150 Years
culture of
excellence

Faszination **Forschung**

TUM Research Highlights
Technical University of Munich | The Science Magazine
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Inspiring Innovation

Special Issue on TUM's Startups

Entrepreneurship Research: The Science of Creating Businesses
Medicine: Vaccine against Stomach Cancer
Protein Engineering and Design: Small Molecules, Big Impact

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Innovation, Creativity: Faszination Forschung!

The key societal importance of the research university, as shaped by the famous education reformer Wilhelm von Humboldt at the start of the 19th century, can hardly be overstated. Equally important, however, is the evolution of this model toward the technical research university. These remarkable institutions are a German success story with international impact. A technical research university reaches beyond the academic to enable engineers and scientists to transform their ideas into useful, economically feasible products and innovative processes; even into new realities. As such, they have helped propel Germany to the ranks of the world's technology leaders. This indeed is what the world knows as "German Engineering".

The Technical University of Munich (TUM) has made a particular contribution to the advancement of Germany's technology capabilities. In the 150th year since our foundation, we pay tribute to our pioneers whose inventions have changed the world. One such example is Carl von Linde, who discovered the principle of machine refrigeration and made it commercially viable. Linde AG was our first spin-off (in 1879) and has long since grown into an international success story – now employing around 57,000 people. Overall, in the last thirty years alone, TUM has inspired over 1,000 startups, creating jobs for more than 15,000 people today. This includes eight companies listed on the US technology index NASDAQ – joined in 2011 by TUM spin-off Celonis, now valued at over 1 billion US dollars (classifying it as a "unicorn").

This present edition of Faszination Forschung introduces students and scientists who, inspired by TUM's hallmark entrepreneurial spirit, are feeding their research findings and inventions into the innovation pipeline. In other words, transferring them to real-world use cases in industry and business. This spirit is something we actively promote right from day one at TUM, giving students the freedom to try out new ideas and live their passion as they embark on the research adventure. The renewed world-beating success of TUM's Hyperloop team in this July's global competition provides impressive confirmation that the next generation has not only been gripped by "Faszination Forschung", but is also carrying it forward into the fascinating world of entrepreneurial opportunity. In addition, it demonstrates the benefits of integrating students into our network of experts and mentors.

But we wouldn't be a proper university if we did not also seek to understand the theory behind successful entrepreneurship. Our Entrepreneurship Research Institute (ERI) investigates the entire entrepreneurial process: from founding a venture, through development and growth all the way to the equally important exit phase. Findings from entrepreneurship research can teach business founders how to avoid mistakes and recognize opportunities. "We want to bring an entrepreneurial spirit into the TUM departments and faculties," declares Nicola Breugst, an ERI professor.

The ERI is part of the Entrepreneurship Center on the university's Garching Campus, run by TUM in partnership with its affiliated Center for Innovation and Business Creation – UnternehmerTUM GmbH. Inaugurated in 2015, the Entrepreneurship Center offers technology-driven spin-offs a unique infrastructure to pursue their goals. This includes MakerSpace, a high-tech workshop, which provides access to machinery, tools and software for building prototypes as well as for small-series production. It also acts as a hub for the creative startup community. And TUM.International GmbH – THE UNIVERSITY COMPANY – brings TUM's knowledge and competency to the international stage. ▷

Picture credit: Astrid Eckert/TUM

This is flanked by TUM's incubator, which provides a perfect stage to nurture young companies and prepare them for market entry through office space, advisory services and coaching. UnternehmerTUM also runs its own venture capital fund to assist technology startups with go-to-market financing.

Personally, I am fascinated by the creativity, drive, perseverance and courage of our entrepreneurs. This is a fitting point to mention our latest "unicorn": After a new round of financing in summer 2018, Celonis is now one of Germany's most successful startups, valued at over 1 billion US dollars. Its founders met during their studies at TUM. In 2015, I had the pleasure of presenting this company with the Presidential Entrepreneurship Award, which is endowed with 10,000 euros. All the startups that have won this prize since 2013 are profiled in this edition of Faszination Forschung: Fos4X, Dynamic Biosensors, Celonis, Orcan Energy, Konux and NavVis. Each one has written its own success story – all underpinned by TUM's support as a true entrepreneurial university.

"Curiosity is anchored at the heart of TUM's corporate identity. We offer a work environment that promotes creativity and innovation."

Prof. Wolfgang A. Herrmann

Many startups are currently exploring topics such as artificial intelligence (AI). They typically focus on how digitalization is transforming industry and business. For information systems specialist Helmut Krcmar, the combination of products with service components – ideally tailored to the individual customer – is the defining innovation of the digital age.

Needless to say, company founders who continue their research and teaching at TUM play a particularly strong role in shaping our entrepreneurial spirit. Leading by example, they strengthen the university's entrepreneurial culture and pass on their experience and enthusiasm to the next generation.

Arne Skerra, for instance, is one of the world's leading protein designers. With his team, he has repeatedly developed innovations in the field of protein biotechnology, several of which have been commercialized through new companies. Planning for his next spin-off is under way, this time based on proteins that can be switched on and off by light.

TUM's entrepreneurial flair also shapes life at its Institute of Medical Microbiology, Immunology and Hygiene, where Dirk Busch and Markus Gerhard are clearly showing that the seemingly contradictory worlds of basic and applied research can, in fact, be seamlessly bridged. Gerhard's company ImevaX is now conducting a clinical trial on what will likely be the first vaccine against *Helicobacter pylori* stomach bacteria.

Even the most ingenious of inventions requires a large helping of determination and resilience to make it to the implementation stage – as Albert Sepp, a civil engineer at the Laboratory of Hydraulic and Water Resources Engineering, knows only too well. Years ago, he came up with an idea for a shaft power plant that would make hydropower more eco-friendly without disrupting the shore area or its habitat. In 2019, the first of these plants is due to go on stream. With this truly innovative idea, Sepp and Laboratory Chair Peter Rutschmann have not only demonstrated an impressive sense of how water flows, but they have also won over numerous skeptics along the way.

Fritz Frenkler's Industrial Design course aims to equip Master's students with an entrepreneurial approach to design, bringing them together with startup teams under the umbrella of the Design Enterprise module. Here, designers work with young scientists and engineers to develop the corporate identity of a new venture through its products or services.

Curiosity is anchored at the heart of our corporate identity. We offer a work environment that promotes creativity and innovation – providing fertile ground for world-class research that leans intuitively toward practical applications. This is a place where innovative product ideas can grow. The TUM culture gives its students and researchers the courage to venture into uncharted terrain by actively embracing the risk of failure that comes with research rather than avoiding risks. No risk – no fascination. High risk – high reward.

As we proudly celebrate our 150th anniversary, we expect an ongoing future of scientific excellence, entrepreneurial inspiration and youthful enthusiasm.

I hope you enjoy this edition of "Faszination Forschung". Be inspired and motivated by the entrepreneurial spirit revealed on these pages.

