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WERNER SIEMENS-STIFTUNG

Our mission

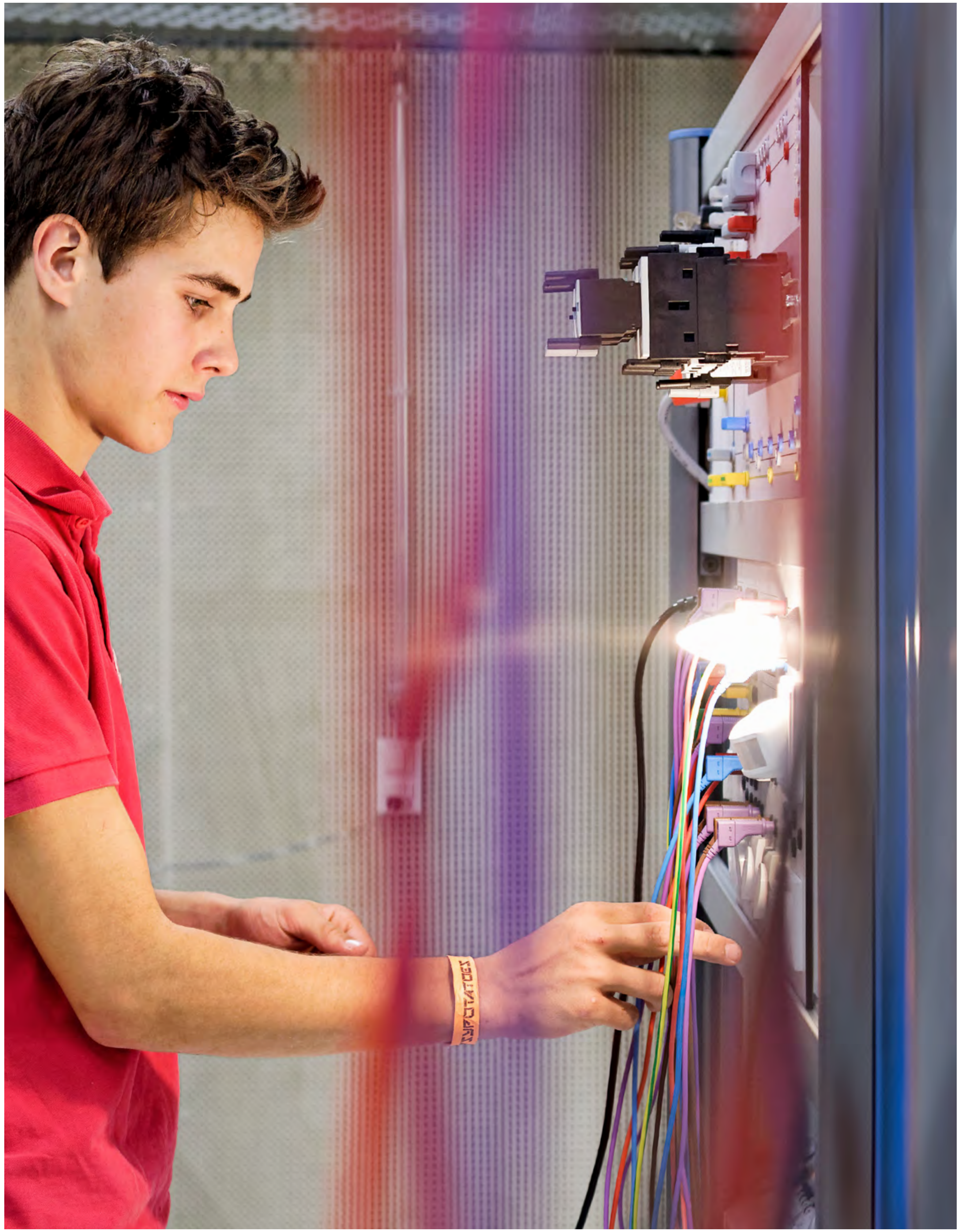
2017 report

Innovation and sustainability at Synthetic Biotechnolgy

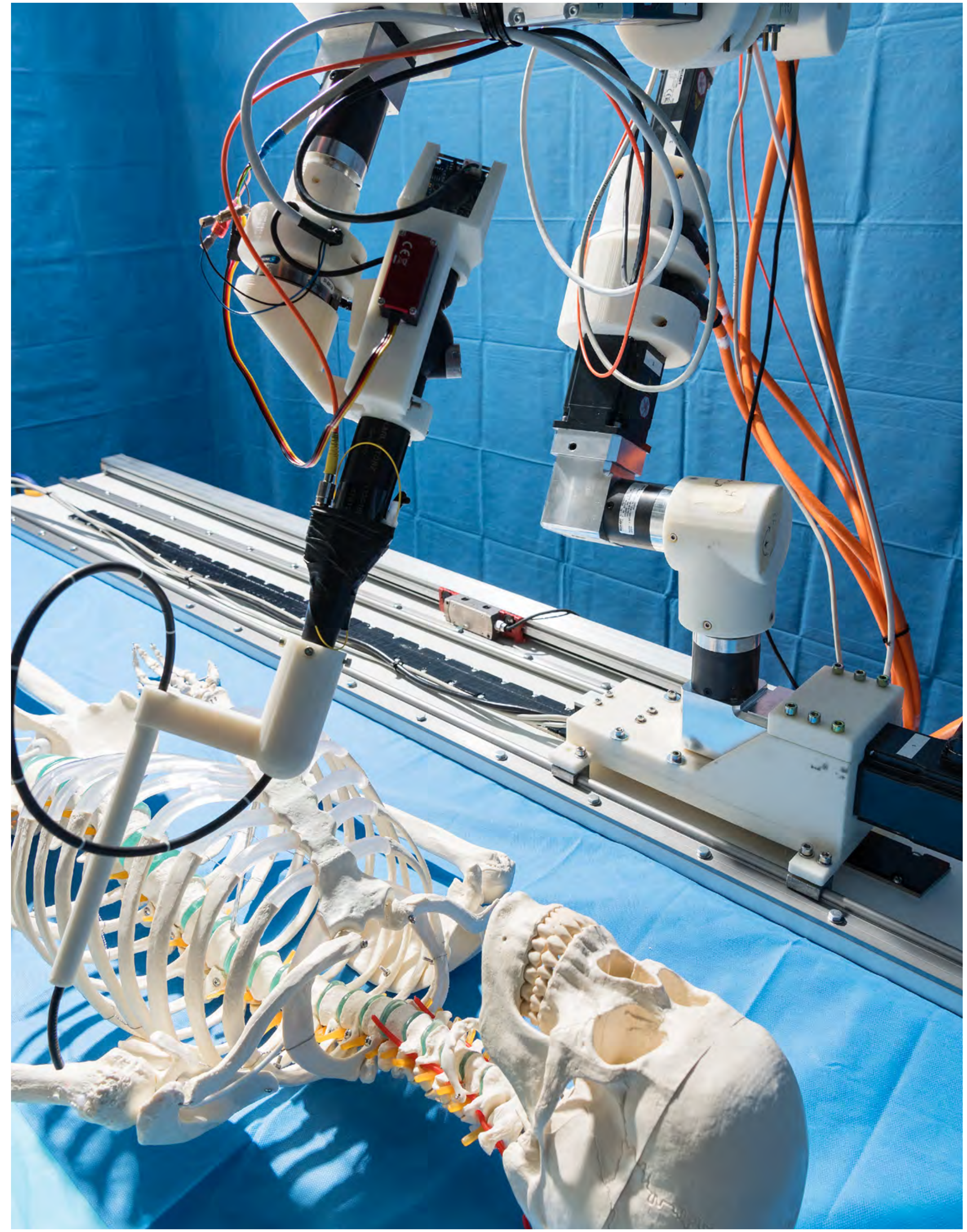
The world's most innovative research vessel

The microchip of the future

Deep geothermal energy



Promoting technical education and training



Operating on bones using laser technology

Fostering talent in the STEM subjects

Diagnostic medical imaging

Promoting innovation in technology and the natural sciences

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

Foreword

“What exactly is so innovative about the geothermic project you are financing?” This question, recently posed by a great-granddaughter of company founder Werner Siemens, met with a prompt response. “It’s quite simple,” we replied. “Geothermal research has the potential to solve the world’s energy problems.”

While that may seem a sweeping statement, it is precisely the goal we at the Werner Siemens Foundation have been pursuing for over ten years. We support projects that address the most pressing issues of our time—with a particular focus on projects that have the potential to translate into viable solutions in industry.

In the past, the Foundation has not put much stock in communicating its activities. This will soon change; after all, we finance many valuable projects, and we feel we need not be shy about letting people know. In the future, we plan to publish a yearly report to provide a succinct and engaging overview of the projects the Werner Siemens Foundation supports. We are now pleased to present you with the very first edition.

Informing interested persons and groups about the activities of the Foundation is the primary mission of this report, which is first and foremost dedicated to the descendants of Werner and Carl von Siemens. Indeed, that the Werner Siemens Foundation is able to support innovative projects is due to the far-sighted endeavours of Marie von Graevenitz and Charlotte von Buxhoeveden, daughters of Carl von Siemens and founders of the Werner Siemens Foundation, in 1923. Additional details on the history of the Foundation are presented on page 104.

Our report paints a fascinating portrait of a twenty-first-century pioneering spirit. We invite you to explore the innovative projects our Foundation is supporting—we believe you will find them full of promise and inspiration.

We thank you for your interest and hope you enjoy reading our report.

Gerd von Brandenstein
Chairman of the Foundation Board

Hubert Keiber
Chairman of the Board of Trustees

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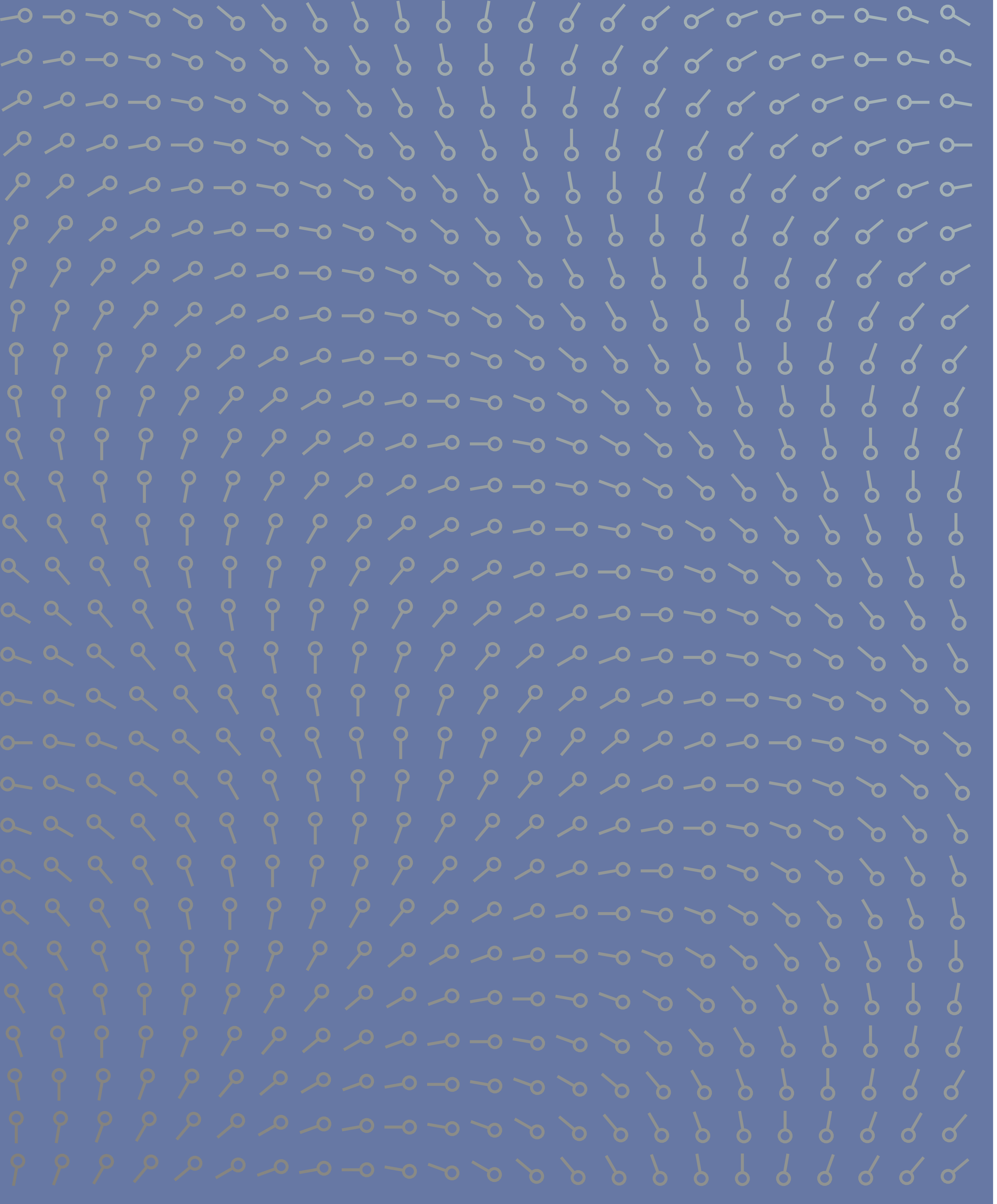
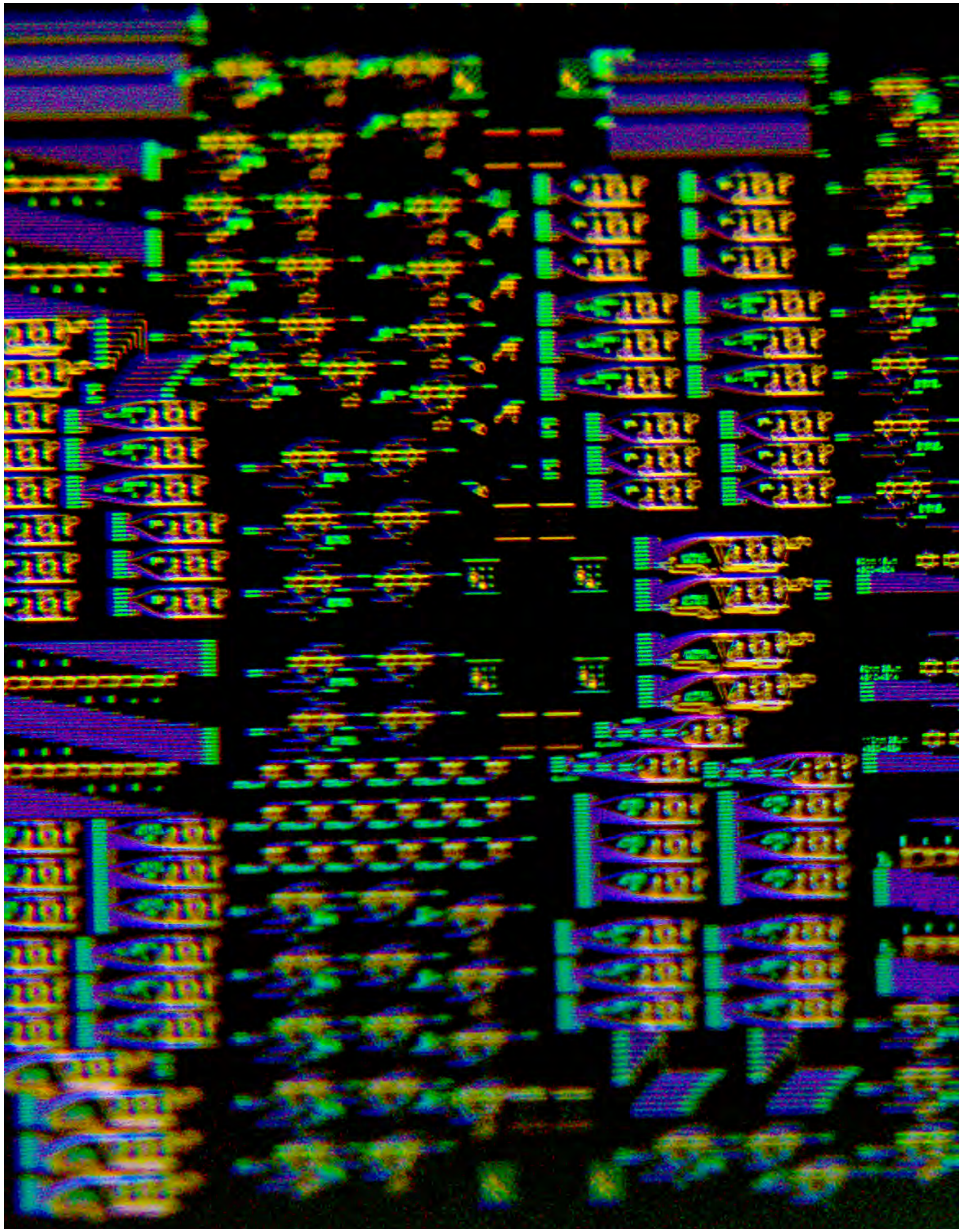
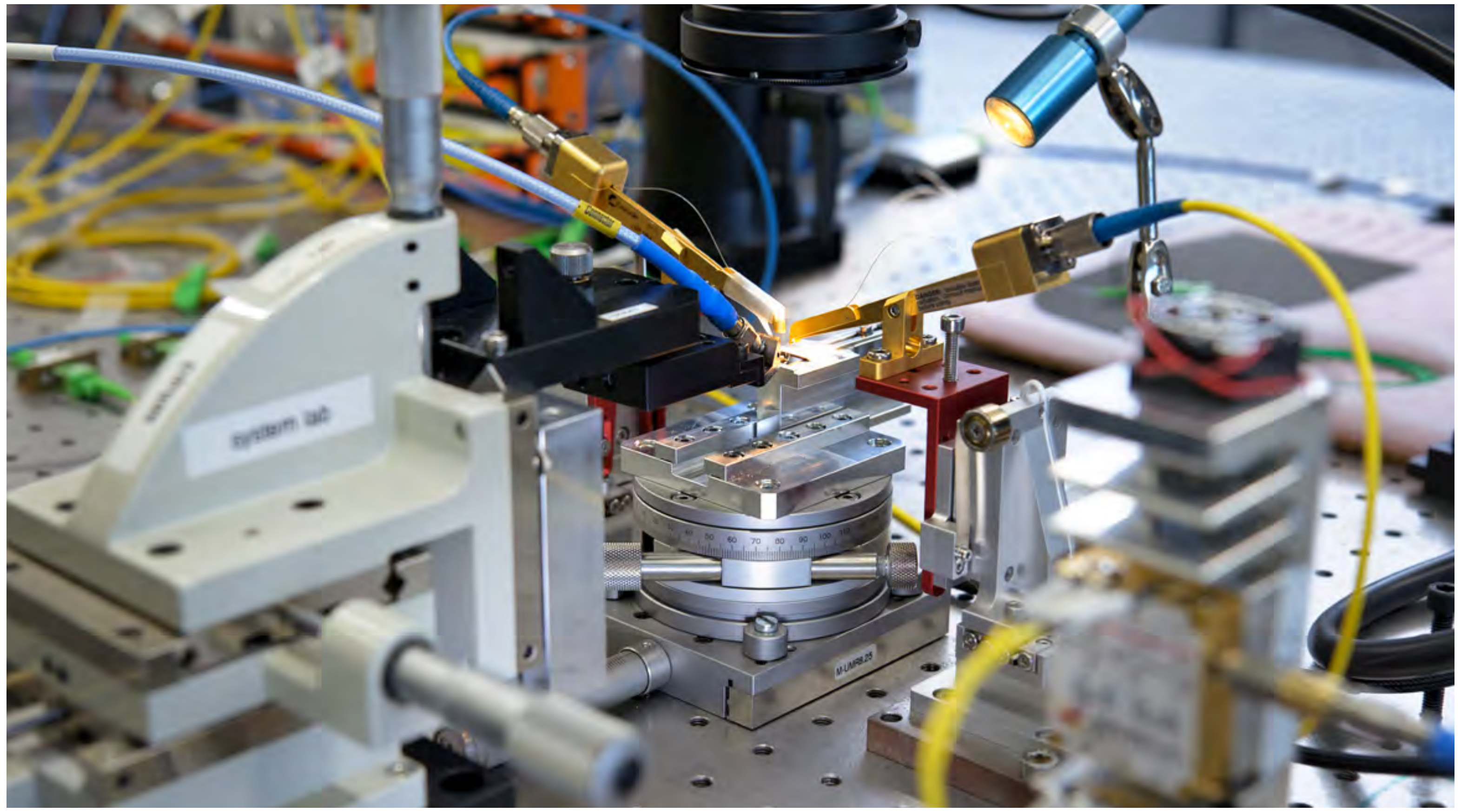


Revolutionary atomic-scale technologies

The microchip of the future



The bright blue-green pixels bring back memories of old computer games from the 80s. But this isn’t a game of Space Invaders—it’s the inner workings of the next generation of microchips, viewed under a microscope.



Everything is tiny: the superfine optical fibres above the yellow gripper arms switch the innovative chips (centre) on and off.

