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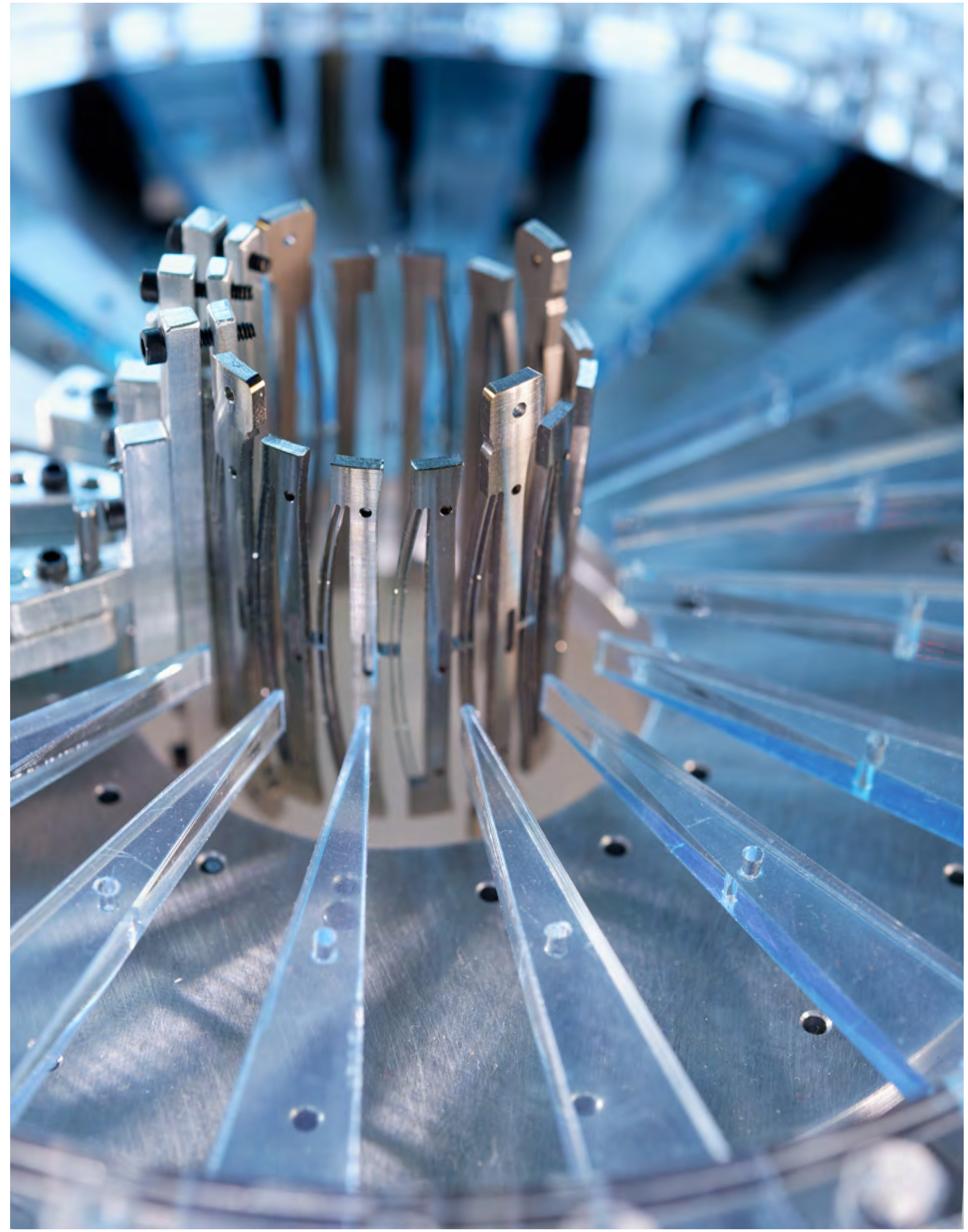
WERNER SIEMENS FOUNDATION

Our mission

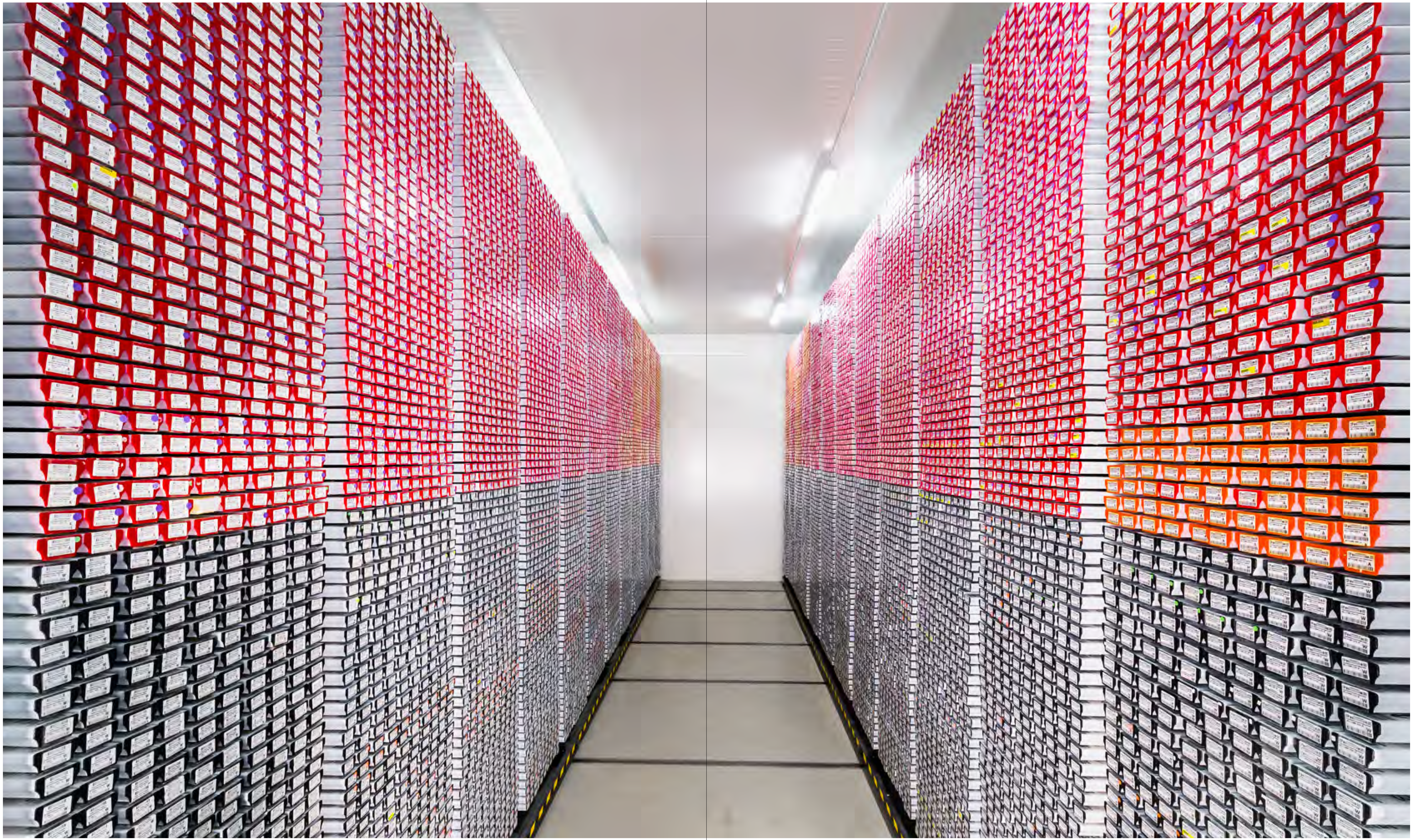
2018 report

Supporting girls with a flair for technology

Start-ups by researchers in the field of medical technology

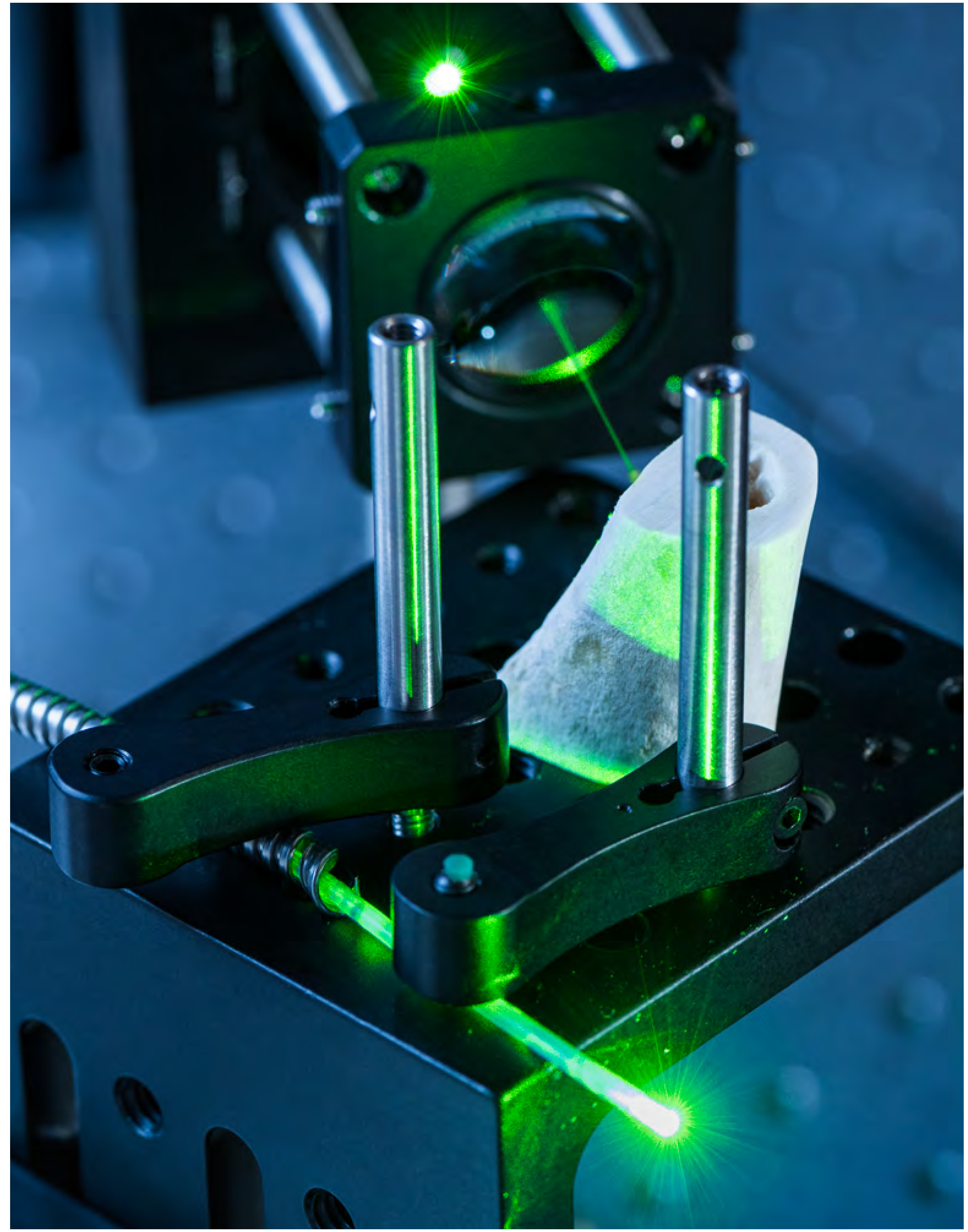


Developing artificial muscles



Monitoring the environment of the deep sea

Synthetic Biotechnology



Bone surgery using laser technology

Monitoring the environment of the deep sea

Developing artificial muscles

Promoting innovation in technology and the natural sciences

The Werner Siemens Foundation supports groundbreaking projects in the fields of technology and the natural sciences. The selected projects in research and education are generally conducted at universities and higher education institutions in Germany 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

Last year, we published for the first time a comprehensive report to professionally document the projects our Foundation supports. Shortly after New Year, we were delighted to distribute the first copies. And when the Foundation's general assembly convened at the end of January 2018, we were curious to hear what the descendants of the Siemens' families, thought of our 2017 report. The numerous positive comments sent a strong signal that the publication was a success. "Handsome and informative", "provides an impressive overview of the Foundation's activities" and "we now better understand what exactly the Foundation is supporting" were the most frequent remarks. The researchers at the higher education institutions and universities in Germany and Switzerland were also very pleased with the detail and clarity of the articles on their projects.

The positive echo convinced us to publish a report on our philanthropic activities every year. The present edition provides details on the highly innovative and promising projects that received funding from the Werner Siemens Foundation in 2018. As always, there is a broad range of topics: from deep-sea research and artificial muscles to promoting start-up companies in medical technology and a mentoring programme for young women with an affinity for technology and informatics.

On a separate note, the increasing digitalisation in the world of work has not bypassed the Werner Siemens Foundation. Although we are not (yet) confronted with "big data", our funding activities have already generated a sizeable number of bytes. To best accommodate the changing situation, we have redesigned our website at www.wernersiemens-stiftung.ch and integrated an online application tool. Researchers can now fill in and submit a form for project funding online. This simplifies the procedure not only for researchers but also for our administration.

Another highlight of 2018 was a journey to St Petersburg taken by some 90 members of the Siemens family. In addition to visiting the city's many historical and cultural sights, the family also sought out the places where Carl von Siemens lived and worked. For example, at the Siemens gas turbine plant in St Petersburg, the family attended a ceremony to unveil a statue of Carl von Siemens. A photo of the event is on our new website, on the page "News".

We hope you enjoy reading about our activities—either at our website or in our publication.

Gerd von Brandenstein
Chairman of the Foundation Board
Werner Siemens Foundation

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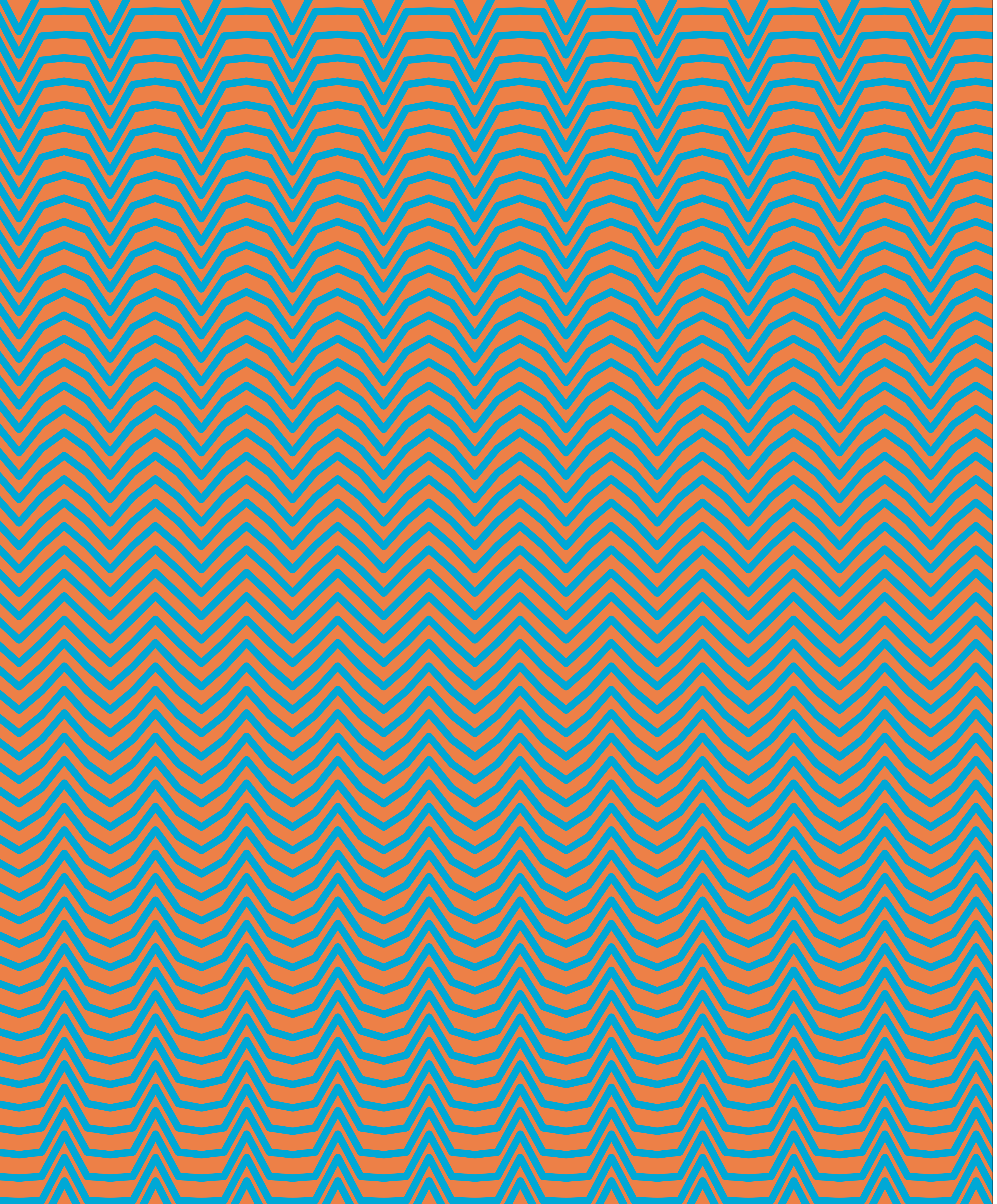
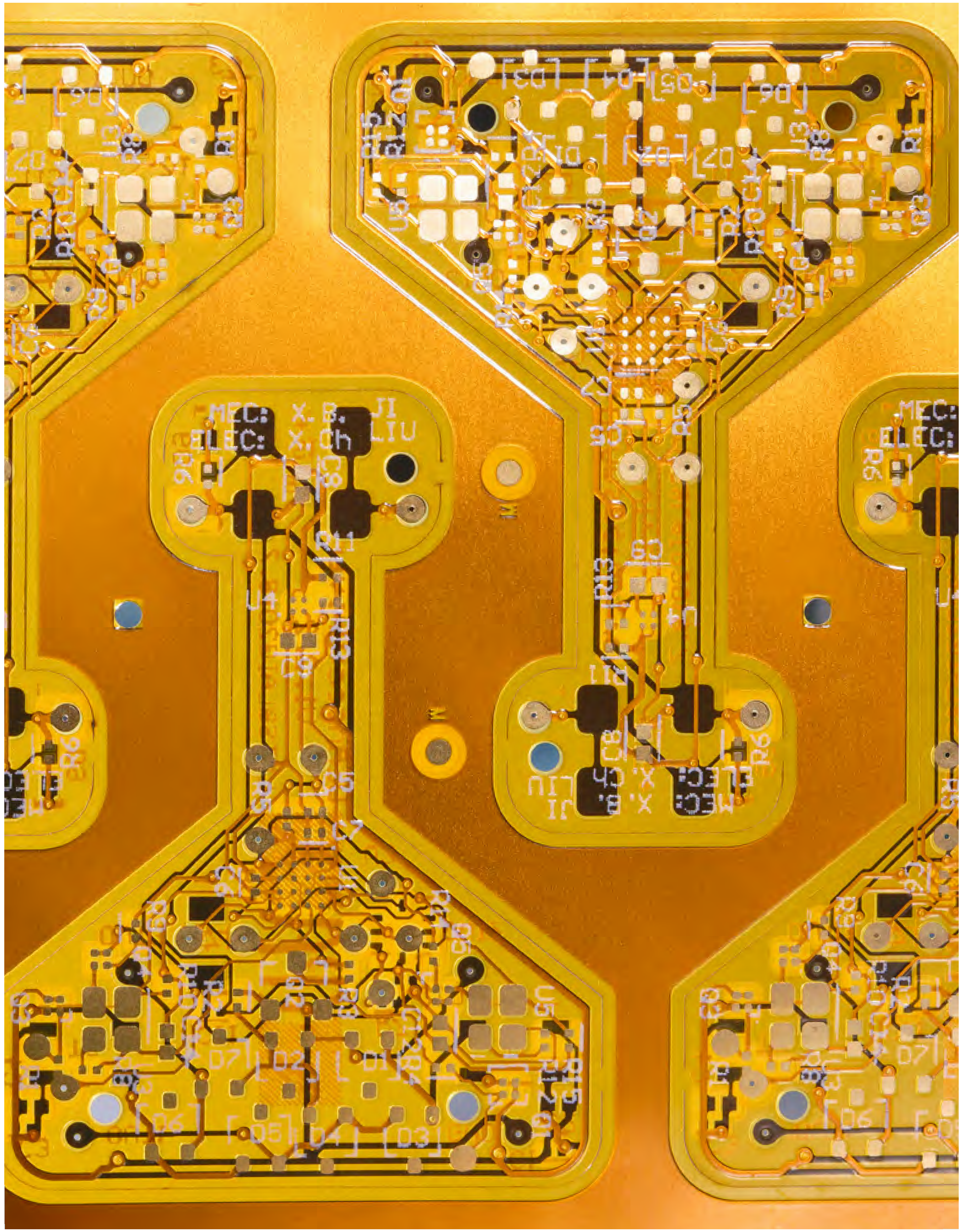


Artificial muscles

Center for Artificial Muscles, Neuchâtel, Switzerland



Shimmering golds and scintillating structures on an electronic printed circuit board: this PCB created and perfected by microengineer Yves Perriard and his team is one of the first steps on the way to a groundbreaking innovation: artificial muscles.

Makes weak hearts strong

Heartening prospects for patients with cardiac insufficiency: a ring around the aorta that helps the heart to pump blood through the body. This state-of-the-art technology is the research focus at the Center for Artificial Muscles in Neuchâtel—and is funded by the Werner Siemens Foundation.

Microengineer Yves Perriard is the architect of the innovative idea to create an artificial muscle powered by an electrical impulse. Yves Perriard is the head of the Center for Artificial Muscles in Neuchâtel, Switzerland, which is financed by the Werner Siemens Foundation.

Shortness of breath, low energy, feeling exhausted: the hearts in patients with cardiac insufficiency—the medical term for a weak heart—are quite literally too tired to circulate enough blood through the body. In Switzerland, cardiac insufficiency affects up to 200 000 individuals, mainly older people. Diseased coronary arteries are generally what weakens the cardiac muscle (myocardium).

Put briefly, these hearts need more muscle power—and making weak hearts stronger is one of the research aims of the new Center for Artificial Muscles (CAM) in Neuchâtel. The centre, which is part of the Swiss Federal Institute of Technology Lausanne (EPFL), was opened at the start of 2018 and is financed by the Werner Siemens Foundation.

A researcher with experience

Professor Yves Perriard is director of the Center for Artificial Muscles, and the 53-year-old microengineer has chosen a research topic close to his heart in the truest sense: several years ago, he had to undergo heart surgery to correct a defective valve. And since his doctoral studies, Yves Perriard has conducted research into technical systems that support heart function, including Ventricular Assist Devices (VAD), which range from simple pumps to actual artificial hearts. As such, Perriard is well aware of the serious drawbacks of current technologies: pumps have to be inserted into the heart and come in contact with the blood, thus increasing the risk of infection and thromboses.

Now, the 10-member team at CAM is pursuing an entirely novel approach to helping people with cardiac insufficiency. The ambitious goal? Creating artificial muscles that support the pumping capacity of the myocardium. The microengineers are currently working on an elastic membrane that can be placed around the aorta as a ring with a diameter of roughly 2.5 centimetres. An electrical impulse then causes the ring to dilate and contract, thus pumping blood through the body. The great advantage is that the operation needed to place the artificial ring around the aorta is less invasive than actual heart surgery. Another plus is that the ring never comes into contact with the blood.

The heart—a mighty muscle

"The biggest challenge is generating the necessary pumping capacity," says CAM director Yves Perriard. "After all, the heart is a strong muscle." The ring must be able to achieve a capacity of one watt to pump over 7000 litres of blood through the circulatory system every day. To increase the performance of the elastic ring, the researchers have integrated into the system a titanium spring that was developed by a Neuchâtel company especially for the project, patent pending. The spring supplies additional mechanical stress to ensure that the ring can exert the requisite pressure on the artery; it is possible that several rings will have to be placed around the aorta to attain the targeted pumping capacity.