Prof. Wolfgang A. Herrmann
President

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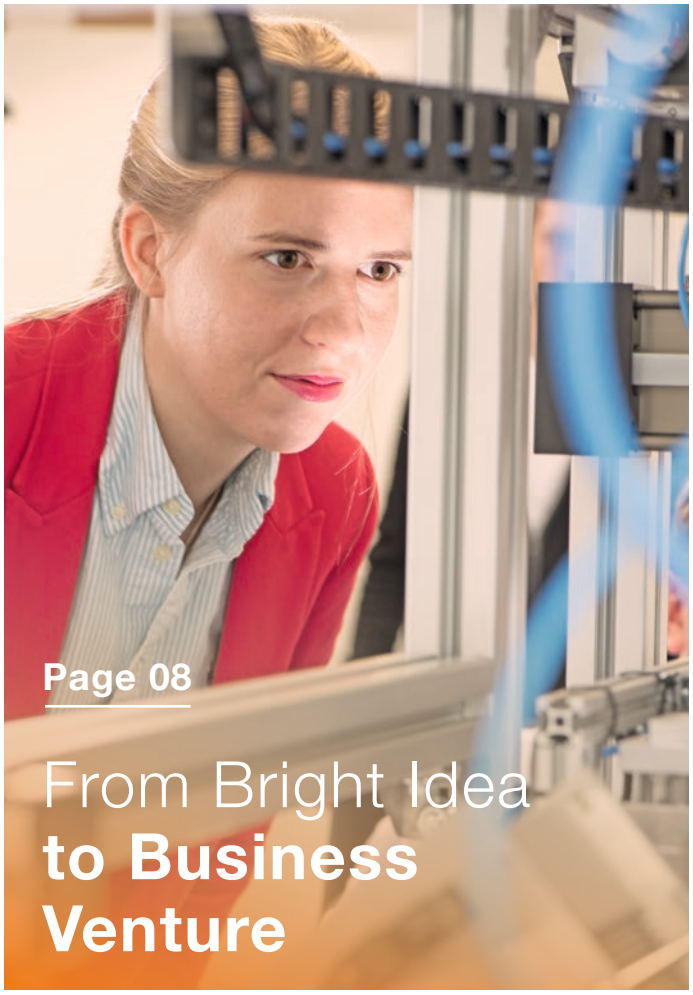

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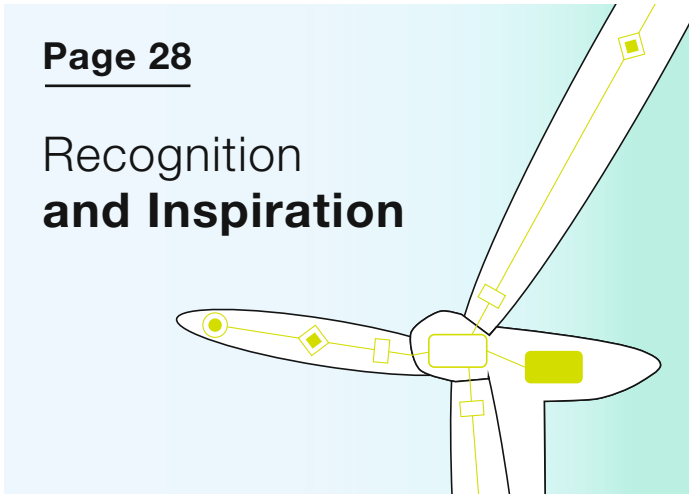
From Bright Idea **to Business Venture**



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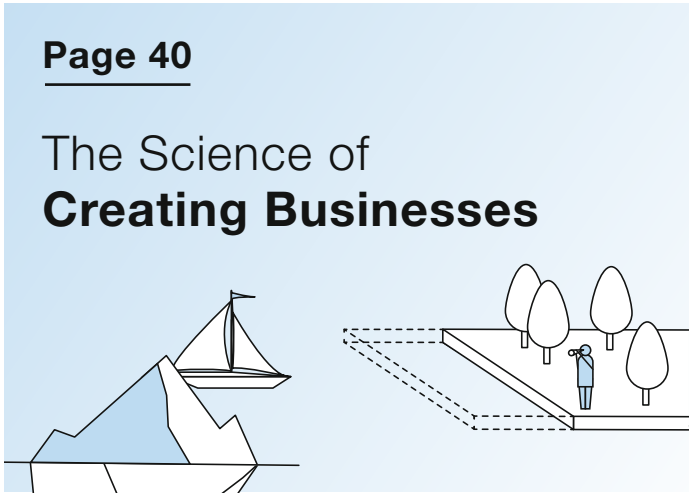
Recognition **and Inspiration**



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The Science of **Creating Businesses**

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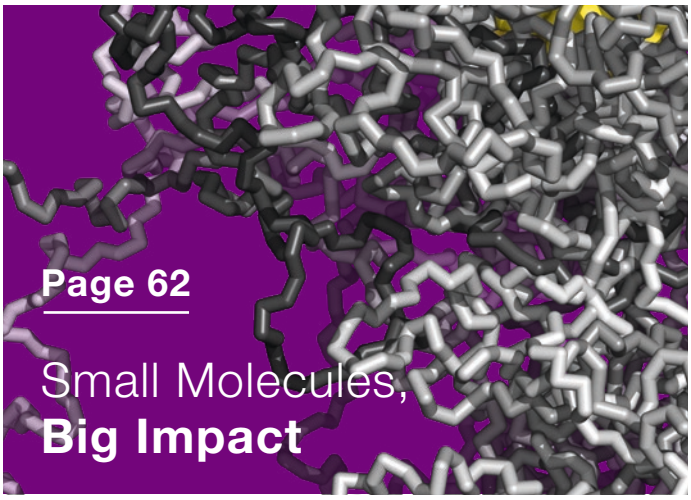


In every Issue

Claudia Doyle

Eigene Ideen umsetzen

Gerüstbau und Pathologie – so unterschiedlich die Branchen sind, die zwei von Studierenden und Alumni der TUM gegründete Start-ups im Blick haben, so sehr ähnelt sich ihre Idee: Sie wollen fehleranfällige oder ermüdende Tätigkeiten automatisieren und damit effizienter und sicherer machen.
Mit KEWAZO entwickeln der Bauingenieur Artem Kuchukov und ein interdisziplinäres Team einen Roboter, der Menschen beim Gerüstbau assistiert und sie entlastet. Der Prototyp kann heute mit einer Geschwindigkeit von bis zu 26 Metern pro Sekunde vertikal am Gerüst entlangfahren und dabei bis zu 60 Kilogramm an Gerüstteilen transportieren. Sensoren erkennen, wenn Menschen oder Gegenstände den Weg versperren.
Das Start-up inveox will den Umgang mit Gewebeproben für die Krebsdiagnostik in Pathologie-Laboren automatisieren. Bislang müssen medizinisch-technische Angestellte unter anderem jeden Probenbehälter einzeln öffnen, das Konservierungsmittel abgießen und das Gewebe in eine Biopsiekassette übertragen, bevor die Probe unter dem Mikroskop untersucht werden kann. All das soll in Zukunft das System von inveox übernehmen und damit Verwechslungen oder Verunreinigungen der Gewebeproben verhindern. Die beiden Köpfe dahinter sind die Wirtschaftsingenieurin Maria Driesel und Dominik Sievert, der sowohl Molekulare Biotechnologie als auch Management an der TUM studiert hat.
Unterstützung auf ihrem Weg von der Idee bis zum Markteintritt erhielten die Studierenden und Alumni durch die Universität und UnternehmerTUM, dem Zentrum für Innovation und Gründung: Das Angebot reicht von kostenlosen Büroräumen über Beratung und Weiterbildung bis hin zur Hightech-Werkstatt MakerSpace und der Bereitstellung von Venture Capital.
Sowohl inveox als auch KEWAZO wollen noch bis Ende 2018 die Vorserie beim Kunden einsetzen, Feedback einholen und Verbesserungsvorschläge umsetzen. Dann wollen sie den nächsten Schritt wagen – die Serienproduktion. □

