acoustic information; the sonar system reliably detects rocks and other obstacles, enabling the vehicle to explore the deep sea even in zero visibility. “It's critical that the vehicle doesn't collide with the seabed under any conditions, as this could damage precious ecosystems like corals,” Bachmayer says.

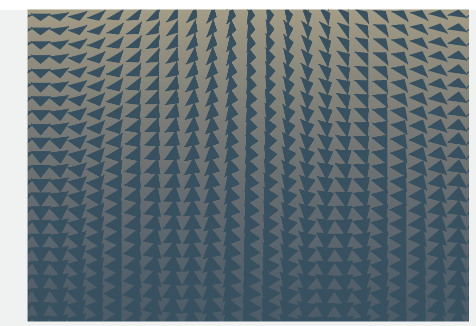
The team can analyse the acoustic and optical recordings in combination with measurements taken by other sensors mounted on the vehicle that simultaneously gather data on water properties such as temperature, salinity, oxygen levels and turbidity.

Energy and computing power

If the vehicle is low on power, it autonomously returns to the monitoring node to recharge its batteries. It continuously transmits data via the fibre optic cable to the well-insulated, powerful computer located inside the station's frame. The computer further processes the data, generates new maps, detects changes, autonomously charts a new path for the vehicle's next mission and extracts information from raw data that can be sent up to a research vessel at a later stage.

SPIRULA also optimises operations of the research vessel. “The team on the vessel can lower our monitoring node and underwater vehicle at the designated site in the deep sea, and then continue on to the next mission,” Michael Schulz explains. “When the research vessel returns to the site, our monitoring system will ideally be able to transmit a complete map of the deep-sea region as well as other environmental information up to its servers.”

Another advantage to the revised system is that it enables recordings to be made over days and weeks. “We can study things like how deep-water corals develop under changing environmental conditions—which is one of our next research aims at MARUM,” Bachmayer says.



Innovation Center for Deep-Sea Environmental Monitoring

Researchers at the MARUM innovation centre in Bremen are developing sustainable observation systems that can be used to identify and monitor ecologically valuable deep-sea regions.

Funding from the Werner Siemens Foundation 4.975 million euros
Project duration 2018 to 2028
Project leader
Prof. Dr Michael Schulz, director (until end of 2024) of MARUM – Center for Marine Environmental Sciences at the University of Bremen

Clever systems for staying safe

Exchanging data on the internet is a risky business. That's why computer scientists at the Centre for Cyber Trust at ETH Zurich are working to develop systems that improve digital security. Now, the group headed by co-project leader Adrian Perrig can report progress in several areas.

Centre for Cyber Trust

The actions of cybercriminals and hackers undermine the faith society has in online data exchange. To remedy this, computer scientists at the Centre for Cyber Trust at ETH Zurich and the University of Bonn are developing a fundamentally new security architecture for the internet. Their aim is to transfer traditional relationships of trust from the physical world to the digital realm.

Funding from the Werner Siemens Foundation 9.83 million Swiss francs
Project duration 2019 to 2027
Project leaders Prof. Dr David Basin, Department of Computer Science, Information Security, ETH Zurich
Prof. Dr Peter Müller, Department of Computer Science, Programming Methodology, ETH Zurich
Prof. Dr Adrian Perrig, Department of Computer Science, System and Network Security, ETH Zurich
Prof. Dr Matthew Smith, Institute of Computer Science, Usable Security and Privacy, University of Bonn

Social media platforms, messaging services, payment transactions, web searches and e-mail exchanges: digital technology has fully arrived as an integral part of our daily lives. But these online systems have serious vulnerabilities. The biggest problem remains verifying the identity or authenticity of a communication partner in an online space, be it a chat group or a bank website.

The aim of researchers at the Centre for Cyber Trust at ETH Zurich and the University of Bonn—whose work is funded by the Werner Siemens Foundation—is to improve cybersecurity for users. "We're working on a wide range of projects and strategies because there are many ways to improve security in digital spaces," says Adrian Perrig, who leads the project with his ETH colleagues Peter Müller and David Basin along with Matthew Smith from the University of Bonn.

Digital reference letter

Over the past year, Perrig's Information Security Group made progress on several different fronts. For example, they developed a solution for improving the encryption protocol of the Signal Technology Foundation seated in the US. The Signal protocol encrypts every message and is used not only in the eponymous messaging platform, but also in Meta's WhatsApp and Google's RCS chat service.

Yet despite utilising this so-called opportunistic end-to-end encryption, without verifying the safety number linked to the identity of both users, the protocol offers no guarantee as to who a user is really communicating with. For example, a hacker could intercept confidential messages, read them—and even manipulate them before forwarding them. These man-in-the-middle attacks are already technically possible—on public WLAN networks, for instance.

The researchers have now developed a security system that works a little like a letter of reference. Once person A has checked and verified person B's safety number, person A can pass the number on to person C. "With our function, people could recommend numbers they themselves have verified, to their friends," Adrian Perrig explains. "That increases security and trust." The researchers are now making a pitch to developers at Signal to convince them to integrate this "trusted introduction" function into their existing encryption protocol.

Ranked trust

Another new development concerns encryption certificates for websites. Today, these certificates are issued by dozens of different organisations around the world. "When we visit a website from the US or China, for example, we have no choice other than to trust the certificate authorities in those countries," Adrian Perrig says. This is because users won't be granted access to most websites if they only trust certificate authorities from countries like Germany or Switzerland.

Perrig's group has now developed a system based on a ranked-trust model that circumvents these restrictions while simultaneously offering greater security. "Let's say that, as a Swiss citizen, I trust European certificate authorities the most, those from the US a little less, and those from another country even less," Perrig says.

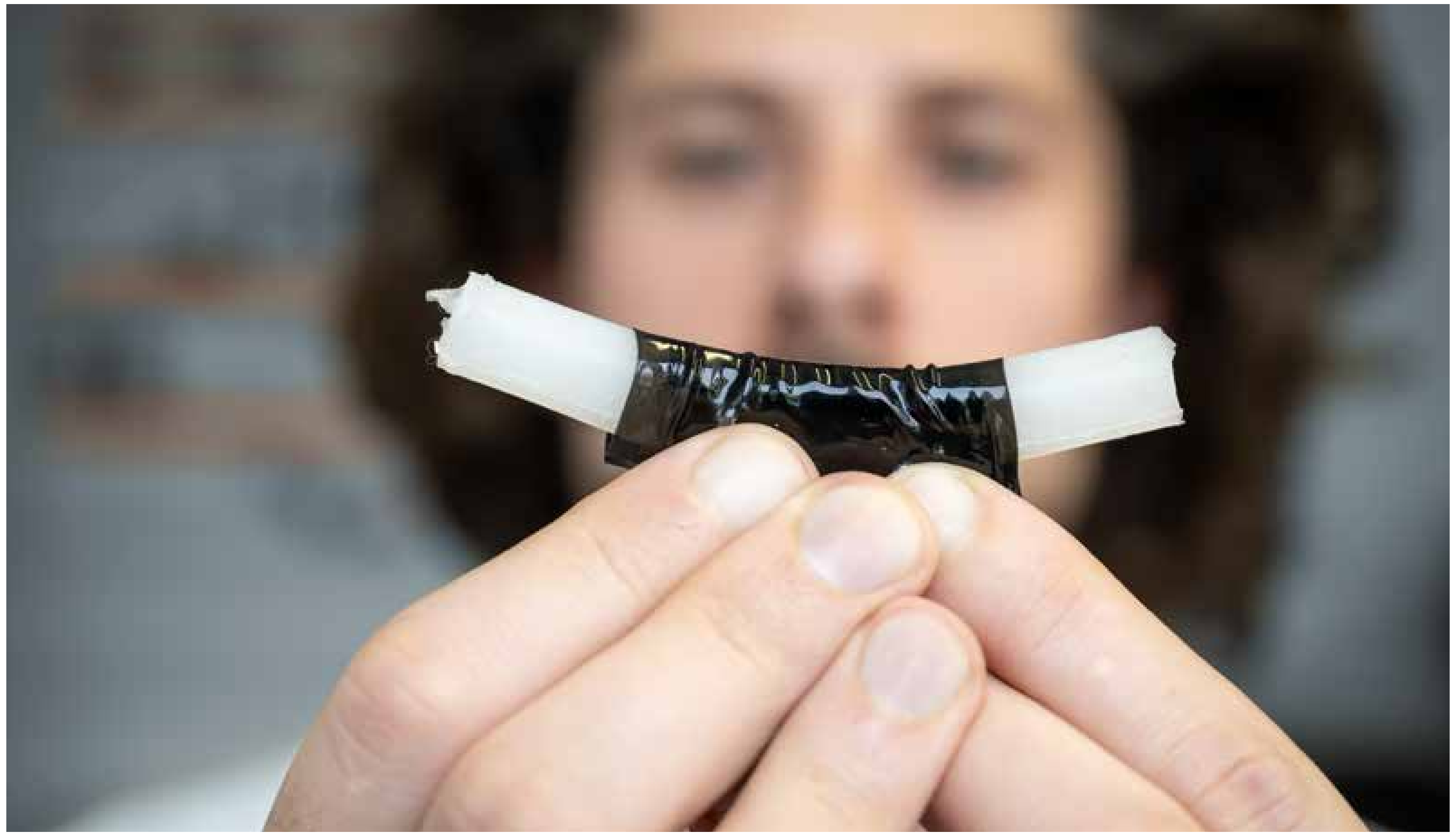
The researchers combine this preference with what's known as an absence proof. "This means I might accept a website certified by a US-based organisation, but only if it first proves the absence of a European certificate for the domain," Perrig explains. "If North Korean hackers create a website pretending to be a Swiss company, access to the website will not be granted." This means that a cyberattack could only be launched by European actors, making it easier for the authorities to track them.