The microchip of the future

100 times smaller and 100 times more energy efficient: the microchip of the future. Researchers at ETH Zurich and the Karlsruhe Institute of Technology are exploring a fundamentally new type of microchip. And to support these innovations, the Werner Siemens Foundation is financing the Centre of Atomic Scale Technologies—potentially the first building block of the next Silicon Valley, located in the heart of Europe.

From espresso machines to huge mainframe computers, microchips are in almost every electronic device we use. In recent decades, the semiconductor industry has made great leaps, with chips becoming ever smaller and ever faster: today, we carry computers in our pockets that would have once filled an entire room. But now, the push to get even smaller has hit a wall: the smaller the components, the less efficient the chip—and too much energy is lost via leakage currents or heat loss.

Greater energy efficiency

“We will need even smaller and more efficient chips in future. And this calls for a fundamentally new technology,” says Jürg Leuthold, professor at ETH Zurich and head of the Institute of Electromagnetic Fields. Leuthold wants to revolutionise the semiconductor industry and has joined forces with Thomas Schimmel, professor at the Karlsruhe Institute of Technology, and an ETH Zurich colleague, Mathieu Luisier, to lay the groundwork for the microchips of the future. The ambitious goal? Chips that are 100 times smaller and 100 times more energy efficient—while at least retaining the current speed of data processing.

Dancing atoms

The researchers have developed a component for microchips that is just 10 nanometres long. But the fundamental innovation is less its size than that it functions at the single-atom level. The nano-component is made of silver and platinum pads that approach one another until only a tiny gap remains. Using minimal electrical voltage, a single atom is then slipped between the two pads, causing a digital signal to be emitted (cf. page 28). This principle is what gave rise to the name “atomic-scale technology”.

In the computers of tomorrow, millions of single atoms will be performing this dance to transmit signals. The basic principle is reminiscent of the human brain, with its fireworks of neurotransmitters and ions that shoot back and forth between billions of nerve cells. “The human brain requires very little energy to achieve its enormous processing power. We want to create comparably efficient structures with atomic-scale technologies,” Leuthold explains.

Amazing possibilities

The new nano-component being developed in Zurich and Karlsruhe is a veritable powerhouse. It can switch processes on and off, and is therefore suitable for use in all electronically steered devices. It also processes and stores data. “It’s the smallest possible storage unit imaginable. As such, we are navigating the borders of physics,” Leuthold maintains.

But the developments aren’t limited to new frontiers. The tiny chip is also a modulator that can transform electrical signals into light signals and vice-versa—an extremely useful feature for transmitting data in fibre optic cables. For instance, when sending signals from a cell phone or a computer, the nano-components can be transformed into optical (photonic) signals, which are reverted to their original form when received. If the nano-components are shunted by the million, they could make a major contribution to managing the continually increasing flow and ever-faster transmission of data in the internet.

Asia calling

The research alliance between Zurich and Karlsruhe is now united in the new Centre of Atomic Scale Technologies. Although the centre is new, the research groups involved were predestined for the task at hand. Thomas Schimmel is a pioneer of electronic circuits at the level of the atom, and Jürg Leuthold has demonstrated in his past research that photonic switches are possible at the atomic level. Moreover, Leuthold was the first researcher able to place both optical and electronic switching elements on the same chip.

As such, it comes as no surprise that major firms from the Asian semiconductor industry have expressed great interest in Jürg Leuthold's research. But the Zurich professor has another aim in mind: "The next Silicon Valley should be in Europe. And now, thanks to the Werner Siemens Foundation, we can take on a leading role in semiconductor electronics." To begin its work, the Centre of Atomic Scale Technologies is using initial Foundation funding to create 14 positions for PhD candidates and postdocs, and to purchase additional equipment to analyse and optimise nano-components.

Industrial application

The nano-components cannot be seen with the naked eye. When viewed under the microscope at Jürg Leuthold's ETH Zurich lab, the rows of chips are reminiscent of the colourful pixels in old computer games like Space Invaders.

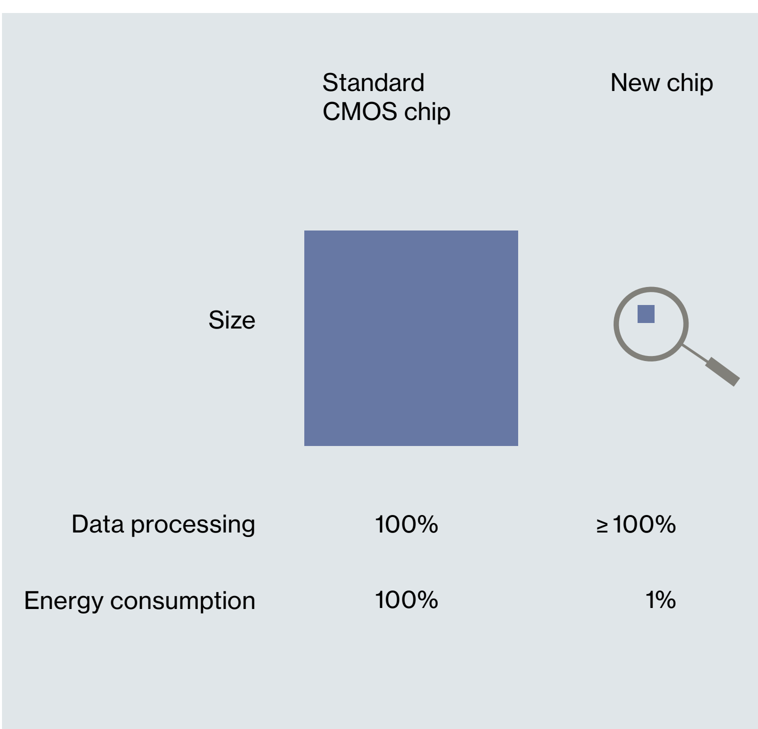
Researchers are, however, less interested in the visuals. Currently, they are testing numerous versions of chips, searching for the optimal order for the individual nano-components and the most suitable materials for production. And at the same time, the theoretical research group under ETH Zurich professor Mattieu Luisier is testing the new creations in comprehensive simulations at the Swiss National Supercomputing Centre in Lugano.

Partnering with industry

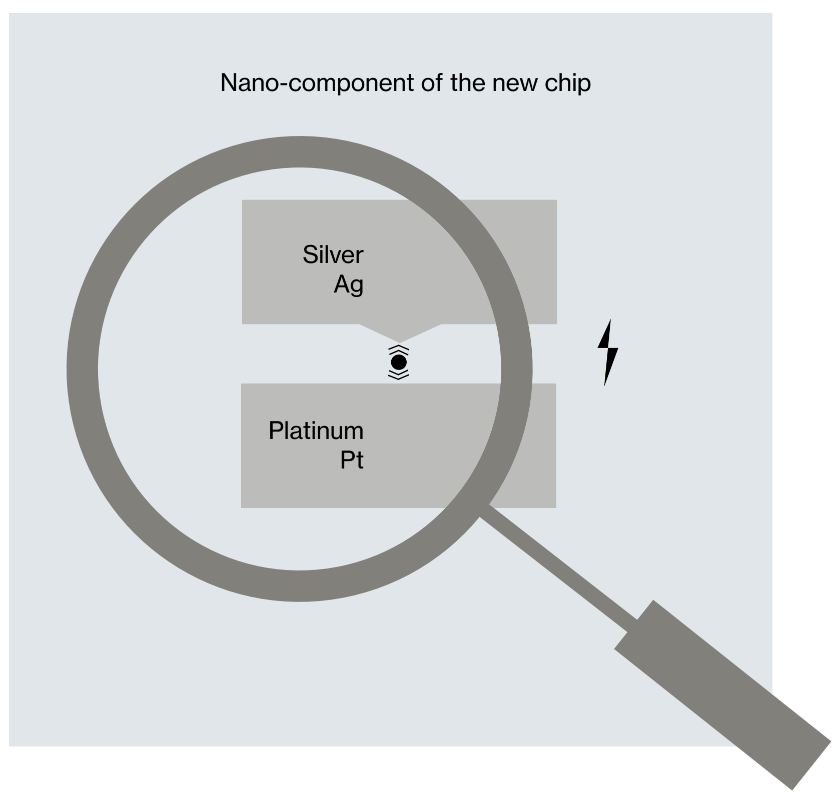
By 2021, the researchers aim to have laid the theoretical and technological groundwork necessary to create a prototype processor with 20 single-atom components. By 2025, they plan to have complex processors ready for production. The ultimate goal is to integrate the new components into common silicon chips (CMOS chips), but the researchers also see potential for use in artificial intelligence, machine learning and autonomous systems.

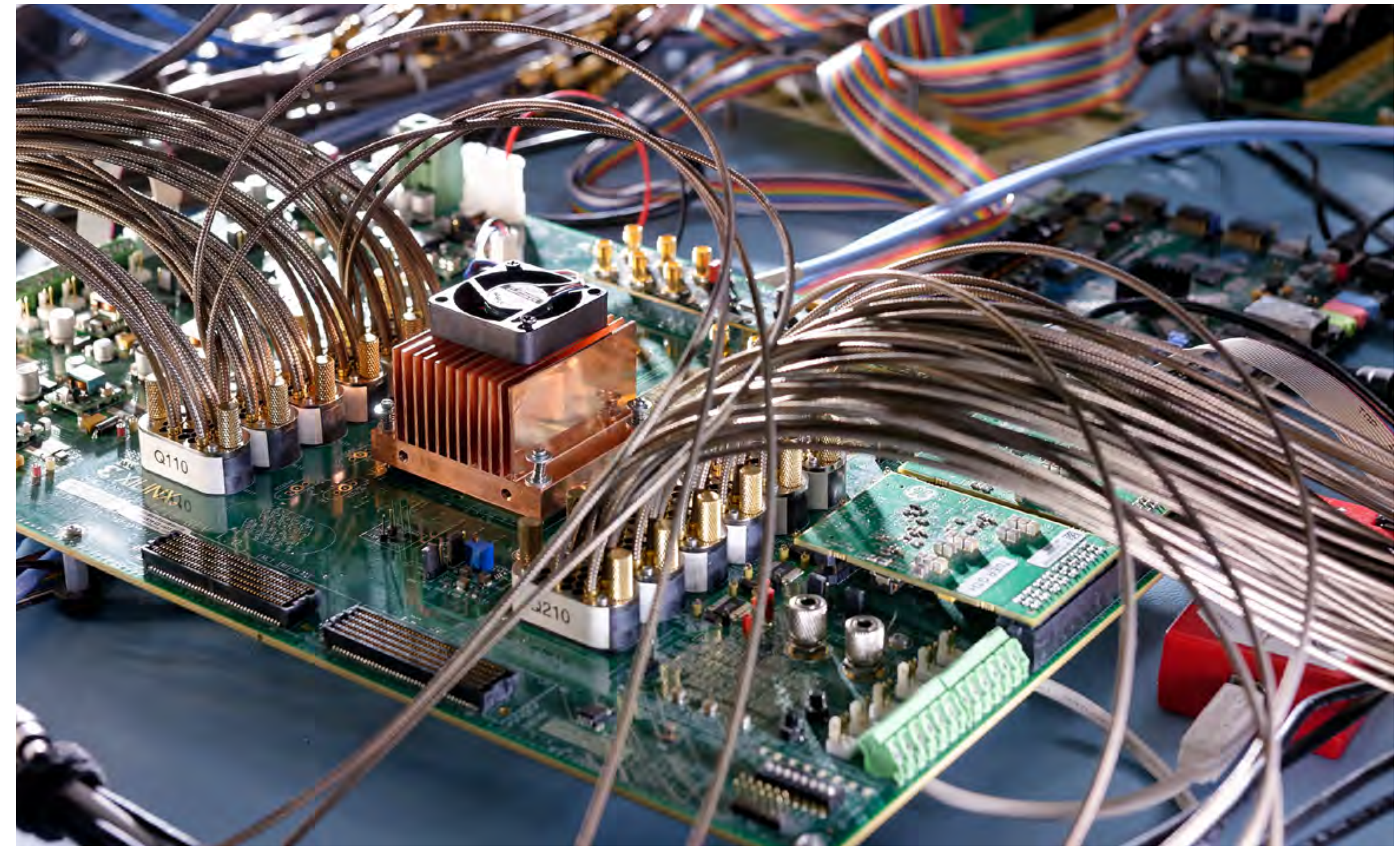
To make the dream of a European Silicon Valley reality, the team will soon need strong partners from industry. To be sure, there should be plenty of interest: the project in Zurich and Karlsruhe holds great promise and has the potential to revolutionise microelectronics—and our everyday electronic devices.

The new chip will be 100 times smaller than standard CMOS chips, yet able to process at least as much data while consuming much less energy.



Minimal electrical voltage is used to slip a single atom between a silver and a platinum pad, causing a digital signal to be emitted.





Standard chips (above) are energy guzzlers compared to the single-atom optical switch.

Professor Jürg Leuthold, head of the Institute of Electromagnetic Fields at ETH Zurich

At the vanguard

Jürg Leuthold wasn't interested in taking over his father's textile factory—a good thing for modern telecommunications. In his work as a physicist, Leuthold develops innovative technologies that have not only caught the attention of the global tech community—they have been further developed and are now standard elements in everyday devices.

The instructions were as brief as they were demanding: "You can go about your research as you like. But in two years, your name has to be known throughout the global telecommunications community." These were the orders Jürg Leuthold received from his boss when he began working as a postdoc at Bell Laboratories in 1999. Bell Labs, in the US, was already *the* institution for state-of-the-art technological research that translates into marketable electrotechnical and telecommunications products.

Jürg Leuthold's daunting task was to develop a chip able to process data faster than any other chip on the market. All earlier attempts had failed, so the pressure was on. "I was definitely in the hot seat, and my boss stopped by every two weeks to check if my calculations were finished and to see if we could create a prototype," Leuthold recalls. But Leuthold remained true to his roots and, with Swiss precision, took seven months to complete his calculations. It paid off: a year after he took on the position, when he was 34, Leuthold presented an innovative optical chip at a global conference for fibre-optic communications.

The chip not only broke the world record for fastest data processing; it came at the right time. It was at the turn of the century and the first music services (such as Napster) were founded and the amount of data in the internet began to increase exponentially. But for Jürg Leuthold, the chip mainly meant mission accomplished: he had become a name in the telecom scene. A few days after the conference, his boss presented him with a company credit card—to set up his own lab.

The repairman's apprentice

Jürg Leuthold comes by his technical prowess naturally. He grew up in rural Toggenburg, in eastern Switzerland, where his father owned a textile factory in the Neckertal region. As a child, Leuthold paid close attention when the repairman serviced the machines, and he took over this task when he was a teenager. But Leuthold didn't want to run the textile factory. "My desire to find answers to fundamental questions was too great. I wanted to know what holds the world together. I wanted to understand what light is," he recalls. He found answers during his physics studies at ETH Zurich, and he soon trained his eye on photonics, the partial area of physics that deals with the optical processes behind transmitting, storing and processing information. At the time, it was a field in which numerous fundamental questions remained unanswered. And a field that held great potential to apply research findings in industry. In short, it was the perfect setting for Jürg Leuthold. For his doctoral thesis, he helped develop processors that function on the basis of light (instead of electrons) and that are thus faster. His work was noted by technology firms, which soon led him to Bell Labs. The chips Leuthold developed there served as a model for later iterations; in slightly different form, they are now used in most wide area networks of fibre-optic technology.

Individuality as the key to success

His success and his experience at Bell Labs taught Jürg Leuthold a valuable lesson: everyone has his or her own approach to achieving a goal. While some researchers want to experiment with prototypes in the lab as soon as they can, others prefer to calculate a little longer. A healthy diversity of approaches is something Jürg Leuthold now encourages in his work as professor and head of the Institute of Electromagnetic Fields at ETH Zurich. "I give my team tasks and responsibilities, but not instructions. They have the freedom to find their own way, although procedures are always critically examined."

His own path led him from Bell Labs to Germany, where he took over as head of the Institute of Photonics and Quantum Electronics at the Karlsruhe Institute of Technology (KIT). Nine years later, he returned to Switzerland and his alma mater, ETH Zurich.

Awards, honours and 25 patents

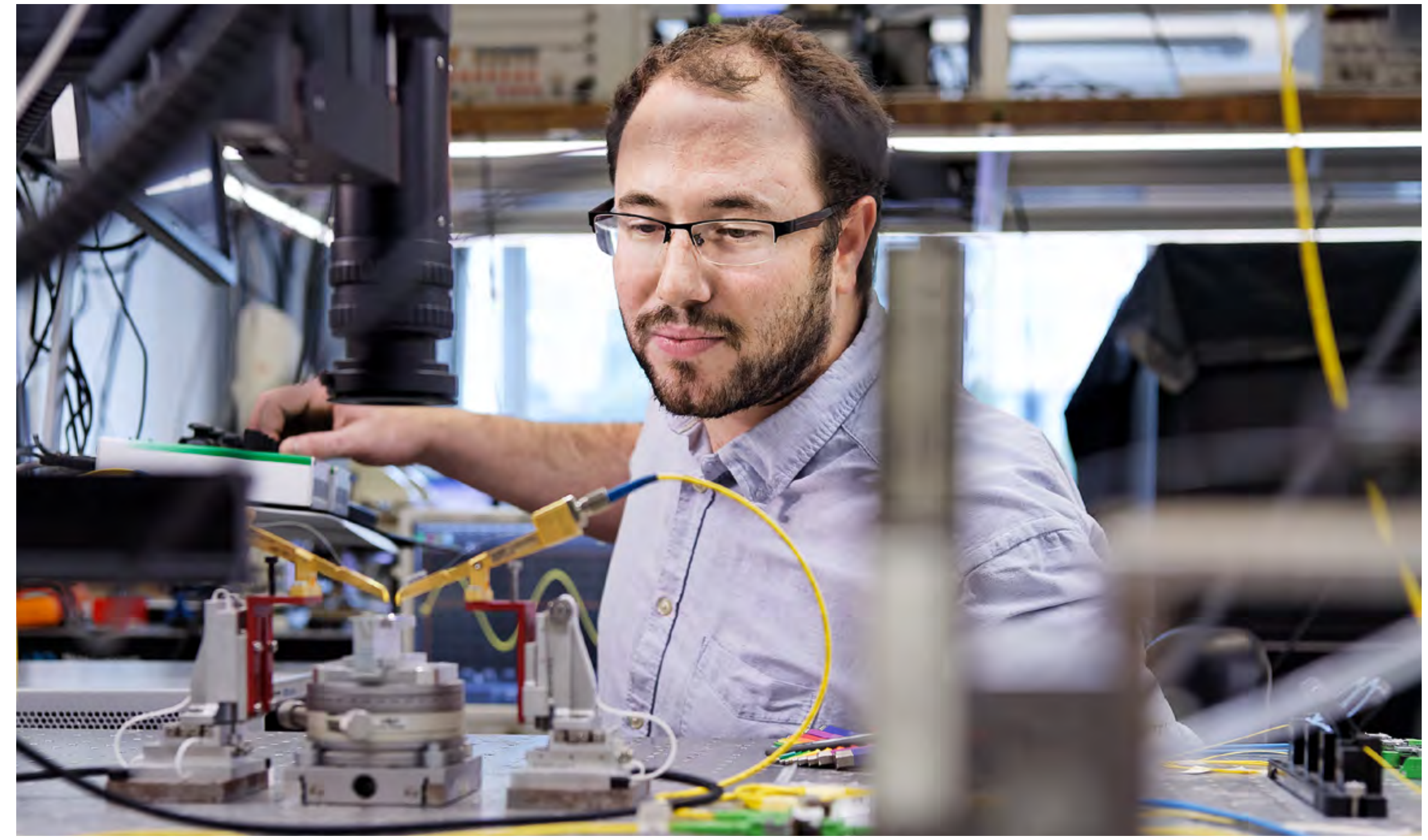
Leuthold carried his early success as a postdoc over to his career in research and development, as is evidenced by 25 patents, numerous awards, including the "Landesforschungspreis" of the German state Baden-Württemberg, and grants from prestigious institutions such as the European Research Council. And yet the core focus of his work has remained the same since his dissertation: high-speed optical communications. "Communicating is a basic human need. My goal is creating innovative communications technologies to make people's lives easier," is how Leuthold frames his research. In his recent work, he has again drawn attention in the telecom branch thanks to his state-of-the art atomic-scale technologies—which receive funding from the Werner Siemens Foundation.

Promoting talent

When it comes to innovation, Jürg Leuthold doesn't hesitate to raise his voice in the political debate. "Our education system should focus more on promoting innovation and technology," he is convinced. Latin as a school subject? That's fine, as long as it isn't required. "Learning how to programme an app would be more useful in today's world," he maintains. At the very least, Swiss secondary schools should offer a concentration in the natural sciences, something that isn't always the case. As such, it is no great surprise that technical higher education institutions in Switzerland have a shortage of students.