The name KEWAZO stems from the Greek word for “to construct” – the startup is developing a scaffolding robot for large construction sites. The team consists of TUM students and alumni Artem Kuchukov, Aleksandar Belberov, Alimzhan Rakhmatulin, Ekaterina Grib, Leonidas Pozikidis, Dmitry Chokovski, Eirini Psallida and Sebastian Weitzel (from left to right).

With their startup inveox, Maria Driesel and Dominik Sievert aim to improve the reliability of cancer diagnoses.

From Bright Idea **to Business Venture**

How can heavy construction work be made less labor-intensive? And how can the processing of tissue samples in histopathology labs be improved? With their business ideas, two start-ups are striving to answer these questions.

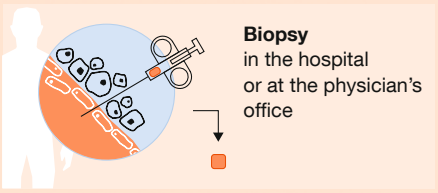
At half past eight in the morning, on the second floor of the Technology and Startup Center "gate" in Garching, Maria Driesel and Dominik Sievert stand with two engineers in front of a man-sized machine. Behind the orange plexiglass cladding, its interior bristles with cables, circuit boards and state-of-the-art technology. The team are discussing the latest modifications. Soon this device will enter series production, automating a complex and error-prone process: the transfer of tissue samples in histopathology labs.

Just one building further along, at the TUM Entrepreneurship Center, civil engineer Artem Kuchukov and his team are packing their laptops and office furniture into moving boxes. On their way out of TUM's startup incubator into bigger premises, they take along their robot, a knee-high, silvery cube. This prototype is designed to transport scaffolding parts and thus relieve people of heavy and repetitive physical tasks. With its robotic transport system, the startup KEWAZO wants to bring automation to the construction site.

While the industries targeted by inveox and KEWAZO are clearly quite different, the two startups founded by TUM students and alumni are very similar in the idea they want to bring to market. Both aim to automate hazardous or strenuous activities, increasing the efficiency and safety of workflows. ▷

Picture credit: Astrid Eckert/TUM

Cancer testing – the laboratory process



Biopsy
in the hospital
or at the physician's
office

Issuing and dispatching
the conventional way

Handwritten examination request + Conventional container

Courier to pathology laboratory

Issuing and dispatching
with inveox

Sample container with integrated filter + Digital examination request

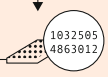
Courier to pathology laboratory

Conventional sample entry
Manual process

Interpretation of handwritten examination request, manual data entry

Open lid and remove formalin

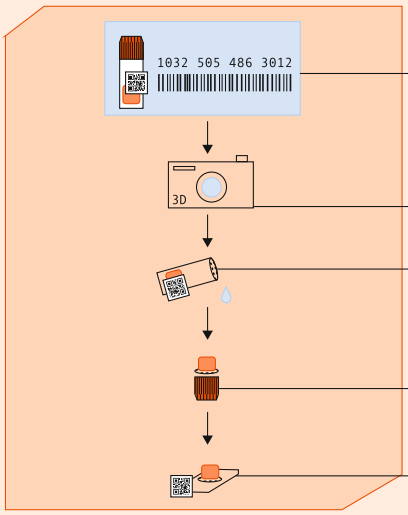
Mark biopsy cassette



Basic sample description

Repack sample from container to biopsy cassette

Touch-free, automated sample entry
with inveox automation system



Processing of several containers at the same time

750
samples per hour

Register code, identify sample, unlock respective digital examination request

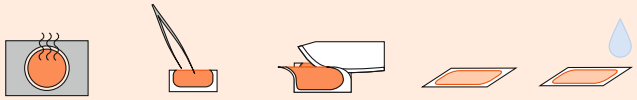
3D imaging: precise sample specification, documentation, quality assurance (QA)

Open lid, formalin disposal

Touch-free transfer of sample into filter, image for QA

Unite filter with biopsy cassette, engrave code into cassette

Further processing of the sample



Dehydration → Paraffin embedding → Microtome section → Slide loading → Tissue staining

Diagnosis and archive

In histopathology labs, tissue samples are tested for cancer, among other things. Sample entry is a critical phase here, because the manual tasks (left) of transferring and recording the sample are time consuming and prone to errors. In order to prevent mix-ups and contamination of tissue samples, inveox has developed a system (right) designed to automate this process.

Starting up

inveox

Startup venture inveox seeks to automate tissue sample processing in histopathology laboratories, preventing errors and reducing monotonous tasks for medical technicians.
The brains behind the operation belong to industrial engineer Maria Driesel and Dominik Sievert, who studied molecular biotechnology as well as management at TUM. Since its foundation in 2017, inveox GmbH has experienced a major growth surge, expanding from just three team members to 23 full-time positions, plus around twice as many student and part-time employees. Driesel and Sievert set great store by diversity here: Their team members come from eight different countries, with the oldest being 64 and the youngest just 18 years old. They also attach great importance to transparency and openness, discussing the company's current situation with their entire staff each week.
Their advice to other founders would be to build a network and use it extensively. Particularly when it comes to routine procedures and standard requirements, their view is that there's no need to reinvent the wheel every time – sound advice from experienced entrepreneurs can sometimes be invaluable and save on costly consulting fees.

Error-prone manual tasks

People quickly lose concentration when they have to repeat the same activity over and over again – and that is where mistakes can creep in. Machines, on the other hand, don't care whether they are performing a task for the first or one hundredth time. However, in many sectors, they have yet to gain a foothold.
Processing tissue samples is a case in point. Doctors take these samples to check for cancer, for example. The tiny pieces of tissue are first packed into small plastic containers filled with formalin, a liquid that fixates and preserves the samples. Medical technicians often just scrawl the patient's name on the outside of this container, which is then mailed to a laboratory with a handwritten examination request. Once there, the time-consuming manual process continues: The sample is opened, the carcinogenic formalin is carefully removed and the notes are deciphered. The sample is then repacked in a biopsy cassette and prepared for examination.