Integrating geographical data

Security of domain certificates is improved even further when they're coupled with data from the physical world. Which is precisely what the researchers have done in another project area—by adding geographical data from Open Streets Maps or Google Maps to the encryption certificates; this increases user trust in the online services and processes of companies or organisations with known locations.

"For example, if I want to log on to the WLAN at Zurich Airport, I can check to see whether the network I select is really the one offered by the airport," Perrig explains. "Or if I'm a tourist and need to withdraw cash from an ATM somewhere in Vietnam, I can review the information to be sure that an ATM is in fact registered at the location in question."

The researchers anticipate that these novel security systems will be interlinked in the future—which would considerably increase the safety of interactions in digital spaces.



The researchers plan to use the artificial muscle (black) to squeeze and then relax the urethra.

Artificial muscle for a common complaint

Last year, the team at the Center for Artificial Muscles in Neuchâtel began focusing on their urinary tract project. Their idea is to develop an artificial muscle that can close the urethra—offering relief to patients suffering from urinary incontinence. The initial developments are highly promising.

The human body contains some six hundred and fifty muscles and, depending on age, gender and fitness, the sum total makes up between a quarter to more than half our body mass. Unsurprisingly, there are also many different kinds of muscular diseases and injuries, and it's unfortunately not always possible to heal a damaged muscle.

At the Center for Artificial Muscles (CAM) at the Neuchâtel campus of the École polytechnique fédérale de Lausanne (EPFL), a team led by director Yves Perriard and managing director Yoan Civet are seeking alternative treatments for muscle-related medical conditions—and are developing novel, extremely elastic materials equipped with electrodes that use battery power to expand and contract, just like real muscles. The researchers are working on systems for using their artificial muscles to increase the heart's pumping capacity in patients with cardiac insufficiency and to help people with facial paralysis.

A third idea is the development of an artificial sphincter for the urethra. More than four hundred million people worldwide suffer from weak bladders, or incontinence, with women affected roughly two and a half times more than men. Depending on cause and severity, treatments include relaxation techniques, muscle training, absorbent products and surgical procedures.

Reducing side effects

In severe cases, patients are fitted with an artificial urinary sphincter—a circular cuff placed around the urethra that is controlled manually to empty the bladder. These devices, which are primarily implanted in men, generally work well, but they have several undesirable side effects—and in about a quarter of all cases they stop working, making a repeat procedure necessary. Yves Perriard and Yoan Civet are convinced that their highly elastic, electric-powered materials can be used to develop better alternatives.

As a first step, the researchers conducted various tests on pig urethras to better understand the mechanical properties of the organ and searched the literature for information about the particularities of the human urethra. "Using this data, we looked into different materials that could potentially imitate the urethra and be used for testing our artificial sphincter," Yoan Civet says. "Because the urethra is an extremely delicate tissue," Yves Perriard adds. "If the artificial muscle applies too much pressure on it, its cells die quickly."

Imitating complex human tissue

The researchers found two materials made of silicone or hydrogel that demonstrates similar mechanical behaviours as human urethral tissue. "We'll continue to analyse and adapt these two materials," Civet says. The work is challenging because the human urethra doesn't react in a linear fashion to pressure; rather, it suddenly stiffens when a certain amount of pressure is applied. "It's possible that we'll need to add fibres to our materials to imitate this stiffening action," Civet explains.

The team are also pursuing another line of research in which they'll fabricate a sphincter made of their highly elastic materials, so-called dielectric elastomer actuators. Here, too, the researchers can report the first positive results: they created "artificial muscle" tubes with a length of four centimetres whose diameter increases via the electrodes. "The results are promising," Yves Perriard says.

Despite this progress, the researchers are also working on a second approach—because one of their main goals is ensuring that women benefit from their artificial sphincter. The urethra of women is so much shorter than that of men that it's not certain whether the dielectric elastomer actuators would have enough contact surface to generate the necessary pressure. That's why the team are also working on fitting artificial muscles on a metal ring that can be placed around the urethra. The movement of the actuators would open or close the ring, much like the aperture in a camera.

It will be interesting to see how the project develops—and what new ideas the Neuchâtel researchers come up with next.

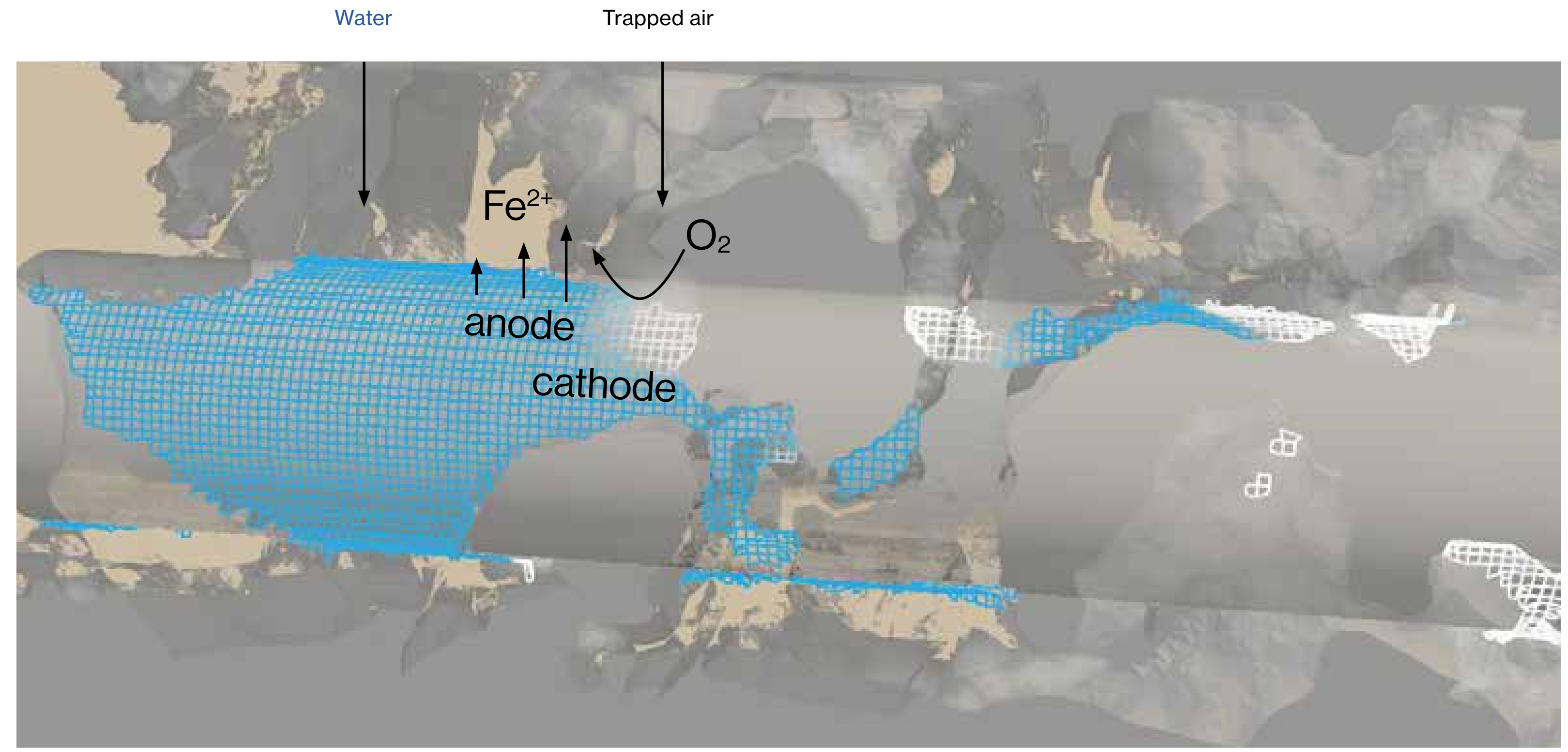
Artificial muscles

Cardiac insufficiency, facial paralysis, urinary incontinence: at the Center for Artificial Muscles at the Neuchâtel campus of the École polytechnique fédérale de Lausanne (EPFL) researchers are pursuing an innovative approach to treating these muscle-related conditions—they're developing artificial actuators made of novel, extremely elastic materials that are fitted with electrodes. When stimulated by an electric current via an external battery worn by the patient, these tissues expand and contract just like real muscles.