The demands placed on the artificial muscle are exacting. For example, the ring has to be extremely elastic, powerful and must not trigger any rejection mechanisms in the body, meaning it must be biocompatible. What material has all these qualities? Perriard and his team hit on the answer with electroactive polymers, which are a type of synthetics.

Huge capacity required

The challenge facing the research team lies in developing a new, specific polymer able to achieve the necessary capacity of one watt. What chemical properties will it have? How thick should it be? To find answers, the team under Perriard and CAM general manager Yoan Civet is currently creating a variety of membranes in a clean room. The researchers then subject the membranes to several tests: for instance, the ring for the aorta must be able to withstand a voltage ranging from 3000 to 5000 volts or even more. And, yes, this is much more than the 220-volt current in a standard European outlet. But not to worry: the artificial muscle will have full electrical insulation and therefore pose no danger to the patients.

Electricity thanks to magnetic induction

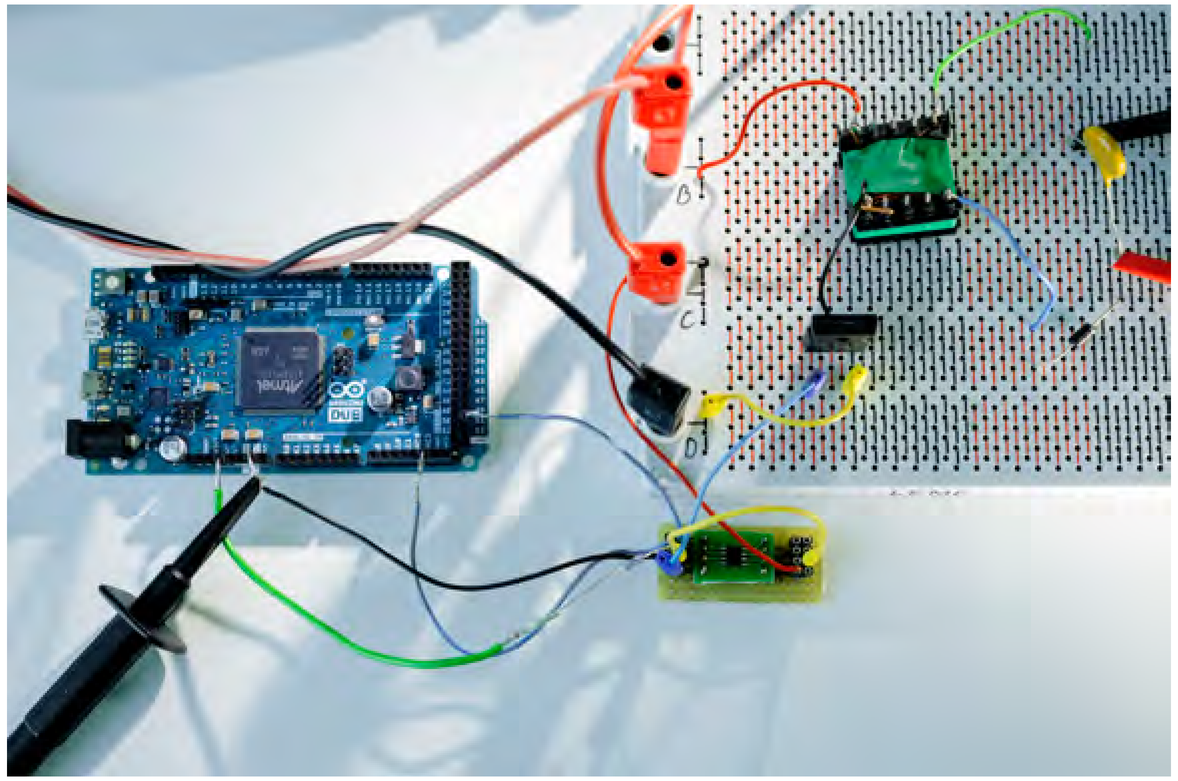
To transfer the electrical power, no wiring will be necessary. The electrical power will originate in a 12- or 24-volt battery placed outside the patient's body—for instance on a belt—and be transferred via magnetic induction: a coil is electrically charged to create a magnetic field, and the power is then transferred to a second coil that is placed inside the body. This is the principle behind wireless charging of the newest generation of mobile phones, and the same technology will be used to ensure that the aorta ring receives an adequate supply of energy.

But the ring's sole purpose is not just pumping blood through the body; it should also function as a sensor. The researchers envision that the polymer will measure various factors such as blood pressure in the aorta, adjust the pressure on the artery accordingly and also synchronise the pumping action with the patient's heartbeat.

Precision technology from the Jura region

These are ambitious goals, and Yves Perriard is the right man for the job. In 2003, Perriard was named director of the Integrated Actuators Laboratory (LAI) at the School of Microengineering at EPFL. The lab is specialised in transforming electrical energy into mechanical motions—researchers have dubbed these minuscule motors "actuators". In the past, the team's research has not been restricted to systems for supporting cardiac capacity but has also branched out into other medical applications such as insulin pumps and surgical instruments.

The Center for Artificial Muscles did not establish its domicile in Neuchâtel by chance. "In the Jura region, you don't have to tell anyone what a micrometre is," Perriard says with a laugh, adding that precision work down to a thousandth of a millimetre has a long tradition here—in the watch-making industry. Today, the same precision is demanded at research institutions and in the bio- and nanotechnology companies now located in the region. One of the hubs for such activities is the so-called "Microcity". Situated in the heart of the capital of Neuchâtel, Microcity is home to researchers and various companies, including start-ups—and Yves Perriard and his research team have also taken up quarters there.

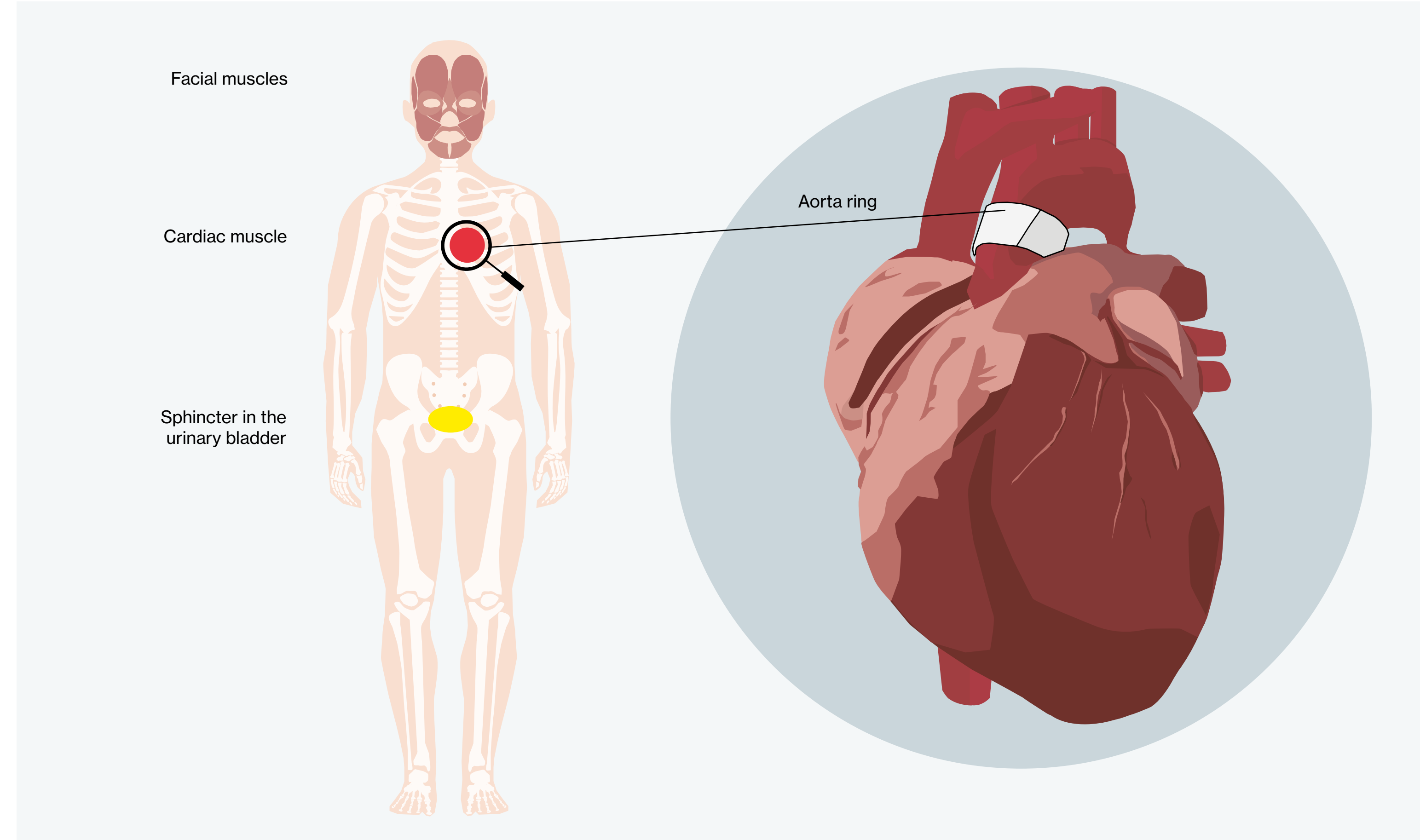


How Yves Perriard and his team convinced the Werner Siemens Foundation: using magnetic induction, an electric current of 5000 volts is generated—setting the muscle membranes in action.

The "bones" of an artificial muscle: a membrane wrapped around a metal object.

The various components of the muscle membrane undergo meticulous testing.

High-precision work in a clean room



Planned uses for artificial muscles: first to support cardiac functioning, then for facial muscles and the sphincter in the urinary bladder.

Mounting anticipation in Bern

Forty kilometres south-east of Neuchâtel, one person in particular is paying close attention to the developments at the Center for Artificial Muscles: Thierry Carrel, renowned heart surgeon and director of the Department of Cardiovascular Surgery at Inselspital Bern. Starting in 2022, Carrel will test the aorta ring in clinical trials (see interview). Until then, the new technology will be studied using a silicon model of an aorta and in animal testing. Dominik Obrist, professor for Biofluid Mechanics and Cardiovascular Engineering at the University of Bern, is in charge of this part of the project.

Artificial sphincters

Ultimately, the artificial muscles created in the Neuchâtel lab should be able to do more than just help weak hearts. In particular, the research team aims to develop an artificial muscle suitable for a wide range of applications in various parts of the human body. This would indeed be a major medical advancement: although prostheses for bones and joints have been established in medicine for quite some time, artificial muscles have remained elusive.

From 2018 to 2029, the Werner Siemens Foundation is supporting this groundbreaking research. During the funding period, the team at CAM will also develop two other applications for the artificial muscle. The first is an artificial sphincter for the urinary bladder to help patients suffering from urinary incontinence regain control over their bladders.

Facial expressions

The second application for the artificial muscle is to restore chewing function and facial expressions to accident and burn patients. In such cases, the artificial muscle will not have the shape of a ring, but that of a small, flat membrane. The researchers in this sub-project anticipate a particularly great challenge because—especially in the face—it is advantageous to connect the artificial muscle to the patient's nerve tissue, thus ensuring that the resulting muscle movements are as natural as possible. To achieve this goal, Yves Perriard is collaborating with Professor Nicole Lindenblatt from the Department of Plastic Surgery and Hand Surgery at University Hospital Zurich. Indeed, it becomes clear that developing artificial muscles requires an extraordinarily multidisciplinary team of specialists from fields as diverse as microengineering, materials science, biomedicine and surgery.

A world's first

The first goal, however, is enabling patients with cardiac insufficiency to benefit from the innovative research conducted at CAM. A system to support heart function in the form of a ring around the aorta—that would be an absolute first in the world of medicine. And with Yves Perriard and Thierry Carrel, a practiced team is tackling the challenge: the two researchers have engaged in professional exchange since their first encounter at Inselspital Bern—10 years ago, when Thierry Carrel successfully operated on Yves Perriard's heart.

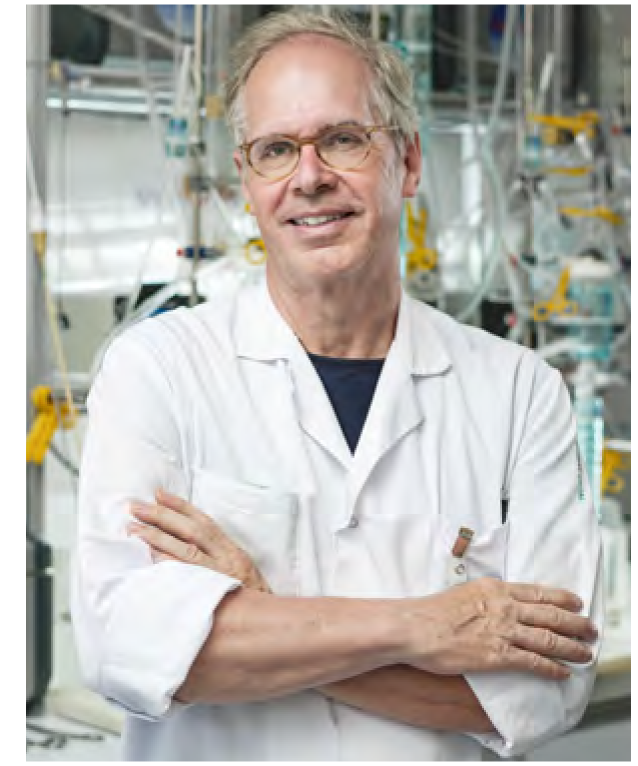
“A valuable new treatment”

The development of an artificial muscle could bring about a major breakthrough in cardiac medicine. In patients with minor cardiac insufficiency, the muscle could be made to fit as a ring around the aorta, ideally even helping weak hearts to recover—this is how renowned Swiss cardiac surgeon Thierry Carrel envisions the new technology.

Thierry Carrel, you will be testing the artificial muscle for patients with cardiac insufficiency in clinical trials. What made you decide to be part of the project?
Thierry Carrel: Fitting a kind of muscular ring around the aorta is a very creative idea. The researchers in Yves Perriard’s team think entirely outside of the box, which is something I admire. I believe the ring would bring about a major breakthrough in cardiology—a factor that is all the more important in light of the increasing number of patients with heart failure, a result of our higher life expectancy. And this number will only continue to grow. Overall, the artificial muscle would be a valuable addition to the various existing treatments for cardiac insufficiency.

What kind of treatments are offered today?
Patients with cardiac insufficiency are generally given medication. If the heart grows too weak, a variety of cardiac support systems are available, for instance pumps to replace the left ventricle or, in exceptional cases, both ventricles. As a last resort, there’s also a heart transplant. But these treatments have serious disadvantages. Medications have side effects and mainly help in cases of minor cardiac insufficiency, while ventricular pumps and transplantations require major surgical interventions that aren’t without risk, especially for older patients. And as we all know: there’s a shortage of donor hearts.

Which patients would benefit most from the new artificial muscle?
The aorta ring would offer an additional way to support—rather than replace—heart function. The ring would benefit patients who currently take medication as well as some patients who rely on a ventricular pump. I believe the artificial muscle is especially promising for patients whose hearts aren’t yet seriously weakened. When a weak heart is supported at an early stage, a full recovery is possible in the best case—and the ring could be removed again after a while. This could delay cardiac insufficiency until an even later life stage. The decisive question for clinical application will be how much pumping capacity the artificial muscle can generate.



Thierry Carrel is a renowned Swiss heart surgeon and director of the Department of Cardiovascular Surgery at Inselspital Bern.

What are your hopes?
It would already be very good if the artificial muscle could muster a third to half of the heart’s pumping capacity—so that we could compensate by the same amount.

What would an operation to place the ring around the aorta entail?
It’s not yet possible to say exactly how it will work because quite a bit depends on whether the electric supply for the muscular ring will be inside or outside the body. The actual procedure to fit the aorta ring won’t require highly complex surgery—contrary to conventional heart operations. The aorta is located right behind the sternum, meaning it would probably be enough to open just a third to half of the sternum. The membrane and titanium spring would be fitted around the aorta and then sealed as a ring. If necessary, more than one ring could be placed to achieve the necessary pumping capacity.

What advantages would the new method have?
One major advantage is that the artificial muscle won’t be part of the circulatory system. This greatly reduces biocompatibility requirements and overall risk compared to today’s ventricular pumps. Think thromboses and infections. The intervention with the aorta ring would also do away with the need for patients to take anticoagulants. These are all reasons why the artificial muscle would be welcome as a gentle, minimally invasive treatment.

The researchers also plan to use the polymer membrane as a sphincter for the urinary bladder and as a small muscle in the face—in stroke patients, for example, who have lost control of their facial muscles. Is it feasible that the artificial muscles could alleviate other health problems?
I wouldn’t rule anything out. Here, too, the decisive factor will be how much power the artificial muscle can generate. It’s possible that, in future, artificial muscles will be able to help patients with degenerative muscle disease (myopathy) or lateral paralysis retain their independence longer. After Yves Perriard and his team publish their initial findings on their research and the current state of development, I can well imagine that they’ll receive calls from specialists in other medical fields. And then it’s possible that applications will be suggested that we can’t yet imagine.

On the whole, how optimistic are you?
In the past few decades, the world of medicine has seen advances in diagnostics and therapies that I never would have dreamt of—for example new systems of artificial heart valves. We have no idea what the medical field will look like in 20 years. Big data, stem cells, chips and sensors. Who knows, maybe there won’t be much use for us doctors anymore … But one thing is certain: the researchers at the Center for Artificial Muscles are extraordinarily innovative thinkers. It’s wonderful that this pioneering spirit exists outside of Silicon Valley.

A team discussion on which material meets all requirements for an artificial muscle

Facts and figures

Project
The Swiss Federal Institute of Technology Lausanne, Inselspital Bern and University Hospital Zurich are collaborating to develop an artificial muscle that runs on electricity.

Support
The Werner Siemens Foundation is funding the establishment of the Center for Artificial Muscles (CAM) in Neuchâtel, Switzerland.

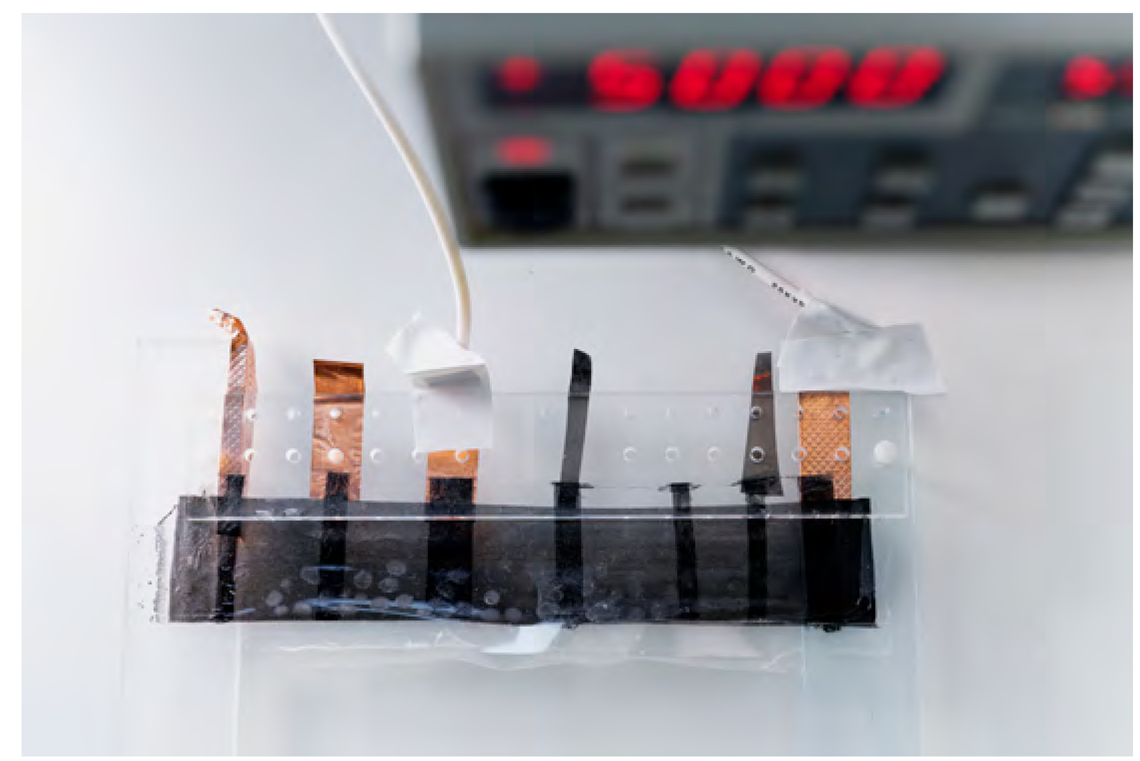
Funding from the Werner Siemens Foundation
12 million Swiss francs

Project duration
2018 to 2029

Project leader
Prof. Dr Yves Perriard, director of the Center for Artificial Muscles and the Integrated Actuators Laboratory (LAI), Swiss Federal Institute of Technology Lausanne

Partners
Prof. Dr Thierry Carrel, Department of Cardiovascular Surgery, Inselspital Bern
Prof. Dr Dominik Obrist, ARTORG Center for Biomedical Engineering Research, University of Bern
Prof. Dr Nicole Lindenblatt, Department of Plastic Surgery and Hand Surgery, University Hospital Zurich

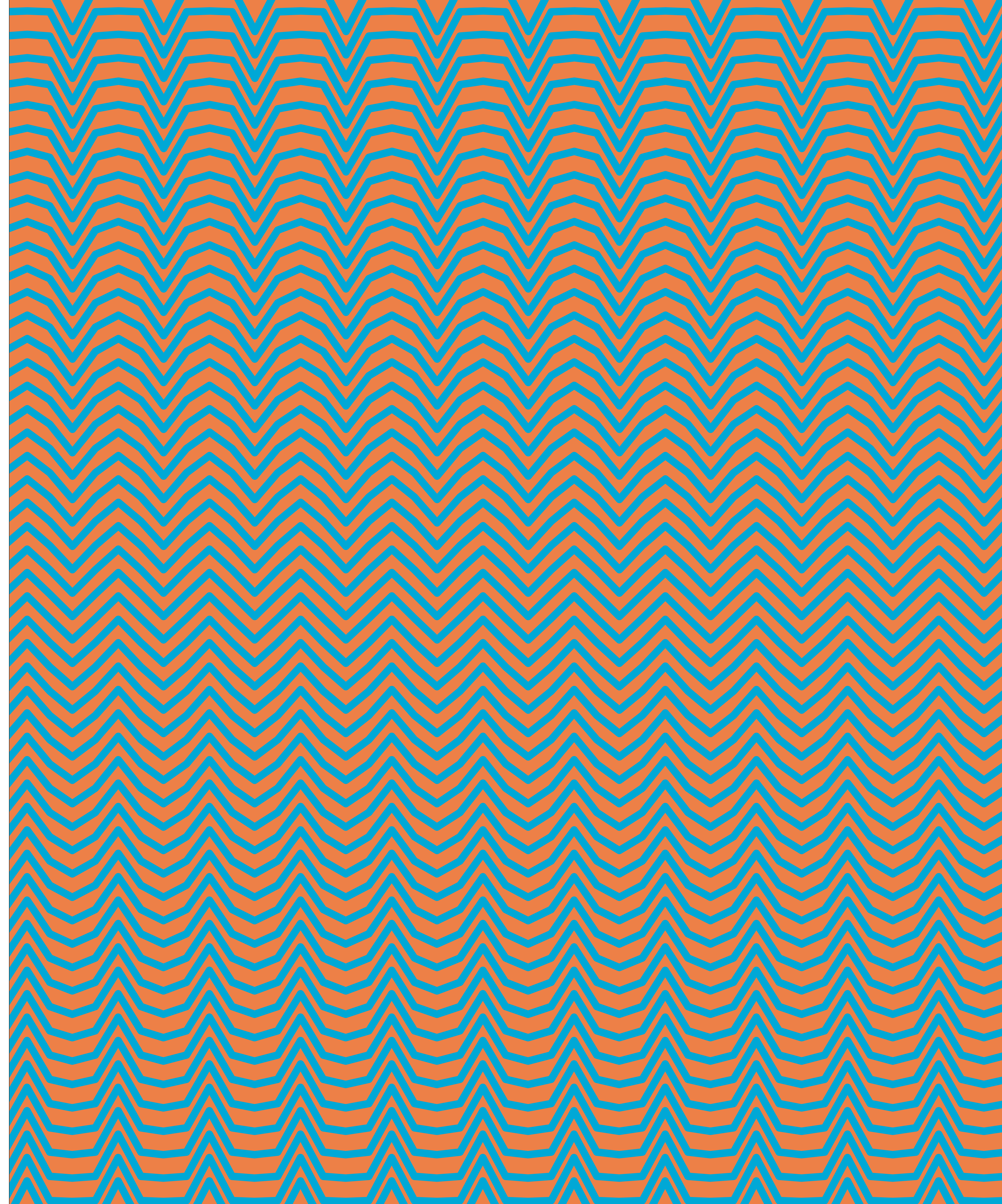
Put to the test: which membrane reacts best to the electric current?