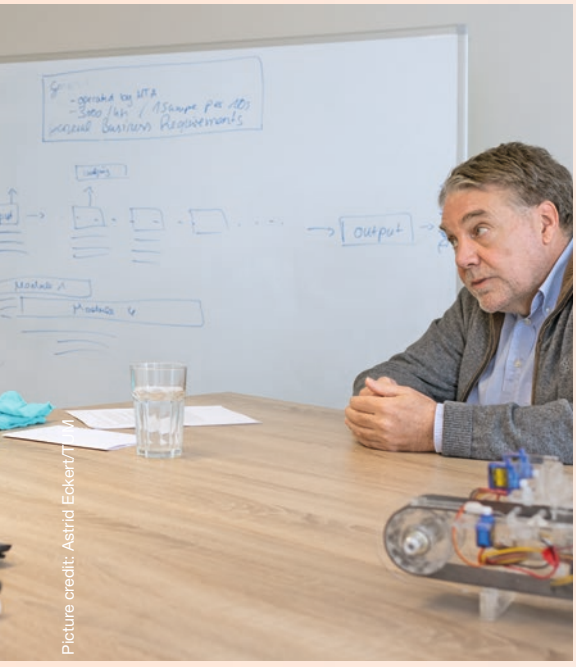
When a histopathologist explained this to Maria Driesel during a study period in the US, her first thought was that, in the 21st century, it could all be so much easier. "I immediately recognized the potential for innovation here," she recalls. With a background in industrial engineering, she previously had nothing to do with medicine. But as a "Manage & More" alumna, she had learned how to identify new business areas. This is a program offered by UnternehmerTUM, the Center for Innovation and Business Creation at TUM, to prepare students for executive positions.
Dominik Sievert, too, was concerned about the sample processing situation. His motivation is very personal: "My grandfather received a flawed cancer diagnosis," explains Sievert, who gained his Bachelor's degree in molecular biotechnology and went on to study management at TUM. Perhaps due to a number mix-up or illegible handwriting – the exact cause of the confusion remains unclear. But the topic has played on his mind ever since. ▷

Graphics: ediundsepp (source: inveox), picture credit: Astrid Eckert/TUM

Having outgrown the TUM startup incubator, the inveox team has found a home at the Garching Technology and Startup Center “gate”, a center for startups and young companies funded by the German state of Bavaria.

The two met during the “Manage & More” program in early 2015. By fall 2016 they were developing their business to automate the sample entry process in histopathology labs – initially squeezed in around their work and studies, and then on a full-time basis. They worked late into the night on their business plan and used modeling clay to make a prototype of their new transport containers for tissue samples – not pretty, but certainly practical. Next, they presented doctors and histopathologists with their concept and asked them for feedback. It quickly became clear that professionals in the field also found the idea promising – and, most importantly, feasible. “With that at the back of your mind, starting a business venture is no longer a scary prospect,” declares Sievert. ▷

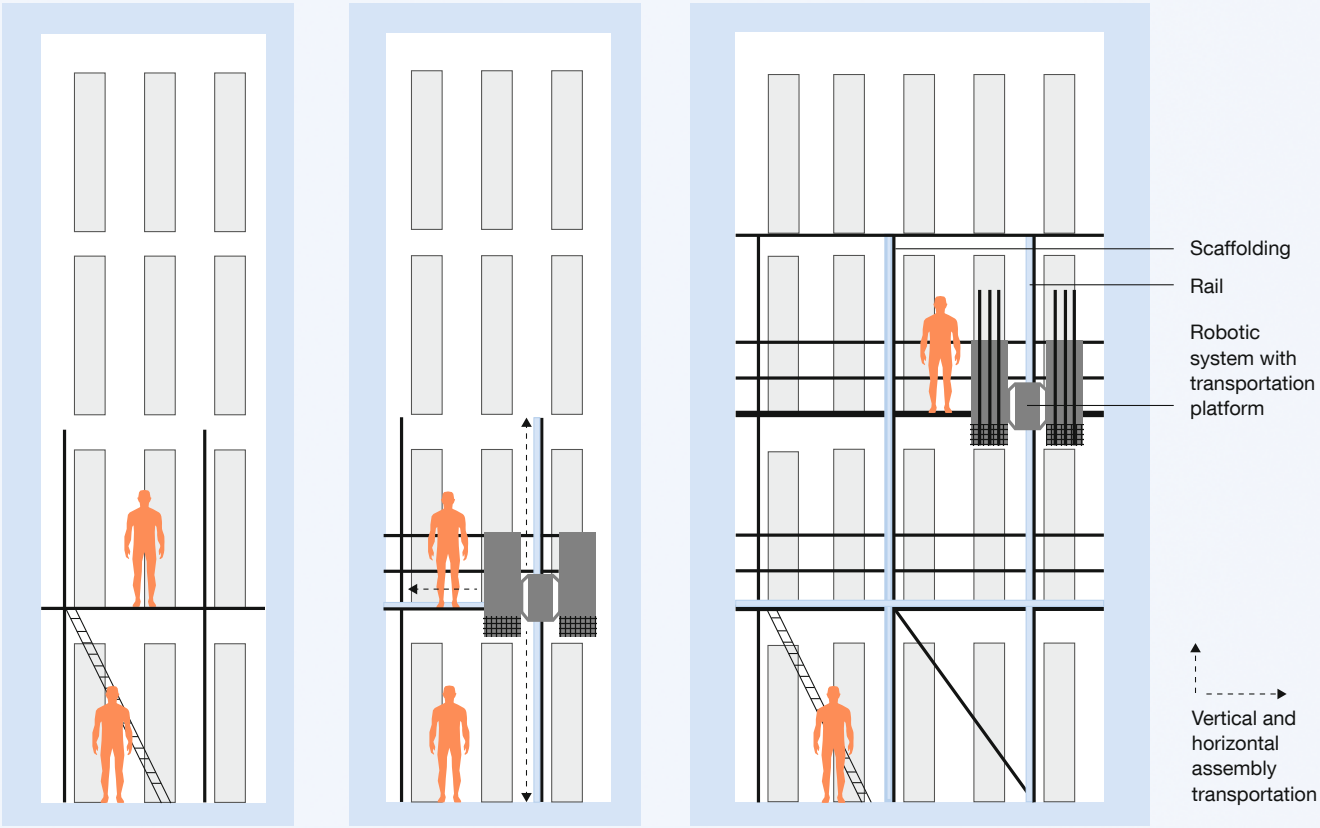
Maria Driesel (right) and Dominik Sievert (second from the right) and their team have been developing an automated entry system for biopsy samples.



Picture credit: Astrid Eckert/TU Graz

“I was determined to create something new and take our idea all the way to market.”

Maria Driesel



KEWAZO's robotic transport system is designed to transport scaffolding components from a storage point to an assembling point, thus saving time and effort. It can operate with only two workers. The control system is semi-automatic, with each scaffolder equipped with a small device that transmits their position to the robot via wireless communication. At the push of a button, the robot travels to the worker's location.