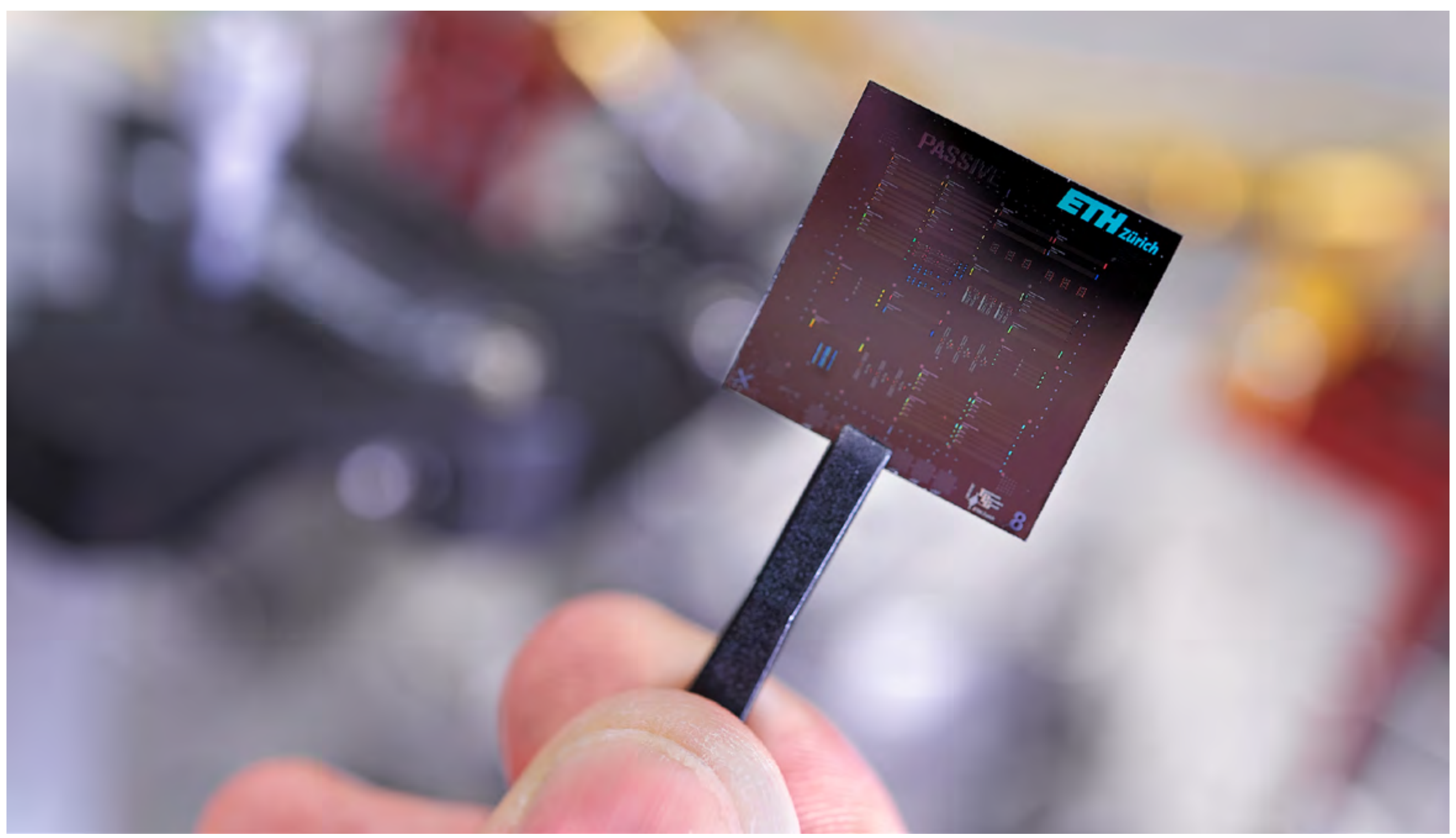
Leuthold believes it is critical to get young people excited about science. And he practices what he preaches with his own three teenage children. In the evenings, a science programme is part of the family entertainment from time to time. And, of course, Leuthold's children want to know what their father is researching at his ETH lab. There's certainly plenty to discuss—for example, atomic-scale technologies.

The Werner Siemens Foundation is the first private foundation to dedicate funding to the field of atomic-scale technology. A commitment that honours the "electric" pioneering spirit of Werner Siemens.



The single-atom optical switch is undergoing extensive testing.

The minuscule chip has the potential to revolutionise the semi-conductor industry.



Facts and figures

Project

ETH Zurich and the Karlsruhe Institute for Technology are researching a fundamentally new kind of microchip that works with single-atom switches.

Support

The Werner Siemens Foundation is financing the establishment of the Centre of Atomic Scale Technologies through a donation to the ETH Zurich Foundation.

Funding from the Werner Siemens Foundation

12 million Swiss francs

Project duration

2017–2025

Project leader

Prof. Dr Jürg Leuthold, head of the Institute of Electromagnetic Fields at ETH Zurich

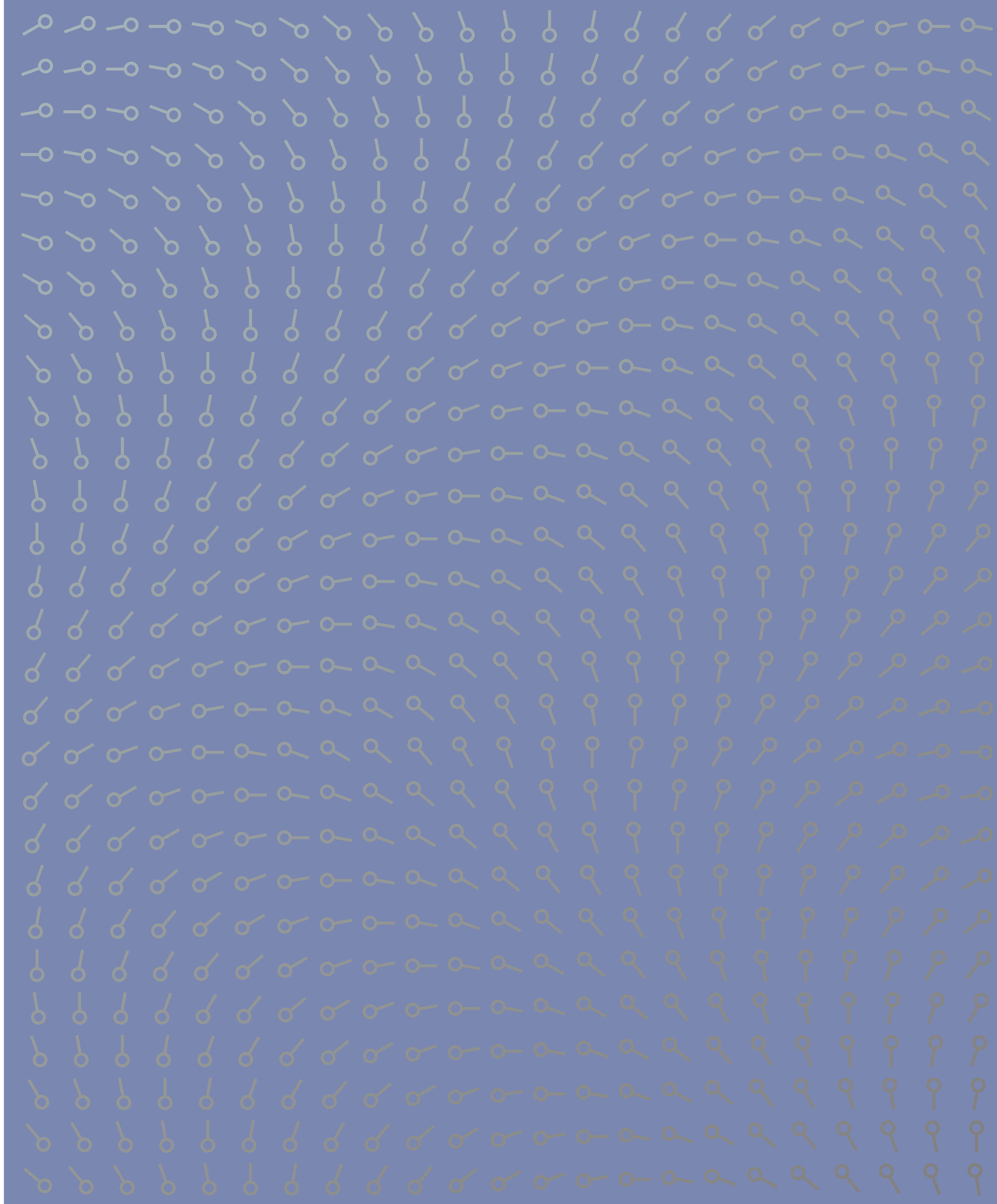
Partners

Prof. Dr Thomas Schimmel,
Institute of Applied Physics,
Karlsruhe Institute of Technology (KIT)
Prof. Dr Mathieu Luisier,
Integrated Systems Laboratory,
ETH Zurich

smarter smaller revolutionary

Innovation

The Werner Siemens Foundation is supporting the development of atomic-scale technologies—because we are convinced that this pioneering approach will provide decisive new impetus in the field of micro-electronics. The new technology has the potential to revolutionise the semi-conductor industry world-wide, leading to still smaller, faster and more energy-efficient processors.



Harnessing the Earth's energy

Geothermal energy

We humans carve coal from the Earth's crust and drill holes in the seabed: exacting and expensive methods for mining petroleum and natural gas. We then burn most of these hard-won resources to generate electricity, yet all the while we live on a ball of fire. The enormous heat within the Earth has the potential to cover our energy needs. Sustainably, for as long as our planet exists.

Tapping into the fireball

The intense heat in the interior of the Earth is one of the planet's largest unused energy reserves. Professor Martin O. Saar and his team at ETH Zurich are exploring ways to harness this energy and generate electricity on a large scale—with funding from the Werner Siemens Foundation. The innovative technology has the potential to generate large amounts of electricity while also reducing carbon emissions.

One of the countless experiments required before the enormous heat in the interior of the Earth can be harnessed to generate electricity

"We're living on a planet with enough energy for humanity until the end of time," says Martin O. Saar, professor of geothermal energy at ETH Zurich. Only the first two to three kilometres of the outer crust of the Earth is ever below 100°C. The vast majority—namely 99% of the entire globe—is hotter than 1000°C. And the Earth's core burns at over 4000°C—hotter even than the surface of the sun.

Tapping into this inexhaustible source of energy to meet the world's energy needs is the goal Martin O. Saar has set himself. Two years ago, he gave up his professorial chair at the University of Minnesota to build a new research group at ETH Zurich and explore geothermal energy and geo-fluids—with funding from the Werner Siemens Foundation.

No cooling in sight

It's hard to grasp that systematically extracting warmth from a body won't cause it to cool down. "But the Earth produces its warmth in the cold universe," Saar explains. "This happens continuously in the interior via radioactive decay." Another little-known fact is that the liquids in the Earth's core are permanently crystallising. "Through this crystallisation process, the inner, solid core of the Earth is formed, and this too releases heat."

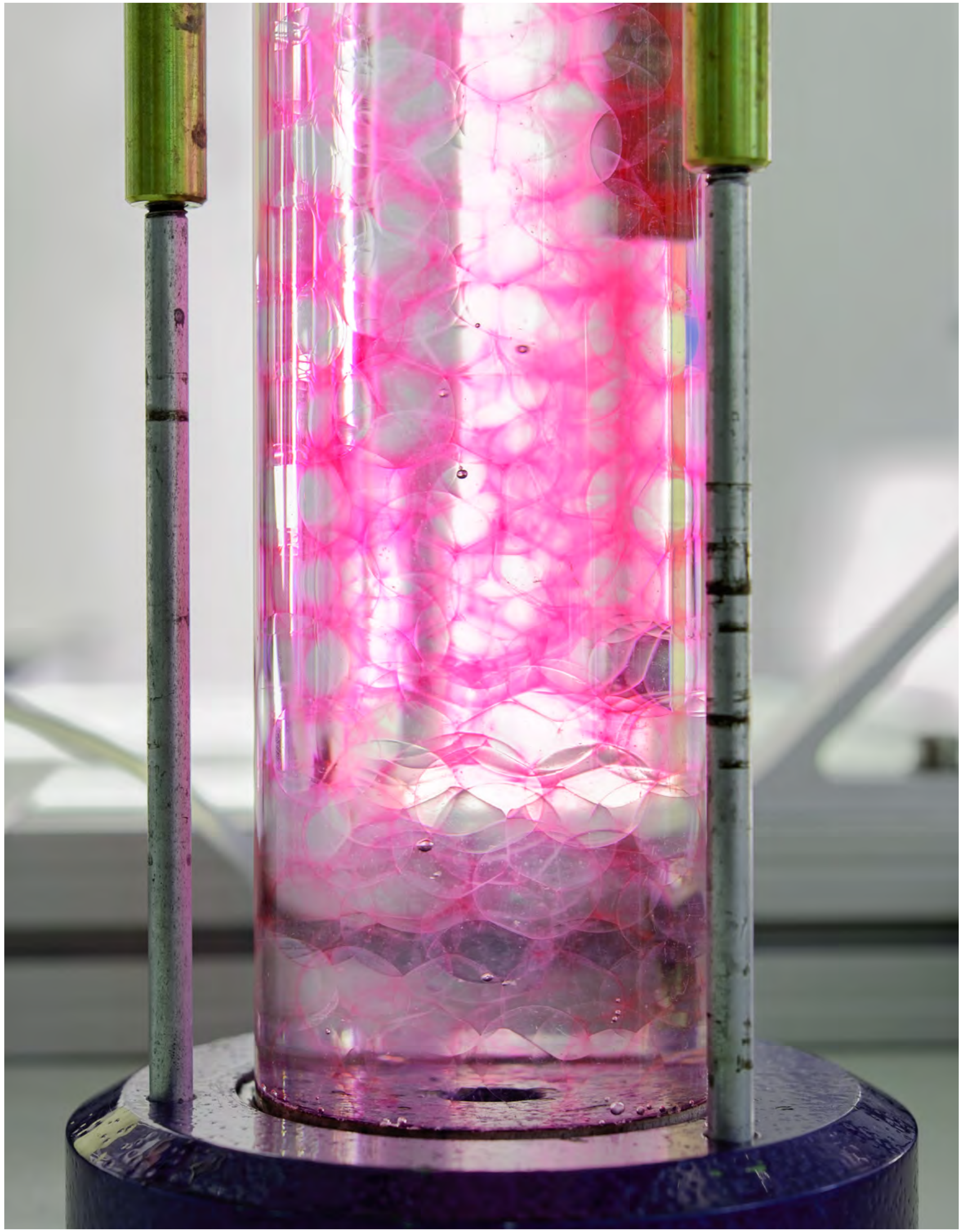
But how to harness this energy? The idea is to drill about three kilometres below the surface of the Earth in order to either retrieve hot water from the depths or to inject water for the purpose of heating it. The heat is used to generate electricity in a steam turbine, and the cold water is then pumped back into the earth. Although it unfortunately isn't quite as easy as it sounds.

In order to pump the water to the surface, it has to flow through layers of rock. If the rocks are naturally porous, as in seismic zones, this is a fairly straightforward undertaking. But water so far below the surface is generally much brinier than seawater, and when it is pumped up, it cools off and deposits minerals that clog the pathways over time. Which is why geothermal researchers have a penchant for earthquakes: in active seismic areas, there is so much movement in the subsurface that water always finds a path to flow through. In Nevada or California in the US, for example, the power plants are built intentionally in seismic zones where there are enough earthquakes to keep the pathways to the substrata open. Without these conditions, operating the power plants over a period of decades would be impossible.

Earthquakes as positive energy

Although the average layperson will associate earthquakes with destruction, researchers see a useful, creative force: "Without earthquakes, we'd have no mountains or rivers. And no access to geothermal energy." And where earthquakes are not a natural phenomenon, researchers become explosives specialists—although they use water, not dynamite. Using high-pressure pumps, they inject water into the rock, thus "stimulating" it into shifting. The art lies in the dosage: instead of causing a large earthquake, the idea is to trigger numerous micro-quakes that are monitored to the last detail.

The method was put to the test on the hard granite of Switzerland's Grimsel massif. In a pre-existing tunnel, the research team joined forces with the "Swiss Competence Center for Energy Research–Supply of Electricity" to conduct



Testing the flow properties of various fluids (grey, yellow, pink) in a lab is quicker than testing in the actual rock layers.

their meticulously planned experiments. They monitored the rock layers from every possible angle, lowering sensor after sensor into deep holes in order to map a 3D image of the movements. To complete the study, they hermetically sealed two boreholes section by section and injected water to trigger tremors in the granite. The procedure made the entire layer of rock porous, without causing large tremors.

Currently, immense datasets are being interpreted. "The more we know, the better we can predict what will happen," says Martin O. Saar. "We're confident that we'll be able to steer the magnitude of our quakes better in future."

High-cost drilling

There is, however, another problem preoccupying researchers. Often, it is necessary to drill as deeply as five to six kilometres before reaching an economically viable temperature of 180°C. And drilling is the most costly part of harnessing geothermal energy. A breakthrough idea for lowering costs came to Saar 10 years ago while on a road trip with a PhD student in the US. At the time, the PhD student was working on simulations of underground carbon reservoirs for the Minnesota Geological Survey. During their discussions, the two researchers hit upon the unorthodox idea of using liquid carbon dioxide to transport heat to the Earth's surface.

Carbon dioxide as a heat conductor

The spontaneous idea proved to be a serious option. Saar's enthusiasm is apparent: "We quickly realised that we can transport heat to the surface better with carbon dioxide than with water." What gives carbon dioxide the advantage? "CO_2 becomes beautifully supercritical at a depth of just one kilometre," Saar explains. Meaning that carbon dioxide achieves an aggregate state between a fluid and a gas, allowing it to flow better than water and to expand significantly more when heated. It also demonstrates a lower density and is highly buoyant—and thus rises easily to the surface. Another great advantage is that accessing geothermal energy via CO_2 no longer requires earthquakes because the nearly gaseous carbon dioxide simply flows through certain rock layers.

Slowing climate change

In the meantime, research on combining underground CO_2 reservoirs and harnessing carbon dioxide for geothermal energy is being conducted worldwide. That it took so long to come upon this idea is almost certainly related to the negative associations attached to carbon dioxide. After all, it is the key cause of global warming and useful applications are therefore generally not even considered.

In the US, underground reservoirs have been used to reduce the country's carbon footprint for some time, although this aspect has not yet entered the political debate in Switzerland. Nevertheless, the Swiss Federal Office of Energy and several companies plan to explore the technology. The prospects are indeed highly promising: should it become possible to extract carbon dioxide from the Earth's atmosphere, store it underground and use some of the stored carbon dioxide to transport geothermal energy to the surface and generate power—we would be capable of slowing climate change.

How will the fluid (pink) carve a path through solid materials (white)? An experiment to answer one of the fundamental questions in deep geothermal energy.

Earthquakes on low heat

Generating electricity in a geothermal power plant—a technology Switzerland has yet to capitalize on, although the US has long profited from this energy source. Martin O. Saar, professor of geothermal energy at ETH Zurich, tells us how and why.

Martin O. Saar, holder of the ETH Zurich professorship for geothermal energy, which is funded by the Werner Siemens Foundation

In Switzerland, hardly a new home or residential building is constructed without a geothermal heat pump being installed. So, why do we still need research into geothermal energy?

Martin O. Saar: In geothermal research, we differentiate between superficial geothermal energy for heating and deep geothermal energy for generating electricity. When we talk about heat pumps, we are referring to geothermal energy close to the Earth's surface. No electricity is generated via the heat pumps; instead, they absorb heat from the sun's rays stored in the earth. They are a special case of geothermal energy, but one that is very important in Switzerland for heating homes. And, by the way, to cool them in southern climates.

What is the current status of using deep geothermal energy in Germany and Switzerland?

Switzerland, specifically its federal government, has only very recently begun to invest heavily in deep geothermal energy. The country's planned nuclear phase-out and the so-called "energy transformation" have increased the pressure to use alternative sources of energy. In Germany, use of geothermal energy is already much more advanced. This is partly due to the slightly better geological conditions, but partly because underground research and mining has a very long tradition in Germany. Much more is known about subterranean conditions, especially way down deep. Another contributing factor is the federalist system in Switzerland, where the 26 cantons often have their own highly specific regulations on accessing underground resources. This makes it difficult for companies and investors alike to establish and advance a geothermal project. And so, Switzerland has not yet begun to use geothermal energy to generate electricity.

In Basel and St. Gallen, experiments on generating electricity in geothermal power plants had to be discontinued due to earth tremors. What went wrong?

In Basel, relatively large amounts of fluid were injected into the ground, which triggered an earthquake. Although it was just a minor quake, it unfortunately caused damage above ground. When fluid is injected underground, we expect earthquakes to occur; the critical part is ensuring they remain very small.

A geothermal power plant is currently being planned in the Jura region. Has research progressed far enough to be sure that the technology is safe?

In Haute-Sorne, a petrothermal power plant that would inject water into the underground is planned. But it isn't yet clear that it will be built. It's precisely because the trial-and-error method used in Basel and St. Gallen should be avoided that my position—and other professorships throughout Switzerland—was created. At the moment, we are collaborating with the "Swiss Competence Center for Energy Research—Supply of Electricity" to ensure that these petrothermal systems don't trigger large earthquakes in future.

How can you do that? How is it possible to test the right dosage for an earthquake?