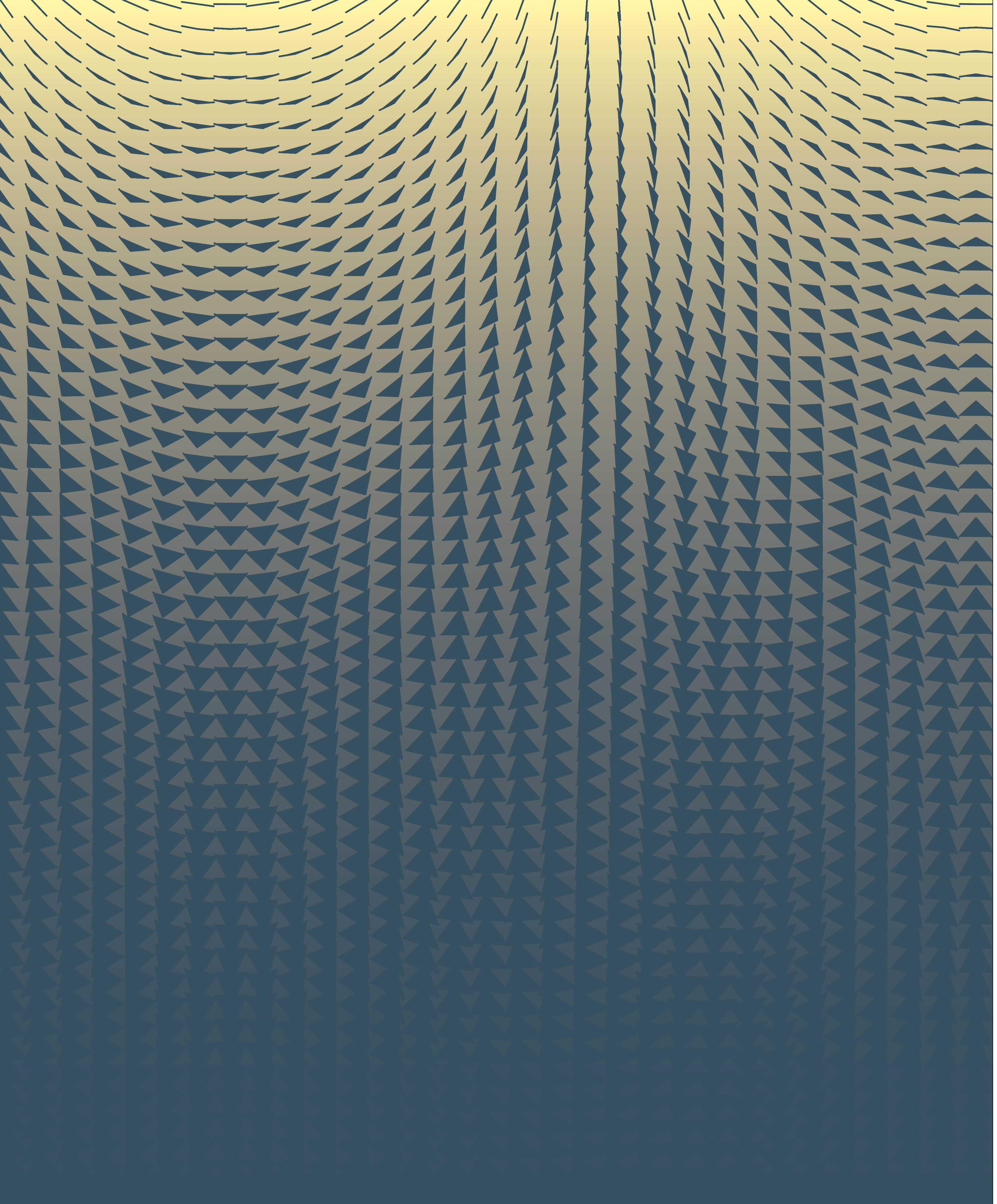


inventive interdisciplinary invaluable

Innovation

The Werner Siemens Foundation is financing the establishment of the Center for Artificial Muscles—because researchers there are taking a highly innovative approach to treating the common condition of cardiac insufficiency: with a muscular ring that promises to make weak hearts stronger from the outside.





Safeguarding the deep sea

Innovation Center for Deep-Sea Environmental Monitoring

The deep-sea medusa still floats in tranquillity, untouched, at a depth of 2900 metres in the South Atlantic Ocean. But its peaceful days are numbered: numerous countries are eager to excavate the valuable resources buried in the deep sea. This means disrupting a largely unknown ecosystem—and possibly incurring damage that impacts the entire planet.

Only a tiny fraction of the deep sea has been explored—crabs, shrimp and mussels in a beard worm colony at an ocean depth of 3100 metres in the Atlantic, off the coast of West Africa.

Marine resources

Over the course of millions of years, the deep sea has evolved into an extraordinary and vitally important ecosystem. Until recently, it has also remained untouched by human hands. Now, however, numerous countries and companies want to mine the treasures that slumber in the deep. The new Innovation Center for Deep-Sea Environmental Monitoring, at MARUM at the University of Bremen, wants to help ensure that mining the seabed does not wreak the same devastation as has mining on land. The Center is financed by the Werner Siemens Foundation.

By definition, the deep sea begins at an ocean depth of 200 metres, with the average depth of all oceans being 3700 metres. And the old adage that there is nothing new under the sun has no validity when it comes to the deep sea. Quite the opposite: over 90 percent of the seabed is a true terra incognita. Yet, the few areas that have been explored have conjured visions of riches: large deposits of copper, zinc, cobalt, rare earth elements, gold and silver have been discovered. And demand for these metals is high—they are used in smartphones, rechargeable batteries, LEDs, plasma screens, electric motors, solar panels, wind turbines, semiconductor technology and other conveniences of our modern world.

Currently, 29 nations and private companies have registered their interest in the valuable resources. Indeed, they have already successfully taken the first step: they hold exploration contracts. The company that has progressed the furthest is Nautilus Minerals, whose majority shareholders are two billionaires, from Oman and Russia respectively. Nautilus Minerals is hoping to start deep-sea mining in 2019. But China, Japan, India, Russia, Brazil and EU countries such as France, Germany, Belgium, the United Kingdom and Poland have also been granted exploration contracts for potentially lucrative marine regions.

New genes from the deep

The treasures buried in the deep sea are also attractive to the medical and pharmaceutical companies that are hoping to discover useful new organisms and genes. “The gene pool in the deep sea may prove more commercially interesting and profitable even than the mineral deposits in the seabed,” says Professor Michael Schulz, director of MARUM – Center for Marine Environmental Sciences at the University of Bremen.

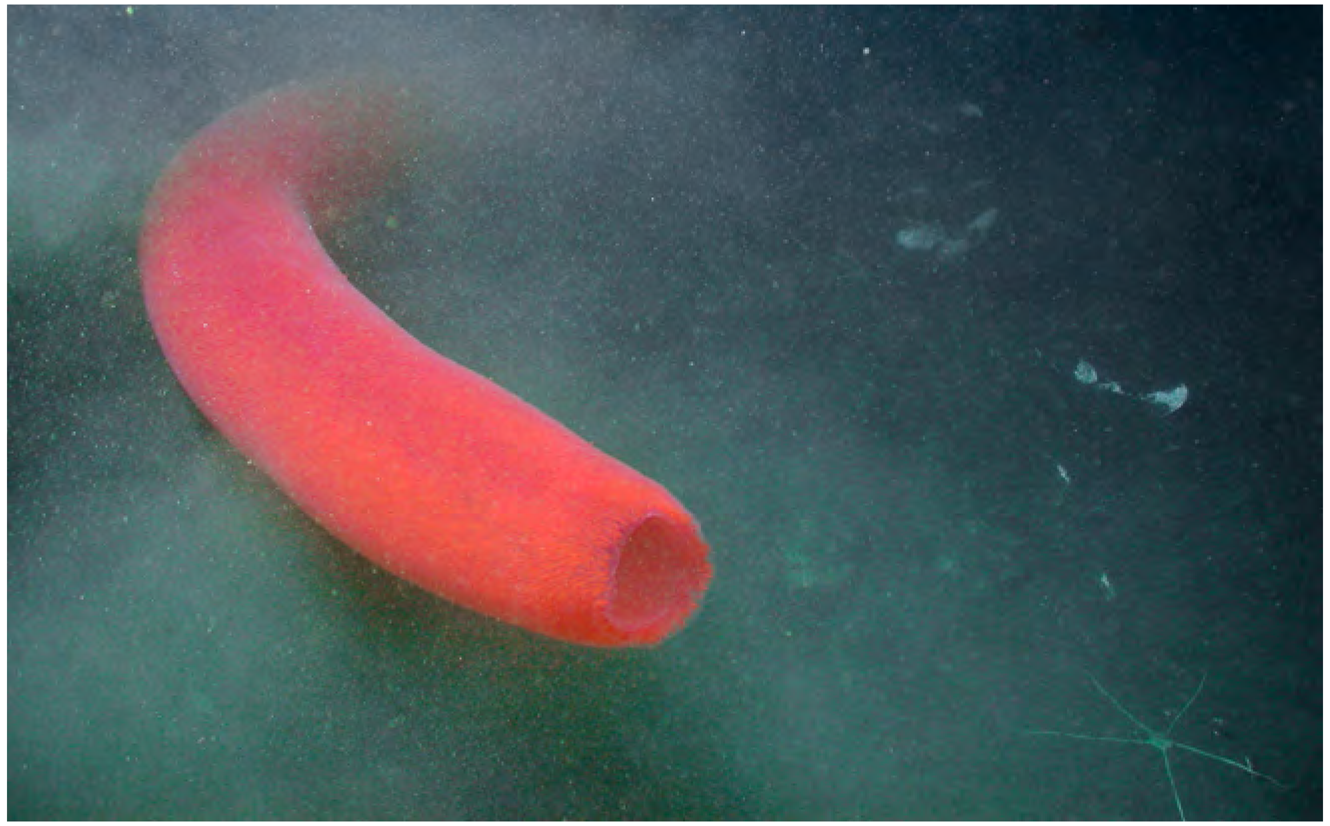
Over a dozen medications with active agents stemming from marine life have already been approved. In future, it is expected that they will number in the thousands. New and fast genetic screening technologies have also spurred the search for useful substances in the seas. “There are vehicles that glide through water, making DNA analyses as they go,” says Michael Schulz. “What’s happening now is completely new.” One example is the American J. Craig Venter Institute, which conducts global ocean sampling expeditions and trawls the waters for genomes of thousands of marine organisms, always on the lookout for interesting gene sequences.

First explore, then exploit

The path from exploration contract to mining contract is—and rightly so—long, demanding and expensive. Nevertheless, the global tug of war for marine resources is in full swing. The first company will most likely begin mining in one to ten years. And as soon as companies are allowed to extract the coveted minerals from the deep, they will inflict damage of unforeseeable dimensions in the largely unexplored ecosystem of the deep sea. MARUM director Michael Schulz has this to say about the hasty excavation of deep-sea resources: “It would be unwise to destroy valuable deep-sea ecosystems through mining only to understand in hindsight their true value for Earth.”

An unusual sort of life

In the deep sea, there are life forms that defy the imagination. Their function in the overall ecosystem of our planet is largely unexplored, but their crucial role is clear.



Pyrosome: a colony of millions of tunicates in the eastern Pacific at an ocean depth of 1530 metres.

In the middle of the Atlantic Ocean, pure hydrogen escapes—a fact that prompted an international team of marine scientists to ask whether life there is inherently possible. Equipped with hydrogen detectors, they set out to answer the question—and found mussels with gut bacteria that oxidise hydrogen. The bacteria respire hydrogen instead of oxygen!

For Michael Schulz, director of MARUM – Center for Marine Environmental Sciences, this is a prime example of how underwater vehicles can be used to test a theory in actual practice. And to come upon completely new conclusions and unknown organisms. “This is what you learn in the deep sea: there are many possible communities of organisms and, in some cases, they have fundamentally different ways of functioning. For instance by using chemosynthesis.” These organisms survive by oxidising inorganic matter from the Earth’s interior, including methane, hydrogen sulphide or hydrogen.

Life under pressure

The deep sea destabilises our understanding of what constitutes life. For every 10 metres of depth, the water pressure increases by about one atmosphere, one atmosphere being the air pressure at sea level. At an ocean depth of 1000 metres, a weight of 100 kilogrammes presses upon every single square centimetre. Roughly a quarter of the entire seabed lies even lower than 5000 metres. No sunlight penetrates the deep sea. And not only is it pitch-dark—it is cold.

Despite the enormous hydropressure, the darkness and cold, life forms thrive in the deep sea, even at its greatest depths. Whales dive to depths of 3000 metres, and fish go even deeper, down to 8000 metres—for the food.

Some like it hot

Most of the permanent dwellers in the abyssal deep sea are molluscs and microorganisms. The habitats of these creatures are frequently near the so-called black smokers and white smokers—chimney-like structures, located in volcanically active areas of the seabed, that spout plumes of hot water. In this extreme environment, shrimp, slugs and crustaceans live in an intricate symbiosis with bacteria. The bacteria convert the hydrogen sulphides dissolved in the water into energy, and they are ingested by other life forms. Over 500 species occur exclusively near the black smokers; these species are considered particularly vulnerable.

The life forms in the seabed itself are even more extreme: for every kilometre of depth, the temperature rises 25 to 30 degrees Celsius. Despite the extremely hostile climate, microorganisms were found in the seabed at a depth of two kilometres off the coast of Japan, where they settled with other terrestrial plant remains 20 million years ago. Today they thrive in the carboniferous sediment that reaches temperatures of up to 60 degrees Celsius. What do these organisms feed on? And what environmental conditions would cause their extinction? No one knows.

Crucial bacteria and archaebacteria

What we do know, however, is that there is a close connectivity between microbial organisms (bacteria, archaebacteria) in this abyssal biosphere and on land (the geosphere). This interrelationship influences the material balance in both seabed and deep sea and thus possibly plays a role not only in the ecosystems of these habitats but in entire food webs, from plankton to fish.

Bacteria and archaebacteria in the deep sea are also crucial agents in the global carbon cycle: the microorganisms living in the sediment of the world's oceans feed on the waste of organic substances—which the deep sea has in great supply. Indeed, the deep-sea sediment is the Earth's largest carbon reservoir.

Irreversible damage

The ecosystem of the deep sea is as vulnerable as it is vital. To illustrate this point, MARUM director Michael Schulz relates an experiment conducted in 1989 by German deep-sea researchers in the Pacific, off the coast of Peru. The researchers ploughed the seabed in order to observe how the environment would react to the upheaval. The results: even 26 years later, the microbial life forms still had not recovered completely and the furrows in the seabed were still visible. "Everything happens very, very slowly down in the depths," says Michael Schulz. "The organisms have fewer progeny, life happens in slow motion—adapted to the cold, the dark and the immense pressure." Which explains why the ecosystem in the deep sea is unable to regenerate quickly and easily. "It is of utmost importance that the same massive disruption caused by mining on land doesn't happen in the sea," Schulz stresses.

Creature comforts

A few areas in the deep sea are already known for being popular with life forms: the slopes of underwater mountains (known as seamounts), black smokers and white smokers, and polymetallic nodules.

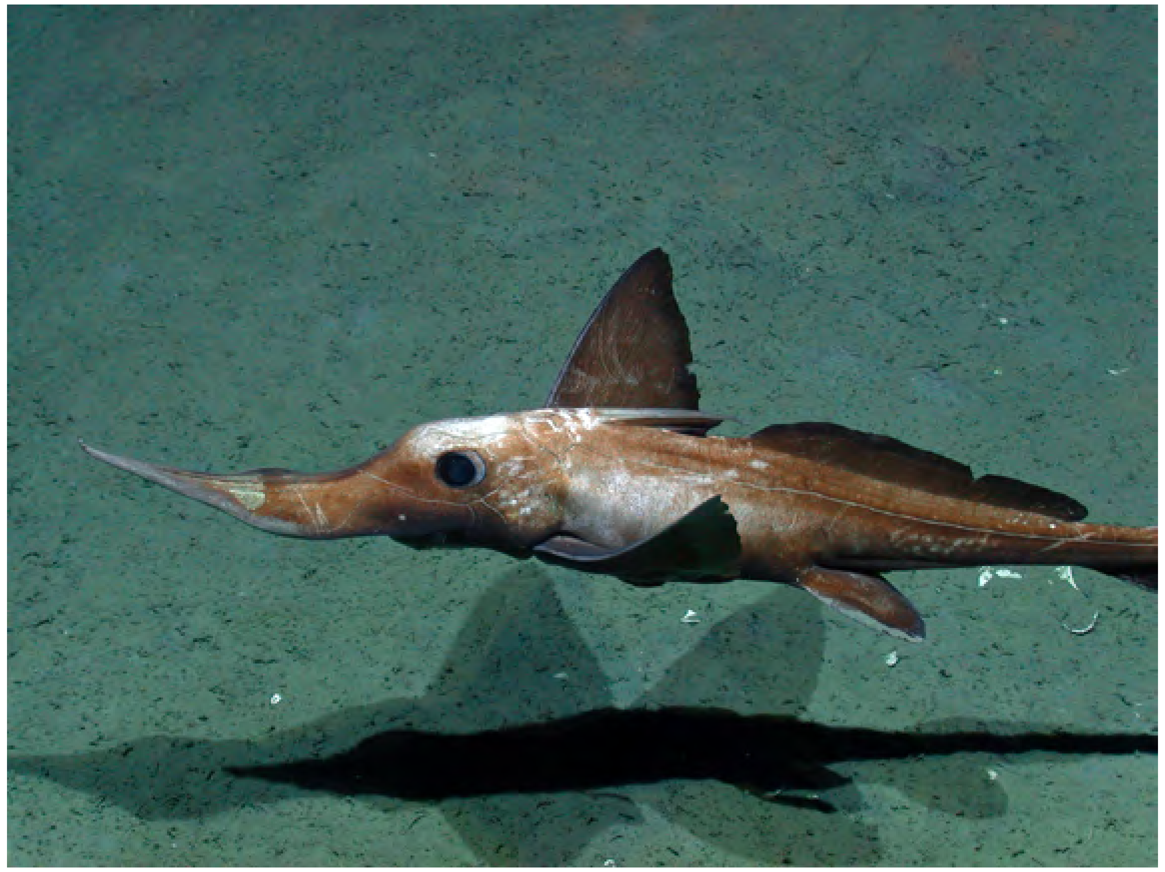
The Census of Marine Life conducted by a global network of researchers registered 240 000 species in the Clarion-Clipperton Fracture Zone, which is 7000 kilometres in length. The researchers estimate, however, that actual numbers are much higher and that there are at least a million different species. Anemones, crustaceans, mussels, crabs, eels, blobfish, deep-sea fleas, squid, octopuses, gorgonians (sea fans), brittle stars, sea lilies, sea cucumbers, pandalid shrimp, bluemouth rockfish, beard worms, sponges, deep sea cold-water corals and slugs populate the deep sea ... as do presumably hundreds of thousands of other species that are still undiscovered. The rich food supply also attracts whales and large fish such as sharks and tuna down to the abyssal regions of the sea.

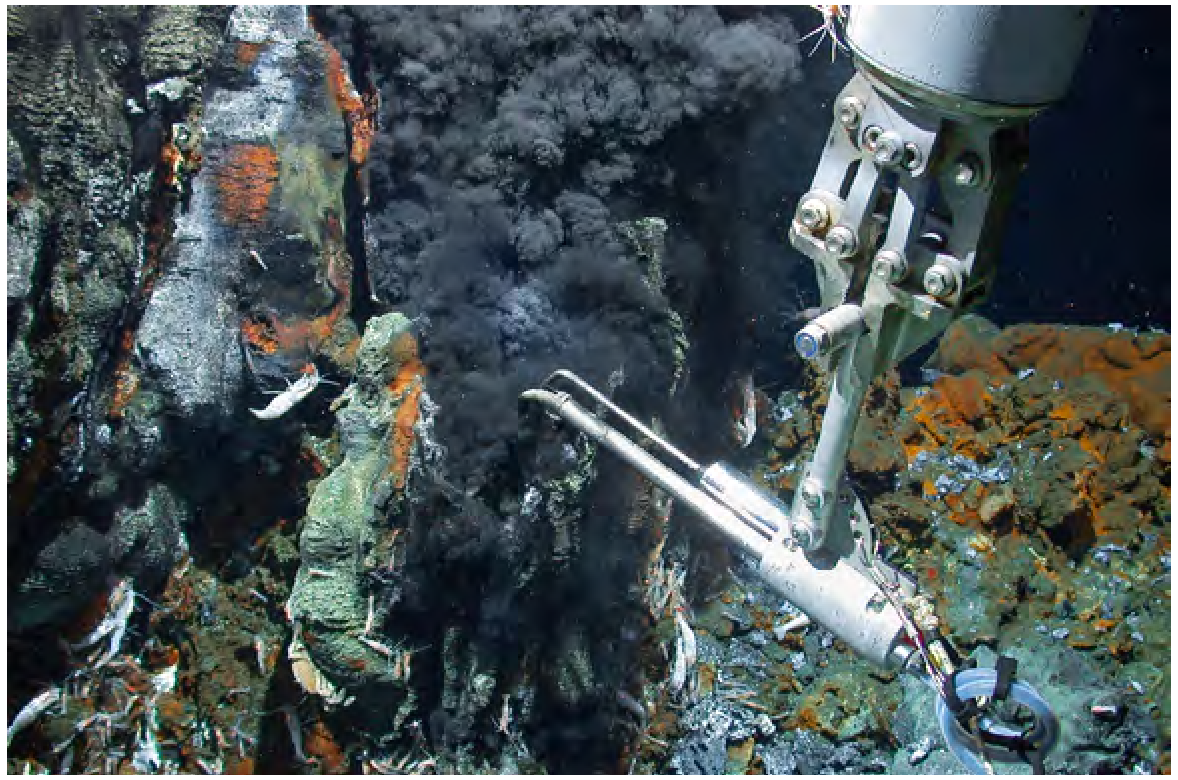
Deep-sea mining impacts

Deep-sea mining will negatively impact biodiversity in the deep sea, both directly and indirectly. Directly, because it destroys communities of organisms that have evolved over millions of years. A multitude of diverse, rare and unique species coexists in the deep sea, and each species is often made up of only a few individuals that are not highly mobile and that reproduce only at a very slow rate. If their habitat is destroyed, they cannot simply "emigrate" to a new location, as their reproductive abilities rely on a specific network of habitat conditions. Yet, these diverse species living in an intricate symbiosis are not "nice-to-haves": they are vitally important to the health of our planet. Functioning ecosystems provide humans with clean water, food and resources—and they stabilise the climate.

Indirectly, deep-sea mining will adversely impact biodiversity because leaching and stripping away the crust causes plumes of sediment to be emitted. These plumes cloud the water and spread great distances, endangering the sponges, corals and invertebrates that need clear water and an environment with very few organic particles to survive; in the worst case, these complex organisms that filter water would suffocate on the particles.