Robotic co-workers

Civil engineer Artem Kuchukov also early on sought out dialog with people working in the field. "Automating tasks on construction sites is a lot harder than it sounds at first," he points out. A construction site changes every day, but many individual areas are highly standardized. Scaffolding is a good example here: the parts have to comply with defined standards. A pipe has a diameter of 48.3 millimeters, and the individual components always connect the same way. Ideal conditions for robots – so Kuchukov decided to take on scaffolding first. Together with fellow student Leonidas Pozikidis, he took part in "Think.Make.Start" – an interdisciplinary seminar held by TUM and UnternehmerTUM for Master's students. There they found three more like-minded individuals for the KEWAZO team: Sebastian Weitzel and Eirini Psallida, both informatics students, and Alimzhan Rakhmatulin, studying Earth-Oriented Space Science and Technologies. The group of five spent two weeks working to turn the idea into an initial prototype: a robot to assist scaffolders and reduce the strain on them. They then immediately visited a trade fair for construction equipment and went from stand to stand, presenting their idea. Shortly after that, Ekaterina Grib joined the team – a student of consumer affairs at the TUM School of Management, who has supported KEWAZO with its business development ever since. One of the most important findings from the team's many discussions and site visits was that 80 percent of scaffolding assembly time is spent moving parts around. And while one person is hauling these parts, the others are held up waiting. The primary task for the robot is thus to transport scaffolding tubes and decks from a storage point to an assembling point. KEWAZO's next move was to apply for an EXIST Business Start-up Grant, part of a German government program to support technology- and knowledge-based startup projects. Kuchukov and his team were duly awarded funding and have been working on their venture full time since April 2017 – now as a team of six. ▷

KEWAZO's prototype of the scaffolding robot was put through its paces outside the TUM Entrepreneurship Center in spring 2018. Here, TUM student and KEWAZO co-founder Alimzhan Rakhmatulin checks the correct gripping of the prototype during operation.

"For hardware start-ups in Germany, Munich is the hub."

Artem Kuchukov

Starting up

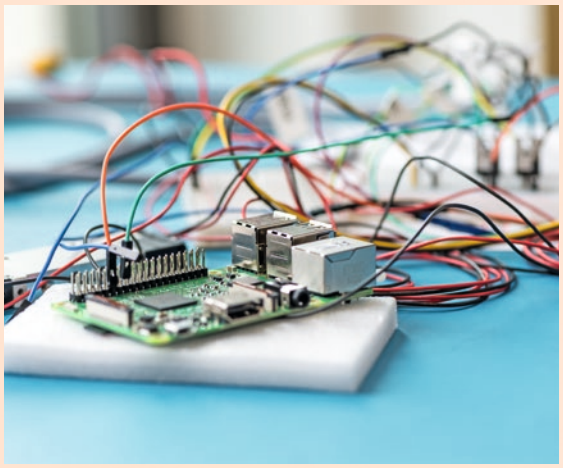
KEWAZO

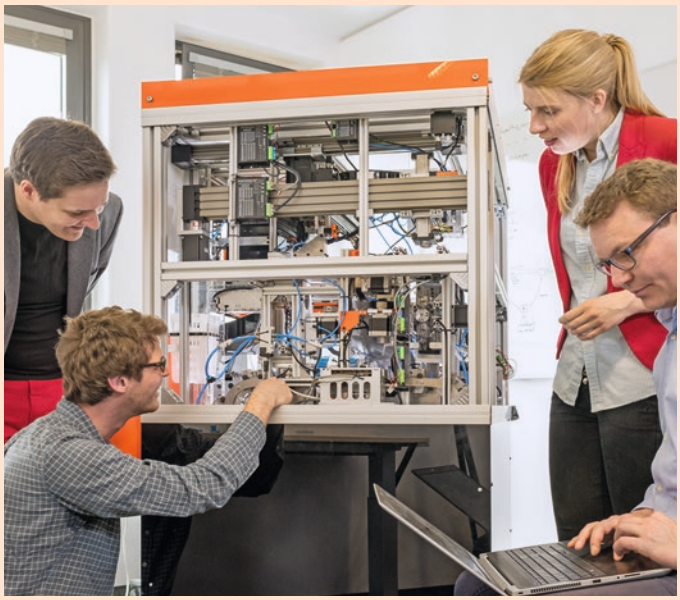
The KEWAZO team aims to bring automation to the construction site. Their robot is designed to assist in scaffolding assembly, relieving workers of heavy manual labor.

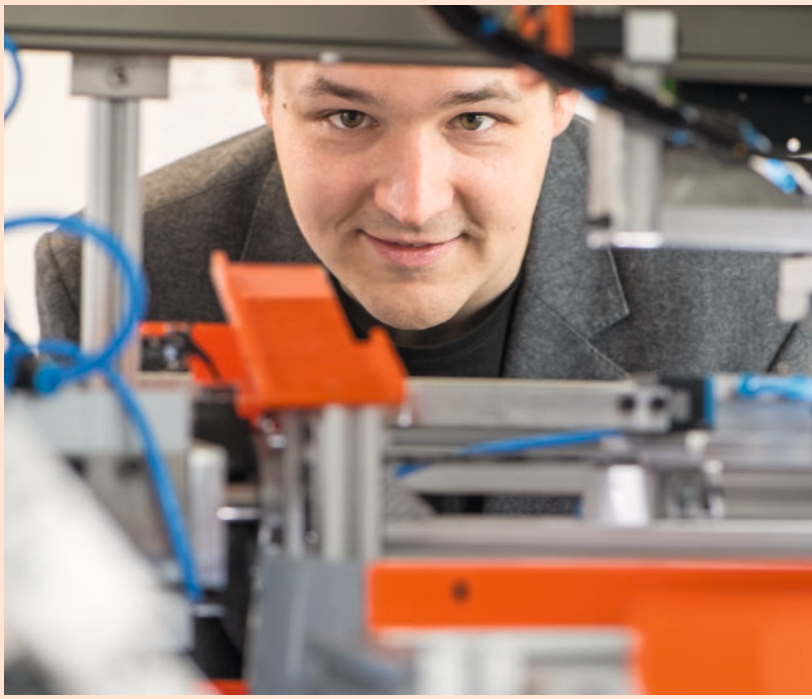
Since the beginning of 2018, the team of eight has been working on the implementation of the system. Their diverse backgrounds in the fields of civil engineering, computer science and economics complement each other perfectly. "Our contacts at various different chairs meant we received a great deal of support from TUM right from the start," acknowledges co-founder of KEWAZO GmbH, Artem Kuchukov (far left). From product development to looking for sponsors, TUM mentors were always on hand with a few tips for the venture.

As far as location is concerned, Kuchukov also feels Munich is ideal for starting a business: "In my view, for hardware startups in Germany, Munich is the hub – so you have the perfect network in place here," he confirms.

Graphics: ediundsepp (source: KEWAZO), picture credit: Astrid Eckert/TUM







At the center of inveox's business idea are the novel-design sample containers (center) as well as the automated sample entry system (above). As a third component, Dominik Sievert and Maria Driesel and their team are developing a web-based platform in order to facilitate the communication between physicians and histopathology laboratories.

End-to-end process automation

Among other scholarships and awards, an EXIST grant has also enabled the founders of inveox to focus fully on their venture since the fall of 2016. At that time, Driesel and Sievert joined the TUM's startup incubator – a facility that provides prospective entrepreneurs with work space and startup coaching. "Needless to say, my parents weren't exactly delighted when I resigned from my well-paid permanent position," recounts Maria Driesel, "but I was determined to create something new and take our idea all the way to market."