To learn more, we conducted a complex experiment in the Grimsel rock laboratory, in the Nagra tunnel; the data are currently being interpreted and should provide answers. The next underground experiment is scheduled to take place in the now defunct Bedretto arm of the Furka Base Tunnel, where we can go even deeper than the 500 metres we managed in the Grimsel rock lab—it will be between one to one-and-a-half kilometres below the Earth's surface.

In the scope of its energy transition goals, Switzerland aims to cover 12% of its energy demand using renewable energies, and this starting 2035. It's estimated that a dozen geothermal energy plants will have to be generating electricity by then. Is this goal realistic?

It will be extremely difficult. Right now, we don't even know whether we'll manage one plant. But a lot of prior research was also needed before nuclear energy could be used. Although petrothermal systems have been researched since the seventies—first in the US—intense work has only been seen in the past 10 years. And in Switzerland, it's only been four years since research has been conducted, not counting the experiments in Basel and St. Gallen.

Before you took on the professorship for geothermal energy at ETH Zurich, you were professor at the University of Minnesota in the US. Does the research conducted there still factor into your work?

I earned my master's degree and PhD in the US and was professor there for 10 years. I still lead a small research group in the US, and I co-founded a geothermal energy company. As such, I have close contact and continue to collaborate in American research projects. The US is a global leader in geothermal power plants that have a capacity of over three gigawatts. But it should be noted that this corresponds to three large coal-fired power plants—a negligible amount compared to the over 600 coal plants in the country.

Is there a reason there are so few geothermal power plants?

Well, it's difficult to convey large amounts of geothermal energy to the surface. In the US, most geothermal power plants are located in California or Nevada where the geological conditions are better. High subsoil temperatures are quite near the Earth's surface and seismic activity is relatively high. Most areas, Switzerland included, don't offer these advantages. Through our research, we aim to access geothermal energy in areas that, up to now, were not suitable for generating electricity.

Planned to the last detail: researchers in the geothermal energy group conduct an experiment in the Grimsel rock laboratory in the Swiss Alps.

Facts and figures

Project

Headed by Professor Martin O. Saar, the research group Geothermal Energy and Geofluids at ETH Zurich is exploring ways to harness geothermal energy and transform it into an economically viable source of electricity.

Support

Over a period of 10 years, the Werner Siemens Foundation is funding a professorship for geothermal energy at ETH Zurich through a donation to the ETH Zurich Foundation; the funds cover daily operations as well as five research positions. The group examines reactive fluids and the flow of geothermal energy in the Earth's crust using computer simulations, lab experiments, field research and research in rock layers.

Funding from the Werner Siemens Foundation

10 million Swiss francs, distributed over 10 years

Project duration

2015–2025

Project leader

Prof. Dr Martin O. Saar, ETH Zurich

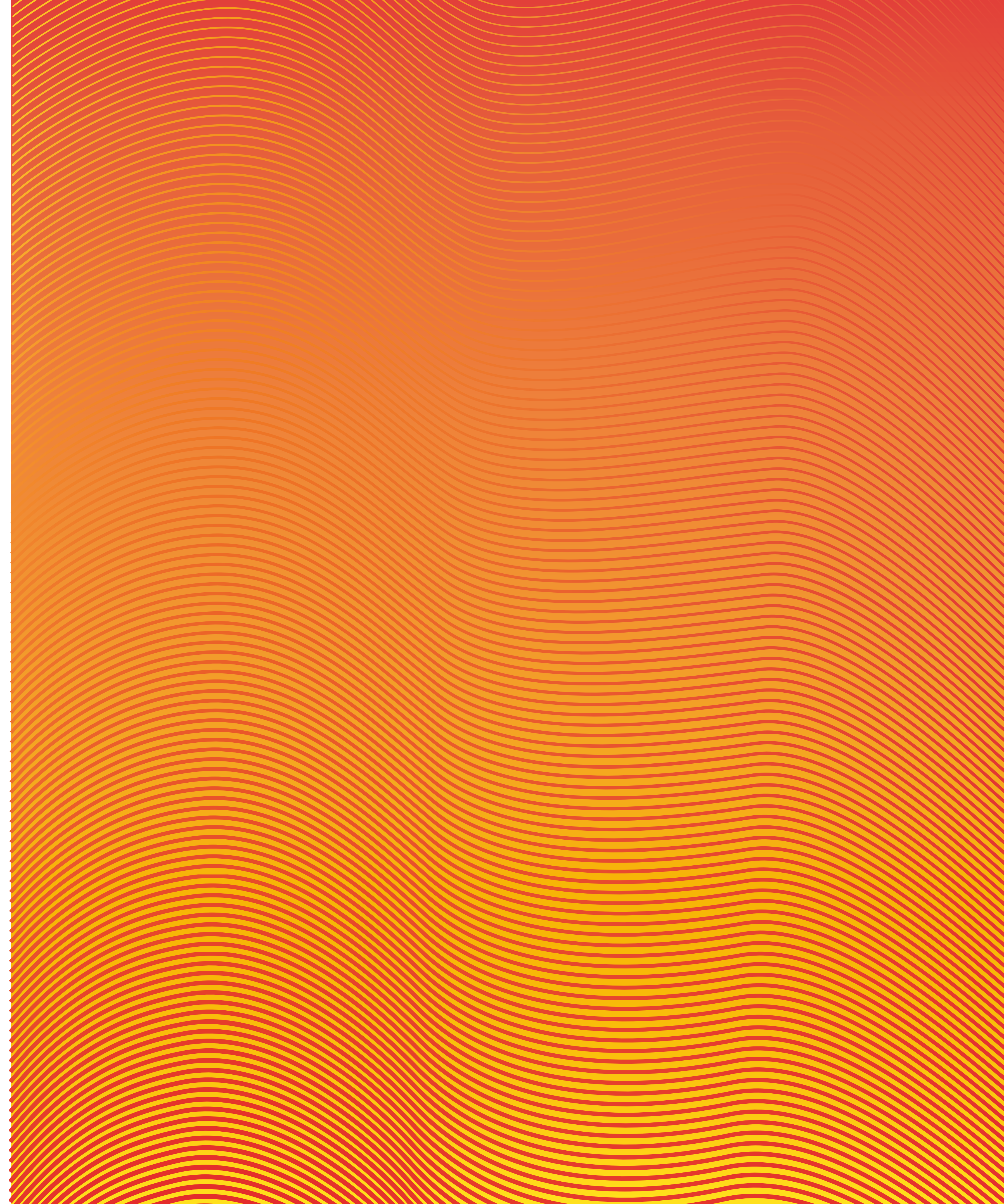
Partners (selection)

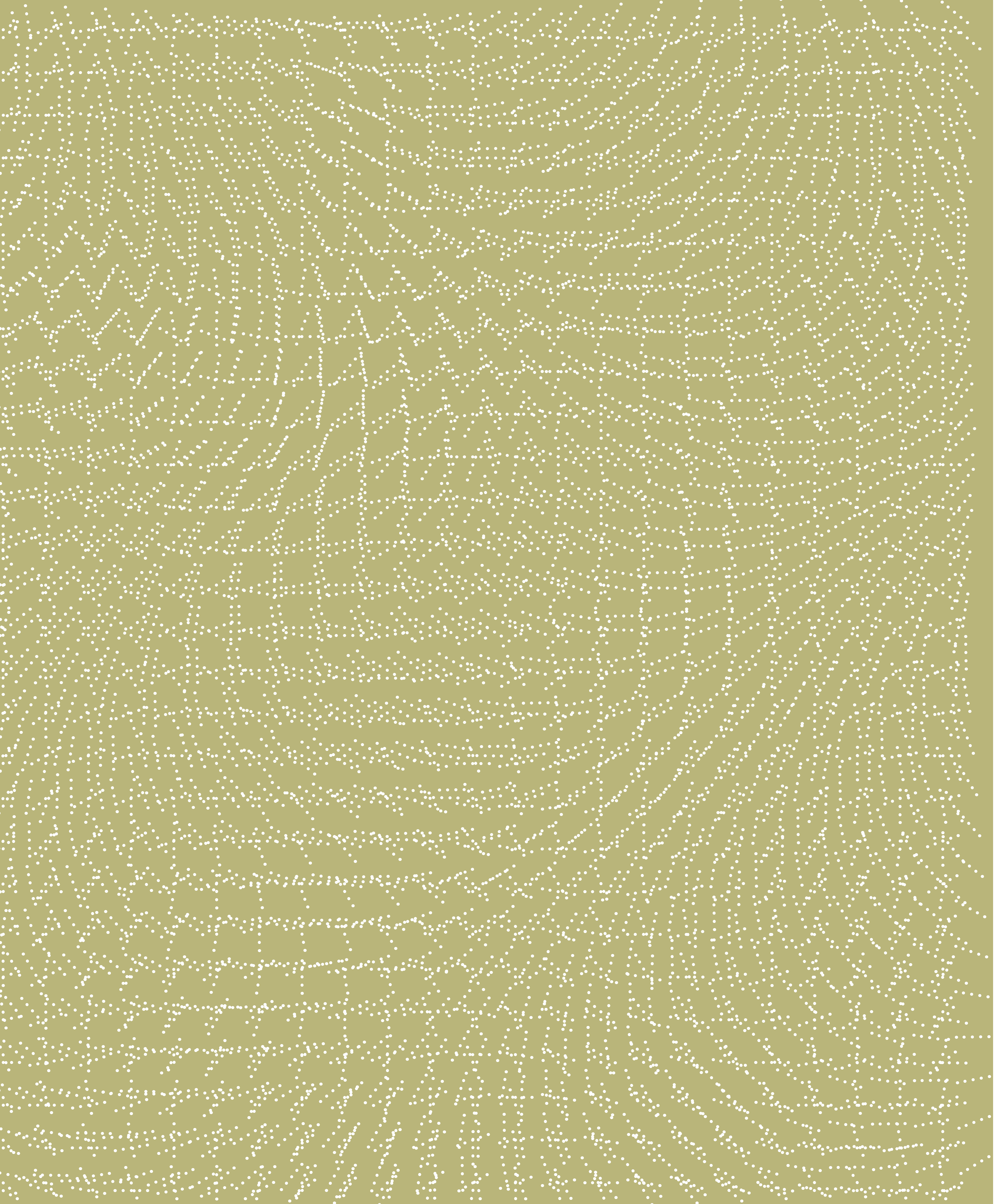
Swiss Competence Center for Energy Research–Supply of Electricity
Geo-Energie Swiss
SwissGeoPower Engineering AG
TerraCOH Inc.
Haelixa
University of Minnesota, Dept. of Earth Sciences
Lawrence Berkeley National Lab
Lawrence Livermore National Lab
Federal Office of Topography swisstopo
US Geological Survey
Columbia University, NYC
Minnesota Geological Survey
EPF Lausanne
Universities of Neuchâtel, Geneva and Bern
Graz University of Technology
Technical University of Munich
Karlsruhe Institute of Technology

clean carbon neutral for everyone forever

Innovation

The Werner Siemens Foundation supports the geothermal research of Professor Martin O. Saar and his team at ETH Zurich—because geothermal energy has the potential to generate electricity that is unlimited, sustainable and available to all.





Tiny organisms writ large

Synthetic Biotechnology

The foamy whitish substance is actually a mass of yeast cultures that produce oil. How yeasts and other natural organisms such as algae can be manipulated into releasing useful substances is the focus of research in the labs of Synthetic Biotechnology.

Bountiful microorganisms

The team at Synthetic Biotechnology are on the look-out for naturally occurring organisms whose metabolic activities generate products that have potential for human use: for instance, oleaginous (oil-producing) yeasts and algae. The researchers analyse and optimise the organisms in the lab, manipulating their metabolism and prompting them to produce materials that can be further processed into chemical building blocks. Industrial-scale production of these building blocks is the goal—and it's hoped they will replace fossil fuels and other problematic resources such as palm oil.

Reaping benefits from the metabolism of microorganism: project leader Monika Fuchs from the team of 25 researchers at Synthetic Biotechnology at the Technical University of Munich

The methodologies and processes at Synthetic Biotechnology are so complex that close collaboration between specialists from the fields of chemistry, biotechnology, bioinformatics, microbiology, genetics and pharmaceutics is indispensable. Currently, a team of 25 such experts are working in the group at the Technical University of Munich (TUM). Headed by Thomas Brück, professor of industrial biocatalysis, the team at Synthetic Biotechnology is pressing forward in the new discipline—an undertaking partially funded by the Werner Siemens Foundation.

Why should so much energy be expended on creating products—for instance, oils—that occur naturally? To answer this question, it's important to look at the larger picture. "The global population is expected to increase by 50% by the year 2050, and the demand for food and energy will rise accordingly," says Thomas Brück, who holds the Werner Siemens Foundation Endowed Chair at TUM. "How are we going to meet this demand with existing resources and without dangerously exacerbating global warming?" Should the increased demand for food be met via additional fertilisation, increased amounts of nitric oxide would be released, further aggravating climate change. Should fossil fuels continue to supply the additional energy required—to heat homes, ensure mobility, produce goods—carbon dioxide emissions would spike dangerously. And should the demand for energy be increasingly met by biomass such as soy or sugar cane, these basic foodstuffs would not be available to feed the growing population. In short: a vicious circle.

The team at Synthetic Biotechnology believes it can help to solve the conundrum. Thomas Brück's team is seeking replacements for petroleum-based products such as kerosene and plastics. In addition, they are developing alternatives not only for the non-ecological manufacturing of products such as palm oil, but also for biofuels made of soya or other plants that would be more wisely reserved for feeding the world of tomorrow. The researchers also hope to produce a series of products that are currently limited in availability, for instance, the main agent in the cancer drug Taxol; in addition, they plan to produce functional fats for cosmetics (such as jojoba oil), and essential omega-3 fatty acids, which are an important ingredient in baby food.

The manufacturing of these products in the lab is carbon neutral and designed to enable future generations to produce enough food and energy to maintain current living standards without triggering uncontrollable global warming.

The Werner Siemens Foundation is convinced by the team's approach: since 2016, the Foundation has financed the new research and education facilities of Synthetic Biotechnology at the Technical University of Munich. Funding from the Foundation has been used to update lab equipment and to found a research centre for schools, where students and their teachers can learn more about the still-young discipline of synthetic biotechnology.

Oil from yeast

One of the breakthrough discoveries for Thomas Brück and his team are yeasts that, during their growth stage, metabolise carbohydrates (sugar) into energy-rich oils rather than alcohol (ethanol), as is normally the case. This feat is accomplished by the yeast *Trichosporon oleaginosus*, which was isolated from a compost heap in Ireland. It is a highly unconventional yeast that can convert diverse carbohydrates into biomass and special oils. With up to 40% fatty acids, the oils produced resemble olive oil.

Trichosporon oleaginosus isn't too choosy when it comes to food: it feasts on the waste of corn, crabs, wheat bran, wood shavings or straw, pulling out every convertible carbohydrate. "The yeast can be added to all manner of existing waste products, which ensures that production is sustainable," says project leader Daniel Garbe. In a series of chemical metabolic steps, the yeast converts the carbohydrates into fat that it can fall back on in lean times—much like our own "padding".

Stress triggers fat production

Normally, a single yeast cell consists of 20% fat, but in times of stress, it increases its fat reserves up to 80%. The researchers take advantage of this reaction and put the yeast on a "diet": during its growth phase, the yeast is deprived of nitrogen and phosphate. The yeast reacts by using all its remaining energy to create emergency fat reserves. "When we view yeast under a microscope, we basically see only fats and a few cell structures," says Thomas Brück. When the yeast reaches this point, the researchers end the "diet". This ensures they have the highest yield because the "hungry" yeast has not yet begun to resort to the fat stores for its own survival.

Profiling fatty acids

By applying the art of chemistry, fats can be transformed into just about anything. One of the research teams in the Synthetic Biotechnology group is now experimenting with a variety of fatty acid "profiles". The team changes various parameters and observes how the yeast reacts. For example, when the researchers feed the yeast different kinds of sugar, the fatty acids produced have different profiles. And a similar effect on the profile of the fatty acids can be attained by varying the temperature or by removing sulphureous substances. These manipulations prompt the versatile yeast to release a different profile of the fatty acids.

Chemically speaking, the different fats and oils are all related: they are structured around a glycerol molecule joined to three different fatty acid units having a different number of carbon atoms. This gives rise to the term "triglyceride" for biologically produced fats and oils. Oils used as food also have many double bonds, in which case they are called polyunsaturated fats, whose antioxidant properties have excellent health benefits.

Depending on the profile, various kinds of oil can be made from the fatty acids: oil for food (palm oil alternatives, fish oil derivatives, omega-3 fatty acids for baby food) or the oily base for biofuels, plastics and cosmetics.

Alternatives to palm oil

To date, many plant oils are harvested from plants that are grown in environmentally detrimental monoculture and that damage or destroy the ecosystem. To produce palm oil, valuable rainforests have been cut down, depriving endangered animals such as the orangutan of their habitat. Palm oil, in the meantime, is an ingredient in numerous food and cosmetic products—and despite its non-ecological production, demand remains high.

"The composition of fatty acids in palm oil unfortunately can't be produced naturally in other organisms." This is how Norbert Mehlmer, genetic engineer at Synthetic

It works: the yeast cultures in the biorefinery produces the right oil.

Biotechnology, frames the problem. To find an alternative to palm oil, the researchers are resorting to new methodologies to insert a foreign gene into yeasts. First, they use the soil bacterium *Agrobacterium tumefaciens* as a door opener for the foreign gene. In a second step, the yeast culture is treated with an antibiotic, causing the *Agrobacterium tumefaciens* to die. What remains is yeast with the desired genetic make-up able to produce tailor-made, high-quality fats and oils—safely, year-round and reliably.

The industrial partners of Thomas Brück and his team at Synthetic Biotechnology see great potential in two other fatty acid profiles: fish oil alternatives and linoleic acid, an omega-3 fatty acid for baby food. "In the next five to seven years, these two oils could be ready for commercial production," Brück says.

Plastic made of crab shells

Thomas Brück and his team are also working on a project to manufacture sustainable plastics (polymers). The raw material here is once again entirely natural: empty crab shells from Ireland. The Irish distributor was more than happy to deliver the waste product to the research team: because crab shells attract bacteria that produce poisons, they must not be disposed of with normal waste. Proper disposal costs 7,500 euros per metric ton.

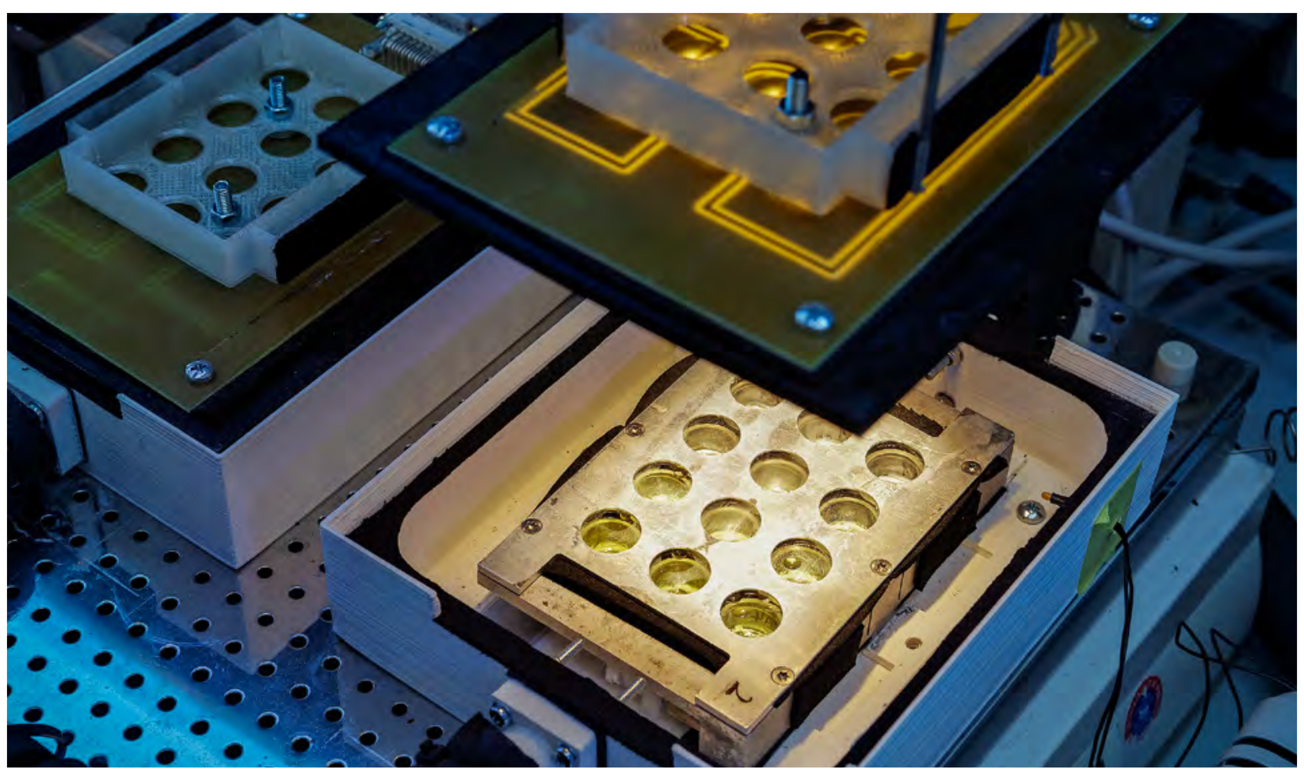
The TUM research team worked with partners from Germany, Czechia, Norway, Austria, Tunisia and Indonesia to develop a way to manufacture high-quality plastic from old crab shells. To do so, they first dissolved out the polysacharide chitin from the crab shells. Then, they optimised the fermentation process and genetically altered the lipids until they could be used to manufacture a particularly high-quality polyamide. Evonik Industries was the industrial partner in this step. The polyamide then served as the basis for medical devices, including dental and bone implants. "This project was a great success," says Thomas Brück.