In addition, excavation releases heavy metals into the sea. When dissolved in water, copper, zinc, manganese, cobalt and nickel in high concentrations are toxic. The contamination with heavy metals is one of the greatest environmental risks of extracting minerals from the seabed. The contaminated water first poisons fishes; heavy metals then accumulate across the entire food chain and, ultimately, land on our dinner plates.


Long-nosed chimaera in the Arabian Sea in 1975, at an ocean depth of 1975 metres

A deep-sea community at a hydrothermal vent on the Mid-Atlantic Ridge, at an ocean depth of 3030 metres


Environmental protection in the deep sea

Which ecosystems in the deep sea are essential? What areas must be protected from the impacts of deep-sea mining at all costs? The Innovation Center for Deep-Sea Environmental Monitoring plans to answer these questions. The centre, which was established in 2018 at MARUM at the University of Bremen with funding from the Werner Siemens Foundation, aims to contribute to better understanding the most important parameters of the deep sea, to explore and to identify the most important ecosystems. This knowledge will then lay the foundation for environmental protection regulations in deep-sea mining.

"We want to find out what measures must be taken in order to ensure that the damage caused by deep-sea mining will at least be kept to a minimum," says MARUM director Michael Schulz. Nevertheless, the marine researcher is convinced that damage will be done. "Sometimes the term 'green deep-sea excavation' is bandied about. But that's utter nonsense—there is no such thing," says Schulz. "There will be negative impacts on an ecosystem that we haven't even begun to understand."

Who wants what where?

Some 30 companies hold a contract to explore the deep sea for resources. Where are the treasures hidden? And who wants them? A brief introduction.

1 Black smokers

In some areas of the deep sea, the seabed is alive with volcanic activity. This is where “black smokers”—or hydrothermal vents—often form: small chimney-like structures that emit a plume of dark-coloured water heated by the magma. The black hue is due to the abundance of minerals the super-hot water (400 degrees Celcius) washes from the volcanic rock. Upon entering the cold seawater, the minerals are precipitated and cascade to the seabed near the black smoker. The resulting deposits are called “massive sulphides”, as they are made of sulphur compounds. They are often extremely rich in metals: gold and silver, copper, lead, zinc and the high-tech metals indium, germanium, bismuth and selenium. These metals are why the black smokers are so interesting to deep-sea mining companies.

Numerous black smokers are found on the mid-oceanic ridges, deep oceanic basins (back-arc spreading zones) and near volcanic arcs, where highly diverse life forms in unique ecosystems thrive—explaining why hydrothermal vents are often termed the “oases of the deep sea”.

2 Polymetallic nodules

Polymetallic nodules (also called manganese nodules) are potato-shaped lumps of rock that form on loose sediment on the sea floor at depths between 3000 and 6000 metres. They contain large amounts of manganese and valuable elements such as gold, iron, cobalt, copper, zinc and nickel, titanium and traces of rare elements such as molybdenum and tellurium. To form, polymetallic nodules need a special, deep-sea bacterium—and an abundance of time: over the course of one million years, a nodule grows only between 0.2 and 10 centimetres.

3 Polymetallic crusts

Polymetallic crusts are layers of sediment that form on submarine ridges and seamounts. They are between two and twenty-six centimetres thick and, like polymetallic nodules, grow at extremely slow rates—just five millimetres every million years. They contain manganese, cobalt, nickel, copper, platinum, cerium, molybdenum, tellurium and tungsten. The crusts at a depth between 800 and 2500 metres are particularly rich in minerals and have consequently generated commercial interest. Two thirds of all polymetallic crusts are located in the western part of the Central Pacific. In total, the world’s oceans contain some 40 million metric tons of dry ore.

4 Rare earth elements

A string of tectonic fissures connected to volcanoes are located near the Chinese coast; in these fissures, metal deposits rich in rare earth elements have accumulated. The term “rare earth element” is, however, misleading, as metals belonging to this group are not uncommon. What makes them rare is that they occur only in very small amounts. Mining them on land is labour-intensive, complicated, expensive—and detrimental to the environment. For years, China held a monopoly in mining rare earth elements, although the country’s market share has decreased significantly in recent years. Rare earth elements are used primarily for renewable energy technologies (solar panels, wind turbines) and electronics (computers, digital cameras, energy-saving light bulbs). They also form the basis for strong, permanent magnets used in electric motors, generators, and modern high-temperature superconductors.

Japanese researchers discovered a large deposit of yttrium and rare earth elements in the Pacific seabed near Minami-tori-shima (Marcus Island) at a depth of 5000 metres. The island is located some 2000 kilometres from the Japanese archipelago.

5 Crude oil and natural gas

It is believed that large reserves of crude oil and natural gas are present in the seabed starting at an ocean depth of 400 metres. The high pressure in these depths makes blowouts extremely difficult to control.

Russia, Canada and Denmark (on behalf of Greenland) plan to drill for crude oil and natural gas at the North Pole.

Myanmar has huge untapped oil and gas reservoirs in the Bay of Bengal. Numerous companies from China, Thailand, South Korea, India, Japan, the US, France and Australia are supplying the conveyor technology.

It is also believed that there is crude oil near the Spratly Islands in the South China Sea; China, Taiwan, Vietnam, Malaysia, Indonesia, Brunei and the Philippines are engaged in an ongoing dispute over ownership.

A Clarion-Clipperton Fracture Zone

The Clarion-Clipperton Fracture Zone in the Pacific Ocean measures 7000 kilometres in length and holds what is currently believed to be the largest reservoir of polymetallic nodules. A contract to explore the zone has been granted to 15 countries and companies domiciled in them. Among the contractors is the German Federal Institute for Geosciences and Natural Resources in Hanover. (Germany also has a contract to search for massive sulphides in the Indian Ocean off the coast of Madagascar.)

In 2014, the environmental protection organisation WWF compiled a background study on deep-sea mining and concluded that, due to the long regeneration cycle of the deep sea, mining would essentially destroy the Clarion-Clipperton Fracture Zone.

B Solwara 1

The mining project that has advanced the furthest is Solwara 1, located in the Bismarck Sea in the exclusive economic zone of Papua New Guinea. The corporation Nautilus Mineral, which is domiciled in Canada, has plans to mine the 100 000 ounces of gold and 80 000 metric tons of copper that are believed to be in the massive sulphides at an ocean depth of 1600 metres. The majority stockholders in Nautilus Minerals (two billionaires, from Oman and Russia) have yet to settle the financing; the planned starting date of mining activities in 2019 is therefore questionable. Because the Bismarck Sea is one of the most biodiverse and ecologically significant ocean regions on Earth, worldwide protests have been staged against the Solwara 1 project.

C Atlantis II Deep

In the Red Sea, at a depth of 2000 metres, lies the Atlantis II Deep: a submarine basin that formed when the African Plate and Arabian Plate drifted apart. The Deep is filled with a thick, metal-rich layer of sediment and is believed to harbour the world’s largest sulphide deposits. Three million metric tons of zinc, 700 000 metric tons of copper, 6500 metric tons of silver and 46 metric tons of gold—worth an estimated 12 billion euros—are believed to be present in the sediment.

a International Seabed Authority

In 1982, the United Nations declared the deep sea and its resources to be “common heritage of humankind”. The 1994 UN Convention on the Law of the Sea defined the rights and responsibilities regarding use of the deep sea, including deep-sea mining.

For a fee of 500 000 US dollars, the International Seabed Authority ISA, domiciled in Jamaica, grants mining companies exploration contracts if they submit a joint application with a country that assumes responsibility for liability and monitoring.

ISA is currently developing a “Mining Code” for excavating polymetallic nodules. In the Code, the following point will be of great ecological relevance: enough protected areas must be designated to ensure that various life forms can repopulate and thrive.

b Innovation Center for Deep-Sea Environmental Monitoring

The Innovation Center for Deep-Sea Environmental Monitoring is financed by the Werner Siemens Foundation. Its primary goal is to conduct research on the hydrothermal vents along the Mid-Atlantic Ridge. Hydrothermal vents are listed vulnerable ecosystems, meaning that mining them would irreversibly destroy them. The researchers are interested in the ecosystems and general environmental factors as well as in how the seabed and water columns adapt and are able to mutate over time and space. In addition, the team at the centre plans to make a series of high-definition optical and acoustic maps of the seabed. This will allow changes to be charted, mainly by comparing the data collected on the environment, including on-site measurements of salinity, the percentage of dissolved oxygen in the water and the pH values in the sediment.

c Germany’s exploration contract

On behalf of the government of Germany, the German Federal Institute for Geosciences and Natural Resources in Hanover has been exploring the contract area of the Clarion-Clipperton Fracture Zone (Pacific) for polymetallic nodules since 2006 and the contract area for massive sulphides in the contract zone in the Central Indian Ocean off the coast of Madagascar since 2015.

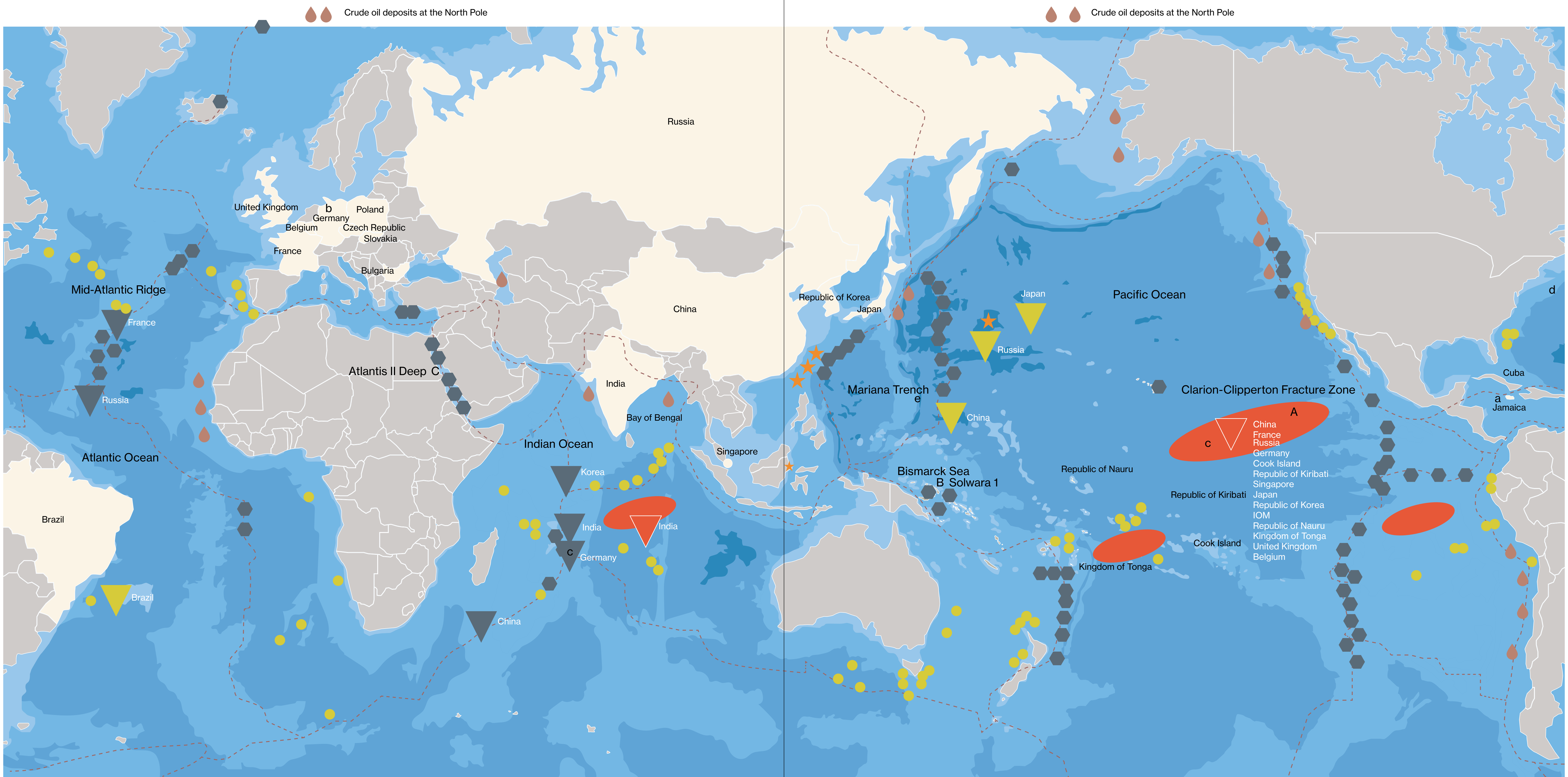
In the Clarion-Clipperton Fracture Zone, the institute is collaborating with 30 European partners in academia and industry (including MARUM) to conduct a test with the International Seabed Authority in April 2019: in the contract zone of the Clarion-Clipperton Fracture Zone reserved for Germany, at a depth of 4000 metres, a polymetallic nodule collector will harvest polymetallic nodules in a limited area measuring 100 by 900 metres. The consortium is hoping to secure for the first time relevant data on the short- and long-term effects of deep-sea mining on the surrounding environment. The findings will be used to develop monitoring schemes and environmental guidelines for future commercial deep-sea mining projects.

d Extensively researched deep-sea zone

The Hudson Canyon, located south-east of New York, is one of the most extensively researched zones in the North Atlantic. An international consortium of researchers has discovered a vast variety of life forms.

e Deepest waters

At 11 000 metres, the Mariana Trench is the deepest natural point in the ocean. It forms the boundary between two tectonic plates in the western Pacific Ocean and belongs to the Ring of Fire, a roughly 40 000-kilometre-long belt where most of the world’s active volcanoes are located and where most earthquakes occur. At this bottom-most point on Earth, the pressure is 1000 times greater than on land. Researchers believe that this supposedly inhospitable area actually hosts completely unknown life forms—and huge reservoirs of natural gas.



The map (above) shows the locations of the most important deposits of marine resources as well as which nations have an exploration contract in which ocean region. Most countries are interested in exploring the Clarion-Clipperton Fracture Zone (A) in the Pacific Ocean. The mining project that has progressed the furthest is in the Bismarck Sea (B).

1 Black smokers
2 Manganese nodules
3 Polymetallic crusts
4 Rare earth elements
5 Crude oil and natural gas

exploration contracts for manganese nodules
exploration contracts for black smokers
exploration contracts for polymetallic crusts

A Clarion-Clipperton Fracture Zone
B Solwara 1
C Atlantis II Deep

a International Seabed Authority ISA
b Innovation Center for Deep-Sea Environmental Monitoring
c Germany's exploration contract
d Extensively researched deep-sea zone
e Deepest waters

Explore to protect

What environmental protection measures are essential in the deep sea? Thanks to funding from the Werner Siemens Foundation, the University of Bremen was able to establish the Innovation Center for Deep-Sea Environmental Monitoring at MARUM. At the centre, researchers are developing methods to define, measure and monitor key parameters. The findings will provide the basis for environmental protection in deep-sea mining.

As a first step, the Innovation Center for Deep-Sea Environmental Monitoring will use existing measurement systems to determine what minerals and organisms actually dwell in the seabed. Hydrothermal vents in the Atlantic are the designated test sites. Then, environmental data will be collected in those areas that are likely to be targeted by deep-sea mining. It may not sound like much, but exact maps are a precondition for navigating through the darkness of the deep sea—and for finding those ecosystems that must be protected.

Because standard ocean maps are charted using satellite data and measurements taken from a ship, they lack detail and precision—for instance, they often completely underestimate the height (or depth) of seamounts. To date, there are detailed maps of less than 10 percent of the deep sea.

The new maps will chart the location of mountains and valleys as well as recording their height, depth and composition. This will enable researchers to draw many important conclusions about the kind of life dwelling there. Slopes of seamounts, for instance, are popular abodes for numerous types of organisms.

Map, observe, sample

Since the start of this century, MARUM researchers have been able to send video-controlled underwater robots down 4000 metres to the seabed from a research vessel. The underwater robots chart high-precision maps and capture images of even the tiniest sea creatures, for instance crabs and beard worms. They also collect samples and can research organisms in their natural habitats—deep-sea

At present, MARUM underwater robots (front) are dependent on expensive "mother ships"—in future, they will be joined by independent marine vehicles with long-term autonomy.

sponges, for example, intensely dislike being brought on-board a ship. The robots are also capable of placing sensors in the deep sea, thus allowing researchers to observe a single region over a longer period of time.

Researchers at the Innovation Center for Deep-Sea Environmental Monitoring will use all these technological capabilities—at the same time, they are further developing the existing systems, with the aim of creating autonomous, intelligent and mobile systems that function independent of a "mother ship".

Experienced director, experienced team

Professor Ralf Bachmayer heads the centre, which is financed by the Werner Siemens Foundation. Bachmayer looks back on years of experience in the development, navigation and steering of unmanned maritime vehicles in the upper thousand metres of the ocean. The position in Bremen is what brought the researcher back home to Germany in 2017, after 23 years in the US and Canada. Ralf Bachmayer studied electrical and mechanical engineering and will work with specialists at MARUM and the University of Bremen from the fields of engineering, informatics, mathematics and visualisation. Their common goal is to master three central challenges: sensor technology, navigation and communication in the deep sea.

Navigation challenges

Navigating the abyssal deep sea without contact to a ship poses considerable challenges—there is no submarine GPS. As a rule, navigation is done with the help of sonar-based maps, acoustic signals and inertial navigation systems (INS). "These are systems that—based on acceleration and velocity—allow us to precisely determine the orientation of a vehicle and estimate the coordinates," Ralf Bachmayer explains.

Smart sensors

Acoustic signals are also used to communicate underwater but have the disadvantage that their energy consumption per bit is significantly higher than optical systems. For their part, optical systems have the disadvantage that their data-transfer range is unable to extend to the thousands of metres required for deep-sea exploration. Ralf Bachmayer's approach to solving the problem? "We're making the sensors so intelligent that they can take on part of the data processing and autonomously create and then transmit an image of the environment from the data collected."

Ultra-high resolution, please

Another challenge is transmitting data from seabed to surface. In the deep sea, light becomes muted and is therefore unsuitable as a long-distance conduit for data. And electromagnetic waves (radio waves), as used on land, transfer data too slowly. What the researchers really want, however, is the best-possible resolution—which are images in 4K. But how to transfer the data accumulated?

In the end, energy efficiency will be the decisive factor. "We can't install a supercomputer with high energy consumption in the deep sea," says Bachmayer. "And there's no data cloud. It all has to happen locally."

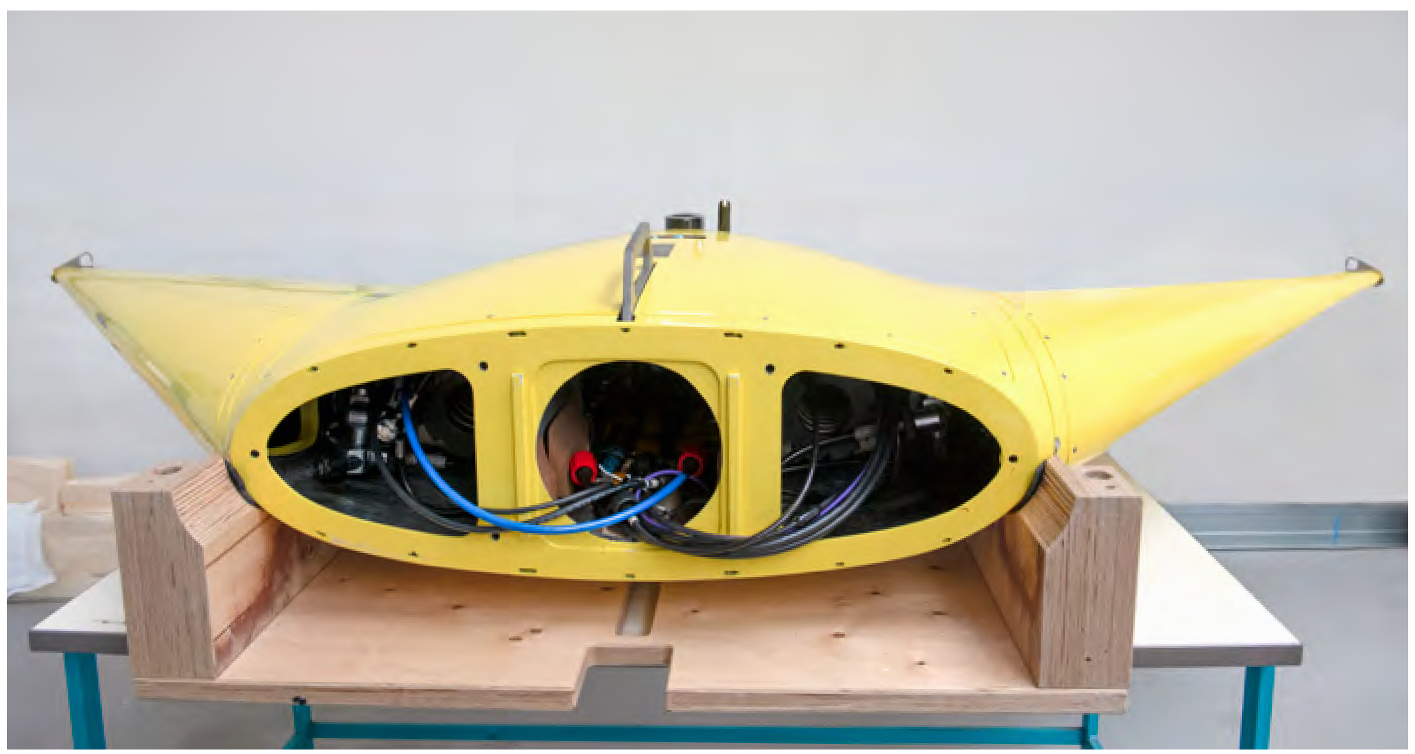
Stationary observatories

To date, the standard approach to data transmission has been to collect data in the deep sea and then analyse them on-board. For the past 10 years, stationary observatories connected to the mainland by cables have also been in use; the secured energy source of these stations provides the advantage of fast data transmission. As partner in an observatory off the west coast of North America, MARUM has installed sonars to map methane bubbles. But the stations have drawbacks. Because the sonars consume so much energy, the equipment must be connected to an outlet. Moreover, these kinds of observatories are incredibly expensive, costing up to hundreds of millions of euros. And there is a risk that, a few years down the road, it will become clear that the location of the observatory is not ideal. Moving is, however, not a viable option because of the cables.

Mobile, autonomous, intelligent

Mobile, autonomous, intelligent systems therefore seem most promising for deep-sea research, and they are also an excellent supplement to the existing stationary observatories. A mobile system is better suited to covering diverse regions of the seabed and charting large areas, all of which would aid researchers in their search for the most important ecosystems in the deep sea. Should climate change cause the water temperatures to rise or the ocean zones to shift, mobile, unmanned systems would be able to move along with them. The new technology would also make long-term observations affordable—and researchers need data collected over longer periods of time to distinguish natural fluctuations from human-induced changes.