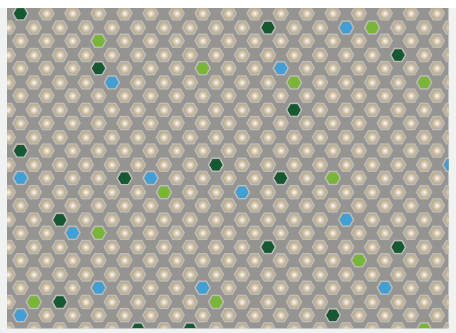
Funding from the Werner Siemens Foundation 12 million Swiss francs
Project duration 2018 to 2029
Project leader Prof. Dr Yves Perriard, director of the Center for Artificial Muscles and the Integrated Actuators Laboratory (LAI), EPFL

The interior life of concrete

Last year, the team led by civil engineer Ueli Angst studied corrosion processes occurring at the pore level in reinforced concrete. Now they plan to analyse how corrosion unfolds at ever-larger scales—with the aim of developing recommendations and tools for enabling ecological corrosion protection in concrete structures.



The chemical and physical processes in concrete pores influence corrosion in reinforced concrete



Climate-friendly reinforced concrete

ETH professor Ueli Angst is studying complex corrosion processes in reinforced concrete under different climatic conditions. In a first step, he and his team are analysing corrosion processes at the molecular level. Later, the knowledge gained will be tested and compared on the medium scale, then on the metre scale. The goal is to provide knowledge, testing methods and models that ensure corrosion protection even in climate-friendly concrete structures. This will enable the construction industry to increasingly use climate-friendly types of concrete and contribute to climate protection.

Funding from the Werner Siemens Foundation 10 million Swiss francs
Project duration 2025 to 2034
Project leader Prof. Dr Ueli Angst, Department of Civil, Environmental and Geomatic Engineering

ETH professor Ueli Angst and his team approach their research questions from the bottom up, and the first step in their WSS project is examining corrosion processes in reinforced concrete at the nano- and micrometre scale. They want to better understand the most common cause of corrosion—moisture that permeates concrete in the form of rain or spray and that, in the worst case, leads to rusting in the embedded rebar.

Water that penetrates the concrete's pore system is never pure, and gases—such as CO_2—dissolving in the water react with substances like calcium and silicates that are also present in the concrete.

Last year, Angst's team studied the role silicates play in corrosion and observed the following: the higher the concentration of dissolved silicon, the slower a transformation process between two iron corrosion products will proceed; in addition, the corrosion product with the larger specific volume is stabilised for a longer period of time. "This is a first relevant finding," Angst says. It's significant because a slow transformation from "bulky" to "smaller" corrosion products influences how cracking in concrete materialises. Precipitations confined to a small area lead more quickly to stresses in the concrete and eventually cause cracking.

Building knowledge

The corrosion experiments are usually carried out by Ueli Angst's PhD students in their ETH Zurich labs, but some studies are also conducted at partner institutions: the Paul Scherrer Institute (PSI), the Swiss Federal Laboratories for Materials Science and Technology (Empa) and other labs with specialised infrastructure in Europe and North America. For example, Fabio Furcas, who led the silicate experiment during his doctorate, has taken a postdoc position at Empa, where he'll continue researching related topics—in collaboration with Ueli Angst. "The process of building up knowledge related to the WSS project is well underway," Ueli Angst says, expressing his pleasure about the growing research community in the field. Now, his team members are no longer exclusively from materials sciences: they're also chemists, physicists, chemical engineers and civil engineers.

For the official start of the WSS project in January 2025, Angst is seeking three to four more PhD students. "Apart from the right scientific qualifications, team spirit is a key requirement," Angst says. "The newcomers should fit in well with our international team."

Skills in microscopy are a requirement for some of the PhD students, as they'll be studying the microstructure in concrete with an ion beam device—specifically, a "Focused Ion Beam Scanning Electron Microscopy" or FIB-SEM that enables a 3D visualisation of the concrete's interior microstructure in the nanometre range.

This makes it possible to conceptualise processes like moisture transport through the fine, intricate pore system and the coupled corrosion processes at the level of the individual pores. "We can finally move away from predominantly empirical testing of specific concrete types—long the traditional approach—and towards attaining a fundamental understanding of corrosion," Angst says.

With FIB-SEM, the researchers bombard a material sample with a focussed ion beam, thereby removing the smallest layers of the porous material. Layer by layer, they scan the sample with a scanning electron microscope, then use the scans to construct a 3D digital model of the porous material. "We can use the digital model to study various processes, including how a water molecule or iron ions move through the concrete," Angst says. The resolution in the nanometre range is so high that the effects of capillary forces in the pores are visible.

Models replace individual testing

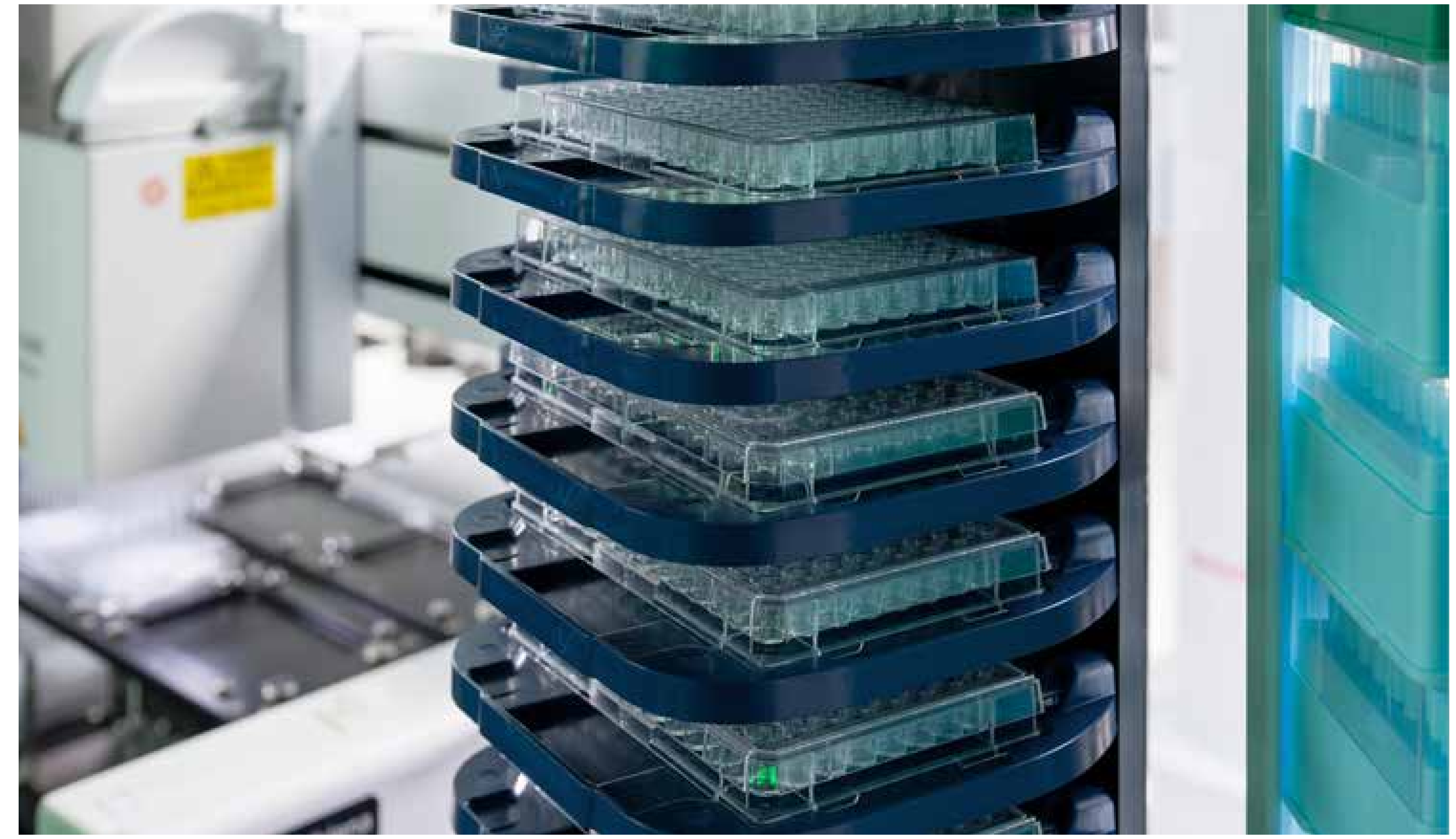
The imaging technique has the disadvantage of being time-consuming: it takes a good one hundred and twenty hours at the microscope before a "digital twin"—as Angst calls the digital model—is fabricated. But it's worth the effort, as the digital twin can model a range of scenarios, including a simulation of changes in the pore system of reinforced concrete when it's exposed to rain, sunshine or temperature fluctuations.

In particular, the team want to find out how capillary forces suck up moisture into the concrete's pore structures, where it then spreads. "It's a very dynamic process," Angst explains. How concrete dries is also fundamental to understanding corrosion—in particular how long residual moisture remains in the pore system.