Fighting cancer with bacteria

In another group at Synthetic Biotechnology, project leaders Monika Fuchs and Norbert Mehlmer focus on relaying new biocatalysts in the metabolism of gut bacteria *Escherichia coli* to ensure the sustainable production of medications such as the tumour drug Taxol.

Until now, the clinically valuable agent used to combat tumours has been produced from plant extracts in a series of chemical synthesis steps. And for every kilogramme of the agent won, another 120 kilogrammes of waste are generated. The methodologies developed at Synthetic Biotechnology allow the team to construct a genetically tailor-made cell factory capable of manufacturing the desired product without generating toxic waste. The genetic changes in individual biocatalysts in the cell factory also open the door to create even more new agents that function in anti-inflammatory drugs or that can be used in biodegradable insecticides.

Searching for high-yield algae: the automatisation process designed by Synthetic Biotechnology to perform high-throughput screening on fast-growing algae



Algae growing at the algae cultivation centre of the Technical University of Munich

Mitigating food competition

The team at Synthetic Biotechnology believes it can help to solve the issues surrounding the potential shortage of raw materials. The raw material "plant oil" is exemplary of the almost intractable problem: already today, 30% of all plant oil is used to generate energy and manufacture chemicals. As a result, it is not available for use in the food industry. Premium vegetable oils are converted into biodiesel, soaps (surfactants) or other oily chemicals that can be used in products such as car lubricants and body lotions. Thomas Brück is convinced: "Plant oils should be used for foodstuffs, not to produce energy or chemicals."

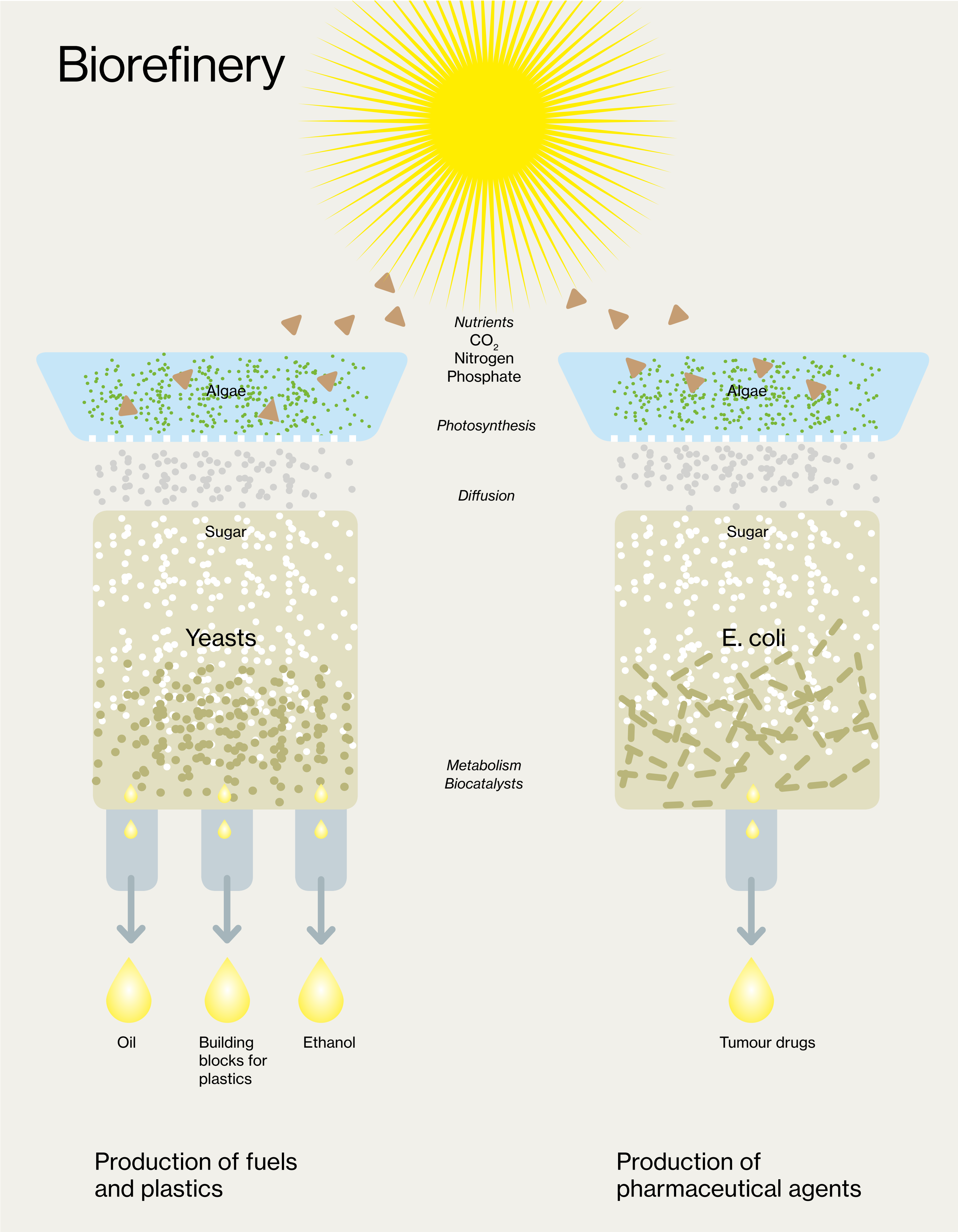
Flying high with algae

The doctoral students under project leaders Farah Qoura and Daniel Garbe have been working intensely for three years on generating fuel from algae—as an alternative to kerosene. Flying with algae—an enticing thought. And there are many good reasons to be optimistic: algae grow 12 times faster than terrestrial plants and require neither freshwater nor cultivated land to thrive. Due to their fast growth, algae are efficient consumers of the greenhouse gas carbon dioxide, which they transform into biomass and biogenic oils.

The first positive results have now been secured: the researchers located various saltwater algae in Australia, Mexico and the Adria that have the potential to produce oils. In the lab, the team exposed the algae to UV rays to isolate new genetic stems that also thrive in very salty water and that are distinguished by a very high oil production. The oils produced by these algae provide the starting point for producing alternative biofuels. Two types of algae are currently the most productive: *Nannochloropsis sp.* from the Caribbean and *Dunaliella sp.* from Australia. Both kinds thrive in extremely salty waters, where the alkaline environment protects them from terrestrial contaminants such as fungi and bacteria—a further advantage over freshwater algae.

Economic potential

The Sahara would hold great potential for large-scale algae production. "Just one percent of the Sahara would be sufficient to fully supply European air traffic with fuel" says Thomas Brück. "But we also have potential locations in Europe," he continues. "The areas near the bluffs on the Greek coasts in particular would be very suitable for terraced algae basins. And the climate would be ideal for growing algae." Brück has already contacted the University of Athens. The project could also be an opportunity for Greece to reduce its economic dependency on tourism and to secure a new source of revenue.



Thomas Brück, Werner Siemens Foundation Endowed Chair for Synthetic Biotechnology

The perfect biorefinery

Thomas Brück and his team at the Werner Siemens Foundation Endowed Chair have developed several designs for a biorefinery able to convert biomass into chemical and pharmaceutical building blocks. But this isn't Brück's only goal.

What is your greatest dream?

Thomas Brück: My greatest dream is a single bioreactor that is able to produce diverse products neatly separated from each other.

What would this bioreactor look like?

It would be a large, multi-part bioreactor from a 3D printer. The top compartment would be for algae that produce sugar via solar light, carbon dioxide, nitrogen and phosphate. The sugar could then be diffused into the next compartment and be used, for example, to feed fatty yeast. The fatty yeast would release the fats and oils it produces into the surrounding area. The oils would then flow through little tubes into yet another compartment. This is how we would also like to produce the cancer drug Taxol: for example, by using tailor-made gut bacteria *E. coli* in the middle compartment.

What would be the advantage over today's methods?

The problem today is getting bioorganisms to release their metabolic product. It takes quite a bit of work before we can harvest the product in its pure form. An organismic bioreactor would render these complex and expensive processing steps entirely obsolete because the end product would flow into special channels. The bioreactor we have in mind is modelled on human organs—for instance, the kidneys.

Facts and figures

Project

The Werner Siemens Foundation is financing the first professorship for synthetic biotechnology, located at the Technical University of Munich.

Support

Werner Siemens Foundation Endowed Chair for Synthetic Biotechnology, Prof. Dr Thomas Brück

New curriculum for students in master's degree programs for industrial biotechnology, chemical engineering, as well as molecular biotechnology and biochemistry

Updating equipment: cutting-edge labs and renovated office space in the chemistry building of the Technical University of Munich, in Garching

Seed funding for the design of a research centre for schools where prospective students can discover the emerging field of synthetic biotechnology

Funding from the Werner Siemens Foundation

11.5 million euros

Project duration

2016–2021

Project leader

Prof. Dr Thomas Brück, Werner Siemens Foundation Endowed Chair for Synthetic Biotechnology at the Technical University of Munich

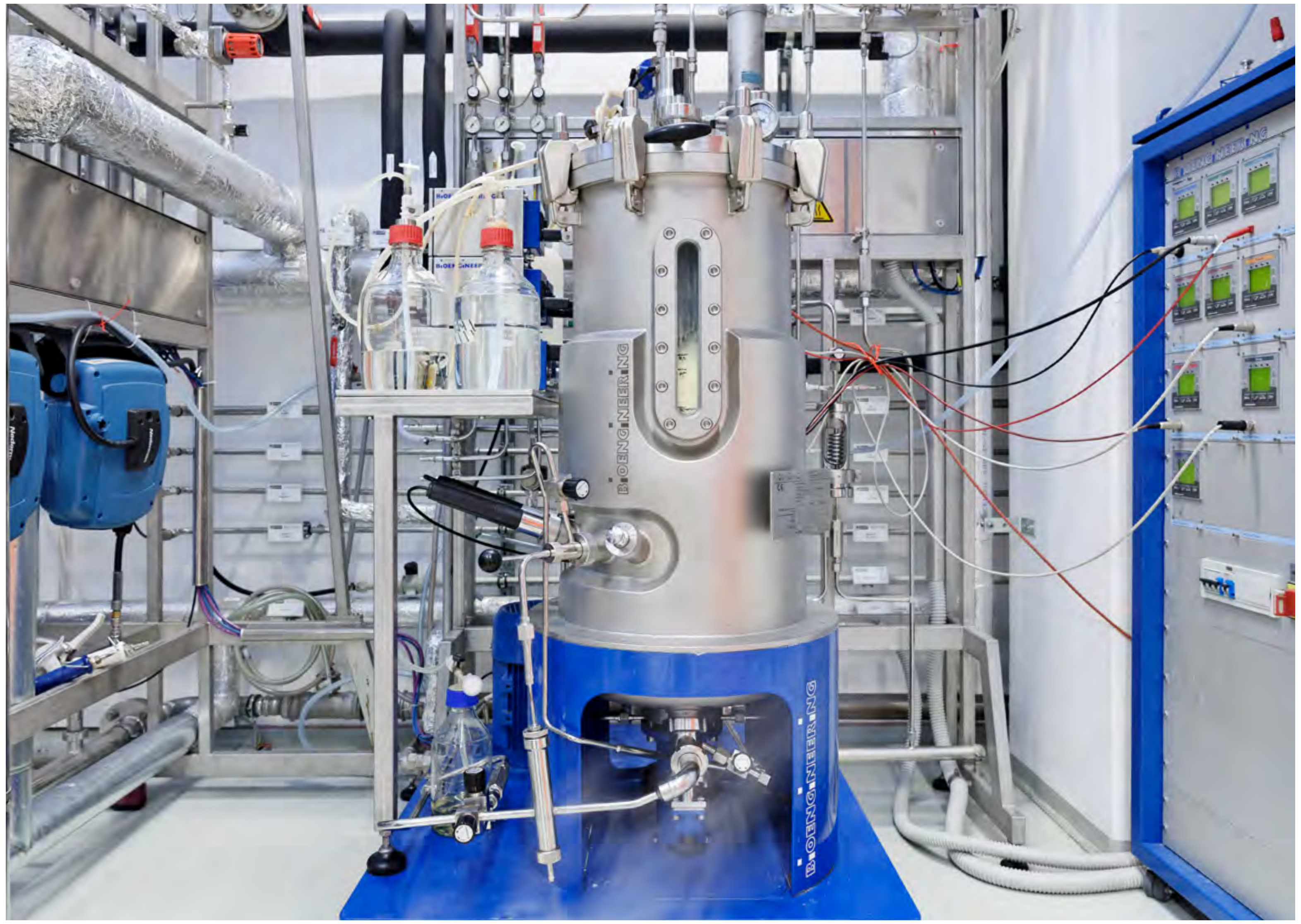
Partners from industry (selection)

Airbus, Siemens, Evonik, Clariant, Bionorica, Phytowelt, Fuchs, Klüber Lubrication, Audi, BBSI, Nautilus Biosciences (Canada), Apronex (Czechia)

Partners from academia (selection)

University of Prince Edward Island (Canada), The University of Queensland (Australia), Energy Institute at the Johannes Kepler University Linz (Austria), University of Angers (France), TU Graz (Austria), Freie Universität Berlin (Germany), Fraunhofer Department BioCat (Straubing, Germany), Max Planck Institut für Kohlenforschung (Mülheim an der Ruhr, Germany)

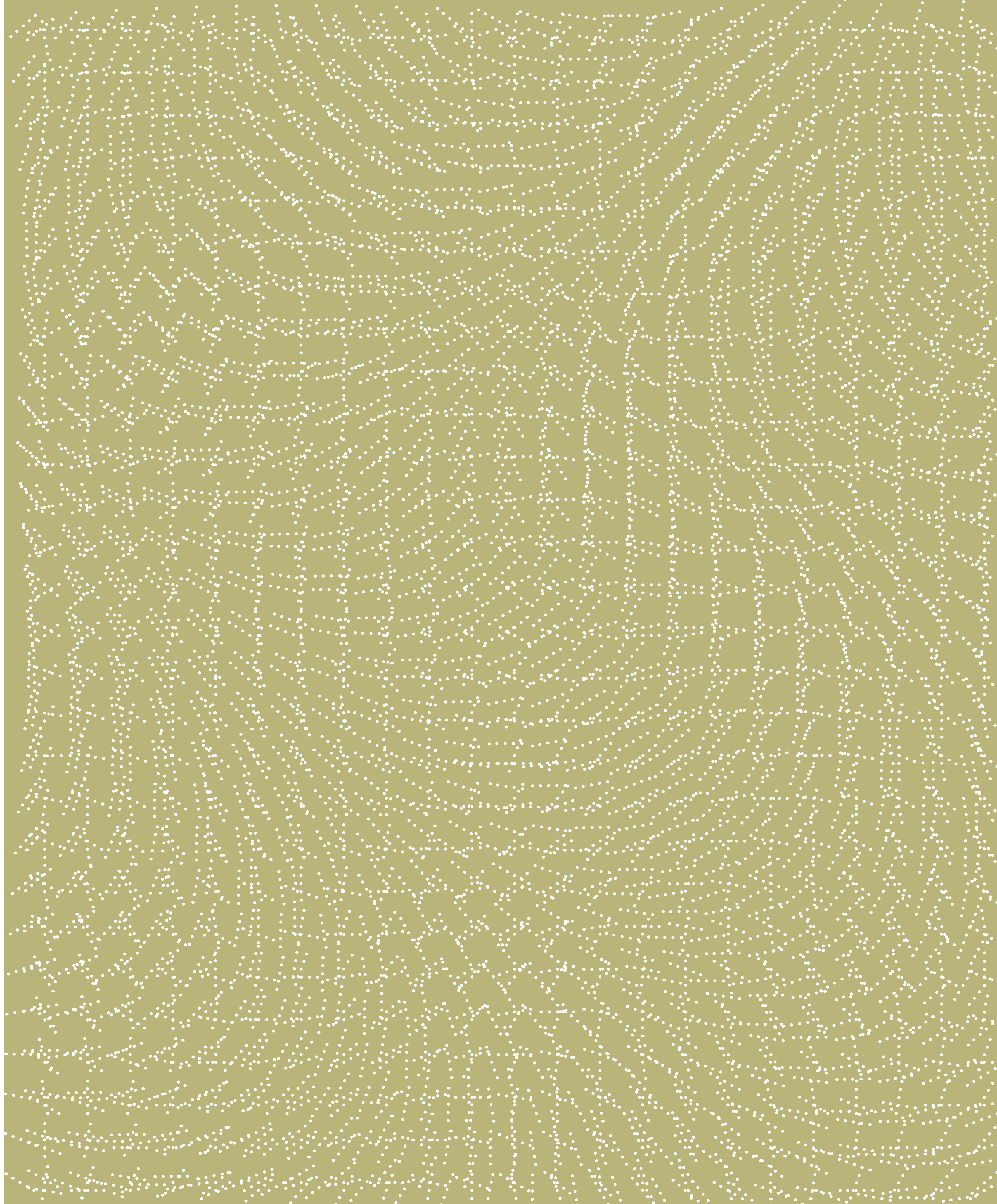
Not quite industrial-scale production, but completely functional: the biorefinery at the Technical University of Munich