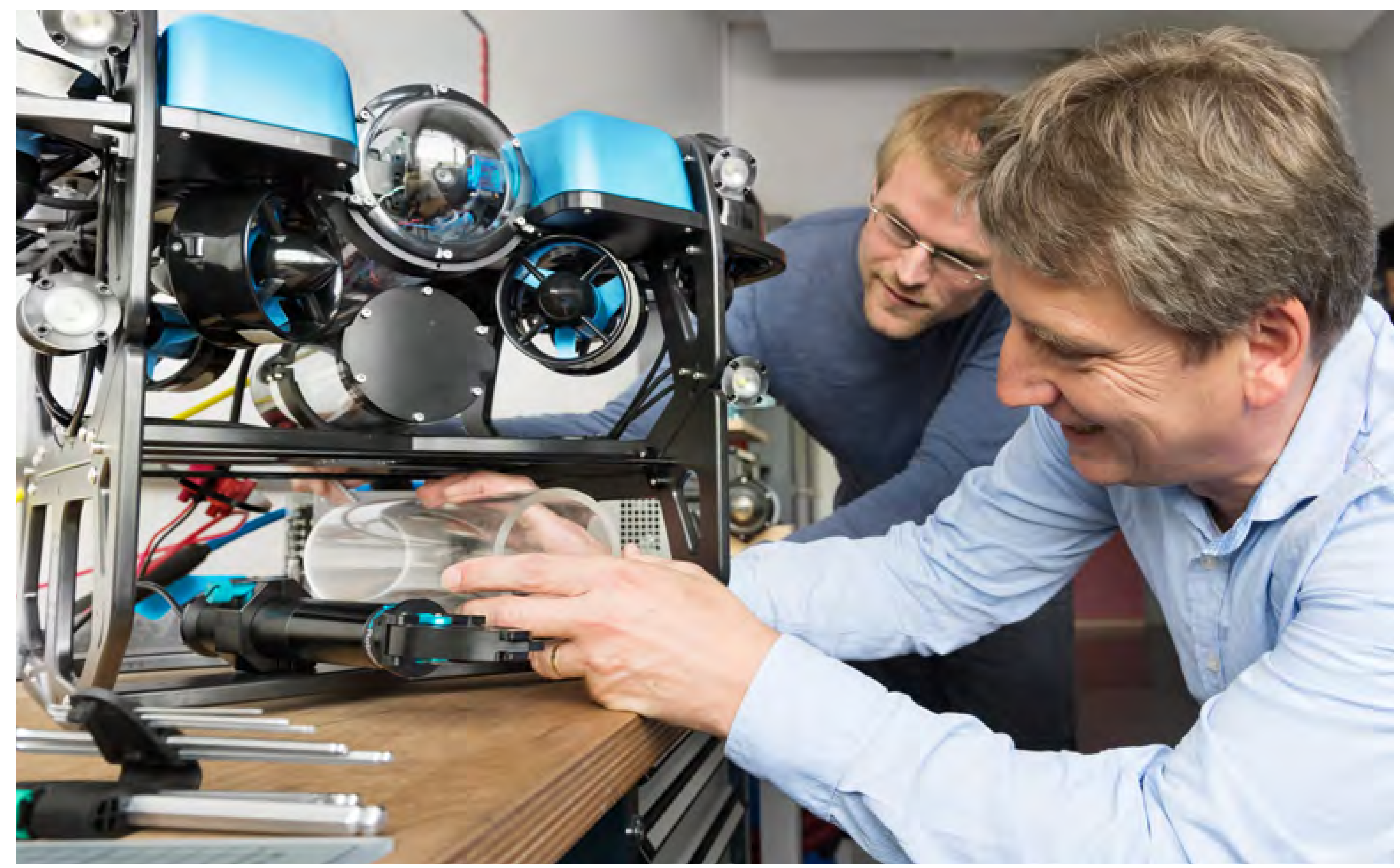
None of this is currently possible. And yet, it is more important than ever: the first mining companies are primed to begin excavating the deep sea. When they begin, at the very latest, it must be clear what protection measures will safeguard the deep sea from irreversible damage.

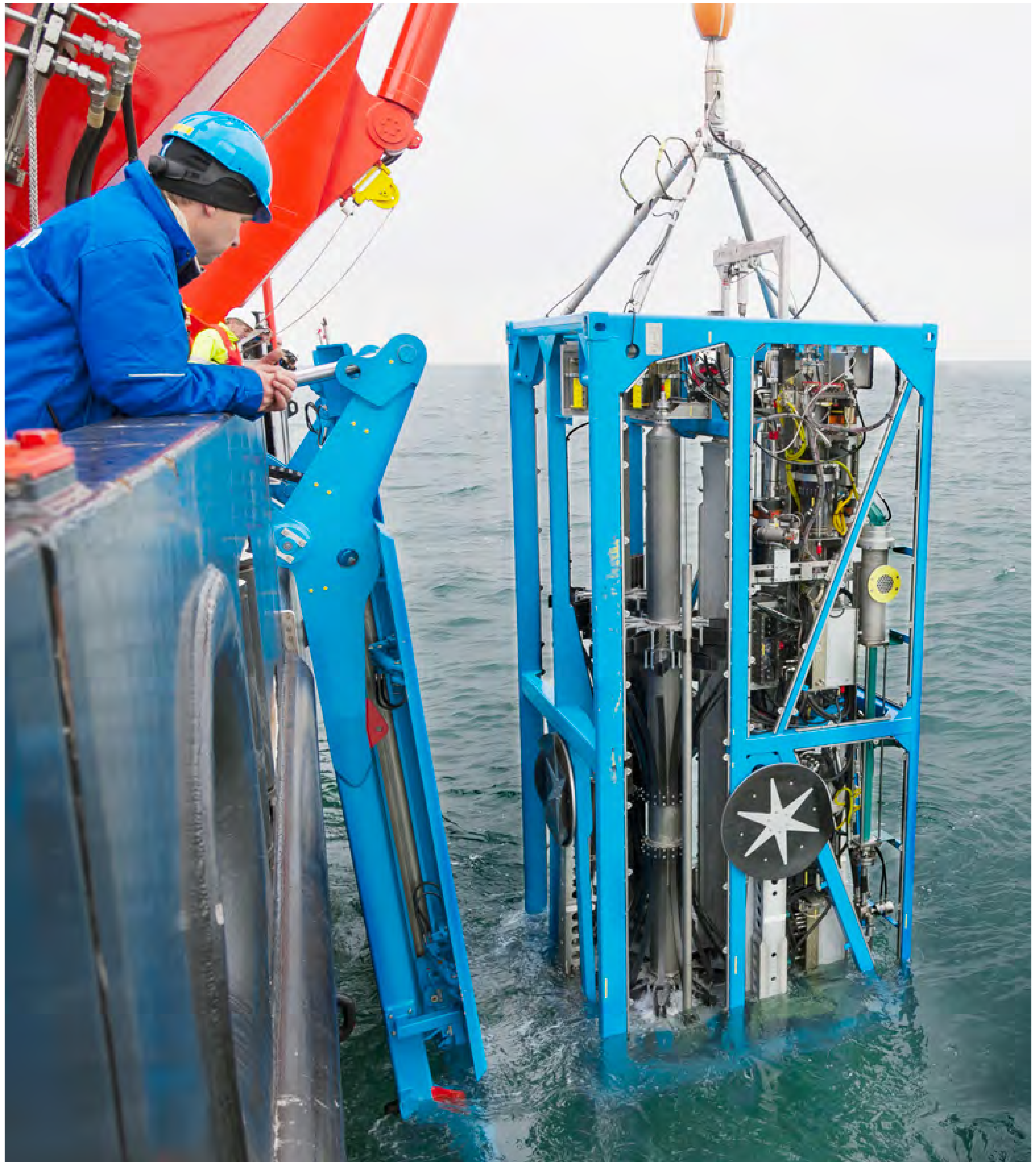


The MARUM SEAL is an autonomous underwater vehicle able to chart high-precision maps of the sea floor.
The technology is being further developed to enable SEAL to react to the data collected and adapt its mission in real time.

MARUM director Michael Schulz (left) and director of the Innovation Center for Deep-Sea Environmental Monitoring Ralf Bachmayer are working to protect the deep sea—in the background: cooled drilling cores that are archived in the MARUM core shed.

Werner Siemens Foundation Endowed Chair Ralf Bachmayer (right) and his colleague Paul Riesen are testing an additional part for a new optical sensor on a small, remote-controlled underwater vehicle.





Developing special equipment to research the deep sea has high priority at the new centre.
In the photograph: a tried-and-trusted MARUM drill that can probe the sea-bed.

Facts and figures

Project

The Innovation Center for Deep-Sea Environmental Monitoring, financed by the Werner Siemens Foundation, aims to develop prototypes for environment monitoring systems. A pilot mission in the deep sea is scheduled for 2025. Afterwards, autonomous sensor networks will be developed in close collaboration with industry partners and then put into operation.

Support

The Werner Siemens Foundation is supporting the establishment of the Innovation Center for Deep-Sea Environmental Monitoring by financing a professorship (Prof. Dr Ralf Bachmayer) and positions for two research associates and two technicians as well as equipping a lab and a workshop. In 10 years, funding of the entire group will be integrated into the core budget of the University of Bremen.

Project duration

2018 to 2028

Project leader

Prof. Dr Michael Schulz

Funding from the Werner Siemens Foundation

4.975 million euros

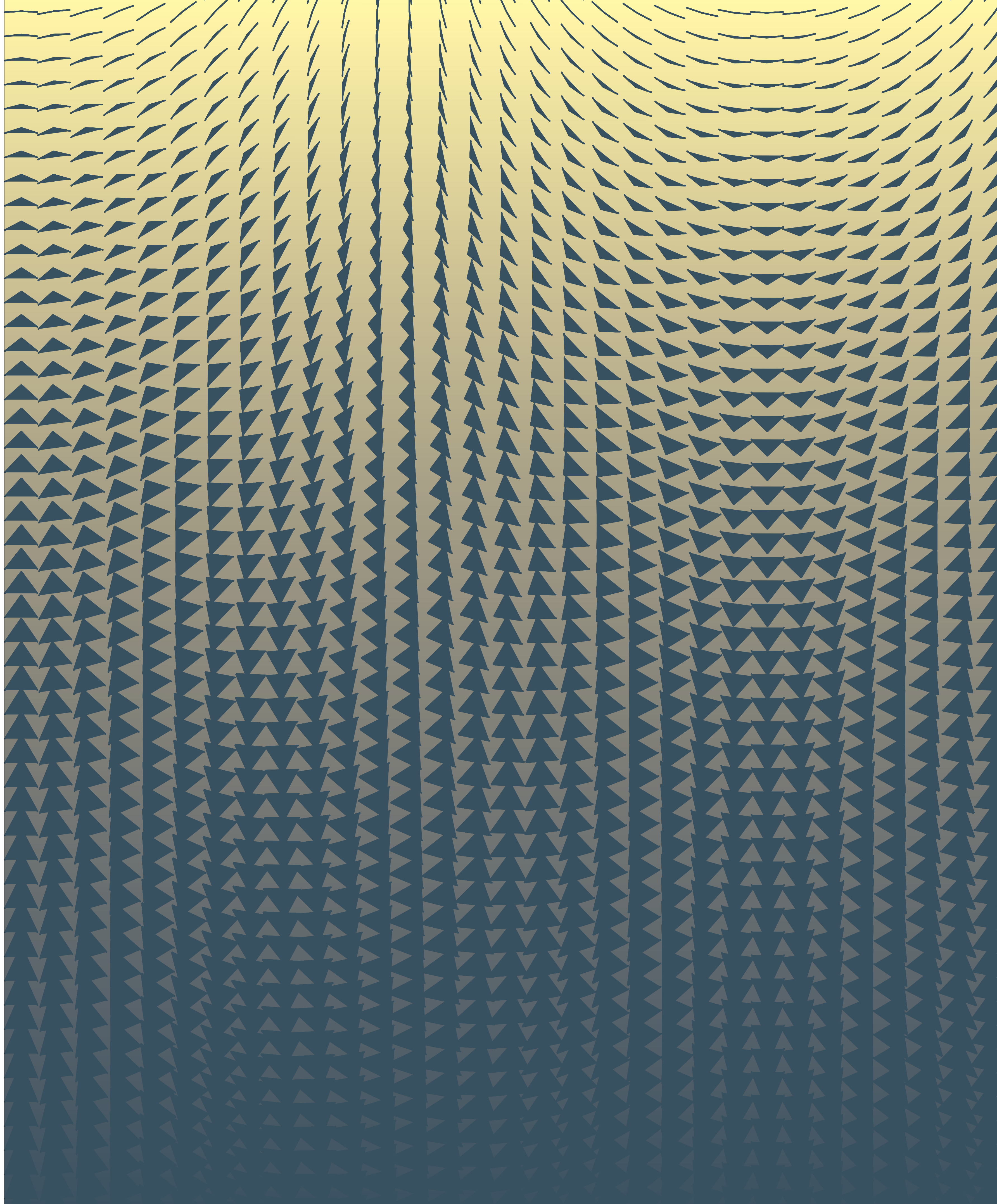
Partners (selection)

MARUM – Center for Marine Environmental Sciences at the University of Bremen

explore
discover
protect

Innovation

The Werner Siemens Foundation is financing the establishment of the Innovation Center for Deep-Sea Environmental Monitoring—because we need to better understand the crucial ecosystems of the deep sea and we need deep-sea research instruments and technologies to monitor the impacts of deep-sea mining.



Girl power for technology

Mentoring programme Swiss TecLadies

What is unusual about this picture? The physicists are all women. Today's reality is still far from such a scenario: no IT company employs exclusively women, nor are there construction sites where only female engineers, architects and building overseers are found. In future, however, what is currently unimaginable will be the new normal.

Mina wants to be an engineer

Girl power for technology: with its mentoring programme "Swiss TecLadies", the Swiss Academy of Engineering Sciences SATW wants to encourage young women to aspire to technical careers. The first mentoring programme will last until July 2019.

Mina meets her mentor, Stefanie Burri, for the first time. The experienced civil engineer wants to show Mina that it is very possible for a woman to succeed in a male-dominated profession.

They are a rare, but highly committed few: women in technical professions. In branches such as information technology and engineering, women are a clear minority, but when the Swiss Academy of Engineering Sciences SATW called for mentors for the Swiss TecLadies programme, no less than 70 women from a diverse range of professions volunteered. From mechanical engineers, to computer scientists and nanoscientists, the mentors give 13- to 16-year-old girls—the mentees—real-life insight into the world of technical professions. By visiting mentors at their place of work and getting involved in their activities, the mentees gain a realistic impression of the professional and personal experiences of women in technical fields. The Swiss TecLadies mentorships are supplemented by visits to companies and personal coaching sessions. Raising the awareness of teachers and parents is also part of the programme.

Tricky questions

The first cycle of the mentoring programme began in September 2018, but not before the mentees had proved their technical prowess in an online challenge with no shortage of difficult questions: How do submarines resurface? What keeps trains on their tracks? How does Google know what shoes I want to buy?

The online challenge on the Swiss TecLadies website (https://tecladies.ch) was open to all interested persons, but only girls aged 13 to 16 who attained the required number of points could qualify for the mentoring programme. The programme is designed to appeal to young women who demonstrate talent and enthusiasm for technical subjects, but who have not yet considered pursuing a degree in mathematics, informatics, the natural sciences or technology—the so-called STEM subjects.

Socialisation matters

But why is the percentage of women studying for technical degrees and working in technical industries so low? (See figure page 67.) Astrid Hügli, head of the Swiss TecLadies programme, believes it has nothing to do with a difference in talent between boys and girls, but is instead due to socialisation differences: fathers tend to involve their sons more in technical tasks such as building and repairing things. And at school, girls receive less encouragement in science and technical subjects.

Hügli stresses that these are only two examples. Compared to the countries of Scandinavia and Central and Eastern Europe, girls in Western Europe have always received less encouragement to pursue technical careers: "Boys are often thought to be more capable of mastering technical subjects and thus technical professions." But this attitude is unfounded: according to the 2018 education report of the Swiss Coordination Centre for Research in Education SCCRE, young women routinely outperform their male peers in final apprenticeship examinations—including in professions with a high percentage of men.

Boosting self-confidence

And yet many girls lack confidence in their ability to learn a technical profession. "That's why we need a targeted pro-

High concentration while getting acquainted: on Welcome Day at the University of Applied Sciences Rapperswil, Mina and Stefanie Burri program a robot arm to make a specific movement.

gramme to support girls," says Astrid Hügli. Although the junior talent programmes at SATW have always been open to both girls and boys, an SATW study clearly showed that girls need more encouragement both at school and at home.

With Swiss TecLadies, SATW is now offering a programme specifically for young women. The online challenge identifies talent, while the mentors give the girls a realistic impression of technical careers and help build their self-esteem—because girls need confidence to take on such professions. "Young women lack role models," says Astrid Hügli. And the chance of meeting a female role model by coincidence is very low. That is why Swiss TecLadies actively brings talented girls and professional women together.

Effective role models

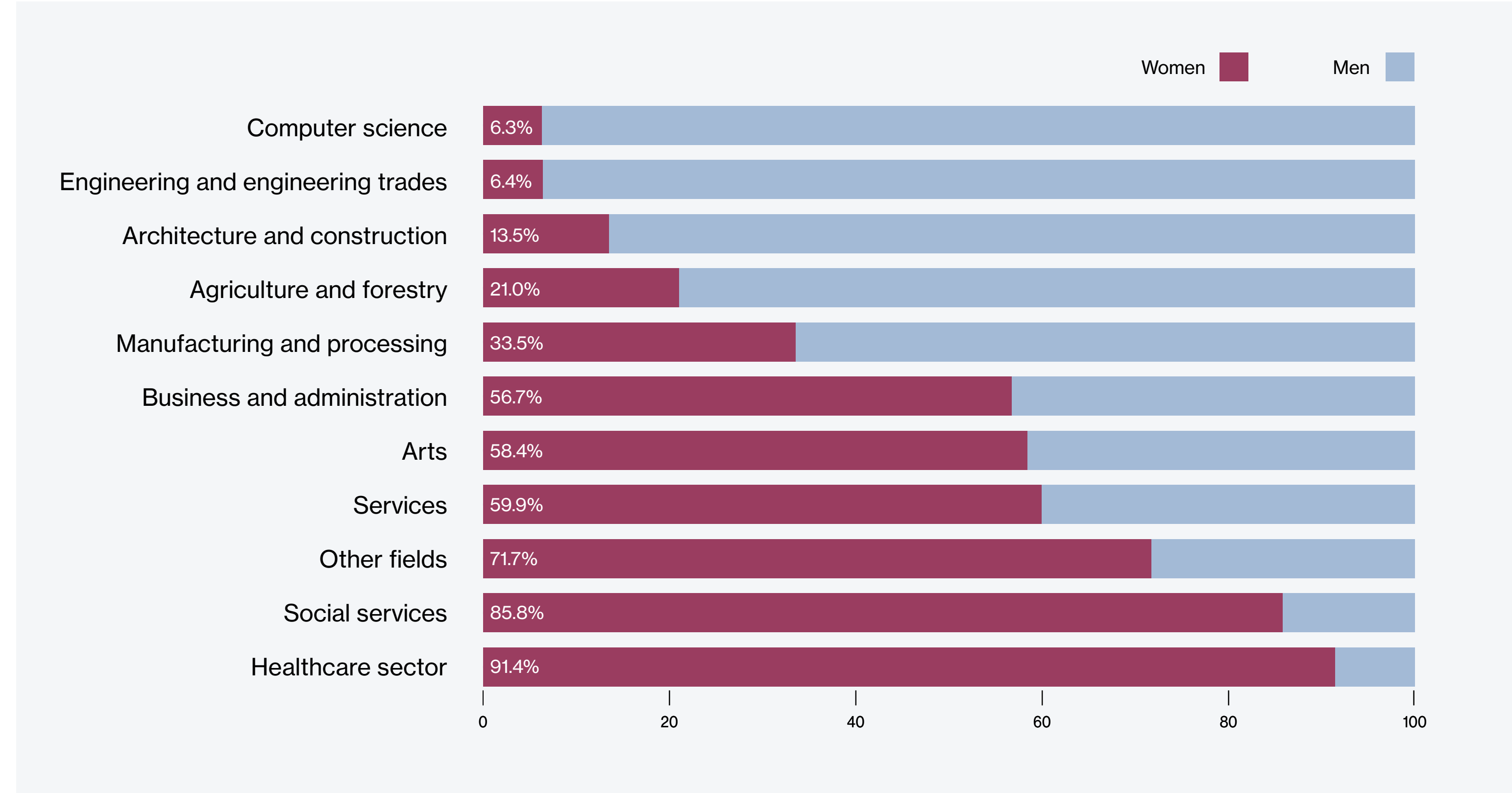
Through the programme, SATW aims not only to counteract the shortage of skilled workers in the long term, but also to foster diversity in technical industries. "Studies show that mixed gender teams are often more innovative," says Astrid Hügli.

Launched at the beginning of 2017, the Swiss TecLadies programme is receiving funding from the Werner Siemens Foundation for a five-year period. Within that time, two programme cycles should be completed: 2018 to 2019 in the German-speaking area of Switzerland, and 2020 to 2021 in both the German- and French-speaking areas. If the programme proves successful, it will continue to take place every two to three years. Swiss TecLadies also receives financial support from the Federal Office for Gender Equality via the skilled workers initiative of the Swiss Confederation.

New professions, new opportunities

Astrid Hügli is confident that the programme will help raise the percentage of women working in technical professions. And fortunately, certain societal developments are leading in this direction—after all, both girls and boys grow up as digital natives with smartphones and laptops. And the new Swiss national curriculum (Lehrplan 21) is addressing the shortage of skilled workers in STEM subjects by introducing technical topics in primary school. Moreover, many new STEM professions are evolving that are not yet dominated by one gender—and this will help break down stereotypes. Whether these future jobs are filled by men or women will hopefully soon be irrelevant. What matters is that career opportunities are pursued with enthusiasm and skill.

Basic vocational training according to gender and subject (2015)



Still today, too few girls pursue an education in computer science, engineering and other technical careers. Source: FSO

“Creating a positive dynamic”

Stefanie Burri, civil engineer and mentor

Can this wall be removed—or would the building collapse? How quakeproof is this bridge? Structural questions such as these are what most fascinates civil engineer Stefanie Burri about her profession. As a project leader for above-ground structures at the engineering agency “ewp bucher dillier AG” in Lucerne, Burri advises architects and building owners on newly constructed buildings and redevelopments. For example, she recently oversaw the completion of a new residential and industrial estate near Lucerne.

Already as a child, Stefanie Burri tested every tool and material in her father’s workshop and was allowed to solder, saw and drill. Her talent for maths and science quickly became evident at school, and it thus seemed natural for her to seek an apprenticeship in a technical profession—as a metal construction designer. “My parents and those close to me always supported my ideas,” says Burri. Nonetheless, at times she felt unsure of herself in this male-dominated profession; she had no female role models to guide her. “As a woman, you stand out,” Burri says, “and you feel you must constantly do a better job than the men. I worried about making mistakes that would prompt the reaction: ‘typical woman!’”

After completing her apprenticeship and earning a federal vocational baccalaureate, she studied for a bachelor’s degree in civil engineering in Lucerne. She currently holds a highly varied job, with planning and calculating in the office on the one hand, and consulting at construction sites on the other. Particularly enjoyable for her is the collaboration with professionals from a diverse range of industries: finding a design solution with the architect, optimising processes with the construction company and discussing technical details with the tradespeople.

These days, Stefanie Burri feels accepted as a woman in the world of construction: “Most professionals in the construction industry are men, but they treat their female colleagues as equals,” she says. She rarely encounters men who are surprised to meet a woman at a building site.

“The important thing is to know who you are and what you can do—that’s all it takes,” says Stefanie Burri today. And she believes it is sometimes even an advantage to be a woman: “As a woman in a male-dominated environment, people tend to remember you more—and that can help generate follow-up contracts.” Nonetheless, she is convinced that it can be difficult for young women to embark on an unconventional path if they lack support and that the low percentage of women in technical professions can be a deterrent. Overcoming these hurdles demands self-confidence, and it is precisely this quality that Stefanie Burri wants to foster as a mentor for Swiss TecLadies. It is her hope that the programme will create a positive dynamic that leads more girls to choose a technical profession—because they have female role models paving the way. “Role models can help reduce fears. I want to show girls how easy it is to be a woman in the technical world.”

“Role models can help reduce fears. I want to show girls how easy it is to be a woman in the technical world.”
Civil engineer Stefanie Burri at a construction site.

“The tech world is more than a series of 0s and 1s”

Gerardina Bello, information technologist and mentor

Gerardina Bello’s path to a technical career was hardly preordained: while studying social sciences at the University of Bern, she was looking for a job and took on a part-time position in the IT department of Swiss Post. After starting out as a clerk, she gradually took on more and more technical tasks—for instance in data preparation. She enjoyed the fast-paced IT environment so much that, after completing her studies, she followed up her years of experience at Swiss Post with a Federal Diploma of Higher Education in Information Technology.