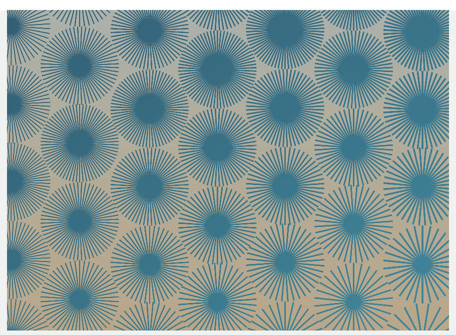
Ueli Angst envisions that corrosion protection measures can be optimised for a specific environment already when planning a structure. This approach makes sense, as "so many different cement types are developed worldwide that testing them all is simply impossible", Angst says. "What's more, established testing methods for new cements and concretes have limited application because they depict processes that, in many new materials, are different to those in traditional concrete."

Next-level search for active compounds

After demonstrating for the first time that ancient dental calculus can be used to produce bacterial compounds, researchers in the palaeobiotechnology project are now aiming to multiply their research output—and have developed diverse methods and platforms for automating the complex processes involved.



Stacks of samples: researchers in the Jena project are devising methods to enable faster testing of their prehistoric data.



Palaeobiotechnology

Is the future of medicine a journey to the past? In the palaeobiotechnology project, chemist Pierre Stallforth and biomolecular archaeologist Christina Warinner are taking an unusual approach to solving the problem of antibiotic resistance: they're analysing the calcified dental plaque of early humans to find ancient compounds that are effective against today's resistant bacteria—and then reproducing these substances in the lab.

Funding from the Werner Siemens Foundation 10 million euros
Project duration 2020 to 2029
Project leaders
Prof. Dr Pierre Stallforth, Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute, Jena
Prof. Dr Christina Warinner, Max Planck Institute for Evolutionary Anthropology, Leipzig, and Harvard University, Cambridge

The palaeobiotechnology project in Jena is progressing in leaps and bounds. Two years ago, researchers led by chemist Pierre Stallforth and biomolecular archaeologist Christina Warinner demonstrated that their idea works: in a widely acclaimed study published in top-tier journal *Science*, they showed for the first time that it's possible to recreate natural products from the dental calculus of early humans—natural products produced by bacteria up to 100 000 years ago.

For this groundbreaking work, the researchers applied customised methods to sequence fragments of genetic material. They assembled these fragments to reconstruct the genomes of numerous bacterial species, which in turn were used to reconstruct a blueprint for enzymes that produce natural products. And after these genes were inserted into living bacteria, they did indeed yield the previously unknown bacterial compounds.

"When people hear we're working with ancient genetic material, they often think it's difficult to find enough," Christina Warinner says. "But that's not the case. Quite the opposite: we have an enormous amount of data—so much, that we'll never be able to test it all." To study as many potential candidates as possible, and to identify the most promising data, it's essential that the team automate the complex tasks involved in seeking and producing these prehistoric compounds.

Three automation steps

This work was the top priority for the researchers last year and—in simple terms—they created three automation steps to realise their objective. The first is to extract and sequence genetic material from the samples. "Robots are already used to run most of these tasks," Warinner explains, "which has increased and standardised our throughput."

In a second step, Pierre Stallforth continues, the objective is to gain as much information as possible from these data. To achieve this, the researchers have developed various software tools and pipelines to automate data analysis; these programmes identify, for instance, DNA sequences that can potentially encode the information for the generation of antimicrobial compounds.

Third and last, the Leibniz Institute for Natural Product Research and Infection Biology has built a new, one-of-a-kind automation platform for creating molecules from the newly discovered sequences and for standardised, high-throughput testing of the new compounds—to determine their antibiotic or antifungal effect, for example.

Interdisciplinary collaboration

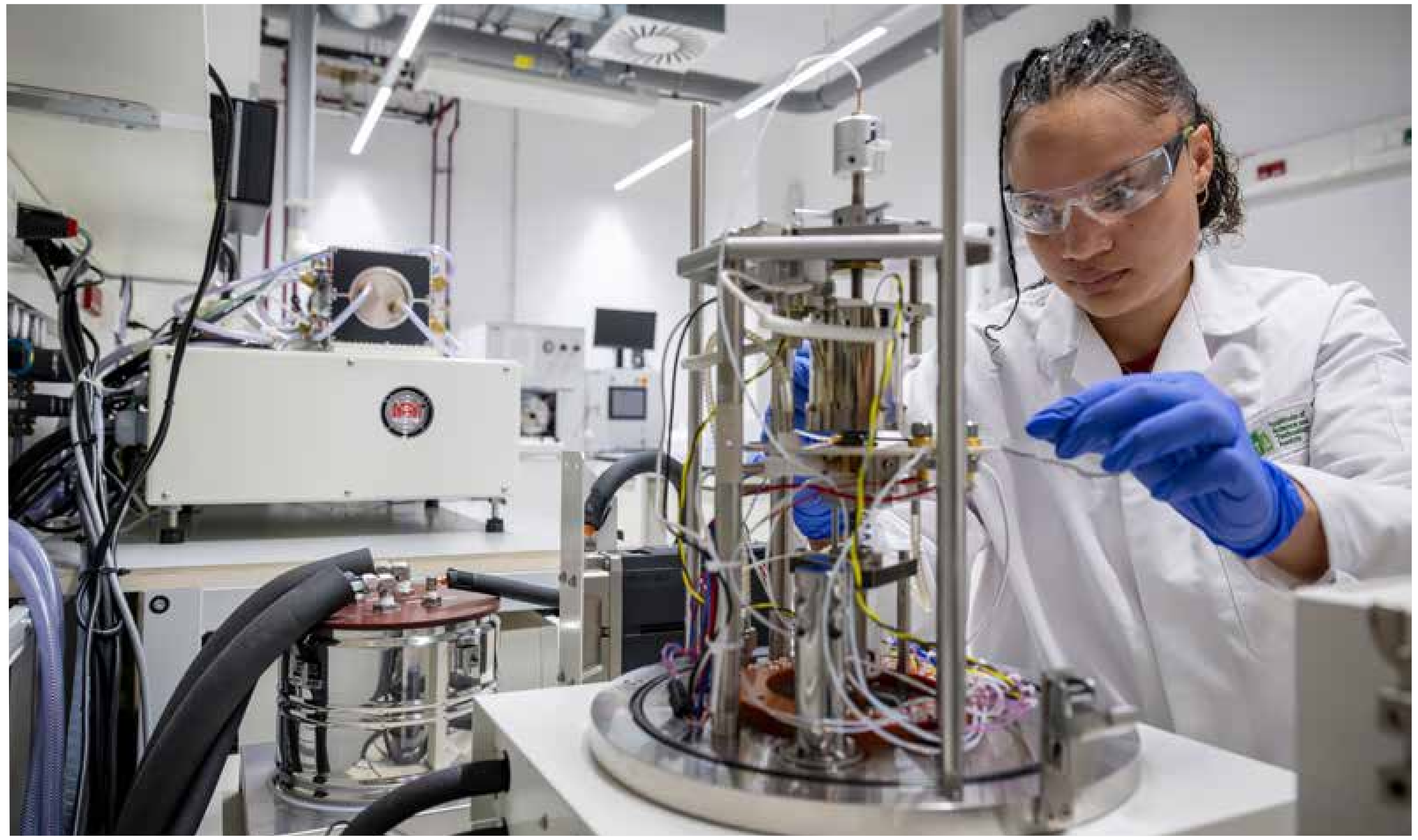
"We've united experts from various disciplines—from chemists to programmers—with the aim of developing the best possible tools," Warinner says. In particular, the aim is to learn what the most important properties for potential natural products are and how they can find systematic processes for filtering out promising sequences. Other open questions are centred around the prediction of biological activities of natural products.

"Answering these questions and developing the necessary tools takes a lot of time," Pierre Stallforth explains. "But once things are up and running smoothly and reliably, the platform will help us to extract an enormous amount of information from our data." Here, the long-term funding from the Werner Siemens Foundation is worth its weight in gold. "Many other funding instruments are limited to two- or three-year terms—and it's simply impossible to develop foundational platforms like this in such a short time span."

Samples from across the globe

Alongside these developments, work on the samples of calcified dental plaque continued. The researchers recorded data from an entire series of Neanderthal skeletons, thus significantly expanding their archaeological collection of genetic material. "At the start, most of our samples came from Europe," Christina Warinner explains. "But now we have new projects in various locations—in Asia, for example, as well as a major study in Oceania." The long-term aim is to obtain data from as many ancient individuals as possible, enabling the team to examine global patterns in the biodiversity of ancient dental calculus.

The palaeobiotechnology project also has good news to report in professional matters: Christina Warinner was promoted to full professor with tenure at Harvard University. This new and prestigious position means that both she and Pierre Stallforth have permanent academic positions. "It's wonderful," Warinner says. "Now we both have a solid basis to further establish and expand on our work in palaeobiotechnology."



Researchers must ensure that every single detail is perfect if their thermoelectric materials are to have the desired properties and perform well.

A game-changing decision

Maria Ibáñez and her team at ISTA are making steady progress in their search for materials that can efficiently convert temperature differences into electricity. They also reached a major decision concerning the high-throughput equipment they've been planning: a specialised firm will now build parts of the system.