Picture credit: Astrid Eckert/TUM

The inveox product idea has long since evolved. While they originally set out to prevent sample mix-ups by offering intelligent containers, Driesel and Sievert are now seeking to automate the entire handling process. To this end, they developed an encrypted web-based data and communication platform that allows physicians to send the relevant data to the lab electronically, as well as checking on the current status at any time. They also designed a device to automate all of the steps previously completed by hand.

The initial concept has thus turned into the man-sized device now standing in the inveox workshop. Inside it, each tissue sample moves through an automated process. First, the device opens up the sample container and pours away the formalin used to preserve the tissue. Next, it automatically transfers the sample to a filter integrated in the original container. A laser beam then engraves a QR code and numerical code onto the cassette, ensuring the sample can always be uniquely identified. In the process, the tissue sample is photographed so that doctors making a subsequent diagnosis can still see what the tissue looked like prior to dehydration and staining. "Using automatic image recognition, our aim is also for the software to learn from these photos how to indicate healthy and cancerous tissue," reveals Driesel.

From office to high-tech workshop

While the inveox team decided to buy in various electronic and pneumatic components, they designed and manufactured the majority of the metal parts for their prototype themselves. To do so they were able to use MakerSpace, UnternehmerTUM's high-tech workshop, handily located just meters from the inveox office. If they were reliant on a service provider, the engineers and designers would have to wait around six weeks for a custom-made part. "As it is, we just pop next door with our plans and can mill the component within a few hours," Driesel enthusiastically explains. ▷

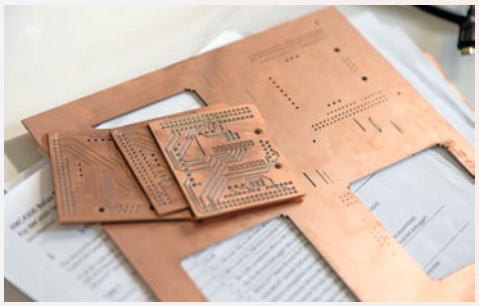
KEWAZO has benefited from this support ecosystem, too. During the founding phase, Artem Kuchukov's team was based at TUM's startup incubator. Here, they developed the prototype of their battery-operated robotic system. In spring 2018, the robot prototype was put to the test on the outside of a building for the first time. It glided along the scaffolding on rails, transporting scaffolding parts to exactly the right place at the right time. The prototype currently transports loads of up to 60 kilos at a speed of 26 meters per minute. The target is to reach up to 100 kilos with a maximum speed of 42 meters per minute.

The control system is semi-automatic, with each scaffolder equipped with a small device that transmits their position to the robot via wireless communication. At the push of a button, the robot travels to the worker's exact location. Sensors detect any people or objects blocking its path. While assembling a construction lift can easily swallow up an entire day, it takes just minutes to mount the robot on a scaffold.

Both inveox and KEWAZO aim to run pre-series tests with customers before the end of 2018, enabling them to gather feedback and implement suggested improvements. They will then be ready to dive into the next phase – series production.

Claudia Doyle

With the MakerSpace high-tech workshop just a few steps away from TUM's startup incubator, the KEWAZO team was able to manufacture parts for their scaffolding robot prototype themselves. This allowed them to constantly test, improve and modify their device.



Picture credit: Astrid Eckert/TUM

Link

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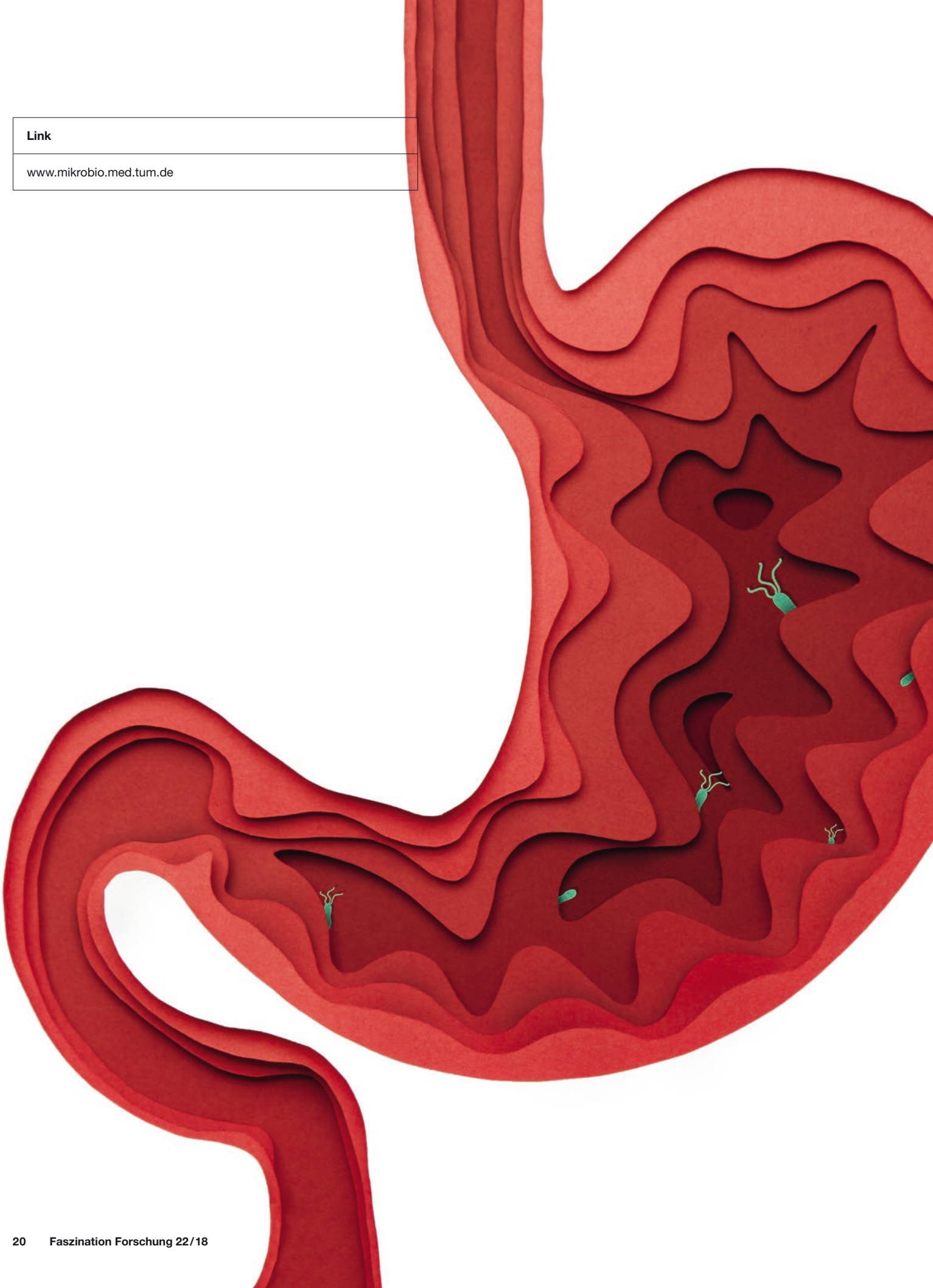


Vaccine against **Stomach Cancer**

In 2005, when the Nobel Prize was awarded to Barry J. Marshall and J. Robin Warren for the discovery of the stomach bacterium *Helicobacter pylori,* TUM medic Markus Gerhard published an exciting scientific finding. This was intended to pave the way for the development of what would likely be the first vaccine against *Helicobacter pylori,* which causes peptic ulcers and stomach cancer. Nine years later, Gerhard – by then Professor of Medical Microbiology and Immunology at TUM – founded ImevaX. The company is currently running clinical trials (phase I) to test the tolerability of its vaccine. Prof. Gerhard's discovery makes this potential vaccine unique: It disrupts a mechanism used by the pathogen to inhibit the human immune system.