From then on, Gerardina Bello knew that she wanted to work in tech, but she also wanted to work with people. And that is a goal she has since realised: in mid-2017, she was appointed head of the SAP Support Team at Swiss Post. Her 15-member team operates and maintains the SAP software systems used in, for instance, Human Resources.

“When I started working at Swiss Post, being a woman in the IT team was an exception,” says Gerardina Bello, looking back. And not a great deal has changed since, at least on a national scale: the percentage of women employed in IT in Switzerland is currently around 15 percent. The fact that it is some 33 percent in the SAP Support Team led by Bello is not because she, as the boss, only employs women: “I was able to take on the team with a high percentage of women,” she tells with a smile, only to recount soberly that, “for the two positions that have been advertised under my leadership, not one single woman applied”.

As a mentor for Swiss TecLadies, Gerardina Bello wants to help increase the number of women working in technical professions. “We should stop thinking in terms of ‘men’ and ‘women’,” says Bello. “What really counts is a person’s competencies and skill, and that they take pride and pleasure in their work.” She is convinced that if there were no predefined male or female professions, more young people would choose a career path that is currently considered the domain of the other sex. Gerardina Bello never had the feeling that she was disadvantaged as a woman, but she can well imagine that young women—and men—are reluctant to choose certain careers if they continually have to justify their choices.

The fact that Gerardina Bello was unfazed by gender stereotypes when she chose her profession is partly thanks to her background: her parents immigrated to Switzerland from Italy. “As the daughter of immigrants, I was already different at school because I had one foot in each culture and language.” But she saw this as an opportunity, not a disadvantage: “My parents always made me feel that being different is an asset. That’s why I had no qualms about taking on a career in a male-dominated industry.”

The satisfaction and pleasure she gains from her profession are something that Gerardina Bello wants to share as a mentor. “We can spark the interest of young women for technical professions if we share our passion and enthusiasm,” she says. And she wants to show her protégées that technical careers, too, are highly versatile: “I work in tech, but that doesn’t mean I only work with figures and algorithms. My world is more than a series of 0s and 1s.”

“What counts is a person’s abilities and that they take pride and pleasure in their work.”
Information technologist Gerardina Bello, director of the SAP Support Team at Swiss Post.

“Women often have to prove themselves first”

Lea Caminada, particle physicist and mentor

The breakthrough was nothing short of a sensation: in July 2012, CERN in Geneva announced that it had discovered the Higgs boson. The elementary particle, whose existence had been postulated by theoretical physicists decades ago, was detected using the largest particle accelerator in the world—a 27-kilometre tunnel, in which the researchers collided protons with protons to produce the Higgs particles.

The discovery of the Higgs boson was also a day of rejoicing for Lea Caminada, a particle physicist at the Paul Scherrer Institute (PSI) in Villigen, Switzerland. She was involved in the construction of the so-called pixel detector, which, by reconstructing the collisions of the protons, enables verification of the Higgs boson. Caminada coordinated the tests and the initial activation of the detector—first at PSI, then at CERN—and says, “It’s a fascinating privilege to help solve some of the world’s most fundamental questions: What is matter made of? How did the universe begin?” Caminada, whose job requires her to commute between Villigen and Geneva, is currently working on evaluating data produced by the detector—and developing the next, even better version.

Her talent and enthusiasm for natural sciences are what led Lea Caminada to study physics at ETH Zurich. The low number of women (20%) during her studies posed no great problem; she felt comfortable and accepted. Later, as a postdoctoral researcher in the US, she enjoyed a more balanced gender ratio among physicists. Upon returning to Switzerland, however, things changed again. She realised that the higher the rung on the academic ladder, the more difficult the situation becomes for women. Sometimes it is subtle, unconscious prejudice that Lea Caminada experiences in working groups: “As a woman, I’m sometimes taken less seriously. Men are seen as more capable in technical professions. Women don’t necessarily have to be better than men, but they do have to demonstrate their abilities more actively and prove themselves.” This makes it all the more important to start at an early age and introduce both girls and boys to technical professions: “Girls don’t just lack female role models—they also know far too little about these professions,” says Caminada.

To be part of the solution, Lea Caminada volunteered as a mentor for Swiss TecLadies. At the same time, the physicist is also herself a mentee: she is currently participating in a mentoring programme at the Paul Scherrer Institute for female researchers who would like to take on a leadership role. Her mentor, however, is a man—there are still not enough women in leadership positions to cover such roles. “Hopefully not much longer thanks to programmes like Swiss TecLadies,” says Lea Caminada.

“We have to demonstrate our abilities more actively.” Particle physicist Lea Caminada, who worked on the experiments proving the existence of the Higgs boson in 2012 at CERN.

The women in charge of the mentoring programme Swiss TecLadies, created by the Swiss Academy of Engineering Sciences (left to right): Edith Schnapper (career development in technology for western Switzerland), Astrid Hügli (project manager of Swiss TecLadies) and Silvia Kraus (marketing manager of career development).

Mastering an assignment together: mentee and mentor at Welcome Day in Rapperswil.

Facts and figures

Project

The Swiss TecLadies programme was created by the Swiss Academy of Engineering Sciences SATW to encourage girls between 13 and 16 to aspire to technical professions.

Support

The Werner Siemens Foundation is supporting Swiss TecLadies for the first five years of the programme.

Funding from the Werner Siemens Foundation

900 000 Swiss francs

Project duration

2017 to 2021

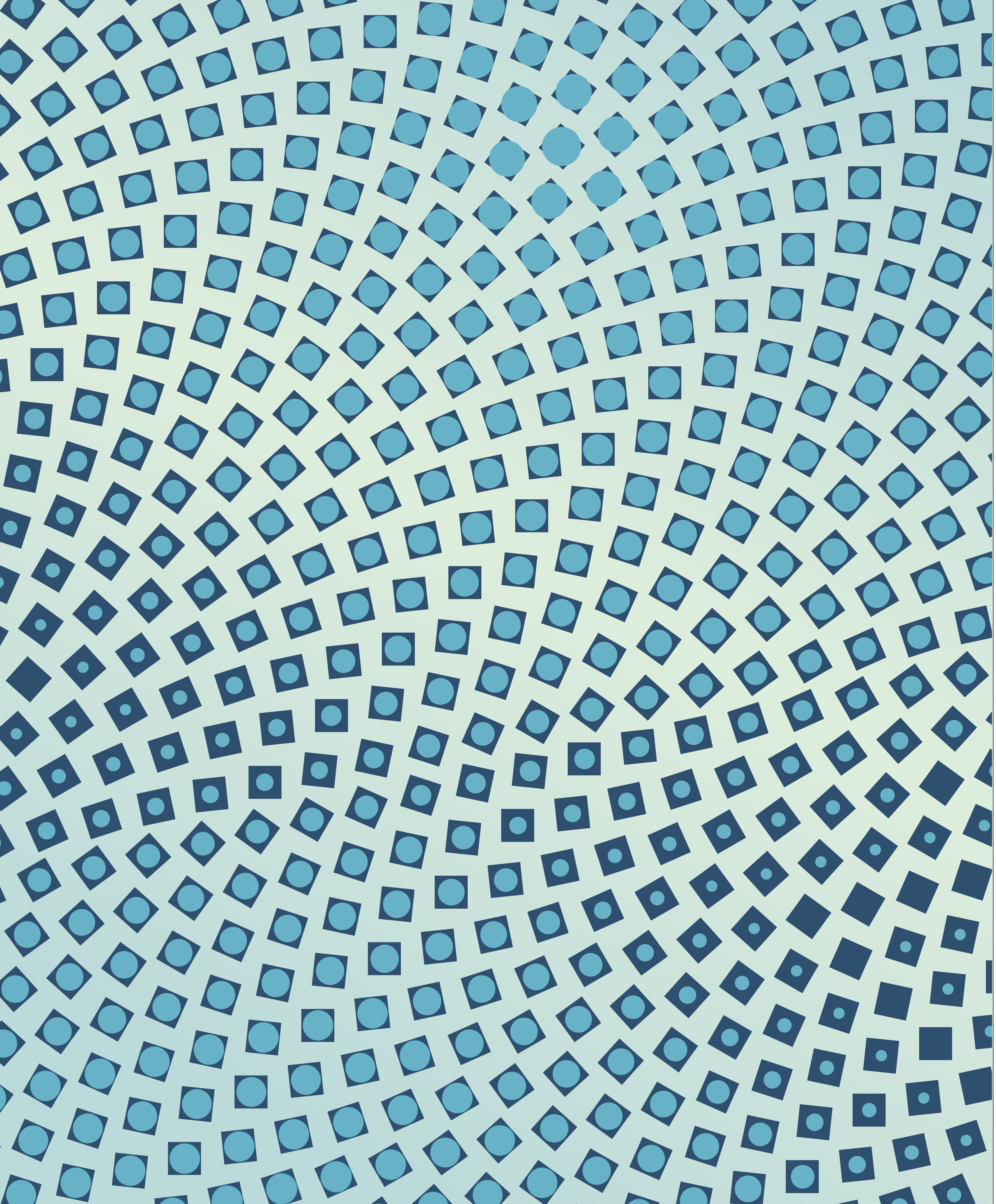
Project management

Swiss Academy of Engineering Sciences SATW

young female science-minded

Innovation

Although they have the necessary talent, very few young women choose a technical career path. By providing female role models, the innovative Swiss TecLadies mentoring programme encourages young women to pursue such careers—a measure that will also help combat the shortage of skilled workers in technology and the natural sciences.



From lab to market

MedTechEntrepreneur Fellowships

Discovering a foreign country. Taking only the bare necessities. Every day a new adventure with no sure conclusion. Testing one's limits, trusting that all will be well in the end. Personal satisfaction, even euphoria with every milestone achieved. The joy of adventurous travels in unknown regions is rewarding—and not unlike the thrill of becoming an entrepreneur.

Healthy business

The path from academia to entrepreneurship is long and arduous—not least in the field of medical technology. To help pave the way for first-time entrepreneurs, the Werner Siemens Foundation is sponsoring the MedTech-Entrepreneur Fellowship at the University of Zurich. The funding programme supports talented junior researchers who want to establish a medical technology firm.

They abandoned the lab to make their discoveries accessible to everyone: successful entrepreneur Daniela Marino and newcomer Yannick Devaud.

A whole 10 years can pass before a medical technology firm can sell a product—the start-up investments are substantial, and the regulatory procedures complex and expensive. This means that many medical discoveries languish in universities, even though they have the potential to help many people. In order to change this, the University of Zurich established the MedTechEntrepreneur Fellowships. The funding programme, which is sponsored by the Werner Siemens Foundation, supports junior scholars at the University of Zurich who would like to found a medical technology spin-off company.

The first Fellowships were awarded in the summer of 2018. Five projects from the areas of cancer research, regenerative medicine, molecular biology, and cell and tissue engineering were submitted. The two successful applications are now being supported with funding of 150 000 Swiss francs.

One of the first Fellows is biotechnologist Yannick Devaud, aged 30. In a discussion with entrepreneur Daniela Marino, aged 36, he learns what will make the difference when establishing his spin-off company. Like Devaud, Marino once studied biotechnology. In March 2017, she founded her own firm: Cutiss AG.

Yannick Devaud, in July 2018 you were awarded one of the first MedTechEntre-preneur Fellowships sponsored by the Werner Siemens Foundation. How will you use the funds?

Yannick Devaud: When surgery is carried out on pregnant women, the membrane of the amniotic sac is frequently damaged. This leads to premature births, which the babies often don't survive. My aim is to protect the membrane by applying a kind of sticking plaster after surgery. During my doctoral studies at the University of Zurich, I developed a device that makes this possible; now I want to develop it further. The 150 000 Swiss francs will be used mainly to pay my salary for the next 18 months.

What are the next steps for you in becoming an entrepreneur?

Yannick Devaud: First of all, I'll develop and test the prototype. In spring 2019, the first experiments on sheep should be possible. If these succeed—and only if—then I aim to found my spin-off towards the end of 2019. The first tests on humans should be possible as soon as all of the approval procedures are complete—probably in about three to four years.

Advice from entrepreneur Daniela Marino (below) on starting a firm: prepare a convincing package to attract potential investors as early as possible. That includes a winning story to show what the problem is and why the new technology is the way to solve it.

Daniela Marino, you work in a related area. Your firm Cutiss AG produces personalised skin transplants for burn patients or patients who have had tumours removed. You established your firm about 18 months ago; today, 10 people work for you. What made you decide to become an entrepreneur?

Daniela Marino: Helping people was always the aim of my research. And to make that happen, there was simply no other option but to turn the research project into a spin-off. After all, publications in specialist journals alone don't change anything for patients. And pharmaceutical companies don't buy ideas that haven't been extensively tested—the risk for them is simply too great. I made the decision to found a spin-off overnight, and I've never regretted it. I wake up every morning with a smile on my face.

Establishing a spin-off involves a great deal of work. What were the biggest challenges?

Daniela Marino: The most difficult thing for me was building a network. As a researcher, I was accustomed to working alone in my lab—far removed from the outside world.

Would you do things differently today?

Daniela Marino: Yes, I would spend more time at networking events, even if they're sometimes a chore. With a spin-off firm, you have no money to pay specialists. And that means you're dependent on your network. People who simply want good ideas to be realised—who work pro bono—really do exist; we just have to go out and find them.

Is networking difficult for you, Yannick Devaud?

Yannick Devaud: Fortunately, I don't really mind approaching strangers and asking stupid questions.
Daniela Marino: You greeted me in the hallway before—for a moment I thought we knew each other. That's quite charming.
Yannick Devaud: What worries me more is the complicated work involved in the regulatory procedures, which can be torturous at times. But I am someone who likes to learn, and I have my sights set firmly on my goal: I want to save those babies. If that means working hard, attending courses and filing reams of paperwork, then I'm ready for that.

Daniela Marino, based on your experiences, what advice would you offer Yannick Devaud?

Daniela Marino: You should make a pretty package for potential investors as early as possible. Because sooner or later, you'll need more money. What you put in that package is up to you, but it had better look very, very good.
Yannick Devaud: What do you mean?
Daniela Marino: What you need is a winning story. You have to show what the problem is and why you're the one who can solve it. And the investors will want to see numbers: how many patients are affected, what the competition looks like and so on. Never think it is too early. It all takes an awful lot of time, so it's best to get started right away.

Daniela Marino, when you started out four years ago, there were no MedTechEntrepreneur Fellowships sponsored by the Werner Siemens Foundation. Would such funding have helped you?

Daniela Marino: Most certainly. It's difficult to find support that extends beyond standard research funding. Regulatory procedures, for instance, can quickly cost up to 100 000 Swiss francs. But you're not allowed to use designated funds for other purposes. We were very fortunate, however, as we received a substantial contribution from the EU.

How can such funding problems be solved?

Daniela Marino: I hope that some of Switzerland's wealthier citizens open their eyes and see that there's no point in hoarding millions. There are so many brilliant young people out there—I meet them every day. Why don't we give them a chance to show what they're made of? It's not as if they were developing a new coffee machine. These young researchers can make a difference in society.

But surely there are venture capitalists who are willing to invest?

Daniela Marino: Of course, but they take advantage of people. They say, we'll give you one million, and the firm is ours. That was never an option for me, nor would I recommend it.

Founding a spin-off also means becoming a manager. Yannick Devaud, can you imagine giving up your research work?

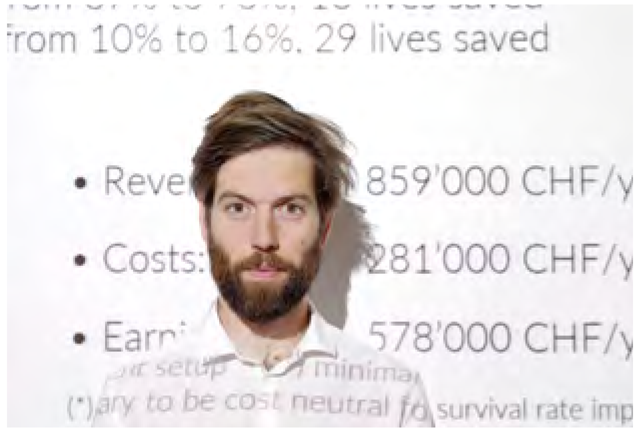
Yannick Devaud: I don't mind if I'm never Switzerland's greatest researcher; my abilities are well suited to the business world. But I'm also not someone who just wants to make a lot of money. If that was my aim, I would have taken a well-paid job in a large corporation. My goal is to help people. I want babies to stay healthy. That is a great motivation.

7 obstacles on the path to success

Cell biologist Gabriele Gut is developing technology to optimise cancer treatments and has plans to establish a spin-off company. Thanks to a MedTechEntrepreneur Fellowship sponsored by the Werner Siemens Foundation, he has the funding to pursue his goal—a company that provides personalised therapies for people living with cancer. Will his venture take off? The following seven points are usually decisive for the success of young entrepreneurs.

1. Idea

Every successful start-up company begins with a brilliant idea, and Gabriele Gut has not come up short: he has developed a technology that increases the success rate of cancer treatments. Now as ever, cancer remains one of the most common causes of death, and finding the right therapy continues to be difficult. Not only does the disease take on innumerable forms, but patients also respond differently to the various medicines available. Gabriele Gut, however, has found a way to improve treatment selection: he cultivates tumour cells of the cancer patient in the lab and tests how these respond to around 60 different medications. An algorithm then determines the ideal combination of medication for a personalised therapy.



2. Money

The Werner Siemens Foundation is supporting Gabriele Gut's idea with 150 000 Swiss francs in seed capital. "Without this support, I doubt I would have proceeded," says Gut. Now, for the next 18 months, he is guaranteed the necessary conditions to further develop his idea; the funding will cover his salary as well as materials required for product development. Gut is currently seeking additional sponsors to cover the cost of establishing his laboratory—an expensive undertaking.

3. Coaching

For years, Gabriele Gut has been able to rely on the feedback and advice of Lucas Pelkman, his superior and mentor at the University of Zurich. Coaching is, however, necessary not only in research, but also in business matters such as strategic, financial and regulatory issues. All recipients of the MedTech-Entrepreneur Fellowship are required to attend special business courses, but these do not feel like an obligation to Gut: "So much is still so new to me. I'm grateful for the support."

4. Infrastructure

"These toys don't exactly come cheap," says Gabriele Gut pointing to several microscopes worth between 400 000 and one million Swiss francs each. Until he can afford his own laboratory, he will continue to work at the Institute of Molecular Life Sciences at the University of Zurich (Irchel Campus) and, in future, perhaps at the UZH Life Science Incubator Lab (Schlieren Campus), where all the necessary equipment has been installed.

5. Networking >>

"The number of emails from people who want to discuss my project has increased dramatically," says Gabriele Gut. Gut is well aware that networking will be central to the success of his spin-off. "I'm dependent on the help and interest of others," he says. In order to develop such relationships, personal contact is essential. And the first opportunities are already available: the instructors of the Fellowship courses are all experts with start-up experience or a background in biotechnology.

6. Industry

If there is one thing Gabriele Gut has already learned, it is that communicating with business representatives is totally different to communicating with researchers. While he saves the “wow factor” for the end when presenting for academics, he is sure to open with it for a business audience: “I completely reverse the order of my presentations,” he says, “otherwise they're out the door.” The initial feedback from industry is positive says Gut, “but nothing is confirmed yet”.

7. Work-life balance

Days in the laboratory are often long. “If an experiment takes 12 hours, well, then it takes 12 hours,” says Gabriele Gut. The long days make breaks all the more important. In his everyday life, cooking distracts him and makes room for other thoughts. But to fully switch off, the 28-year-old prefers multi-day hikes—far from Switzerland and without mobile devices. Recently, he travelled to Tajikistan with his partner; the couple loaded their hiking packs with a tent, sleeping bags, gas cooker and food—and set out. “A week cut off from the world is as relaxing for me as three weeks at the beach.”

Facts and figures

Project

Talented junior researchers who wish to establish a company receive funding from the University of Zurich throughout the start-up phase in the form of a MedTechEntrepreneur Fellowship. The Fellowship programme was launched to promote spin-offs in the field of biotechnology; in 2018, the Werner Siemens Foundation began financing additional spin-offs in the area of medical technology.

Support

The Werner Siemens Foundation is sponsoring MedTechEntrepreneur Fellowships at the University of Zurich, including the costs of equipping and operating the Life Science Incubator Lab at the university’s Schlieren Campus. A maximum of five junior researchers per year are awarded a MedTechEntrepreneur Fellowship. The programme comprises funding of 150 000 Swiss francs and access to infrastructure, coaching and networks.

Funding from the Werner Siemens Foundation

10.67 million Swiss francs over a period of ten years (to be reviewed after four years)

Project duration

2018 to 2027

Project leader

Prof. Dr Michael Schaepman, Vice President Research, University of Zurich

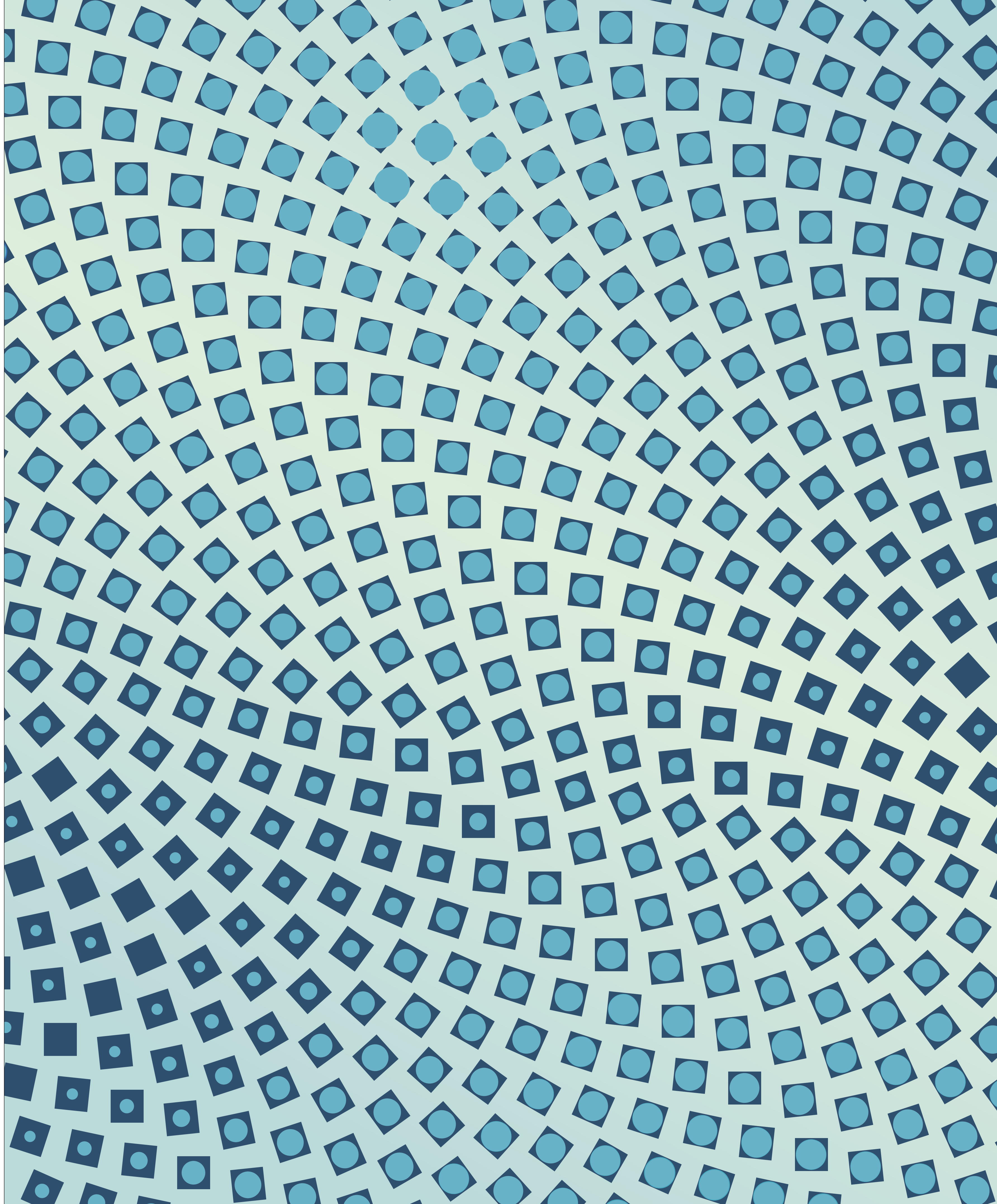
Main partner

Institute for Regenerative Medicine, University of Zurich

discover produce market

Innovation

The Werner Siemens Foundation supports junior researchers on their path to entrepreneurship—because developments in medical technology should not be confined to university laboratories, but used to benefit the whole of society.