Fabricating thermoelectric materials is a complex and time-consuming process. The most minuscule changes are what determines whether or not a material has the right properties, and when researchers have to produce every new potential material by hand in their lab and then test it individually, progress is painfully slow. That's why physicist Maria Ibáñez at the Werner Siemens Thermoelectric Laboratory at the Institute of Science and Technology Austria (ISTA) has chosen a different strategy: she wants to use a high-throughput system that can fabricate and test a large number of materials in a highly automated process.

Ibáñez had originally planned on developing and constructing the custom-made, high-performance unit in her own lab. "But that proved to be problematic," she says. The work depended too much on a single employee: the first person hired to construct the high-throughput system took a job in the private sector, and then their replacement was ill for quite some time. "We lost both expertise and time," Ibáñez says.

Specialised Swiss firm

After this experience, she decided to seek an external solution for part of the system. Her search led her to Switzerland, where she found a company specialised in the construction of these kinds of highly complex devices. "I had various conversations with the people in charge there, we developed the platform concept together—and the agreement is that the firm will build the platform in the course of 2025," Ibáñez says. In the end, she's very pleased with her decision: "In some way, it was a step backwards, but I'm convinced the project is now headed in the right direction."

Parallel to this work, Maria Ibáñez and her team have also made major strides in researching and fabricating thermoelectric materials in recent months. For example, they conducted a study that demonstrated the production steps leading to differences in a material's purity—and hence differences in its thermoelectric performance. "This knowledge is crucial," Ibáñez explains. "Without it, we'd otherwise be doing guesswork when we analyse various parameters in the high-throughput device. In addition, the descriptions of these steps in some scientific publications aren't detailed enough, which means the results aren't reproducible."

Pellets from 3D printers

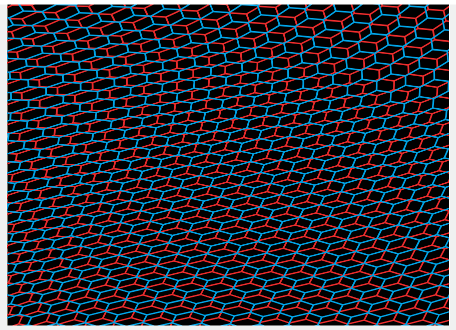
In another notable publication, the researchers worked with silver selenide (Ag_2Se) as an example material to demonstrate a production pathway that can be used to precisely control the microstructure of a composite material. They devised a three-step synthesis strategy: producing silver-selenide particles in a solution, cleaning and drying the particles into a powder, and then solidifying the resulting powder into a type of pellet.

In the high-throughput system, this solidification process is very time-consuming, which is why the ISTA thermoelectric team decided to modify a 3D printer, enabling it to print the pellets that the researchers then analyse for their thermoelectric properties. "The 3D printer is extremely fast, and we're saving material and energy by using it," Maria Ibáñez says. "Right now, we're using this method to fabricate materials that achieve record performance at room temperature."

More robust, less fuss

This new development also has consequences for the planned construction of the high-throughput infrastructure. The team's original idea was to convert their powder into a type of ink that could be sprayed onto foils. "But it takes a lot of time to find the right conditions to manufacture good layers for each material—which is what enables us to characterise the material properties," Maria Ibáñez explains. And so the team opted to develop inks for 3D printing instead. "Another advantage is that analysing the 3D pellets is both easier and less error-prone."

In sum, it seems the outlook is rosy for the thermoelectric project, and that the researchers will be able to fabricate and analyse a whole host of promising materials in future—materials that will lend new impetus to power generation and temperature control.



Thermoelectric materials

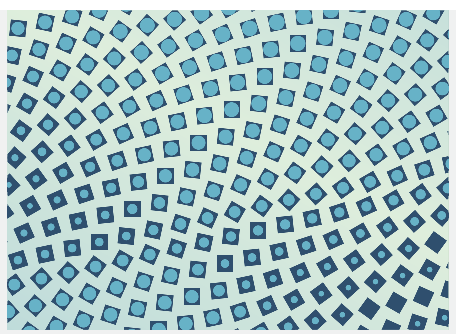
Whether in a computer or a refrigerator, on a windowpane or the human body: wherever temperature differences are found, they can theoretically be used to generate electricity. At present, however, the technology is inefficient and expensive. But now, physicist Maria Ibáñez and her research group at the Werner Siemens Thermoelectric Laboratory at the Institute of Science and Technology Austria (ISTA) are working to change this. They're seeking new materials that, thanks to precisely defined nanostructures, have the right properties to enable efficient, cost-effective power generation.

Funding from the Werner Siemens Foundation 8 million euros
Project duration 2020 to 2028
Project leader Prof. Dr Maria Ibáñez, Institute of Science and Technology Austria (ISTA)

Success in his blood

Whether as an elite athlete, a successful molecular biologist or a budding entrepreneur, Kevin Yim gives his all. Thanks to a University of Zurich MedTechEntrepreneur Fellowship in 2024, he founded his start-up company EVIIVE to market his efficient diagnostic and prognostic method for patients with sepsis and melanoma.

Former racing cyclist, present-day entrepreneur: Kevin Yim has developed blood tests for diagnosing various diseases.



From idea to company

The University of Zurich Entrepreneur Fellowships were created to support talented junior researchers who want to establish a firm on the basis of their research findings. Thanks to funding from the Werner Siemens Foundation, fellowships in the field of medical technology were added to the programme in 2018. Since then, a total of twenty-two junior researchers have received a MedTechEntrepreneur Fellowship and six new companies have been founded.

Funding from the Werner Siemens Foundation 10.67 million Swiss francs
Project duration 2018 to 2027
Project leader Prof. Dr Elisabeth Stark, Vice President Research, University of Zurich

Before Kevin Yim became a researcher and entrepreneur in Zurich, he was a competitive racing cyclist in his native Hong Kong. When he was twenty-two, he ranked among the top twenty racers in Asia—and realised he had reached his limit. But that was less of a problem for Yim, because he had already discovered a new passion while studying biology at the University of Exeter in England: molecular biology. Or more precisely, extracellular vesicles (EVs). Put simply, EVs are "words" that cells use to communicate with each other. Put in more scientific terms, EVs are nanometre-sized membrane particles that are released in large quantities from both healthy and pathological cells and that transmit a complex set of information to other cells.

Yim was fascinated, and he wrote both his master's dissertation and his PhD thesis on EVs. For this, he moved to the Institute of Experimental Immunology at the University of Zurich (UZH), where he also developed a novel test method for skin cancer and sepsis on the basis of EV analyses. The new method works with just a single drop of blood and delivers results within two hours—much faster than conventional blood tests that also require venous blood sampling.

Resilient and tough

When asked what has helped him most in his fast and successful transition into the world of science, he answers: "I'm pretty resilient and tough." He explains that competitive cycling taught him that his own performance won't guarantee a victory every time. "Like all researchers, some of my experiments fail, but I pick myself up again and carry on."

He hit the first major roadblock in his research when he had just begun work on his PhD. His original idea had been to develop an EV test for infections in newborns, but he was unable to obtain the blood samples he would have needed. So he switched to the Cancer Immunobiology Lab headed by UZH professor Richard Chahwan, where he was able to test his EV-based diagnostic method on cell samples from adult skin cancer patients and then later again in a sepsis study at the University Hospital Zurich (USZ).

The patients participating in the USZ study had all been admitted to hospital with unknown infections. Yim's diagnostic method achieved very good results: "Our method correctly identified that in ninety-three percent of the cases the patient examined would develop septic pneumonia."

Real life and practical application

After completing his doctorate, Yim wanted to enter "real life", as he says with a wink. Specifically, he wanted to make his innovative method widely available, so he applied for a UZH MedTechEntrepreneur Fellowship. Endowed with one hundred thousand Swiss francs, the scholarship—which is financed by the Werner Siemens Foundation—equips researchers with the knowledge and skills they need to set up their own business.

In the meantime, Yim has not only created a diagnostic kit for sepsis with his method: he's also developed a prognostic method to predict how successful a standard therapy for melanoma will be. "In cases of skin cancer, doctors can use our kit to learn whether a patient will respond well to a standard therapy before the treatment even begins," Yim explains. In addition, it can be used as a simple way to monitor the therapy's success. "The method can, if necessary, be used on a daily basis to see if the therapy is effective, or if the cancer has returned."

Setting up EVIIVE

In October 2024, Kevin Yim, Professor Chahwan and other partners founded the start-up EVIIVE. Financing has been secured for the next fifteen months—which theoretically means Yim would have time to relax a little. "Oh, I never really relax," he says with a laugh. Obtaining the next round of financing is already keeping him busy: EVIIVE has to deliver yet more data from clinical trials to convince venture capitalists that the firm is worthy of investment.

Yim estimates it will take another eighteen months for the diagnostic and prognostic kits to be ready for market—a market that the future CEO envisions as very large: "First we're planning to launch a melanoma test centre in Switzerland, then one in the US, then in Australia."