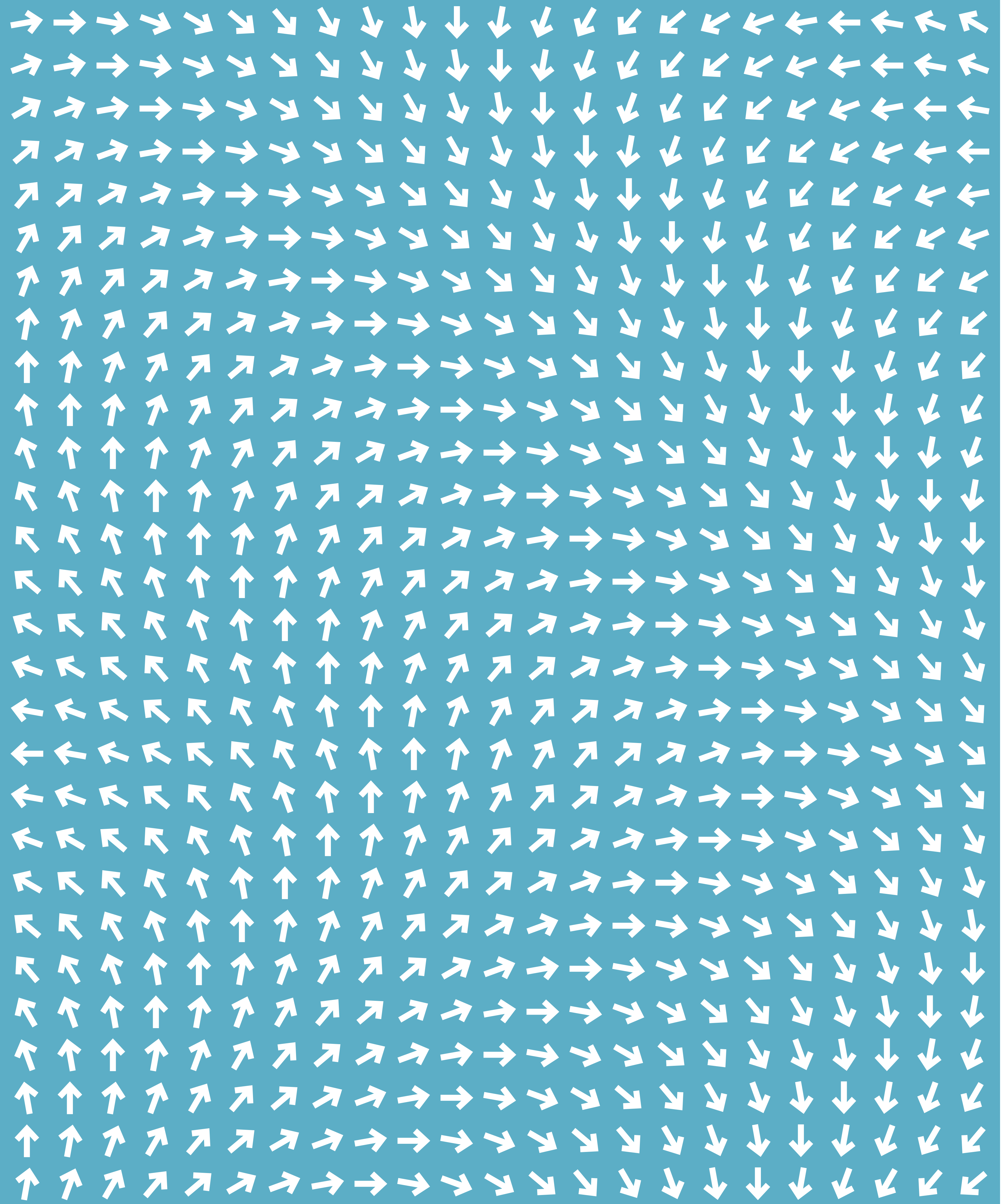


innovative interdisciplinary renewable

Innovation

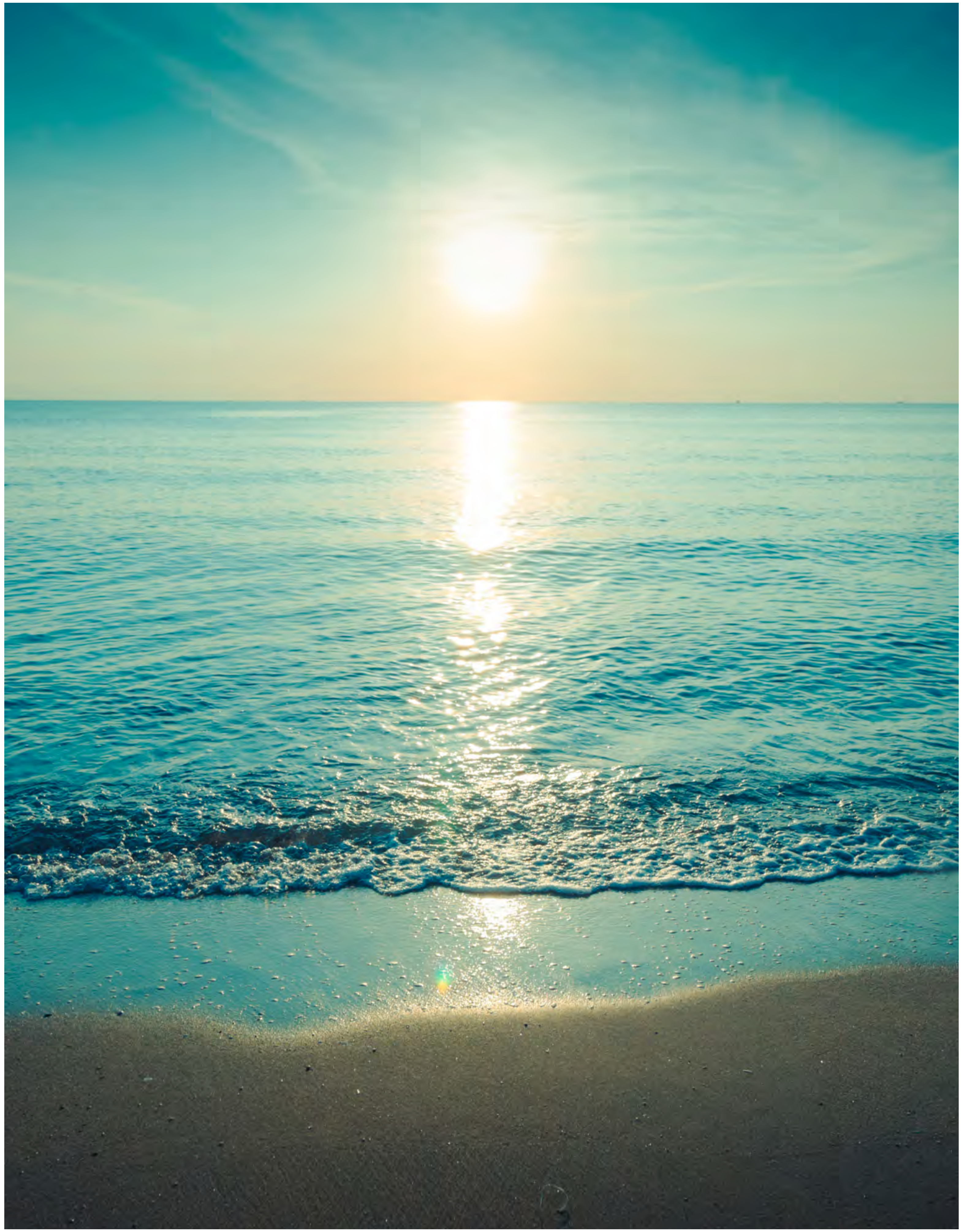
The Werner Siemens Foundation is supporting Synthetic Biotechnology at the Technical University of Munich—because this promising new discipline develops novel approaches and methods to industrially produce sustainable chemical and pharmaceutical substances.





The pure ship

Marine science and climate change research



For most of us, this picture conjures up thoughts of a relaxing holiday. For marine researchers, however, the beautiful azure expanse conjures up thoughts of work—albeit work they have sought out for themselves. Next year, a research crew will embark on a voyage to the Cape Verde archipelago to analyse seawater, cubic metre by cubic metre. They will set sail on a bespoke sailing yacht that is the first of its kind: despite its massive size, the vessel can glide over the waves without polluting the water. After all, the ocean should be treated with utmost care.

Oceans ahoy!

The date is set: in the summer of 2018, the greenest research vessel in the world will be put to sea and embark on its maiden voyage.

The world's oceans play a decisive role in our climate system. They absorb most of the atmosphere's heat as well as the greenhouse gas carbon dioxide. Yet, what is bad on land is also bad at sea: too much carbon dioxide is harmful. Has global warming already adversely affected the oceans? How healthy are the seas today? In the coming years, these questions will be answered by a team of scientists sailing on a state-of-the-art research ship—and with funding from the Werner Siemens Foundation.

In the past 50 years, the temperature in the upper 75 metres of the ocean waters has risen by 0.11°C per decade, making the water a total of 0.55°C warmer. Although this may sound like a minor change, it's highly significant. And the waters must not become any warmer. Researchers believe that one degree warmer is the upper limit (which corresponds to the warming of the atmosphere in the same time period). That higher ocean temperatures will generate serious problems is a basic consensus among experts. "Not only would the sea levels rise dangerously," says palaeoclimatologist Gerald Haug, "the ocean currents might also change." And this would have devastating consequences for the climate of our planet.

Gerald Haug is director of the Max Planck Institute for Chemistry in Mainz and a professor at ETH Zurich. A highly renowned palaeoclimatologist, Haug has conducted extensive research into the climatic conditions from earlier eras, for example, during the Ice Age, and he discovered that major climate change can contribute to the downfall of advanced civilisations, as was the case with the Maya and the Tang Dynasty in China. Over the next five to 10 years, Haug plans to document how the oceans are changing in the age of global warming.

Gigantic biomass

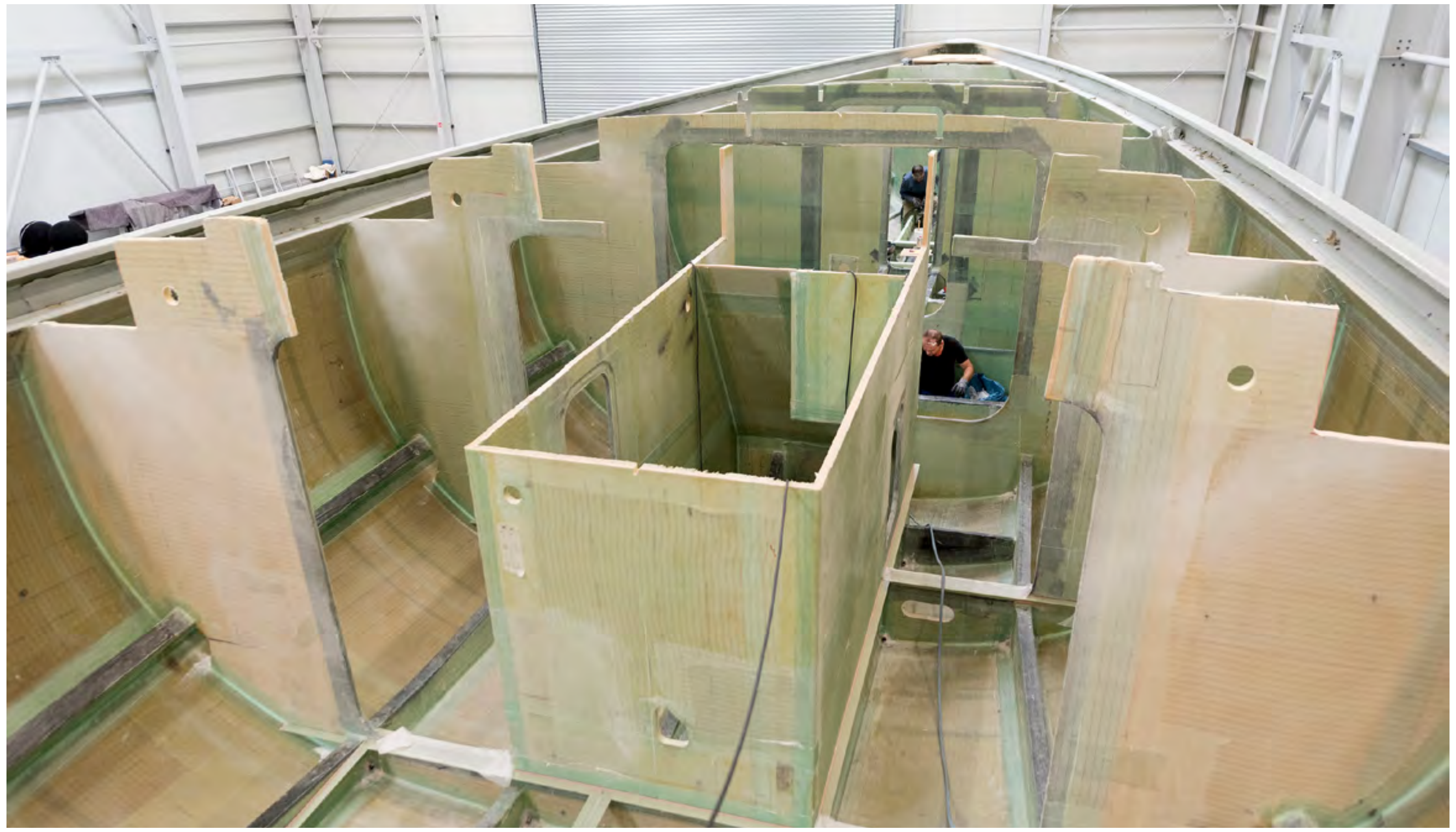
Till now, the ocean has functioned as a huge buffer zone for carbon dioxide and warmer temperatures. Due to its sheer size—two-thirds of the Earth is covered by water—the ocean can accommodate an enormous amount of biomass. Plant life in the seas, especially algae, absorbs more carbon dioxide than all terrestrial plants combined, making marine plants the most important carbon dioxide buffer in the world. And that's not all. The ocean performs another essential service by absorbing some 90% of human-made heat. But the ocean doesn't work for free. The price we pay is that the oceans are warming, that they are becoming more acidic and that they can absorb less oxygen.

Fears of a permanent El Niño

Warming seas will also have a large influence on the Earth's major air and ocean currents—and thus on our entire climate system. Higher temperatures can potentially alter the course of the Gulf Stream, which largely steers our climate. "And a climate that is warmer by one to three degrees will probably result in our having to deal permanently with the weather phenomenon El Niño," says Gerald Haug. Till now, El Niño has occurred every two to seven years in the Pacific between South America and Indonesia and Australia. The weather phenomenon triggers unusually high water temperatures at the American coast, resulting in mass fish mortality and enormous amounts of rainfall, flooding and strong wind storms.

How healthy are the seas today?

Many of the complex interactions between water, sun, air, land masses and living creatures are now well understood. But not all, and certainly not fully. And so, Gerald Haug and his team have decided to systematically investigate how the oceans are changing in the warming climate. The researchers will test the physical properties of seawater (temperature, salinity), its biological make-up (algae, microorganisms)



The hull of the Eugen Seibold is finished; time now to install the interior fittings and research equipment.

Plans to test the world's waters: Gerald Haug, director of the Max Planck Institute for Chemistry in Mainz and professor at ETH Zurich

and chemical composition (concentration of oxygen, carbon dioxide and trace metals), and they hope to predict how the seas will develop over the next 10 to 15 years.

A greener voyage

It's a task of Herculean proportions—one that requires more research ships. "Our studies will be particularly interesting if we can conduct them in summer and winter," Haug says. "The seasonal differences are decisive in understanding the climate. But for that, we'd need a ship every three months—which would be very expensive." The German research ships "Sonne" and "Meteor" cost roughly 40,000 euros per day. They also have to be booked three years in advance and can be used for only four weeks at a time. Another disadvantage is that the steel hulls and motors of these ships contaminate the very water and atmosphere the researchers want to test. And the ships are too big and heavy for many tests. "Some of these expensive, mammoth ships can pull nets that are only 60 cm long to collect plankton," Haug explains. What's more, the research ships are often not available when needed. "The last El Niño, one-and-a-half years ago, was foreseeable. That no research ship was available to examine the bio-geochemical properties of El Niño is, from a scientific point of view, more than regrettable," says Gerald Haug. "And we're still feeling the after-effects of El Niño—for example, the drought at the Horn of Africa and the ensuing famine."

A vision becomes reality

All these drawbacks inspired Gerald Haug and his team to envision the perfect research ship: the vessel should have all the necessary research equipment on board, but should still be light and fast ... its exhaust fumes shouldn't pollute the water or the atmosphere ... it should always be available to the research team ... and it should be affordable. With these requirements in mind, Gerald Haug began seeking partners to realise his vision; in 2015, he found them in German shipyard owner Michael Schmidt—and in the Werner Siemens Foundation, which financed the construction of the innovative research ship.

For two years now, construction has been underway on the world's greenest research vessel: a fast and safe sailing yacht that has all necessary research equipment on board and that is ecological and economical to operate. In May 2018, the ship—named "Eugen Seibold" in honour of the renowned German marine geologist who died in 2013—will set out to sail the seas.

The mission of the Seibold

The date is set. In the summer of 2018, the Seibold will embark on its maiden voyage: a research trip to the Canary Islands and the Cape Verde archipelago. There, the six-person crew will literally test the waters—examining the biological, chemical and physical properties of the sea. By night, the two captains will steer the research vessel to the targeted research destination; by day, the researchers will spend roughly 10 hours collecting and analysing seawater, phytoplankton and zooplankton specimens. “It is very hard work,” says palaeoclimatologist Gerald Haug—and the “inventor” of the Seibold speaks from first-hand experience. That’s why the Seibold will dock in a harbour every three weeks for a seven-day break and to rotate the crew.

1 Sails

The Seibold is a very fast vessel and could circumnavigate the globe in a single year, while carefully collecting specimens along the way. A sail area of roughly 350 m² guarantees a speed of eight to ten knots.

2 Hybrid motor

For safety reasons, a hybrid motor (diesel and electrical) is installed in the Seibold as a back-up in the unlikely event that the crew should encounter slack winds or other troubles on the high sea. The 4,000 litres of reserve diesel fuel are enough to bring the crew safely to shore from the middle of the Atlantic. "Our goal is to operate the greenest research vessel in the world," says Gerald Haug. "But no one should go to sea without a diesel motor."

3 Propeller

The Seibold's propeller is unusually large, as it powers the generator that supplies electricity. The electricity is stored in an 80 kWh lithium battery, which provides enough energy for roughly 10 hours of specimen seeking. The generator also provides all the electricity needed to propel the yacht as well as the power used in the lab to operate the mass spectrometers, analysis equipment, refrigerators and freezers.

4 Multisensor

The multisensor is lowered into the water, where it registers the physical properties of the ocean to a depth of 2,500 metres: temperature, salinity, pH, fluorescence, chlorophyll etc. This allows the team to examine the ocean layers, the supply of nutrients and the permeability between upper and lower layers.

5 Mass spectrometer

To measure the oxygen and carbon isotopes ($\partial^{18}O$, $\partial^{13}C$) and other parameters, the seawater is continuously monitored using a mass spectrometer. The researchers observe how much oxygen the marine plants produce via photosynthesis—which has been coined the "biological productivity" of the ocean. The mass spectrometer also measures metal isotopes; these are sent to the labs at the Max Planck Institute for Chemistry, ETH Zurich and other international partners, where they are analysed in detail.

6 Vacuum hose

On board the Seibold, there is a very large "air vacuum cleaner" with a ten-metre long hose attached to the vessel's mast. The hose is extended as high as possible into the air, where it sucks in air and delivers it directly to the lab for analysis. Among the particles in the air is dust, which plays a major role in the climate system: dust can have a cooling effect because it reflects the sun's rays. Moreover, dust contains iron particles and other micro nutrients that fertilize the seawater and promote the growth of algae, which leads to a reduction in CO_2 levels.

7 Nets

The researchers use newly constructed, particularly light plankton nets to fish for ocean dwellers such as foraminifera (single-cell animals with a chalky shell), which are the most important proxies in palaeoclimatology research.

8 Flow cytometer

The flow cytometer records which microorganisms, such as picoplankton (e.g. cyanobacteria) and algae, are in the water. The upper 500 metres of the sea have the most life because the sun's rays penetrate this layer. But the researchers also lower their probes even further, up to 2.5 kilometres deep.

9 Chlorophyll

Algae form chlorophyll, thus triggering photosynthesis. The amount of chlorophyll indicates the so-called "biological productivity" of the algae.

10 CO_2 reservoirs

Every year, humans release approximately 10 gigatons of carbon into the atmosphere, where it is oxidised to carbon dioxide. The ocean absorbs roughly 25% of this CO_2, causing its waters to acidify. This, in turn, endangers marine animals and plants: the further from the North Atlantic to the Pacific, the more dead biomass in the oceans' depths. The deep layer of the ocean has 60 times more carbon dioxide than the atmosphere. Moreover, it has numerous layers: this thermal stratification in the lower latitudes and the polar regions forms a kind of "lid" to retain carbon dioxide in the depths. The "lid" in the North Pacific and the South Sea is, however, only 200 to 400 metres thick. If the temperature of the Earth and the oceans rise, these lids will disappear and rise to the surface like a freshwater lens. This in turn allows CO_2-rich water to come to the surface; carbon-dioxide is then released into the atmosphere, causing it to warm even more.

11 pH value

Seawater is alkaline, with a current pH value of 8.1. Through the absorption of atmospheric carbon dioxide, seawater has become some 30% more acidic since the advent of the Industrial Revolution 150 years ago, with its pH dropping from 8.2 to 8.1. In a negative feedback loop, the water then absorbs less carbon dioxide, leading to reduced capacity in its reservoirs.

12 Plastic detectors

Plastic has a catastrophic effect in the ocean because it is non-biodegradable and because it kills fish and birds that mistake it for food. Moreover, microplastics can be stored in animal tissue, which causes poisoning and infertility. In the end, these plastics find their way into the food chain and sometimes into the human body.

13 Temperature and salinity

Sensors on the vessel's hull measure the temperature and salinity of the ocean. Global warming could cause Greenland to melt, which would flood the Gulf Stream with freshwater. As a result, the North Atlantic would lose salinity and become lighter, causing the water levels to rise. Today, the Gulf Stream flows like a steep waterfall into the deep North Atlantic Ocean and propels circulation; after 2,000 years, the water particles complete the cycle and return to the Pacific. The cycle is called the "global ocean conveyor belt", and many researchers believe that warmer seawaters would disrupt the system.

Facts and figures

Support

The Werner Siemens Foundation financed the construction of the innovative research vessel Eugen Seibold. The Max Planck Institute will operate the vessel and interpret the data collected; positions for six postdoctoral researchers, six doctoral students and one lab technician are also funded.