Virtual reality in hospitals

Update on MIRACLE—minimally invasive bone surgery with laser technology

MIRACLE breakthrough: since the start of 2018, doctors at University Hospital Basel have been using SpectoVR software to plan complex surgical interventions. Developed in the scope of the MIRACLE project, the 3D technology shows patients why an operation is necessary, and it enables surgeons to prepare the best-possible surgical procedure—in collaboration with colleagues from all over the world.

Using SpectoVR software and special 3D glasses, doctors and patients can take a virtual tour of the body and make optimal preparations for surgery. The technology enables precise observation of bones and tissues—even blood vessels in the brain.

Step by step, researchers at the University of Basel's Department of Biomedical Engineering are nearing their goal of providing minimally invasive bone surgery using robot-guided lasers. In 2017, the team led by professors Philippe Cattin and Hans-Florian Zeilhofer developed the arm of the robot used to steer the high-precision laser "scalpel" (see our 2017 report). Then, in 2018, they optimised the components of the robot arm and developed, among other things, a six-millimetre force sensor that reacts to compression and tension. And researchers in the MIRACLE project achieved another breakthrough with the SpectoVR navigation software.

Breakthrough in 3D imaging

SpectoVR is a software program that converts medical data collected from, for instance, a CT scan into a three-dimensional image. So far, the program enables tissues, bones and blood vessels to be viewed in 3D. Special glasses allow surgeons and patients alike to navigate through a virtual body and see the areas that will be operated on: arteries can be traced, the spine can be rotated around its own axis and tissue can be viewed from every possible angle.

SpectoVR has been in use at University Hospital Basel since January 2018. The three-dimensional images of a surgical site allow doctors to virtually plan complex interventions. What is more, patients also benefit from the technology because it helps them to better understand why an operation is necessary and what exactly a procedure entails.

Planning complex interventions

Surgeons at University Hospital Basel can now use SpectoVR to prepare complex procedures such as surgery on enlarged cerebral vessels (aneurysms) or on the spine. Neurosurgeon Raphael Guzman is full of praise for the technology: "By virtually entering the human brain, we can view the details in the diseased vessels—for instance in the case of an aneurysm—from all angles and better understand the overall situation. This makes a procedure safer, and probably shorter as well." Surgeons are also increasingly using SpectoVR to perform operations on the spinal column. The first intervention planned using SpectoVR software was for a case of Bechterev's disease, a rheumatic ailment that causes a complex malalignment of the spine.

Improving doctor-patient communication

University Hospital Basel has equipped several rooms with SpectoVR 3D software, enabling doctors to show their patients exactly where the problems are and what parts of the body are affected. Patients greatly appreciate the new technology. "After my first shoulder operation, I still had pain," one patient says. "But with the 3D image, the doctors could see that the pain was caused by a pinched nerve near my spine and that another surgery was necessary. The 3D pictures helped me to accept the fact that the second operation couldn't be avoided."

Highly sought world's first

The software also allows surgeons to discuss complex surgical interventions in real time with specialists from all corners of the globe: they can meet in a virtual room created by SpectoVR to consult with one another and plan the best-possible surgical procedure. That SpectoVR enables discussions on actual cases is a world's first—and a feature that has generated international demand.

Uses in medical training

SpectoVR is also proving to be a valuable tool in medical training: much like a flight simulator enables future pilots to practise in a virtual environment, the software projects a realistic image of the interior of the human body for medical students. A summer school on the technology has already been held.

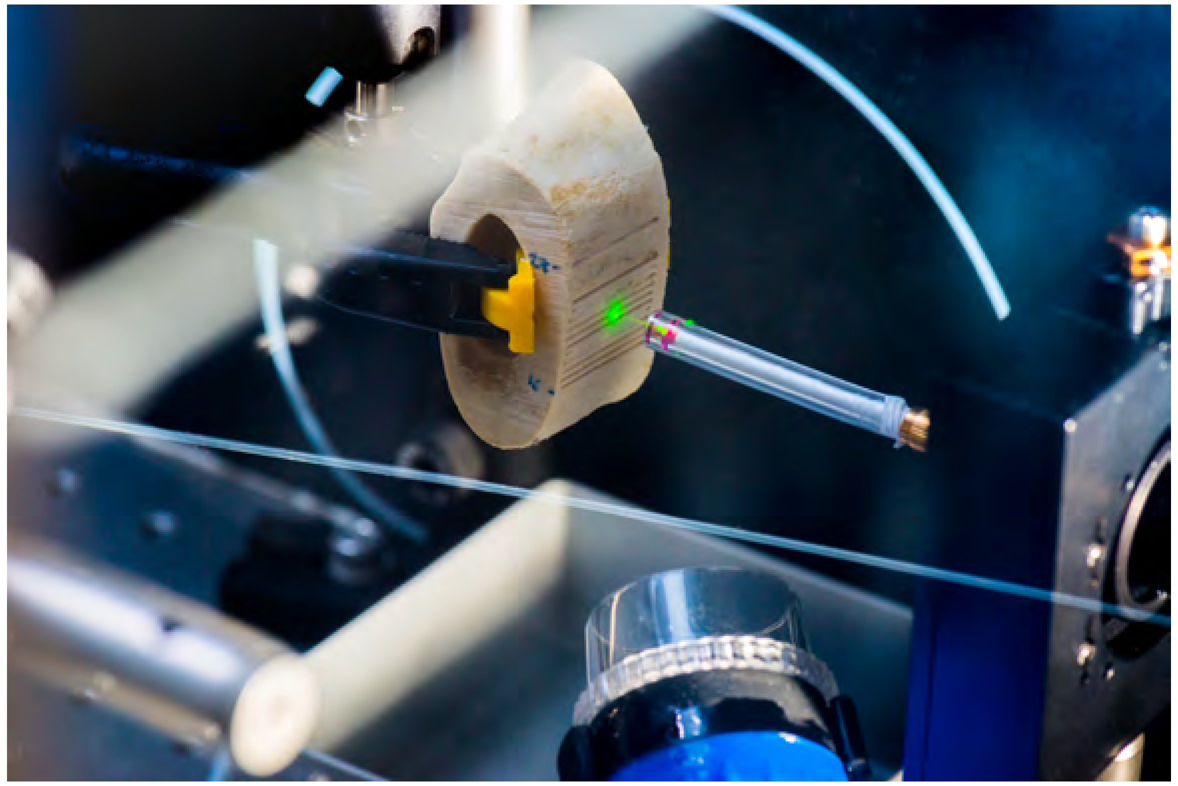
And last but not least, the researchers are developing SpectoVR for use as a steering mechanism in minimally invasive bone surgery using laser technology—the centrepiece of the MIRACLE project. In 2025, surgeons should be able to conduct high-precision interventions using a laser-guided robot arm and SpectoVR software.

Funding from the Werner Siemens Foundation

15.2 million Swiss francs

Project duration

2014 to 2021



In 2018, the MIRACLE team optimised the endoscope ...

... and explored ways to achieve intuitive control of the robot arm.

Be gone, pest!

Update on Synthetic Biotechnology—tiny organisms writ large

2018 brought good fortune to bees—and to the team at Synthetic Biotechnology. In February 2018, the EU issued a ban on conventional pesticides from the neonicotinoid group, which are known to harm pollinators such as bees. As chance would have it, Professor Thomas Brück and his team at Synthetic Biotechnology presented a biologically degradable pest deterrent soon after the ban was issued. The innovative substance does not poison insects but simply repels them, much like a mosquito spray. “The echo generated by our discovery was unbelievable,” says Brück, who holds the Werner Siemens Foundation Endowed Chair at the Technical University of Munich.

Werner Siemens Foundation Endowed Chair Thomas Brück has hit a winner with his innovative pest repellent: "Aphids are a big problem for sugar beet growers, so it's natural that they want to work with us to address the issue of pest control quickly."

The EU ban on seven internationally approved, highly effective pesticides from the neonicotinoid group caused an uproar in the agricultural sector. Farmers' associations immediately began demanding a replacement, and they want it fast. Growers of sugar beets and wheat—two major crops in Germany—are in particularly dire need of a new pest-control product.

To be sure, scientists have long provided evidence that neonicotinoids kill not only sucking and chewing pests such as aphids or whiteflies but also bees, bumblebees, butterflies, beetles, grasshoppers and other beneficial insects. The contact and systemic poisons in pesticides attack the insects' nervous systems, leading first to cramps, then death. Nevertheless, neonicotinoids continued to be used widely in farming. Until, that is, the publication of a 2017 study by Wood and Goulson demonstrating the adverse effects the substance has on the ecosystem of the most important pollinators.

The EU has also recognised that the decimation of bees and other pollinators is "collateral damage" from the use of neonicotinoids—and that we simply cannot afford to lose more bees, especially in light of the bee colony collapse disorder observed in a variety of regions. After all, without pollinators, the world's food supply is seriously at risk. As a consequence, the EU issued a ban on neonicotinoids in February of 2018. And ever since, Thomas Brück has been inundated with requests for the innovative pest-control substance developed by his team at Synthetic Biotechnology, at the Technical University of Munich (TUM).

Repel, not poison

Rather than functioning like a conventional pesticide, the innovative technology works more like a mosquito spray. "Our organic pest spray doesn't kill insects. Instead, it repels them for a certain period of time," says Brück. The innovative spray consists mainly of the molecule cembratrienol—a natural pest repellent—and is biologically degradable. True to their general approach, the researchers at Synthetic Biotechnology took inspiration from nature and naturally arising organisms when developing the active agent for the spray. This time, the model was the tobacco plant, which produces cembratrienol in its leaves. To date, the efficacy of the product has been tested only on aphids—because "they can't run away, meaning we can keep count of them", explains Professor Thomas Brück. The initial results were very promising.

A resounding echo

On 6 June 2018, TUM issued a news release about the tests, triggering a barrage of requests for the technology. The Landwirtschaftsministerium (Ministry of Agriculture) in Bavaria and even the German Federal Ministry of Food and Agriculture have contacted Brück and his team. As have big names in the agricultural sector, including German food company Südzucker—Europe's largest sugar producer—as well as agricultural chemical companies from the Netherlands, Austria and Switzerland.

A threat to sugar

Because sugar in Germany, the UK and the Benelux countries is produced mainly from sugar beets, the production of sugar in northern Europe is particularly affected by the ban on nicotinoids. Brück says, "Sugar beets are vulnerable to a virus carried by aphids, so it's natural that sugar beet growers want to work with us to address the issue of pest control quickly." In an initial step, the team at Synthetic Biotechnology is working with the Institute of Sugar Beet Research at the University of Göttingen—the key research facility for the development of sustainable sugar beet production in Germany. TUM and the Institute of Sugar Beet Research are also collaborating with the Bavarian Ministry of Agriculture and the German Federal Ministry of Food and Agriculture to test the pest-control spray and evaluate its effect on sugar beet aphids.

Even greater success

"We have to devise a special formula for the cembratrienol," Brück says. "Formulating the agent as an oily substance would lengthen its retention time and thus significantly improve the protection it offers." When Thomas Brück mentions an oily substance, he naturally thinks of "his" oil-producing yeasts, which he would like to use to improve the active agent in the pest-control spray. "We've begun producing oils with the repellent odour in genetically optimised yeasts," he explains. "This allows us to spray our formulation for the agent directly on the sugar beets, wheat and other plants." The active agent should also repel whiteflies and fruit flies (which damage fruit crops) and, as such, "could even protect the aromatic apricots grown in Valais", Brück says with a nod and a wink towards Switzerland.

From spin-off to EU approval

The various agricultural chemical companies that have contacted Thomas Brück plan to add the innovative pest-control substance to their own products in order to achieve the best-possible protection. Now, the TUM professor and Werner Siemens Foundation Endowed Chair is entertaining the idea of a spin-off company that would produce the substance and sell it to the agricultural chemical industry. Ideally, Brück sees a broad range of uses for the substance—from industrial-scale farms to private gardens.

But the goal will be difficult to achieve. The largest obstacle is posed by the EU regulators responsible for approving new agricultural chemicals. "It takes between three and five years for a new agent to be approved," Brück explains. During the waiting period, Synthetic Biotechnology will have to invest its own funds to guarantee that the team can maintain their innovative momentum and transform the initial product into a market success.

Oil and folic acid from algae

The pest repellent was not the only progress made by the team at Synthetic Biotechnology in 2018: *Microchloropsis sp.*, an oil-producing microalga, proved itself to be a major production organism: it grows faster and binds more oil than other kinds of algae. *Dunaliella sp.*, by contrast, is better suited to producing folic acid. It generates extremely high folate values, 10 times higher than in folic-acid-rich vegetables (such as white beans) or fruit (for instance honey melons). Over the course of the next two years, Brück expects that the procedures to produce folic acid can be marketed as patent licences.

Cancer drug Taxol

Another highlight in 2018 at Synthetic Biotechnology was the successful conclusion of the project to sustainably produce the cancer drug Taxol. The team found a new way of producing the Taxol precursor that pharmaceutical companies can use to produce the sought-after cancer drug. Although the pharma industry has signalled its interest, the approval procedures for new pharmaceutics are both very complicated and very expensive. "It's a tightrope act," says Brück, "and only large pharmaceutical companies can afford to be contenders. Funds in the amount of 100 million euros are easily used up before a process is certified." It is not yet clear which company is willing to step in.

Despite the open questions, work on further expanding and diversifying the technology platform for producing Taxol is underway: a proposal with partners from France, Israel, Italy, Australia, Austria and Germany has been submitted to the EU. In this case, the goal is to translate the gains made at Synthetic Biotechnology into the production of new cancer therapies, antibiotics and anti-inflammatory agents for the pharmaceutical sector.

A bioreactor from a 3D printer

Last but not least, Thomas Brück has come closer to realising his dream of the perfect bioreactor—a device in which yeasts and algae go in at the top and come out at the bottom as the targeted products—for instance oils or Taxol. At the start of 2019, an important step will be taken: the team can take up quarters in a new space furnished with state-of-the-art equipment. Then it is full steam ahead with the 3D printing of the bioreactor. For this project, the team at Synthetic Biotechnology is basing its methodology on the food industry rather than taking inspiration from nature. Already today, food companies like Nestlé or Danone use 3D printers to tweak the consistency of foods such as yoghurt and pudding, and the team at Synthetic Biotechnology is modifying these processes for its purposes. There is a futuristic element to the entire endeavour—and, indeed, it will most likely be another 10 years before 3D printers are ready to produce just about anything, including new foodstuffs—and entire bioreactors.

Project

The Werner Siemens Foundation is financing the first professorship for Synthetic Biotechnology at the Technical University of Munich.

Funding from the Werner Siemens Foundation

11.5 million euros

Project duration

2016 to 2021

Project leader

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

Partners (insect spray)

Kuratorium für Versuchswesen und Beratung im Zuckerrübenanbau; Bavarian Ministry of Agriculture; Bavarian State Ministry of Food, Agriculture and Forestry; German Federal Ministry of Food and Agriculture; Institute of Sugar Beet Research at the University of Göttingen; Südzucker AG; W. Neudorff GmbH KG (Germany); Andermatt Biocontrol AG (Switzerland); Clariant (Switzerland)

What substance can best channel heat from the Earth's interior up to the Earth's surface?—Carbon dioxide!

Earth's powerful core

Update on deep geothermal energy—harnessing energy from the Earth's interior

Werner Siemens Foundation Endowed Chair Martin O. Saar and his team are working on a novel way to generate electricity: using carbon dioxide to channel thermal energy from underground while at the same time removing the toxic greenhouse gas from the atmosphere—a technology that promises to slow global warming.

Martin O. Saar is convinced that deep geothermal power plants could help to significantly reduce CO_2 emissions while also generating large supplies of renewable energy. But in most regions of the world, Switzerland included, accessing temperatures high enough to generate power means drilling up to five kilometres into the Earth's crust—where rock layers are practically impenetrable. In order to channel heat to the surface, the standard method is to inject water to break up the rock, but this procedure can also trigger earthquakes. As a result, there are currently no viable petrothermal systems to generate electricity.

Exploiting CO_2

A few years ago, Professor Martin O. Saar and one of his PhD students in the United States hit upon the idea of using not water but carbon dioxide to transport heat from the Earth's crust. Under certain pressure conditions, CO_2 attains a supercritical aggregate state with the highly interesting advantage of being able to transport even relatively low levels of heat, channelling it through rock layers. This innovative method would make it possible to tap into geothermal heat located far below the Earth's surface in a variety of regions. And, what is equally important: the amount of CO_2 released into the atmosphere could be inhibited by permanently sequestering the greenhouse gas underground.

In the meantime, the idea has generated a patent and a company. Martin O. Saar had his "Carbon Dioxide (CO_2) Plume Geothermal – CPGTM" patented, and he founded the company "TerraCOH" in the US to market the CPG technology. Another newly founded company, CO2 POWER, will be responsible for commercial development of the technology in Europe and other countries. CO2 POWER is an ETH Zurich spin-off and will soon launch in Zurich.

CO_2 turbines

Researchers are currently developing the first-ever geothermal power plant that uses carbon dioxide to channel energy from far below the Earth's surface; the system will also sequester large amounts of CO_2 underground. Together with an international energy company, Martin O. Saar and his team of 20 researchers are developing a CO_2 turbine for the new power plant. The pilot test is scheduled for 2020 and will take place in a closed loop above ground. Later, the cycle will be tested underground; a location with the right conditions is currently being sought. What is needed is a saline reservoir (which otherwise has no practical use) at a depth of two to three kilometres. The CO_2 will be pressed into the reservoir, where its temperature increases. It is then harnessed again so that it can be conducted through turbines to generate power. In the end, the carbon dioxide will be returned to the reservoir.

Ultra-efficient battery

But Martin O. Saar and his team are not yet ready to rest on their laurels. They plan to further develop the CPG technology to create the ultra-efficient "Earth Battery" and will soon be ready to register the next patent. The battery will support other renewable energy sources—for example wind and solar power—that are not always on supply and therefore require a storage system in order to provide continuous energy. When integrated into a CO_2 geothermal power plant the new Earth Battery will be able to store energy in the range of gigawatt-hours for hours to months. Moreover, with the addition of geothermal energy, three times as much energy will be released from underground as was originally fed into the system.

Ecological energy supply

According to the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change, there are enough reservoirs in the Earth to sequester all human-induced CO_2 emissions for over 100 years. "If only a fraction of them were connected to a CO_2 geothermal power plant and a few of them had an Earth Battery, it would be a major contribution both to securing the energy supply we need and to reducing global warming," says Martin O. Saar.

Project
Development of technologies to harness the Earth's heat to generate power, especially the environmentally friendly use of carbon dioxide for channelling heat and underground CO_2 sequestration.

Funding from the Werner Siemens Foundation
10 million Swiss francs, distributed over 10 years

Project duration
2015 to 2025

Project leader
Professor Martin O. Saar, Werner Siemens Foundation Endowed Chair of Geothermal Energy and Geofluids at ETH Zurich

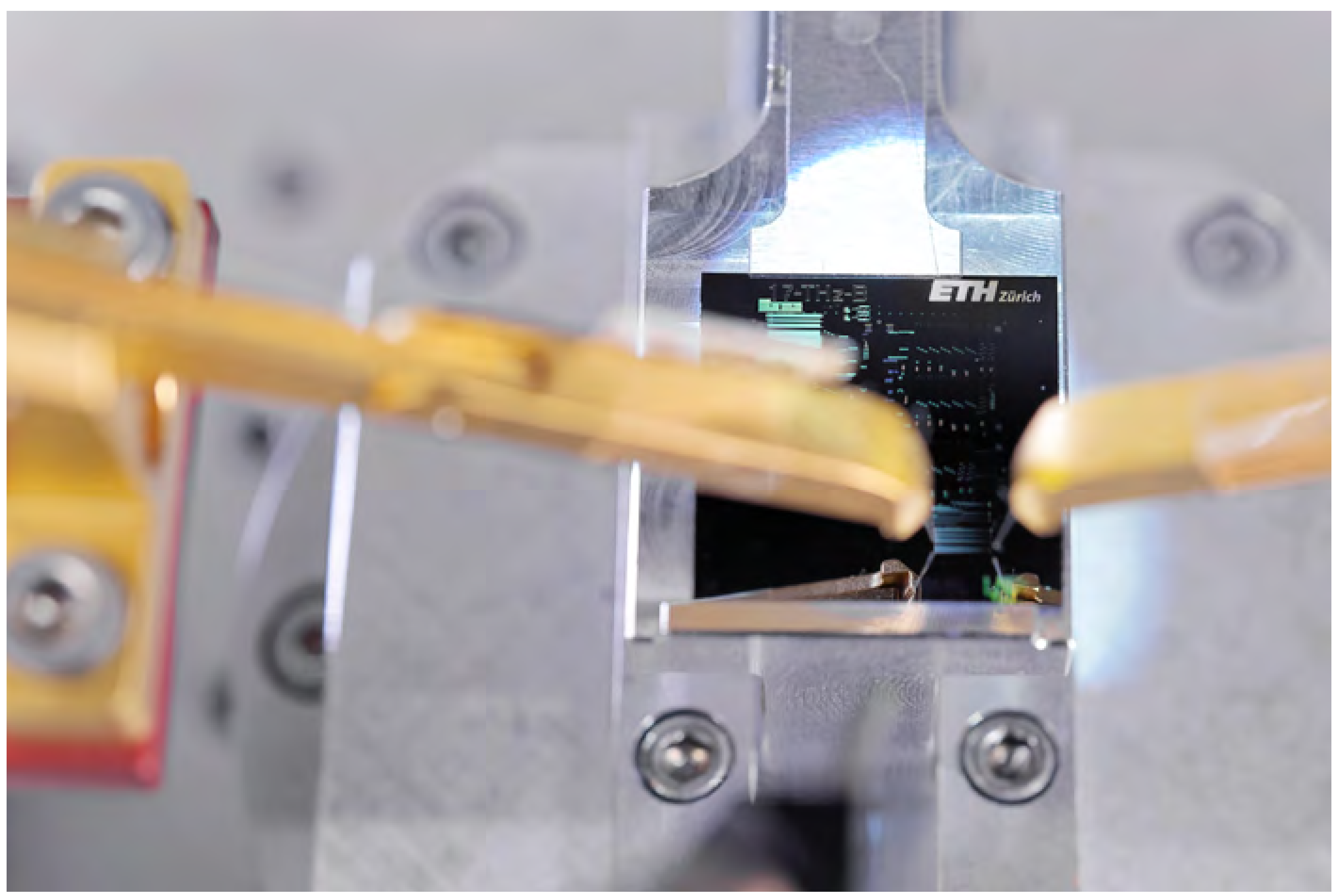
Partners from academia
ETH Zurich (diverse departments)
University of Minnesota (United States)
Ohio State University (United States)
Lawrence Livermore National Laboratory (United States)
German Research Centre for Geosciences (Germany)

Partners from industry
Siemens
CO2 POWER
TerraCOH

Brilliant single-atom switches

Update on the Centre of Atomic Scale Technologies—the microchip of the future

Its speed, efficiency and reliability surpass even the wildest hopes of its creators: the microchip of the future.



A microchip that is 100 times smaller and 100 times more energy efficient—this is the stated goal of the research team at the Centre of Atomic Scale Technologies, which receives funding from the Werner Siemens Foundation. Now, after a short year's work, the ambitious goal no longer seems utopian. On the contrary.

Despite his passion for physics, and despite having won numerous distinctions for his work, ETH professor Jürg Leuthold never ceases to be amazed by what he discovers: "As soon as we think we've reached the limits of physics, we learn that a great deal more is possible."