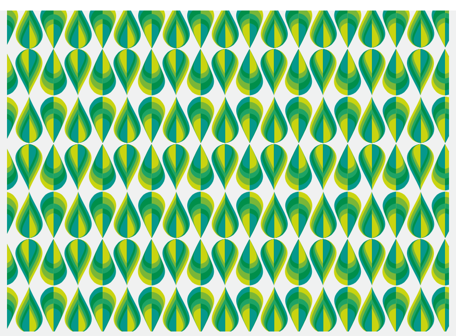
Support systems

Setting up a business is an exciting and challenging undertaking. When asked who the most important person was for him on this rocky path, he answers, "My wife," adding that there were naturally also mentors, professors, business partners and other kinds of support that were very instrumental and appreciated. But because a young entrepreneur has to knock on a lot of doors—mostly to hear: sorry, not interested, too soon, a bad fit—maintaining the energy and motivation to keep trying is essential. "For that, a partner is indispensable."

Preventing guess-work in climate policy

Researchers in the CERES project have hit the ground running. The various project teams have already prepared or published several scientific studies—including one in top-tier journal *Science* that identifies the most effective climate policy measures.

The CERES researchers analyse and model their data in their own data centre.



FutureLab CERES

The FutureLab CERES team at the Potsdam Institute for Climate Impact Research (PIK) are seeking to understand which policy instruments best promote the sustainable management of natural resources. The spotlight is placed on countries like Brazil, Indonesia and the Democratic Republic of the Congo, where biodiversity is exceptional, where climate change is a particularly large threat—and where huge revenues are generated through the extraction of fossil fuels and other natural resources.

Funding from the Werner Siemens Foundation 10 million euros
Project duration 2022 to 2031
Project leader
Prof. Dr Ottmar Edenhofer, co-director and chief economist at the Potsdam Institute for Climate Impact Research (PIK), Potsdam bei Berlin

In the CERES project, which is financed by the Werner Siemens Foundation, researchers are analysing which policy instruments can genuinely make a contribution to the sustainable management of global public goods. The main questions address the political measures that would effectively protect our climate, biodiversity, oceans and soils—and what stops policymakers from enacting these measures.

Research in the project is divided into four work packages, all of which have made significant progress in just a short time. Last summer, a research group led by Nicolas Koch from the Potsdam Institute for Climate Impact Research (PIK) and the Mercator Research Institute on Global Commons and Climate Change (MCC) in Berlin, from the division "Machine learning-based ex-post policy evaluation", even published a study in renowned journal *Science* that gained international attention.

A lack of good measures

The study compared and evaluated the effectiveness of fifteen hundred climate policy measures that have been enacted over the past twenty-five years—in no less than forty-one countries on six different continents. The team benefitted from a collaboration with the Organisation for Economic Co-operation and Development OECD and drew on data that had not yet been published. For the study, they divided the various measures into four sectors: buildings, electricity, industry and transport.

"We were looking for successful policy interventions that achieved a drop in emissions in one of the sectors by at least five percent," Nicolas Koch explains. The team discovered that, in the past two decades, only sixty-three cases had met the requirement. Koch believes the rather poor result indicates that climate policy measures are often—or often have to be—tried out without enough solid scientific evidence.

However, there's also good news: successful policy measures can have a strong impact. The analysis demonstrated that effective policy packages reduced targeted emissions by nineteen percent on average. Some—like the instrument mix in the UK's electricity sector—achieved a reduction of forty to fifty percent within just a few years.

Policy mixes make the grade

The researchers identified interesting and significant features shared by all sixty-three success stories: for instance, in not one single case did a ban alone—of coal-fired power plants, for example, or combustion engine cars—lead to a meaningful emission reduction. "Major reductions in emissions were found only when several measures were introduced at the same time," Nicolas Koch relates. Concerning the electricity sector in the UK, policy makers set a minimum carbon price and combined this measure with a government programme to foster renewable energies and a timetable for phasing out coal-fired power generation, which is particularly detrimental to the environment.

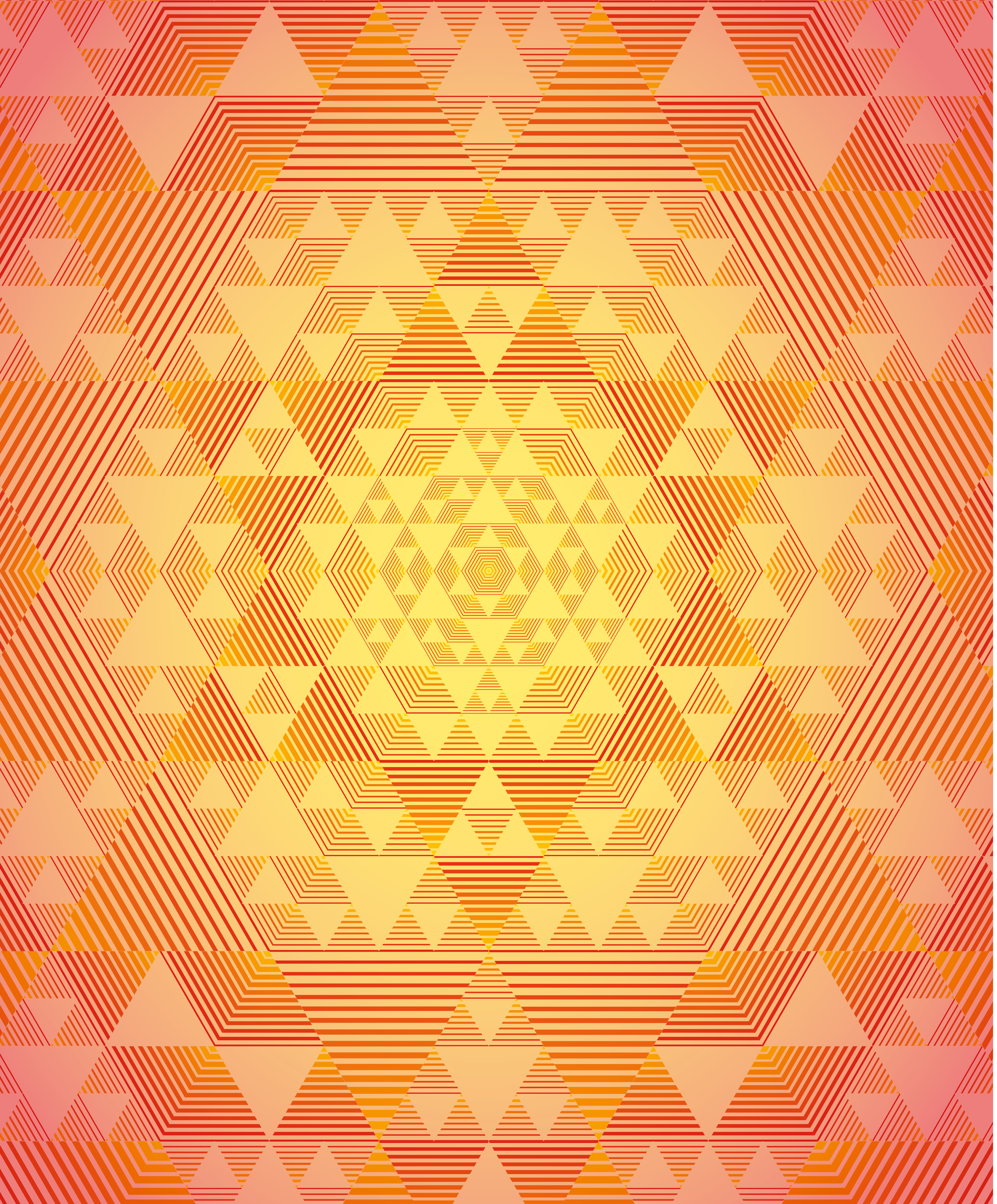
The study also revealed notable differences between industrialised and developing or emerging countries, depending on the sector. In the electricity sector, for example, pricing instruments in developing countries yielded only negligible reductions in emissions, probably because their electricity markets operate very differently. "In these countries we tended to see a positive effect brought about by subsidies and regulations like quotas for the electricity mix," Koch says.

The CERES study is the largest-ever evaluation of climate action measures that is based on established statistical methods. As a result, it closes part of the evidence gap that gave governments no other choice than taking a stab in the dark when setting policy. As part of this effort, Nicolas Koch and his team have developed an interactive web tool where climate protection officers and other decision-makers can study the sixty-three effective interventions and incorporate them into their own strategies and projects.

Other studies in the pipeline

Indeed, providing policymakers and industry actors with information critical to the sustainable management of global public goods is a declared aim in the CERES project. There are plenty of approaches that can be taken to achieve their goal, as evidenced by the many other papers that the team either prepared or published last year. As just one example, an article exploring the impacts of VAT reform on EU foodstuffs has been submitted.

Other examples include an investigation that aims to quantify the existential risks of global warming as well as a study presented at a workshop that demonstrates how our perceptions and behaviours are influenced by the ways in which climate change is portrayed. And finally, a publication on differences between how younger and older people view climate change is currently in the home straight.



Who we are

When it's "halfway decent outdoors", that's where Gianni Operto can be found.

"I want to understand how things work."