Markus Bernards

Impfen gegen Magenkrebs

Seit Beginn seiner Karriere in der Gastroenterologie beschäftigt sich Prof. Markus Gerhard mit dem weit verbreiteten Magenkeim *Helicobacter pylori.* Das Bakterium kann Magengeschwüre und Magenkrebs auslösen. Zwar gibt es wirksame Antibiotika gegen *H. pylori,* doch zunehmend erschweren Antibiotika-Resistenzen die Behandlung.
Markus Gerhard und sein Team fanden heraus, dass das Bakterium ein Protein absondert, das die menschliche Immunabwehr lahmlegt: Die gamma-Glutymyltranspetidase, kurz gGT. Diese Arbeiten führten zu einem neuen Ansatz bei der Entwicklung eines Impfstoffs. Markus Gerhard ließ die Zielstruktur patentieren und gründete die Firma ImevaX, die nun den Impfstoff klinisch testet. □

Graphics: ediundsepp

"I wanted to get to the bottom of it!" After a great deal of lab work, Markus Gerhard (left) was finally able to determine why the human immune system is unable to combat *H. pylori* stomach bacteria effectively.

Half of the world's population is infected with *Helicobacter pylori* – a type of bacteria that was only discovered in the early 1980s. Infection usually takes place during childhood, and the microbes then remain in the stomach lining for a lifetime. While this often goes unnoticed, the bacteria can also cause stomach inflammation (gastritis), peptic ulcers and even stomach cancer. Worldwide, 950,000 people are diagnosed with this type of cancer each year – and in almost 80 percent of cases, *H. pylori* is responsible. The only treatment for infection with this pathogen is a complex combination therapy consisting of two antibiotics and an acid blocker. But even this is problematic: The bacteria are becoming increasingly resistant, so treatment is failing more and more frequently.

As a doctor, Markus Gerhard became interested in *H. pylori* early on in his scientific career. He was keen to find out how these bacteria trigger inflammation of the stomach lining. Although the human immune system does respond to the pathogen, it is not able to combat it effectively. So Gerhard and his team wanted to see how they could give the immune system a helping hand. How could they vaccinate against this bacteria?

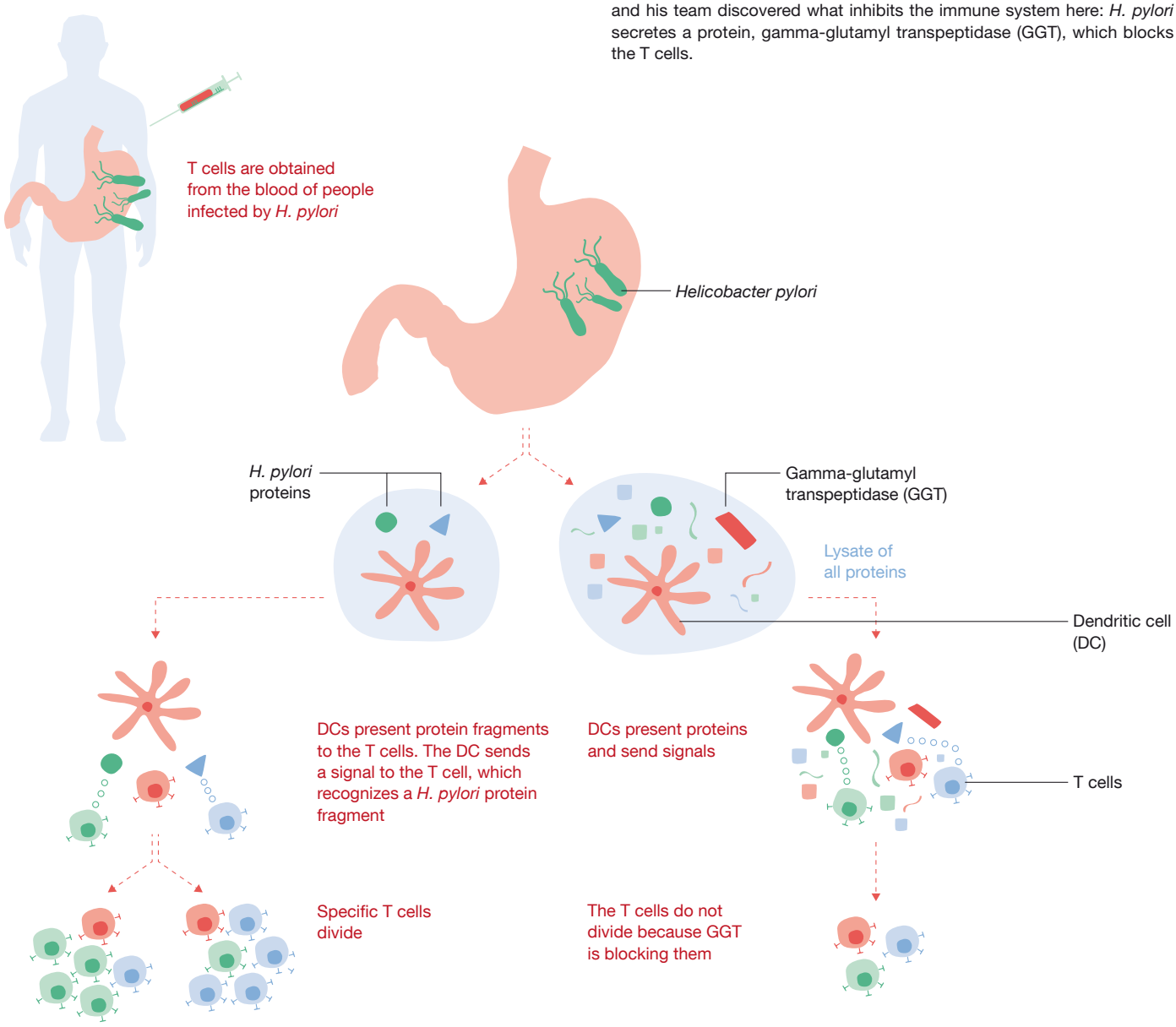
The scientists began by systematically adding single *H. pylori* proteins to specific immune cells, which they obtained from the blood of people infected by *H. pylori.* As it turned out, a whole series of these proteins clearly activated the immune cells. The idea was to intensify this immune response by adding an adjuvant (or boosting substance) to the vaccination. What failed to work, however, was one of the controls, consisting of broken-down *Helicobacter* bacteria (a lysate). This protein mixture was supposed to induce rapid division in specific immune cells, known as T cells. Strangely, the T cells did not react at all – although all the other control experiments worked as expected.