Funding from the Werner Siemens Foundation

3.5 million euros

Project duration

2015–2018

Project leader

Prof. Dr Gerald Haug, director of the Max Planck Institute for Chemistry in Mainz and professor at ETH Zurich

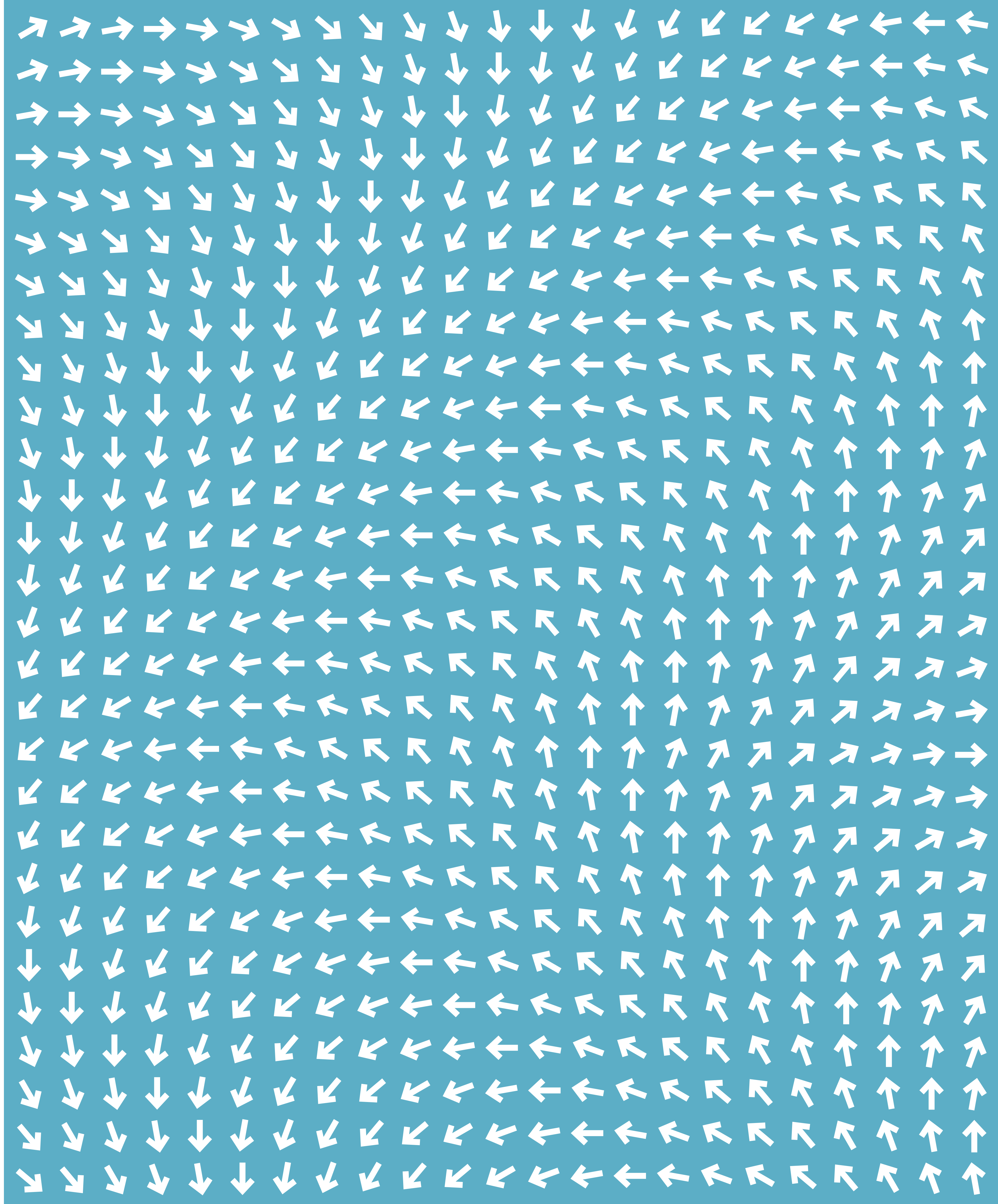
Partners (selection)

Michael Schmidt Yachtbau GmbH, Greifswald, Germany
Max Planck Institute for Chemistry in Mainz, Germany
ETH Zurich, Switzerland

A strong team for the world's seas: Johannes Malzahn, managing director of the shipyard; Michael Schmidt, owner of the shipyard; and Professor Gerald Haug, "inventor" of the Eugen Seibold

A glimpse into the shipbuilding hall in Greifswald, Germany

green light efficient



Innovation

The Werner Siemens Foundation financed the construction of the Eugen Seibold—because this research vessel tests the waters without polluting them.

Open minds

Fostering talent in the STEM subjects

To venture into the unknown, to try something new in a spirit of fun and adventure. This open-minded attitude is embraced by the gifted students at summer schools funded by the Werner Siemens Foundation.

Summertime, and the learning is easy

The students invited by the Swiss Study Foundation to take part in one of four summer schools are among the best in their fields. But there's more than just high intelligence in the equation: these bright young minds are also curious and not the least afraid to take on new challenges. Not just a few of the 80 participants select a week-long course in a subject that is almost entirely unrelated to their studies.

A scene akin to a painting of Classical Antiquity meets the eye: young adults, eager for knowledge, gather around revered scholars who pass on their wisdom while engaging thoughtfully with their students' questions and critical observations. No final exam looms, no late-night cramming is necessary. The group sits comfortably in a lakeside garden; students and masters alike are engrossed in deep discussion. Birds chirp happily in the palm trees as the mild September sun warms the air.

This idyllic setting is, however, not a painterly depiction of Classical Antiquity, but present-day reality in September 2017, at a summer school in the small town of Magliaso, at the Lake of Lugano in southern Switzerland. The scholars in the scene are Carel van Schaik, professor of anthropology and zoology, and Hans-Peter Mathys, professor emeritus of theology. The two men—who lead the summer school on cultural evolution and religion—are sitting with their students in the park of the conference and recreation centre Centro Evangelico. A physics student has just asked why Christianity was able to assert itself over other world religions. "Well," begins theologian Hans-Peter Mathys, "it was certainly instrumental that Christ approached and took interest in all human beings, down to the peasants and the disabled. He wasn't distant or inaccessible like the god of Judaism, nor was he disinterested like the gods of Antiquity. Probably people were ready for something new. And then, the language of Christianity was Greek—not Latin, as is often thought—and Greek was in those days what English is today." In the ensuing discussion, one thought leads to the next, many of which are new and inspiring for the young students of physics and engineering sciences.

A similar scene is taking place in the building next door, except there the topic of the summer school is big data and the participants are discussing algorithms, "decision trees" and false positives. The students are puzzling over statistical studies of large data sets that repeatedly produce nonsensical connections and false results. For example: green jelly beans cause acne. Co-course leader Servan Grüninger begins to explain the phenomenon. A few students understand immediately and put forward their theories, while others type busily on their laptops. That morning, a crash course on big data was offered to students who, in the past, had less exposure to the subject; the course was apparently already bearing fruit. "We want everybody to grasp the basic principles and develop their own line of thinking—the medical student and the philosopher alike," is Servan Grüninger's credo.

Another two houses further, twenty young adults are wracking their brains over ways to create a functioning healthcare system with modest resources. After tackling a variety of tasks in groups, they present their ideas to the entire class. Course leader Aliya Karim briefly evaluates the strategies and gives each group feedback. "You've improved a lot", she encourages one of the groups, "but you can make your ideas even better. Keep working! 85% isn't good enough!" In an aside she whispers, "That's not true. They're doing well." Her summer school on managing healthcare with limited resources challenges future engineers and IT specialists to adopt new, pragmatic approaches to problem-solving.

The summer schools were organised by the Swiss Study Foundation, which invited outstanding students at higher education institutions throughout Switzerland to apply. Although all disciplines were addressed, most students are from the STEM subjects, that is, they study subjects in the natural sciences, technology, engineering or mathematics. Nevertheless, the summer schools host a diverse group of 60 to 80 future civil engineers, physicists, biologists, doctors, philosophers and IT specialists.

Many of the students are here for the second time because they wholly endorse the idea behind the summer schools: learning and engaging in intense dialogue with outstanding experts and with peers who are equally curious, open-minded and hungry for knowledge. And the experience of forming new friendships—whether they last for the week or for a lifetime—is not just personally rewarding: the students will benefit from these contacts later in their professional careers, especially when they take on leadership roles, work in complex projects, head a team or even an entire company. When a problem can only be solved by applying a multi-disciplinary approach, it is essential to have a broad network to fall back on.

The Werner Siemens Foundation takes great interest in supporting promising students in STEM subjects and pursues novel avenues to achieve this aim. In 2016, the Foundation resolved to grant annual funding to selected summer schools of the Swiss Study Foundation. "Future leaders in STEM subjects should have a broad education and possess excellent social skills," explains Peter Athanas from the Werner Siemens Foundation. "It is important that they understand the diverse challenges of our day and that they are motivated to play an active part in society—and that they are willing to use their exceptional abilities to bring about positive change."

*

The afternoon has slipped away and the 6.30 dinner bell summons the students to their evening meal. They flock to the dining hall of the Centro Evangelico in Magliaso and sit at the large, round tables. One student chooses a vegetarian meal, another a beef stew, and all eat together and share their stories. Now and then the students chat with some older tourists at the centre whose love of hiking brought them to Magliaso, or with one of the guests in a wheelchair who is part of a disabled group on holiday at the Centro Evangelico. In addition to all the other lessons learned at the summer school, the gifted young students gain insight into their good fortune. They are healthy and can jump into the pristine Lake of Lugano before classes begin. They are young and full of life, gaining more energy from late-night discussions than from actual sleep. They are so passionate to see the world that they don't rest on their day off, choosing instead to take the four-hour hike from Monte Lema to Monte Tamaro—not to mention the two-hour ascent and descent at either end.

It's all about teamwork at the summer schools.

Maximilian Mordig

Subject: physics, computational science and engineering
Summer school: healthcare management with limited resources
20 years old

"I skipped four grades at school, and earned my university entry qualification aged 15. I then started studying physics at the Federal Institute of Technology in Lausanne—because of the French language and the relaxed way of life in French-speaking Switzerland. I earned my master's at the age of 20. Because I was still young, I first lived with a host family in Lausanne, but I often went home on the weekends to my family in the Basel area. My parents are both doctors and I also have two brothers and a sister. We are an active family; I jog and cycle.

"I'm most productive when I work under pressure and do many things at the same time; my best ideas come to me right before a deadline. In addition to my studies, I read all sorts of books, most recently works by Balzac and Albert Schweitzer. I also like discovering new places. When I was 16, I spent eight weeks in Qingdao learning Chinese. At first I couldn't understand a word or even order a meal—it was a very strange experience. But I got the hang of it after three weeks.

"My next step is to complete my compulsory military service, preferably as a paramedic or an Alpine specialist. In the military, I'll have to learn to work with people from all walks of life—an invaluable skill if I later have a leadership position; my analytical approach is, of course, only one way to solve a problem. I would like to become a professor of theoretical mathematics. Algebra fascinates me. Everything is founded on basic theorems and definitions that can be built upon to reach results; there's a beauty—almost magic—to it. On the other hand, I could also see myself founding an IT start-up. When I do the same thing for too long, I get bored."

Joy Schuurmans Stekhoven

Subject: electrical engineering and information technology
Summer school: cultural evolution and religion
22 years old

"I inherited my flair for all things technical from my father, who runs a medical technology company. I was always fascinated by the fact that a technology—like prosthetics—has the potential to help so many people. Even though my parents have modern, emancipated attitudes, for a long time I didn't believe I could be good at mathematics as a girl. Thank goodness I got over that! Even as a seven-year-old, I loved to solve simple equations that my father would set for me. Today I'd describe myself as a feminist, although I don't restrict feminism to women—men also experience discrimination. There is still much to be done in our society before gender-related prejudice becomes a thing of the past.

"The summer academy on cultural evolution and religion was my first choice—perhaps inspired by my travels last year to Japan, Indonesia, Thailand and Australia, where I encountered many lesser known religions. I'm an atheist myself, but my parents are Christians and I shared their faith as a child. Even though I no longer believe in God, I appreciate that religion can foster a strong sense of community. It's a source of peace for many people and very helpful in some situations.

"Contemporary art fascinates me and I often visit museums. In Singapore, I went to a crazy exhibition on transhumanism; an artist presented a project for storing the energy of the dead with a battery—which of course begs the question as to what we should power with such a battery …"

Roman Blum

Subject: microtechnology
Summer school: cultural evolution and religion
23 years old

"As a teenager, I often revamped bikes; I liked converting them into fixies without using any additional parts. It more or less worked, but they were a devil to ride! A year ago, I finally bought myself a real fixie. I'm fascinated by their special dynamics.

"I completed the bilingual Swiss university entry qualification (German/English) with a focus on Russian and now study microtechnology at the Swiss Federal Institute of Technology in Lausanne. I feel that I can have the greatest impact in the area of the natural sciences; it inspires me to create something new that is objectively better than its predecessor. My dream is a computer that uses photons rather than electrons for data transmission.

"Over the last two years I've become an avid photographer. Before my studies abroad in Sweden, I bought a single-lens reflex camera; I now take it everywhere. I photograph landscapes, cities, people and my own still-life arrangements, not to mention diverse events of the student society 'Association des Etudiants en Microtechnique'.

"I gained my first leadership experience in the military, where I completed my service as a non-commissioned officer for nuclear, biological and chemical defence. I don't have a problem with tough leadership, as long as the situation requires it.

"I'm attending the summer school on cultural evolution and religion. I like how the discussions can continually evolve without a specific goal in mind, and I enjoy discovering more about the history of humanity. I find such knowledge very important for my generation; we often lack a sense of the bigger picture."

Nicole Speck

Grant recipient of the Werner Siemens Foundation
Subject: human medicine
Summer school: big data
24 years old

"I would like to specialise in reconstructive plastic surgery. This branch of surgery repairs damage to the face or other parts of the body in burn victims or in patients who have had large tumours removed; breast reconstruction after a cancer operation is just one example.

"Next year I'll be travelling to South Africa for a month to gain experience in trauma surgery and intensive-care medicine. In South Africa, the incidence of emergency patients with stab or gunshot wounds is much higher than in Switzerland. After that I would like to immerse myself in ear, nose and throat surgery in Australia. My plans to study abroad are why I applied for a grant from the Werner Siemens Foundation: for financial assistance during the internships. I also find the exchange with other grant recipients very inspiring.

"After finishing my master's degree, I'll probably go to California to work in stem-cell and skin-replacement research; I've made it a priority to gain international experience. Last year I was in an operating theatre in Oxford. It was astounding to see how differently they work there. These diverse experiences will help me to develop my own methods as a surgeon.

"I'm also fascinated by the fine arts, especially sculpture and architecture: they're not so far removed from plastic surgery. Aside from anatomical knowledge, plastic surgeons have to cultivate an eye for what looks natural and works well in the overall picture. I can spend hours in the sculpture collection of the Louvre in Paris observing how the objects change according to the light and perspective."

Aline Steiner

Subject: veterinary medicine
Summer school: healthcare management with limited resources
26 years old

"My doctoral thesis is a critical literature review that calls into question previous studies using laboratory animals. I posit that the type of anaesthesia used in animal testing influences the results, which in turn adversely affects the comparability of the studies. I'm convinced that too much animal testing is carried out in the pre-clinical phase. Animal testing should be authorised only when it is 100% necessary and completely thought through, and when the quality of the study is high. And where animal testing is truly necessary, it must be conducted under conditions that take the welfare of the particular species into account. For example, under the current standards for keeping animals, laboratory rats and mice lack any challenging activity. Moreover, rats can be tamed, but not mice—mice are actually distressed by attempts to tame them. That's why I believe that animal-testing should be conducted on the species that suffers least under the tests.

"I haven't had much leadership experience to date. In addition to working on my thesis, I work as a resident physician at the veterinary hospital in a very large team. I think good leadership depends much on appreciation and respect, as well as on strong inter-personal skills.

"My whole family is active in animal protection. My brother and I worked as helpers in a Romanian animal shelter, which was extremely meaningful and rewarding. Now I advise the liaison team for Casa Cainelui when they have medical questions. I also have my dog from there.

"This is the fourth time that I've attended a summer school: the learning approach and inspiring surroundings fit perfectly with my ideal picture of scholarship."

Servan Grüninger

Subject: computational science and engineering
Summer school: co-leader of big data
26 years old

"The biostatistician Stephen Senn once wrote that statisticians are second-class mathematicians, third-rate scientists and fourth-rate thinkers. That may have a hint of truth, but it also means that statisticians have strong interdisciplinary skills and can make a positive contribution in a variety of fields—that suits me well. I have a bachelor's degree in biology, with three minors in neuroinformatics, political science and law, and a master's degree in biostatistics from the University of Zurich. And to brush up on my second-class mathematical skills, I'm currently completing a second master's degree in computational science and engineering at the Federal Institute of Technology in Lausanne.

"I've attended summer schools before as a student, but this time I'm co-leading the summer school on big data. We've created a programme that aims to give as many students as possible an insight into big data, including those who have no prior knowledge of the subject.

"I've always worked during my studies—first as a salesperson, then in a book shop, and then in research. Since 2014, I've been writing blogs and freelance articles for the newspaper Neue Zürcher Zeitung. For over three years now I have worked in a science think-tank called 'reatch—research and technology in Switzerland' that strives to promote a science-friendly culture in society. Our goal is to harness the full potential of science, but without technocratic decisions riding roughshod over societal concerns. We want to strengthen people's trust in science while also promoting a strong sense of social responsibility among scientists."

Facts and figures

Project
The Werner Siemens Foundation supports the diverse scholarship and talent programmes of the Swiss Study Foundation.

Support
The Werner Siemens Foundation financed the following summer schools of the Swiss Study Foundation in 2017: Sensomotoric principles of social cognition; Healthcare management with limited resources; Cultural evolution and religion.

Werner Siemens Fellowships: every year, the Foundation awards excellence grants to 10 outstanding students in the fields of mathematics, informatics, natural sciences, technology, medicine and pharmaceutical science.

Funding from the Werner Siemens Foundation
19,800 Swiss francs annually for each Werner Siemens Fellowship holder
360,000 Swiss francs annually for the summer schools

Project duration
2015–2025

Project management
Prof. Dr Cla Reto Famos, director of the Swiss Study Foundation, Zurich
Dr Sarah Beyeler, academic associate, Swiss Study Foundation, Zurich

"The learning approach and inspiring surroundings fit perfectly with my ideal picture of scholarship": future veterinarian Aline Steiner (right) and other students try their hand at something new: designing a fair healthcare system on a tight budget.

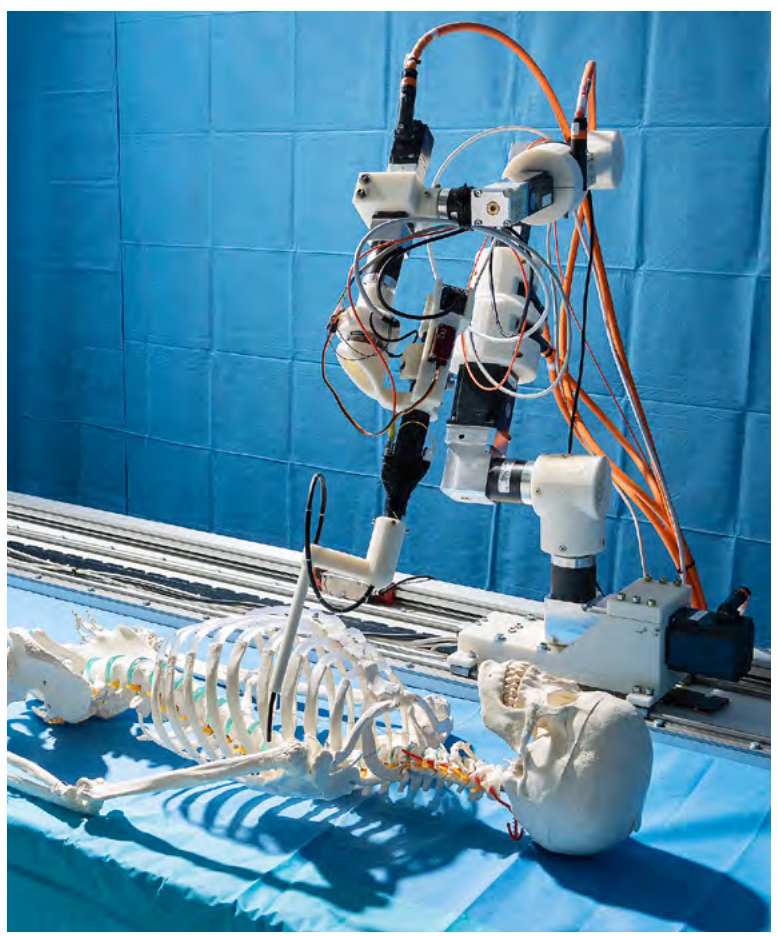
promoting educating connecting the brightest minds

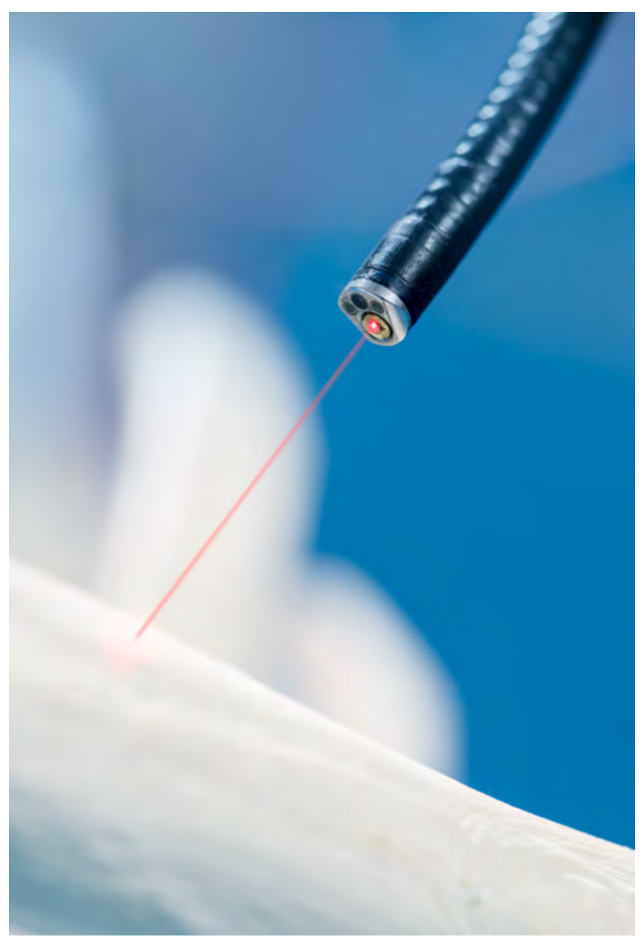
Innovation

The Werner Siemens Foundation is proud to support the scholarship programmes of the Swiss Study Foundation and its excellent educational, mentoring and advisory services for young talent in the STEM subjects.