When Gianni Operto goes about doing something, he does it right. And in the WSS Scientific Advisory Board, which he chaired for the past twelve years, he poured his heart and soul into "his" projects. Now, upon reaching the mandated age limit for the Board, he's passing on the torch. In the following interview, he discusses his career, his time at WSS and his plans for the future.

Gianni Operto, you celebrated your seventieth birthday last March and are stepping down as Chair of the WSS Scientific Advisory Board, in accordance with the Foundation's statutes. Over the course of your career, you championed projects in the area of sustainable power generation. Are you satisfied with the progress we've made so far in the energy transition?
Not entirely. Although solar and wind power have gained momentum—and even conservative circles now support the energy transition—in Switzerland, the switch to renewable energies has repeatedly been hampered by something engrained in Swiss culture: popular opposition. Time and time again, efforts to expand power generation from new renewable energy sources have been torpedoed by some false, oftentimes very flimsy claims. That solar panels are reflective and the glare will disrupt local fauna, for example, or that tapping into deep geothermal energy will inevitably trigger earthquakes. All the while, the real problem is climate change. It's scientifically proven that global warming is by far the main driver in loss of biodiversity—not solar panels or wind turbines. These "environmentalists" should be reviewing their priorities, as it's crucial that the energy transition is accomplished as quickly as possible to mitigate the effects of climate change.

How do you think the energy transition can be realised?
Through a mix of energy sources, especially hydropower, solar, wind and geothermal energy, and a generous amount of storage capacity as a buffering mechanism. I'm particularly optimistic about geothermal energy, the technology is much farther advanced than many people in politics and society are aware. And I'm also convinced we'll no longer rely on large production centres to provide the energy supply for industrial needs and households. Rather, we'll be seeing a marked shift towards distributed power generation and supply.

Today's power system can't cope with high volatility in incoming power and distribution—yet the energy supply from solar plants and wind farms isn't programmable.
In the past, consumers have used power indiscriminately—on the spur of the moment, as it were—and production and distribution were designed to follow this demand. The system worked well. However, the precise system control of in large, new renewable energy plants isn't achievable efficiently. That's why, more and more, we will also have to control consumption, which is increasingly feasible thanks to digital communication. In addition, large storage capacities are already being added as buffer mechanisms. In this scenario, geothermal energy would be a good, stabilising baseload source for a secure and cost-effective energy supply. Depending on demand, we could tap into the heat from the Earth's interior to a greater or lesser extent in summer and in winter.

"For me, there were never really certain things to do on certain days."

It's clear that you're one-hundred percent committed to renewable energies?
Well, my "problem", as it were, is that I'm incredibly interested in so many things, mainly in the natural sciences and technology. I want to understand how everything works, and my fascination for technical mechanisms dates back to my childhood. Still today, I have a book called *How Does It Work?* that I had repeatedly asked for when I was a child—and that I eventually got.

Your inquisitive mind has stood you in good stead over the last twelve years as Chair of the WSS Scientific Advisory Board. Especially at the start of your tenure, you and your four colleagues had to go out and actively seek innovative research projects for the Foundation.
Yes, but in the meantime, most higher education institutions have built up and professionalised their staff and services for third-party funding. And now, institutions increasingly contact WSS with visionary ideas that have high potential—like the development of a single-atom switch, which has the potential to revolutionise the semiconductor industry.

The Foundation's centennial anniversary in 2023 made WSS and its policy of funding large, visionary projects more widely known. What was the most difficult part about selecting the projects to be funded?
To respectfully say no if we didn't believe in a project. We venture capitalists who are familiar with the concept of "ethics" have the following rule: the second-best answer you can give a young entrepreneur is a quick "no". As Chair of the Scientific Advisory Board, I upheld this principle when I had to deliver bad news. I was always very careful to be respectful, but still very clear.

WSS project funding is a non-recuperable contribution, and supported researchers aren't obliged to deliver defined results. However, WSS maintains close contact with the researchers, paying regular visits to their labs and institutes. What advantages do you see in this funding practice that is unique to WSS?
The USP of the Foundation's model is the long-term nature of the project funding offered. Because we provide generous, secured financing for roughly ten-year periods, the project leaders can concentrate on the most important tasks, in particular building an outstanding team—that's a core issue that we discuss transparently with project leaders in one-on-one discussions. This aspect is important because we want the money to be invested in excellent researchers, not in buildings. On another note, we want to increasingly promote dialogue between existing project leaders and find ways of creating synergies between projects.

During your career, you built up a large, diverse network. Is networking something you enjoy doing, or do you see it more as a rather regrettable necessity?


Gianni Operto says working on the Scientific Advisory Board of the Werner Siemens Foundation was a wonderful experience.

I've always done what I enjoy doing. My cell phone has reached capacity with the some six thousand contacts in my address book, and the only way you can have such a large network is if you enjoy talking to people and are willing and able to listen to them. But then, the real work always starts after meeting someone. You also have to cultivate these contacts.

That you have such a large network is also due to the fact that you've worked in very different industries. Let's take a brief journey through the key positions. You started out as a young ETH graduate with a degree in mechanical engineering, and you chose to start working in industry instead of pursuing a doctoral degree, as your professor had recommended. Was it the right decision in retrospect?
Yes, absolutely. The job I took at ABB led me to taking on incredibly interesting work in countries all over the world. That kind of career was a dream come true for me as a young engineer. The fact that I didn't hold a PhD was never a problem.

Not even when you were the only person on the WSS Scientific Advisory Board who neither has a PhD nor was a professor?
Throughout my professional career, I always had a very close relationship to the world of academia and research. Not having a PhD was never an issue when I started something new, and the same goes for my role at WSS. In rare cases, however, when I would introduce myself as Gianni Operto in German-speaking academic circles, it sometimes caused brief confusion. A few people just called me "Dr Operto" straightaway, or they would ask in a roundabout fashion who my PhD supervisor was. But it was never a problem.

In the 1990s, you switched to the City of Zurich electric utility, a public company, where you led the transition to renewable energies and energy efficiency. But instead of staying there until your retirement, you took another surprising decision and became a venture capitalist.
The first time I heard the word "venture capital", I understood about as much as a child does about the charging process of a two-stroke engine. But the idea of making temporary investments in new, innovative start-ups in the energy and environment sector was appealing. So I entered the business and participated in setting up three venture capital funds, the most recent of which being Good Energies, where, in 2007, I took over the investment division for future technology. Compared to the first two funds, it was the next step up: Good Energies invested four hundred million Swiss francs per year in a range of clusters like solar, wind, hydropower and green buildings.

What was it that made you decide to set up your own company, Cleantech Consulting, in 2011?
The short-term thinking focused on

maximising profits and the way decisions were made began to bother me more and more. I don't mean to criticise investment bankers per se, but some have absolutely no clue about technology and the pathways that will lead to market success. Instead, they get carried away by the most unrealistic ideas—cold fusion, for example—if someone promises amazing profits. With my technical background, I sometimes thought: why don't we just go to a casino in Las Vegas? The chances of winning there are higher. I didn't want to be on board when the whole thing came crashing down.

Your career has taken many different turns. Looking back, which role was the most rewarding?
Beyond doubt, the most interesting job in my career was at WSS. Because of the diverse responsibilities and the visionary projects that WSS could launch. And also because of my fantastic colleagues on the Scientific Advisory Board. It was wonderful. A gift.