It wasn't too long ago that Leuthold was certain that microchips simply couldn't be made any more minuscule. At some point, when the chips used in cell phones or coffee machines become too small, they begin to lose efficiency. But then Leuthold, an experienced photonics researcher, made a revolutionary discovery: instead of functioning via electrons, the microchips of the future will work on the single-atom level or via ions. "This means they'll function much the same way our brains do," says Leuthold. What's more, the new microchips are proving much more efficient than conventional microchips. And the fact that computers lose energy in the form of heat is a sign that there is still untapped potential to optimise the technology. "The human brain can process a lot more without requiring a cool-down phase," says Leuthold.

Jürg Leuthold is professor at ETH Zurich, where he heads the Institute of Electromagnetic Fields. Together with Professor Thomas Schimmel of the Karlsruhe Institute of Technology and Professor Mathieu Luisier from ETH Zurich, he is working on quite literally revolutionising the semiconductor industry. In particular, the researchers are developing a new kind of microchip: one that is 100 times smaller and 100 times more energy efficient—and able to at least match the current speed of data processing. To support these innovations, the Werner Siemens Foundation financed the establishment of the Centre of Atomic Scale Technologies in 2017.

Energy efficiency exceeds expectations

In 2018, Jürg Leuthold once again had good reason to be amazed: the tests conducted by the Karlsruhe group pushed the limits of what researchers generally believed physically possible. "Until quite recently, we thought a single switch would need 40 to 50 millivolts of energy," Leuthold says. "In the tests under lab conditions, however, six millivolts were already enough."

This means that the microchip of the future would not be just 100 times, but up to 10 000 times more energy efficient. To be sure, a long road lies ahead before theory is put into practice. But the results show that it is absolutely possible to imagine the microchip of tomorrow in entirely new dimensions—thanks to single-atom technology.

When the project began, the researchers gave themselves until 2021 to develop an initial processor with 20 components, and until 2025 to build more complex processors. Not quite one year later, Leuthold still thinks the ambitious schedule is realistic, saying the team has not only made major progress in the area of energy efficiency but also regarding speed. Moreover, the technology has become increasingly reliable.

First digital photodetector

The ETH research team is currently building the various components necessary for the tiny single-atom switches, which measure only a few nanometres. Already last year, they succeeded in developing a modulator that takes an electrical signal and converts it into an optical (light) signal. Now they have also presented the counterpart to the modulator: a photodetector. And not just any photodetector, but the smallest that has ever been built—and the first digital photodetector, full stop. But Leuthold is not yet satisfied. "There's still room to optimise energy efficiency."

The next step is to develop what is probably the most important component for the single-atom switch: the transistor, which is a type of on-off switch. Some day, billions of these transistors will be built into microchips—which is why both minimising size and maximising energy efficiency are so critical. Another goal for the coming year is to create the memory component that stores information.

In the meantime, 10 specialists in the fields of electrotechnology, materials science and engineering, and fundamental physics are working on the project, and four more will soon join the team. The researchers regularly publish their findings in renowned journals. And they are reaping the benefits: it is no rare occasion that respected researchers travel long distances to visit the centre and gain first-hand information. Jürg Leuthold is delighted: "For us, it's a sign that our project is gaining more and more exposure."

Funding from the Werner Siemens Foundation
12 million Swiss francs

Project duration
2017 to 2025

Project leader
Prof. Dr Jürg Leuthold, head of the Institute of Electromagnetic Fields, ETH Zurich, Switzerland

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

Intellectual adventures

Fostering talent in the STEM subjects – summer academies in Magliaso, 2018

Kai Sandbrink explores questions relating to consciousness and the brain's functioning. A student of neuroinformatics, he spent two semesters in Hong Kong during his bachelor's programme and will study the next semester at Tsinghua University in Peking. Afterwards, he plans to write his master's thesis in the US. Sandbrink has multiple interests and holds bachelor's degrees in environmental engineering and biotechnology. He is currently a Fellow of the Werner Siemens Foundation.

Johannes Fankhauser has an unquenchable thirst for knowledge about the world and nature that naturally led him to study physics. In the course of his master's studies in physics at ETH Zurich and in the philosophy of physics at Oxford University, he discovered that theory should not be applied uncritically. Next semester, Fankhauser will commence doctoral study in fundamental physics at Oxford University. He is a former Fellow of the Werner Siemens Foundation.

Anja Meier believes the right combination of idealism and realism is essential in addressing societal issues. Her main interest lies in sustainable and high-quality international collaboration, especially in civil matters. Meier is studying international relations in Geneva and can well imagine addressing the topic of digitalisation in international relations in her bachelor's thesis. In spring 2019, she will complete an exchange semester at St Petersburg University, Russia.

Studying, sitting exams and earning credit points often dominate day-to-day student life, leaving precious little time for reflection. The Swiss Study Foundation fills this gap with its summer academies, a programme that receives funding from the Werner Siemens Foundation.

In the summer academies held in Magliaso, in Italian-speaking Switzerland, gifted students have the opportunity to dedicate an entire week to exploring a single topic in an interdisciplinary group. In 2018, the topics were digital societies, determinism and free will, and reproducibility and copy. What is it that motivates students to spend their holidays at a summer academy? We asked three participants: Kai Sandbrink, Anja Meier and Johannes Fankhauser.

You all study at excellent Swiss universities. What do the summer academies offer over and above university learning?

Johannes Fankhauser: At the academies, we can step back and take an outside perspective. In addition, the groups are made up of students from a variety of disciplines, which makes for a stimulating environment and expands the horizons of all participants.

Kai Sandbrink: I really enjoy being able to do things here that aren't related to my studies in neuroinformatics. It has always been important to me to look beyond my own specialist area.

Anja Meier: In my academy group, for example, nanotechnologists sit alongside law students. It's fascinating to discuss the opportunities and risks of the internet in such a diverse group. Some participants are enthusiastic advocates, while others ask critical questions about its impact on society.

There isn't a strong connection between your university specialisations and the academies you have chosen. What, for example, do physics and free will have to do with each other?

Fankhauser: What has always really interested me about physics are the fundamental questions: What is the nature of reality? Where does everything come from? My second study programme in philosophy of physics encompasses a kind of mindset that helps us challenge established concepts in order to discover something new.

Has the summer academy provided answers?

Fankhauser: Yes, we address topics relevant to my subject area that I often contemplate, for instance, whether the world is deterministic or whether true coincidence exists. It's easy to assume that there are simple answers to these questions. But that's not the case at all. That's where quantum theory exposes the limits of our knowledge.

Kai Sandbrink, you study neuroinformatics but have chosen an academy with a humanities-based topic: reproducibility and copy. What do you stand to gain from this?

Sandbrink: I can contribute certain ideas that give the discussions a new impetus. For instance, in the group we discussed metaphors used in the field of genetics—such as "linearity"—that can be understood from a literary perspective but often have a mathematical origin. The various group members had very different understandings of the models and the terminology, which I found very inspiring.

Anja Meier, how does your academy on digital societies connect to your studies in international relations?

Meier: We examined the developments in a few countries, such as Estonia and Singapore, that are front runners in digitalisation. We can learn much from these countries in regard to efficiency and mass communication. But highly digitalised countries are also exposed to risks in the areas of data protection and democratic processes. I was astounded to discover that it's not necessarily democratic countries that are leading the way in digitalisation.

The topics at the academies are generally introduced in lectures and explored by reading set texts and holding discussions. How does this working method differ to university studies?

Meier: The academy on digital societies isn't linear in structure. In one morning, we had a session with a historian, then a philosophical discussion with a theologian, followed by a session with an economist. This approach gives us a broad insight into a variety of aspects, and no specific outcome is defined. Instead, it provides for deep—often impassioned—discussions. In the end, it's not possible to simply walk away with a single, clear-cut message. You have to be willing to accept that.

Fankhauser: Precisely that gives us a certain freedom. We can also get up, go for a walk and then come back—whether in our thoughts or in the beautiful grounds here.

You are all very enthusiastic about the summer academies. Do you have any qualms about the exclusive nature of the study week?

Meier: It's certainly a fine line, but all the participants stayed very down to earth. What I find particularly rewarding is that here we can discuss abstract concepts and bizarre niche topics for hours, which isn't possible in my day-to-day world. It's a wonderful experience.

Is the "analogue" format of the summer academies still relevant in our digital world?

Sandbrink: Here, we can focus deeply on one topic for a whole week as a group. It's a setting that would be very difficult to replicate in a digital environment—the distractions would be endless. It's really something special to come together daily as a group and continue working on a topic.

Are the summer academies an ideal learning format for you, and would you like to do more in this direction?

Fankhauser: I'd have no objections, particularly as a complement to my degree programme. Time to step away from my studies and process what I've learned. It deepens my understanding and helps me develop new thoughts and ideas.

Meier: The level of personal interaction that we enjoy here with the lecturers is simply not possible in a university setting. I see that as a great advantage of the summer academies.

Funding from the Werner Siemens Foundation

360 000 Swiss francs for the summer academies

Smooth sailing

Update on the sailing research lab "Eugene Seibold"—marine science and climate change research

Fortune favours the bold. Which is why the innovative idea of literally testing the ocean waters on a light, eco-friendly sailing yacht has become reality: the "Eugen Seibold"—a sailing research lab—was built in just four years, thanks to generous funding from the Werner Siemens Foundation. At the end of 2018, the extraordinary vessel embarked on its maiden voyage.

For a brief time, the sailing yacht "Eugen Seibold" was the property of the Werner Siemens Foundation. Then, on 20 August 2018, in international waters off the coast of Norway, the Foundation transferred ownership of the research vessel to the Eugen Seibold Foundation, which was established expressly for the purpose of operating the ship.

The architect of the world's greenest research vessel, Professor Gerald Haug, is brimming with enthusiasm about the first, rather stormy voyage, which led from the German city of Greifswald, up to Kristiansand in Norway and then back to Germany and the harbour in Bremerhaven. "The test run with winds of up to nine Beaufort was fantastic. The vessel proved truly seaworthy."

Measurement tools installed

After the test run, the "Eugen Seibold" remained docked in Bremerhaven until mid-October. While in harbour, all technical systems necessary for marine research were installed: the multisensor to register the physical, chemical and biological properties of the ocean's waters (pH, temperature, salinity, chlorophyll etc.); the mass spectrometer to analyse oxygen and carbon isotopes or to measure oxygen/argon; the flow cytometer to quantify the cells of microorganisms such as picoplankton, algae and bacteria; the "air vacuum cleaner" to analyse the air's chemical make-up and particles; computers to conduct an initial analysis of the data collected; and modern satellite communications technology.

From the Canary Islands to Cape Verde

In November, it was all hands on deck and hoist the sails! The "Eugen Seibold" embarked on its maiden research voyage, and the six-person crew set course for the first destination: the Canary Islands. To be sure, the home port was chosen less for its beautiful beaches than for its good infrastructure. The harbour at Lanzarote has a 100-ton crane that can raise ships out of the water for repairs, and there are hotels and restaurants as well as a hospital should one of the crew become seasick. In addition to the experienced skipper and first mate, there are researchers, doctoral students and postdoctoral researchers on board, all of whom will hopefully keep their sea legs even when the waters are uneasy.

How healthy are the seas today?

Over the next several years, the "Eugen Seibold" will be conducting research on various zones of the world's oceans. By summer 2019, the goal is to have tested the tropical ocean waters south of the Cape Verde archipelago up to the sea ice edge north of Iceland. While underway, the team on the world's greenest research vessel will collect a comprehensive range of samples from the different marine regions of all climate zones. They also plan to study the next large El Niño in the Tropical Eastern Pacific.

With the help of the data collected, the current condition of the oceans—in the age of global warming—can be scientifically documented, and a pattern of how the ocean has changed over the course of time can be charted.

Of global consequence

The Werner Siemens Foundation financed the construction of the research vessel "Eugen Seibold". Operating the ship and interpreting data lie in the responsibility of the Max Planck Institute for Chemistry in Mainz, where Gerald Haug is director of the Department of Climate Geochemistry in addition to his professorship at the Department of Earth Sciences at ETH Zurich.

Anticipation is high as to what results the marine researchers will glean over the next few years. How healthy is the largest and most important ecosystem on our blue planet? The answer is naturally of vital importance to us land dwellers.

The "Eugene Seibold" performed beautifully on its first, rather stormy test voyage.

Funding from the Werner Siemens Foundation
3.5 million euros

Project duration
2015 to 2018

Project leader
Prof. Dr Gerald Haug, director of the Department of Climate Geochemistry at the Max Planck Institute for Chemistry in Mainz, Germany, and professor at ETH Zurich, Switzerland

Who we are

Global enterprise, family loyalty

What turns of fortune led Charlotte and Marie, the daughters of Carl Siemens, to establish the Werner Siemens Foundation? A closer look at the founding years of the Siemens company provides answers.

Werner Siemens had 10 siblings. Two of his younger brothers, William and Carl, were instrumental in his telegraph manufacturing company, “Telegraphen Bau-Anstalt von Siemens & Halske”, which he had founded in Berlin together with mechanic Johann Georg Halske in 1847. While William was responsible for the business activities in England, Carl led the Russian branch of the enterprise.

In Russia, Siemens & Halske held government contracts to construct a telegraph network of 9000 kilometres in length and to lay the world’s first submarine telegraph cable. In order to supervise construction, Carl travelled in 1853 to St Petersburg, where he proved himself to be a highly competent manager and decision maker. Werner rewarded his brother’s success by reorganising the Russian branch as an independent subsidiary, which Carl then ran with his own capital. This proved a fortuitous decision: the Russian subsidiary went on to contribute substantially to the fortunes of the parent company in Berlin.

Russia in crisis

The Crimean War triggered a first downturn in business; in 1856, the state of Russia’s finances was so desolate that no new contracts were awarded to Siemens & Halske. In the same year, Carl’s daughter Charlotte was born in St Petersburg. Although the maintenance contract for the telegraph lines in Russia assured the family a constant income for 12 years, this was not enough to satisfy Carl and Werner Siemens. They sought new investment opportunities and, in 1864, purchased a copper mine at Kedabeg in the Caucasus.

The founders of the Werner Siemens Foundation and their families: Charlotte von Buxhoeveden (left) and Marie von Graevenitz. The sisters Charlotte and Marie grew up in the St Petersburg of the tsars where their father, Carl Siemens, successfully managed a key branch of the Siemens company.

Copper mine in the Caucasus

With the Russian subsidiary in decline and Carl’s wife, Marie, suffering from poor health, Carl and his family left St Petersburg and relocated to Tiflis (today’s Tbilisi) in Georgia, where he took on the management of the copper mine. After a difficult start, the venture became a viable business.

London and the submarine cable business

When Carl’s beloved wife died in 1869, aged only 34, Carl moved to London. For the next 10 years, he worked alongside his brother William, who had concentrated the firm’s activities on the high-risk submarine cable business. Carl took on the Herculean task of constructing a continuous telegraph line from London to Calcutta (today’s Kolkata), a feat he accomplished within two years. The Indo-European Telegraph Line revolutionised communication between Europe and India; it was also a huge success for Carl and catapulted Siemens & Halske into the top league of international telegraph companies.

Transatlantic cable

In 1874, Carl took on management of the firm’s flagship project: laying a transatlantic cable. Despite periods of bad weather, acts of sabotage by the competition and misinformation, Carl and William successfully completed the high-risk, capital-intensive project in 1875. This triumph generated follow-up contracts: by the end of the 19th century, Siemens & Halske had laid nine of the sixteen total transatlantic cables and had completed business projects in Asia, Africa, Australia, South America, China and Japan.

Recognition by the tsar

Despite his extraordinary success, Carl grew restless in London, where he stood in the shadow of his older brother William. In 1881, he returned with his two daughters to St Petersburg and rejuvenated the Russian subsidiary with new products and ventures: electric railway construction, city lighting systems, telegraphy equipment and cables as well as railway signalling systems. In recognition of his services to Russia’s economy, Carl was raised to the hereditary nobility in 1895 by Tsar Nicholas II.

Reorganisation as an incorporated company

Throughout his life, Werner insisted that the firm remain a family business. Carl, on the other hand, observed the competition and saw that incorporated companies had greater financial flexibility. Nonetheless, Carl never contested Werner’s decision—he respected him as his older brother and as the founder of the firm—and waited until after Werner’s death to list the company on the stock exchange. In 1897, Siemens & Halske was re-formed as a limited company with a market capitalisation of 35 million Reichsmark. Initially, all shares remained in the family’s ownership.

Carl’s idea of a family foundation

Carl’s sense of family loyalty was also borne out by his idea of establishing a fund to support the younger generations of the Siemens family—and it was this seed of an idea that eventually led to the Werner Siemens Foundation. Carl’s intentions are first recorded in a letter from 1900. Devas-

Carl Siemens oversaw the construction of the massive Russian telegraph network; the project's success contributed substantially to the fortunes of the parent company in Berlin.

tated by the recent death of his son, also named Werner, at the age of 44, he wrote to a nephew: "I have told my daughters of my plan to establish a fund for the benefit of my descendants and those of my siblings, and they are highly enthusiastic about the idea."

Charlotte von Buxhoeveden

Those daughters were Charlotte and Marie. Both had spent their childhoods in Russia, from where the family embarked on numerous travels. On one such journey, Charlotte met her husband, Alexander (Axel) Peter Eduard Baron von Buxhoeveden, a highly respected nobleman from the Baltic region who stood in the service of the tsar; they married in 1884 in St Petersburg. A few years later, Carl Siemens purchased Gostilitzy, a traditional estate situated 40 kilometres south of St Petersburg, which became the Siemens family's Russian country manor.

First World War

Carl Siemens died in 1906. He was not to witness the collapse of the Russian Empire, the Communist ascension to power, or the Red Army's persecution of the former ruling class. His daughters, by contrast, were to feel the full force of the new regime. In 1919, Charlotte's husband, Alexander, was murdered by the Bolsheviks in Estonia; she herself was rendered stateless, leaving her little choice but to abandon her property and flee Russia with her children.

Loss of the copper mine

Charlotte and Marie had jointly inherited the struggling copper mine, which they tried unsuccessfully for many years to revive. With transit routes now blocked by the new Soviet-Turkish border drawn in 1918, this undertaking, too, had to be abandoned. An expansion of the transport routes to enable the copper mine to operate in Turkey was not feasible; the years of negotiations had come to nothing. Charlotte and Marie were faced with the sobering reality that their efforts were futile: their inheritance and investments were not to be recouped.

Stateless nobles

After fleeing Russia, Charlotte lived with her five children in Germany and Italy; in 1922, she entered Switzerland at Kreuzlingen with her son Carl Otto. When the federal authorities rejected the family's application for residency, the baroness tried again, this time in Liechtenstein. In 1924, her efforts were finally rewarded: the Prince of Liechtenstein granted her citizenship, albeit not for entirely altruistic reasons: Liechtenstein's economy was also suffering the effects of the First World War, and the Principality was shoring up its finances by allowing the purchase of citizenship. Charlotte was, however, not to enjoy her new home long; she died just two years later, aged 66.

Carl Siemens made a viable business out of the copper mine Kedabeg in the Caucasus—his daughters, however, lost the mine to Communist Russia after the First World War.

Marie von Graevenitz

The second founder of the Werner Siemens Foundation was Charlotte's younger sister, Marie. At the age of 24, Marie married Baron Georg Ludwig von Graevenitz, a descendant of an ancient noble family from Altmark that had been settled in Russia for over 150 years. Georg Ludwig von Graevenitz was active in diplomatic service, holding the elaborately entitled role of "imperial Russian real state councillor and resident minister in the office of stable master of the imperial court". After their wedding, Marie lived with her husband for several years at the tsar's court in St Petersburg where she bore five of her six children and was a lady of the court. At the age of 29, she inherited the Gostilitzy estate from her father. She then resided with her family in the stately home—until the Russian Revolution.

Destruction of Gostilitzy

After the October Revolution, the von Graevenitz family, too, were obliged to abandon their property and flee Russia. Intense battles broke out on their estate; the troops of the Imperial Russian Army twice took up quarters in Gostilitzy and caused considerable damage to the property. After the Communist victory, the estate was expropriated and declared a state-owned farm.

Foundation established in 1923

It was perhaps the considerable hardships Marie and Charlotte endured at this time that reminded them of their father's idea to establish a trust for the benefit of the Siemens' descendants. In 1923, 23 years after Carl first shared his idea, they established the Werner Foundation. The foundation's purpose for many years was to financially support relatives of the large Siemens family who had fallen on hard times. Ultimately, the Werner Foundation developed into the Werner Siemens Foundation, which today supports innovative projects and young scholars in the fields of technology and the natural sciences.

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.

Selection process

Funding criteria

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

As a rule, each approved project is awarded generous funding of 5 to 15 million euros. Projects are selected in a series of steps by the Advisory Council, the Board of Trustees and the Foundation Board of the Werner Siemens Foundation.

In addition to projects, the Werner Siemens Foundation funds 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.

Project proposals

You are invited to submit a proposal if your project fulfils the funding criteria of the Werner Siemens Foundation. The selection process is as follows:

1 The project must fulfil the funding criteria
2 Application form is requested online
3 Preliminary assessment by the Advisory Council
4 Additional information requested, if necessary
5 Proposal evaluation by the Board of Trustees and the Advisory Council
6 Decision
7 Contract

The selection process takes six months.

Contact

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Presenting Christina Ezrahi

Christina Ezrahi has been a member of the Foundation Board of the Werner Siemens Foundation since 2015. As a direct descendent of Werner Siemens, she is mainly responsible for representing the interests of the Siemens family. Christina Ezrahi holds a doctorate in history, with a specialisation in Soviet history, and has lived for the past nine years with her family in Israel.

Christina Ezrahi is the great-great-great-granddaughter of Werner Siemens. As a member of the Board of the Werner Siemens Foundation, she is responsible for representing the interests of the Siemens family.

What is it like to work on the Foundation Board and with the Board of Trustees?

Christina Ezrahi: Working on the Foundation Board is highly rewarding. It's a lucky stroke of fate to have been born into a family like ours. When I was appointed to the Foundation Board in 2015, I saw it as a unique opportunity to give back to my large family—and to society.

It's fascinating to work with the Board of Trustees and, on the one hand, translate the founders' original vision to our own times and, on the other, support groundbreaking research projects in the scope of the Foundation's philanthropic mission. It offers great opportunities coupled with a good deal of responsibility.

The Foundation Board and the Board of Trustees work together like two well-oiled cogs in a wheel, and over the years, a deep sense of mutual trust has developed. What I find particularly interesting is the link between family history and Foundation history, and between past, present and future. Because time never stands still, change is always happening.

What do you think the Foundation means to the Siemens family?

As a historian specialised in Soviet history and as a mother who has lived the past nine years with two small children in the Middle East, in Israel, I am reminded on a daily basis how individual lives are determined by the good or bad fortune of birth, by geographical conditions, nationality, religious denomination, by the changing tides of politics—and how often lives are destroyed. During the October Revolution, the Siemens women who established the Foundation experienced first-hand the tragic impact of conditions beyond their control—and with incredible foresight, they created a family trust to at least soften the blows of fate. It's invaluable. By contrast, the philanthropic arm of the Foundation offers the family the wonderful opportunity to give something back to society and to help brilliant minds—like our Werner—launch their research projects. As such, we are making a contribution that we hope will make the world a better place.

The Foundation fosters many innovative and fascinating projects. Which is your favourite?

Last year, I probably would have had difficulty choosing between the single-atom switch and Professor Martin O. Saar's research group Geothermal Energy and Geofluids at ETH Zurich. Looking back on the oppressively hot summer of 2018 and the horrific forecasts made in the latest reports on climate change, however, I'm now even more interested in Professor Saar's plans to generate electricity by tapping into the heat of the Earth while at the same time reducing the world's carbon footprint. Among other things, the group is exploring ways to pull carbon dioxide out of the atmosphere and sequester it underground, and then use the CO_2 in a closed-loop cycle as a cost-efficient conduit to transport geothermal energy to the surface, where it can be used to generate electricity. It would be a win-win situation: generating sustainable electricity and reducing our carbon footprint.

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