Bone surgery using laser technology

Operating on a humerus using robot-guided laser technology





Researchers at the University of Basel are working towards making minimally invasive bone surgery reality – using robot-guided lasers, a technique that could greatly reduce patient recovery times and even be used to treat patients with overall poor health.

Since the early days of laser research in the 1950s, surgeons have dreamt of using powerful, consolidated light beams to operate on bones. After numerous setbacks, researchers at the University of Basel believe they are now close to realising this dream, thanks to the project MIRACLE—Minimally Invasive Robot-Assisted Computer-Guided Laserosteotome. In the future, it is hoped that surgeons will be able to conduct minimally invasive operations using a robot-guided laser osteotome.

An osteotome is a surgical device used to cut through bone—for example, a chisel, a drill or a bone cutter. Operations using laser osteotomes promise numerous advantages, first and foremost: greater precision. Lasers can cut through bone with utmost accuracy and achieve highly complex incisions. As a result, bones knit more quickly after an operation and require less complex fixation techniques. In addition, laser surgery guards against heating and damaging the surrounding tissues—a common side-effect when using a bone cutter. A further advantage is that large incisions in the skin will no longer be necessary: surgery using a laser osteotome will require only a small hole through which the endoscope is inserted.

This less invasive procedure leads to shorter hospitalisations and more rapid recovery times. As such, it is also suitable for patients with overall poor health. This is all the more important as the increase in general life expectancy will be accompanied by an increase in wear and tear on bones and joints.

Innovative laser osteotomy can be used in various scenarios, for example, in knee and back surgery, and to remove tumours from bone tissue. Ideally, the technique will also be used to transplant bone and cartilage.

The Werner Siemens Foundation is proud to support the MIRACLE project, which pursues four main goals: channelling laser technology for application in bone surgery; developing a robot for minimally invasive interventions; designing innovative technologies for 3D navigation to guide the robot in high-precision operations; and developing tailor-made bone implants using a 3D printer.

Building on past achievements

MIRACLE is a lighthouse project of the Department of Biomedical Engineering at the University of Basel. It is located at the Switzerland Innovation Park Basel Area, in Allschwil, near Basel. The interdisciplinary team combines the expertise of some 30 researchers from the fields of medicine and the natural sciences.

The project is headed by Philippe Cattin, professor of medical image analysis, and Hans-Florian Zeilhofer, head of the Clinic of Oral and Maxillofacial Surgery at the University Hospital Basel. Phillipe Cattin's research group has extensive experience in medical image processing: Cattin was head of a project exploring robot-based laser osteotomy at the National Centre of Competence in Research "Computer Aided and Image Guided Medical Interventions" of the Swiss National Science Foundation. Hans-Florian Zeilhofer is specialised in 3D planning of complex surgical interventions and has been at the forefront of research on laser osteotomy for the past 15 years. Together, Cattin and Zeilhofer designed an initial laser osteotomy system to perform operations via an open skin incision. Now, researchers can build on this experience to develop a completely novel, minimally invasive technology.

Current state of research

Funding from the Werner Siemens Foundation has enabled two additional assistant professorships to be instituted in the MIRACLE team: Azhar Zam is head of the group Medical Laser Physics and Optics, and Georg Rauter is head of the group Medical Robotics and Mechatronics.

In June of 2017, the researchers were able to present GG1, an initial prototype for a minimally invasive laser robot. The group has also made advances with innovative implants and in 3D navigation; in addition, 3D visualisations of the body (virtual reality) created using their new software SpectoVive can be used to expedite operation planning—and to better anticipate the actual conditions. Moreover, surgeons can use augmented reality technology (via special glasses) to move virtually through a patient's body, thus ensuring greater precision. The value of the advances made by the researchers in Basel is, however, not limited to just laser osteotomy: these techniques are applicable in a variety of surgical procedures—which is why it comes as no surprise that the MIRACLE project has already generated three spin-off companies in the past two years.

The schedule is ambitious: by 2021, the team aims to have tested bone operations using robot-guided laser technology on animal cadavers and human bodies donated for research. By 2025, laser osteotomy should be ready for clinical application.

Funding from the Werner Siemens Foundation

15.2 million Swiss francs

Project duration

2014–2019

Energy transition in Valais

Putting theory to practice: trainees learn how to make electrical switch circuits at the technical upper-secondary vocational school in Valais.

After completing compulsory schooling in Switzerland, many young people who would like to learn a technical trade lack sufficient skills in maths, physics and chemistry. They struggle in their apprenticeships; some lose motivation and even drop out. But the situation has improved in recent years, at least in the Canton of Valais, thanks to two projects of the Werner Siemens Foundation that support vocational training for technical professions.

The first project initiated by the Werner Siemens Foundation aims to support apprentices in the Swiss Canton of Valais learning a profession in the fields of automation, auto-mechanics and electricity. Over the past five years, workshops, laboratories and remedial courses have been established at the technical upper-secondary vocational school in Sion to support students. In the labs, the young apprentices can deepen their theoretical knowledge and apply it in practice. In materials science, for example, the learners discover through experiments that although hardened steel is stronger and can generally withstand more pressure before breaking, it is less elastic and thus breaks more quickly under sudden high pressure than regular steel. In the mechanics workshop, the future auto mechanics delve into the motors, clutch mechanisms, electronics and other components of cars and motorbikes. And another large workshop is fitted out with practice stations for electrical systems as well as an electrical laboratory where the students learn to assemble an electrical circuit and to repair faults.

In the training workshops, extra courses are offered to help apprentices from different trades brush up on a variety of practical skills. These courses are also open to students from commercial and university-track schools who would like to pursue a technical career—they can catch up on the practical aspects of a profession at the workshops. And apprentices who are struggling with working methods or self-management receive coaching and individual support.

The success of these efforts is plain to see. “The completion rate for technical apprenticeships in Valais has now reached 93%,” confirms Bernard Dayer, director of the technical upper-secondary vocational school in Sion. With a federal certification under their belts, the young professionals—in mediamatics, electronics, automation assembly, multimedia electronics, auto and electronic mechanics, polymechanics, industrial design, plumbing, electricity and cableway systems—are in high demand on the job market. And that is a boon for Jean-Pierre Tenud from the department of economics and education of the Canton of Valais: “Today there is almost no unemployment in the technical professions.”

With the first project concluding at the end of 2017, the Werner Siemens Foundation was inspired by its success to launch a follow-up project. As of 2018, apprentices and students in Valais will also be able to complete an education in the fields of building cladding, building technology, energy-efficient building renovations and energy-balance optimisation. The program covers the latest standards in insulation, energy conservation, electronic control systems, heat technology and solar energy. In addition, a laboratory is planned where the students can put their theoretical knowledge of planning, cladding, heating, ventilation and sanitary facilities into practice. And when the seed funding from the Werner Siemens Foundation runs out in five years’ time, the Canton of Valais will carry the costs to maintain the follow-up project as well.

Thanks to this second Werner Siemens Foundation project, the Canton of Valais can help train the specialists that Switzerland urgently needs to implement its energy transition strategy, a plan that was approved by the Swiss electorate in May 2017. The young professionals from Valais will be in high demand: there is a host of old buildings in need of an energy overhaul.

Funding from the Werner Siemens Foundation

Project AFOTEC (2013–2017)
2.6 million Swiss francs
Project AFBAT (2018–2022)
1.6 million Swiss francs

Project management

Jean-Pierre Tenud, Canton of Valais, office for industry, commerce and employment

Partners

Professional association “Tec-Bat Valais”
Suissetec Haut-Valais
Upper-secondary vocational schools of Sion and Martigny
Vocational school of the Haut-Valais region

Future scans

State-of-the-art scanner at the Werner Siemens Imaging Center at the University of Tübingen

The Werner Siemens Imaging Center and the University of Tübingen are playing in the premier league of medical imaging research. The overarching goals? To better understand illnesses. To diagnose them earlier. And to treat them more effectively.

An MRI image of a painful back, a PET scan in case of a suspected tumour: medical imaging techniques such as magnetic resonance imaging (MRI) or positron emission tomography (PET) have become indispensable instruments in clinical care and medical research.

At the University of Tübingen, medical imaging techniques number among the core research priorities. The Werner Siemens Foundation has been supporting this work since 2007 and, in 2014, founded the Werner Siemens Imaging Center (WSIC)—the only one of its kind in the whole of Europe. The centre, which quickly became an internationally leading research institution for medical imaging, places its focus on preclinical research, namely, basic research done on cell and animal models, including the development of medical imaging instruments for small animals such as mice. The findings should shed light on how illnesses arise, develop and spread through the body, with the ultimate objective of developing better treatments. The spectrum of disciplines encompasses oncology, neurology, cardiology and immunology.

Physicist and biomedical specialist Bernd Pichler is head of the centre and holds the Werner Siemens Foundation Endowed Chair for Preclinical Imaging and Medical Imaging Technology.

Integrated equipment

The approximately 60 members of the team at the Werner Siemens Imaging Center unite specialist knowledge from the fields of biology, physics, medicine, chemistry and engineering science. The team's core interdisciplinary approach has already achieved considerable success: for instance, the world's first scanner able to combine magnetic resonance imaging (MRI) and positron emission tomography (PET) in a single instrument was developed at the centre. Indeed, the Siemens group has already incorporated this innovative technology into its line of medical instruments.

The researchers' interdisciplinary approach continues to lead them even further. They are currently working to integrate medical imaging techniques with analyses and research findings from areas such as microscopy, protein analysis (proteomics) and metabolic analysis. "Our goal is to create multimodal instruments capable of depicting and combining information from various analyses. This would greatly improve physicians' ability to diagnose a disease and thus allow a more precise, personalised therapy," says Bernd Pichler.

In order to manage the huge data volumes produced by medical imaging techniques, the team at the centre is working to improve data interpretation via artificial intelligence. Key measures include "machine learning" and "deep learning"—techniques in which algorithms are used to analyse data and, for instance, to recognise pathological changes in cells and organs that are depicted on the images.

Innovative biomarkers

Earlier diagnosis, better understanding and targeted treatments of disease are the goals, but improved medical imaging is not enough—tiny little helpers, so-called biomarkers, are also essential. Biomarkers are radioactive or fluorescent chemical compounds able to indicate certain diseases. Medical research worldwide is now intensely searching for such disease-specific biomarkers. They are invaluable in medical care, as they allow diseases to be diagnosed more easily and with a lower incidence of error. In addition, biomarkers help to monitor the course of a disease and the success of a therapy.

The Werner Siemens Imaging Center plays a major role in biomarker research, with particular focus placed on biomarkers that can be traced using medical imaging techniques. Among the centre's major achievements is its research into pulmonary infections caused by the fungus *Aspergillus fumigatus*. Many infected patients die because the fungal infection is extremely difficult to differentiate from a bacterial infection; as a result, it is frequently diagnosed and treated incorrectly. The researchers have now succeeded in developing biomarkers able to indicate infected areas in the lungs of mice at a very early stage.

In addition to its work on medical imaging, the centre has received international acclaim for its research in neurology and oncology. In these fields, priorities include developing biomarkers for neurodegenerative diseases such as Alzheimer's or Parkinson's disease, and examining the efficacy of innovative immunotherapies in cancer treatments.

From research to clinical care

To ensure that patients profit as soon as possible from the latest findings, the Werner Siemens Imaging Center collaborates closely with the University Hospital Tübingen. A group of researchers and physicians at the centre are working on translating promising basic research into clinical care. At present, the team is engaged in clinical studies on diagnosing *Aspergillus fumigatus* infections and working towards better diagnostics of breast cancer.

Funding from the Werner Siemens Foundation
12.3 million euros (2007–2016)
15.6 million euros (2016–2023)

Project begin
2007

Who we are

The history of the Foundation

“Ridiculously simple” is how Werner Siemens described the contraption he had concocted out of a cigar box, bits of iron, tin and insulated copper wire. It was the year 1847, and the contraption was a simple home-made telegraph that would become the cornerstone of a renowned international firm. Shortly thereafter, Siemens built the first telegraph connection between Berlin and Frankfurt, and in March of 1849, he landed a coup by announcing the election of Friedrich Wilhelm IV to German Emperor. Whereas it took the royal delegation a week to convey the message from Frankfurt to Berlin, Siemens and his telegraph needed only one hour.

The company soon established branches abroad, and two of Werner’s younger brothers joined the business: Carl was in charge of the Russian holdings and Wilhelm saw to affairs in Britain. In 1874, the company laid the first transatlantic ocean cable, and all three brothers were knighted for their technical and entrepreneurial achievements: Werner von Siemens in Germany, Carl in Russia and Sir William in Great Britain.

In addition to their technical and business acumen, the brothers demonstrated a pioneering spirit in their role as employers: they gave their employees a share in the company’s success, and, in 1872, they founded a company pension fund—a pioneering step. This pronounced sense of social responsibility was characteristic of the Siemens family—a trait possibly strengthened by the early death of their parents. Already in 1900, Carl had envisioned a foundation for the Siemens family, and his daughters Charlotte and Marie immediately embraced the idea.

The First World War, however, put the company under great strain. Business was hobbled in Germany, and the British branch fell under the financial control of the government. Nor did the family remain personally unaffected by the upheaval of the era: Charlotte’s husband was murdered in the Russian Civil War, and she was forced to flee with her son in the aftermath of the October Revolution. She was later granted citizenship in Liechtenstein.

After the war, Charlotte and Marie finally gained access to the inheritance left by their father and, after a twenty-year delay, realised Carl’s vision: on 7 November 1923, they invested 200,000 Swiss francs in the Werner Siemens Foundation in Schaffhausen, Switzerland. The funding was originally intended to support Siemens family members who were caught in the political and economic turmoil in Germany and Russia. In the following years, three additional women from the Siemens dynasty contributed significantly to the fund: first Anna and Hertha, the daughters of Werner von Siemens, and later Eleonore, the daughter-in-law of Carl von Siemens.

Charlotte von Buxhoeveden, née Siemens (left), and Marie von Graevenitz, née Siemens, established the Werner Siemens Foundation in 1923.

The Werner Siemens Foundation was founded by the daughters of Carl Siemens, who fulfilled their father’s long-cherished ambition of establishing a fund to support members of the Siemens family—a goal that was initially delayed by the outbreak of World War I.

The Werner Siemens Foundation

“Research was my first love—the love of my youth—and a love that has burned brightly into old age. And yet, I was also driven to make scientific findings useful in everyday life.”

Werner Siemens, “Personal Recollections”, 1892

Werner Siemens: visionary inventor and entrepreneur

Between 1923 and 1941, five women of the Siemens family—Charlotte, Marie, Anna, Hertha and Eleonore—donated funds to the newly established Werner Siemens Foundation with the goal of supporting the descendants of Werner and Carl von Siemens. A look into the Siemens family history helps to explain this mission.

The early loss of his parents had a major impact on the life of Werner Siemens. His mother died in 1839, his father only one year later. At the time, Werner was 24 years old, and he took responsibility for his younger siblings, especially regarding their education. His brothers Carl, Hans, Friedrich and William all became engineers and businessmen—which soon proved a wise career choice.

In 1847, Werner Siemens founded a telegraph manufacturing company, “Telegraphen Bau-Anstalt von Siemens & Halske”, with Johann Georg Halske. The company was soon profitable and expanded to other countries. As of 1897, Werner’s brothers and other family members joined the firm, contributing to its success. Their collaboration and common goals forged a sense of community in the many branches of the large Siemens family.

Today, some 430 descendants of the Siemens company founders live in all corners of the globe, although mainly in Europe. The far-sighted Siemens women were originally thinking of their family’s financial security when they established the Werner Siemens Foundation and formulated its mission: for 80 years, the Foundation’s primary goal was to help members of the Siemens family in need of financial support.

Thanks to the solid financial development of the Siemens group, the original mission of the Foundation could be expanded in 2003, which is when the Werner Siemens Foundation began supporting philanthropic endeavours outside the family. This work is focused primarily on groundbreaking, highly promising projects in the natural sciences and technology—projects whose innovative character makes seed funding essential.

The Werner Siemens Foundation also promotes young talent, especially in the STEM subjects of science, technology, engineering and mathematics as well as in medicine and pharmaceutical science.

The expanded mission of the Foundation also has its roots in Werner Siemens’s biography: his father was a tenant farmer who was in debt and thus had no money to send his gifted son to university. To start his company, Werner depended on a loan from his wealthy cousin, Johann Georg Siemens. This was seven years after the death of his parents, and, had no one believed in the ideas of Werner Siemens, an international company would never have been realised.

The Werner Siemens Foundation is particularly interested in supporting the challenging starting phase of innovative research projects: it provides seed funding, thus enabling promising ideas and methodologies to be further developed and tested—with the goal of translating these technologies into practical applications. Or as Werner Siemens put it, to make them “useful in everyday life”.

Governing bodies

Foundation Board

The Foundation Board oversees the governing bodies of the Werner Siemens Foundation. The Board bears responsibility for the overall management of all Foundation activities and acts as the supervisory body of the Foundation.

Board of Trustees

The Board of Trustees manages the daily business of the Werner Siemens Foundation in consultation with the Foundation Board and the Advisory Council. The Board of Trustees also acts as the managing body of the Foundation.

Advisory Council

The Advisory Council of the Werner Siemens Foundation is an independent body that supports the Board of Trustees in finding suitable projects. Council members review and evaluate projects that fall within the mission of the Werner Siemens Foundation.

Project selection

Project selection

The Werner Siemens Foundation funds up to three ground-breaking projects per year in the fields of technology and the natural sciences. The projects are generally conducted at universities and higher education institutions in Germany and in Switzerland, and may be in research and teaching. 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 15 million euros. Projects are selected in a series of steps by the Advisory Council, the Board of Trustees and the Foundation Board. In addition to projects, the Werner Siemens Foundation supports education programmes and young talent in the STEM subjects.

The Foundation does not support activities in the arts, culture, sports, leisure, politics, disaster relief, permanent projects, commercially-oriented projects, project co-sponsoring with other foundations, individual scholarships, costs of studying or doctoral theses.

Contact

Werner Siemens Foundation
Guthirthof 6
6300 Zug
Switzerland

+41 41 720 21 10

info@wernersiemens-stiftung.ch
wernersiemens-stiftung.ch

Presenting Germain Mittaz

Germain Mittaz has been associated with the Siemens group for over 40 years—first for Siemens Switzerland Ltd, then for the Werner Siemens Foundation, where he was in charge of financial accounting and human resources. He retired at the end of 2017.

Germain Mittaz, long-time head of finance at the Werner Siemens Foundation

How did you come to be part of the Werner Siemens Foundation?

Germain Mittaz: I worked at Siemens Switzerland Ltd in Zurich from 1974 to 2003, most of the time as head of accounting and taxation. Working in finance at a major industrial company was fascinating because the business is so dynamic. For instance, I was a first-hand witness to the innovations in telecommunications technology in the 1980s. After working some 30 years at Siemens Switzerland Ltd, I was contacted by Manfred Nagel, who was then both chairman of the board at Siemens and chairman of the Board of Trustees at the Werner Siemens Foundation. He told me the Board was looking for a member to lead the finance section. This was right before my 60th birthday and I decided I was ready for a new challenge. The part-time position at the Foundation was also appealing because at the time I was a member of the Parliament of the Canton of Zurich and a member of the board at the Zurich Kantonalbank. That's how I was elected to the Board of Trustees at the Werner Siemens Foundation in 2002. I had a broad range of responsibilities such as defining investment strategies and monitoring the markets as well as dealing with issues concerning human resources and taxes at the Foundation.

What were the highlights of your time at the Werner Siemens Foundation?

Thanks to its solid financial position, the Foundation could move beyond supporting the Siemens family and, as of 2003, began to fund other projects, including those at universities. This new direction provided me with unique insight into highly diverse technological innovations. It was always a particular pleasure when projects went on to succeed after receiving seed funding from the Werner Siemens Foundation—the Werner Siemens Imaging Center in Tübingen is a prime example. In addition, I had the opportunity to meet many interesting people over the past 15 years, and it was a great honour to personally get to know the Siemens family at the annual meetings.

Now, at 75, you are retiring in accordance with the statutes of the Foundation for members of the Board of Trustees. What are you looking forward to most?

Officially, my work at the Werner Siemens Foundation was over at the end of 2017, but because I'm responsible for the accounts from the past year, I'll be present at the annual general meeting in March of 2018. After that, I'll pass the baton to Beat Voegeli. I'm certainly looking forward to spending more time with my wife, my family and my grandchildren, and to being out in nature more often—for hikes, snowshoe tours and golf. And I hope to have more time to read and attend cultural events. Being from the Canton of Valais, I'm also always drawn back to my old home. And, who knows? Maybe I'll even find time to visit my brother in Ecuador.

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Adrian Ritter, Baden
pp. 23–34, 96–97, 100–101, 110–111

Brigitt Blöchlinger, Zurich
pp. 51–64, 67–80, 83–94, 98–99, 106–107

Sabine Witt, Zurich
pp. 37–48

Guido Stalder, Zurich
pp. 104–105

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Felix Wey Fotostudio, Baden
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Mary Carozza, Oberrohrdorf
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