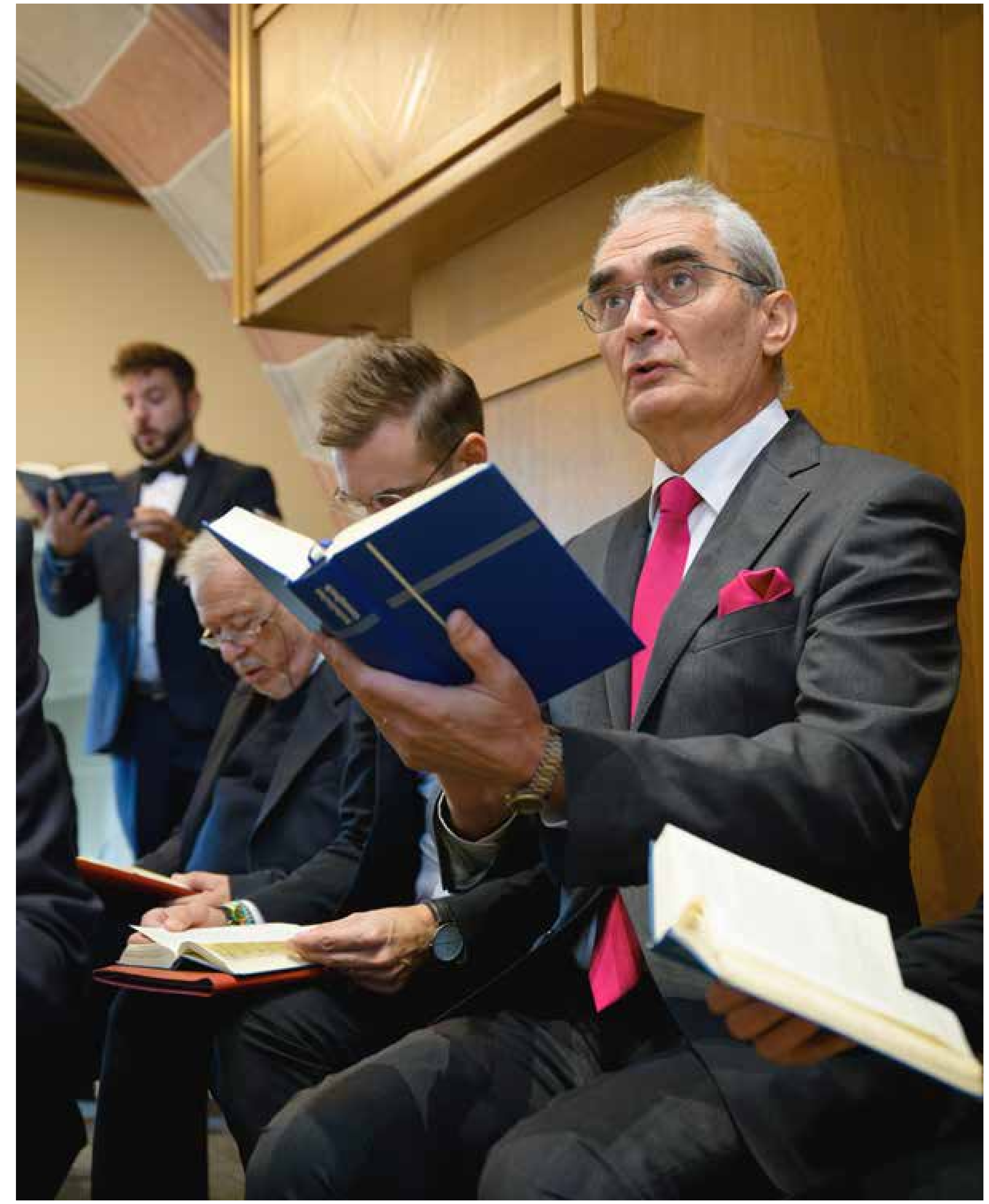
You're retiring at the start of 2025. What are your plans?
I want to be there for my family and support them when needed. By looking after my grandchildren, for example. I'm very fortunate in that my oldest grandson loves to go cycling with me. And the two younger ones almost get into a fight when I have to choose between them to go to the parent-child singing group. I also have a pile of books that I've been wanting to read for a long time. My wife has hiking plans. And then I'd like to devote more time to music. I sing tenor in several choirs.

How did you, a technical whiz, get interested in singing?
To answer that, I need to give some background information. My father had two years of schooling, my mother fifty percent more: she went to school for three years. But they nonetheless loved "bourgeois" music. My father had memorised the libretti from Italian operas. As a child, I would have loved to have played the piano, but my parents couldn't afford lessons. My voice teacher at secondary school in Zurzach noticed I could sing well and that I understood music theory. That motivated me to take the final exam in singing, which went well despite the fact that my voice changed. That's how I discovered singing, and I've stuck with it ever since.

What will a typical Monday look like when you retire?
For me, there have never really been certain things to do on certain days. I'm afraid, I'll continue to have a lot of ideas about how to spend my time. I'll write a list, as has always been my wont, and then prioritise my ideas. What I do in particular will also depend on the weather. When it's halfway decent outdoors, that's where I want to be. Usually on my bike.

Your parents were among the first Italian foreign workers to move to Switzerland for a job. You and your sister were born here. Your stellar career is somewhat unusual for the circumstances. How did your family background shape you?
To explain that, I again need to give a little background information. My sister and I spoke such good Swiss German at an early age that no one noticed we were Italians. But in the mid 1960s, the anti-immigration Schwarzenbach initiative was launched to limit the foreign population in Switzerland to ten percent. The public debate was very heated, and we often heard people grumbling about "dirty dagoes". It was incredibly hurtful, and we were afraid we'd have to leave Switzerland. Our parents did their best to support us by modelling their values, their sense of responsibility and their pride in their heritage.

What did that look like?
They told us stories about their native Piedmont, about the anti-fascist resistance movement—which both were active in—and about their core values: keeping your word, taking on responsibility, doing your best. During summer holidays at our grandmother's place, they borrowed cars from friends and relatives to show us the Piedmontese Baroque style. And they also taught us to be proud of our roots, that we had no need to bow down before anyone—and that includes the Swiss. Pride in what you are, standing up for yourself with dignity and confidence, and using your gifts to help others—these principles have always helped me overcome the many difficulties that a person can encounter during a lifetime.



Gianno Operto began singing as a boy—and still sings tenor in several choirs.

An illustrious addition to WSS

Professor Michael Hengartner is the new Chair of the WSS Scientific Advisory Board.

Michael Hengartner has been named Chair of the WSS Scientific Advisory Board. The molecular biologist, aged fifty-eight, is one of the most respected voices in Swiss research: he served as President of the University of Zurich and currently presides over the ETH Board, the body responsible for strategic management of the ETH Domain.

Outstanding research projects are generally not found waiting by the roadside. Seeking such projects, assessing their feasibility and, if necessary, asking critical questions and offering advice to improve them is the core mission of the Werner Siemens Foundation's Scientific Advisory Board. To execute this demanding work, Board members must be first-rate researchers—who are also experienced in project evaluation and who have access to an extensive network in the scientific community.

Professor Michael Hengartner fully meets the qualifications. Hengartner, who is succeeding Gianni Operto as Chair of the WSS Scientific Advisory Board, is a molecular biologist. During his active research career, he worked with the model organism *C. elegans*, a nematode, and was one of the world's leading researchers in the area of apoptosis, also called programmed cell death. From 2014 to 2020, he was President of the University of Zurich, Switzerland's largest university and, since 2020, has served as President of the ETH Board, the ETH Domain's management and supervisory body.

Finding the right people

Hengartner says he was delighted to receive the invitation from WSS. "It's a very meaningful role with high relevance to society—and I'm confident I can support the Foundation Board in seeking and finding worthwhile projects." He believes that WSS's practice of offering long-term project funding—and the associated willingness to take great risks—makes it one of the most unusual and interesting research funding organisations in the German-speaking world.

He adds that gauging the potential of these types of large-scale projects also takes much more than a quick look at a completed application form. "It's a similar situation to evaluating a start-up," Hengartner explains. "Although having a solid business or research plan is important, success will always depend heavily on personal qualities—those of the project leader and the team." Identifying people in the scientific community with the right qualities calls for the right kind of network—and engaging with candidates in person.

Foundations have greater freedom

Hengartner has been involved with science foundations for several years already, and he believes that these kinds of organisations represent a key, supplementary source of financing in addition to the basic funding offered by universities and through competitive public funding programmes. Although state funding—at least as it's done in Switzerland—is a successful model, science philanthropy is becoming more prevalent, Hengartner says. "In the past, Swiss foundations have traditionally supported music, art or sport. But in recent years I've observed that financing research has gained traction."

This trend is encouraging for researchers. Public funders like the Swiss National Science Foundation must adhere to strict rules concerning the allocation of public money, Hengartner says, adding that not every good idea will fit the bill. "But because foundations have such diverse missions, researchers have a greater likelihood of finding funds for highly specialised projects." In addition, he says foundations have greater freedom and can prioritise an individual research area or a specific goal.

Endowed chair in Zurich

Michael Hengartner's own story serves as a prime example of what private foundations can achieve. "If it weren't for foundations, I probably wouldn't be here in Europe," he says. Hengartner was born in St. Gallen, Switzerland, but his family soon left the country, settling in Quebec, Canada, where his father was a professor. Hengartner went to school in Quebec, studied biochemistry at Laval University and earned his doctoral degree in the United States, at the Massachusetts Institute of Technology (MIT) in Cambridge.

He worked and led a research group at the Cold Spring Harbor Laboratory in New York. "At some point, someone told me there was a new endowed professorship at the University of Zurich, and that, as a Swiss citizen, I might be interested." It was the Ernst Hadorn endowed professorship for molecular biology that had been instituted by Charles Weissmann, professor and co-founder of biotech company Biogen.

Up until then, Hengartner says he hadn't considered returning to Europe. "But the offer was very enticing—and we researchers go where we can get an interesting and secure position." And so, he emigrated to his home country, made his name in research—and is now doing his part to support outstanding researchers in the German-speaking world.

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.

Oliver von Seidel
Chair
Düsseldorf, Germany

Dr Christina Ezrahi
Member
Tel Aviv, Israel

Alexander von Brandenstein
Member
Hamburg, Germany

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 is an independent body that supports the Foundation Board in identifying suitable projects. Board members are responsible for reviewing and assessing the quality of proposals submitted to the Foundation.

Prof. Dr Michael Hengartner, Chair
President of the ETH Board,
Zurich/Bern, Switzerland

Prof. Dr Gerald Haug, Member
Max Planck Institute for Chemistry
Mainz, Germany, and
ETH Zurich, Switzerland

Prof. Dr-Ing. Dr h. c. Matthias Kleiner,
Member, former President of the
Leibniz Association, Berlin, Germany

Prof. Dr Bernd Pichler, Member
University of Tübingen, Germany

Prof. Dr Peter Seitz, Member
EPFL, Switzerland

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 five to fifteen 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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