"I want to know what's up"

"At some point I just thought: this is getting on my nerves; I want to know what's up," declares Gerhard. It took four years, but then the scientists had their answer: The bacteria secrete a protein, gamma-glutamyl transpeptidase (GGT), which blocks T cells. "This protein was so effective that the T cells didn't even react to substances like interleukins, which normally cause them to start dividing like crazy," recalls Gerhard, clearly still impressed with this discovery.

T cells blocked by protein

Individual *H. pylori* proteins stimulate the T cells to divide, but a lysate of broken-down *Helicobacter* bacteria fails to have this effect. Markus Gerhard and his team discovered what inhibits the immune system here: *H. pylori* secretes a protein, gamma-glutamyl transpeptidase (GGT), which blocks the T cells.



Graphics: ediundsepp (source TUM), picture credit: Juli Eberle/TUM

Gerhard and his team worked out just how important the secreted protein is to the bacteria in tests using mice: Bacteria lacking the protein were essentially unable to colonize the stomach lining of the rodents. The professor had thus found a promising candidate for the treatment of *H. pylori* infection: a protein essential to the pathogen. “If we could deactivate this protein either chemically, using an inhibitor, or immunologically through vaccination, we could enable the immune system to respond to the microbe. So that’s how the two application scenarios were born.”

Gerhard patented the target structure and published the results in scientific journals. But he had yet to work out how to turn the idea into a vaccine… In theory, he could have granted a license for the patent or entered into a strategic partnership with a company. But there was a hitch. “Nowadays, you can’t sell a patent that still requires that much development work. The pharma industry wants to see data that will enable it to transition directly to a clinical application.” Additionally, there was no real interest in a *H. pylori* vaccine back then, since the assumption was that the infection could be treated effectively with antibiotics. So Gerhard made up his mind to develop his discovery independently and start a company to secure the necessary funds. The physician was certainly passionate about his project: “I wanted to be in the driving seat myself. This was our baby – we’d figured out the underlying mechanism and I just wanted to take it as far as possible.” ▷

Researchers in the laboratory were able to identify gamma-glutamyl transpeptidase as the target structure in combating *H. pylori.* This was the starting point for the vaccine, which is now undergoing clinical trials.

Markus Gerhard thus drew up a plan of action and – with the help of a friend from business studies – wrote his first business plan in 2007, which he then took to the Munich business plan competition (MBPW). Not only did he win that competition, he also gained a jury member as a freelance startup coach.

Nevertheless, there was still a long, hard road ahead to get the company up and running. “I had no idea what I was letting myself in for,” Gerhard recollects. “I think I made almost every mistake in the book. Above all, there were many things I underestimated – development effort, timelines and financial requirements.” His initial patent was already a major hurdle: the newly founded Bayerische Patentallianz (BayPAT) patent agency rejected the application that had the backing of TUM. So Gerhard went on to file the patent privately. “Financially, that was almost the end of me,” he states. “I don’t know if I would ever do that again.” Still, supported by friends and family, it worked out in the end and he subsequently signed the patent over to the newly founded ImevaX, which now holds the rights.

For three years, Gerhard benefited from the Bavarian Science Ministry’s pre-seed funding program. In 2009, he applied for the GO-Bio program run by the German Federal Ministry of Education and Research (BMBF) – and was rejected. “They

"We'd figured out the underlying mechanism and I just wanted to take this discovery as far as possible."

Markus Gerhard

told us that two parallel approaches – the chemical GGT inhibitor and the vaccine – was too much; we wouldn't manage this," he reports. So Gerhard and his team limited their second application to vaccine development only and ultimately received three years of support from GO-Bio, starting in 2011. The next setback could easily have marked the downfall of the project: Gerhard's team had placed an order with a small biotech company for large-scale production of the vaccine proteins – and that company failed to produce the goods. The money was gone. But Gerhard persevered, reallocating funds with the support of the BMBF to commission a more experienced company. Finally, in 2014, it all came together: ImevaX was launched and, with venture capital and additional funding from the GO-Bio program, the company was able to undertake its first clinical trial (phase 1) to test the tolerability of its potential vaccine in humans.

The company is on the right track

Markus Gerhard was then holding down two "part-time" jobs, working mornings and afternoons as a university professor at TUM, then late into the evening as the scientific director of ImevaX. Or the other way around. "That was certainly a challenging time – and hard on my family too," he acknowledges. Two years later, with the company on the right track and the phase 1 trial under way, Gerhard's job there was done and he returned to TUM full time. Despite all the challenges, it was a role he enjoyed – but he also values the freedom that comes with basic science. Building on his experience as a company founder, he now channels the clinical application perspective into his basic research at a very early stage. He is still involved with ImevaX in an advisory capacity and is very eager to see how *Helicobacter pylori* will respond to "his" potential vaccine in humans.

Markus Bernards

Picture credit: Juli Eberle/TUM

Prof. Markus Gerhard

Basic research and clinical application

Markus Gerhard began studying medicine in the German cities of Heidelberg and Hamburg. After receiving his doctorate in 1996, he embarked on his medical career at TUM's Klinikum rechts der Isar university hospital. From 2004 to 2006, he worked at the Netherlands Institute for Developmental Biology in the research group led by Prof. Hans Clevers. Then, in 2010, he was appointed Associate Professor of Medical Microbiology and Immunology at the Institute for Medical Microbiology, Immunology and Hygiene at TUM.

Gerhard has received several awards in recognition of his scientific and entrepreneurial achievements. In 2007, for instance, he won first prize at the Munich business plan competition (MBPW). He then went on to win the DZIF Prize for outstanding translational research awarded by the German Center for Infection Research (DZIF) in 2015. As the DZIF's own commendation states: "The development of a *Helicobacter pylori* vaccine is a particularly good example of a successful translational project resulting from closer collaboration between basic researchers and clinicians."

“The ability to bridge both worlds **is what makes this institute so special”**

Prof. Dirk Busch, Director of TUM’s Institute of Medical Microbiology, Immunology and Hygiene, has founded two companies: STAGE cell therapeutics GmbH and T-Cell Factory B.V. The launch of STAGE Cell Therapeutics was supported by IBA GmbH, which holds a license for the Strep-tag system developed by TUM professor Arne Skerra (see page 62). The products STAGE offers are based on Streptamer technology.

Prof. Busch, you yourself founded two biotech ventures that were bought by major pharmaceutical companies in 2015. What prompted you to start your own companies in the first place?
I still find it fantastic that both of those companies are now “big pharma”. Essentially, the startup route was the only realistic path forward. In terms of the Streptamer technology, it was clear from the outset that our development work was pointing toward the production of a clinical product. And that’s a long road, involving cost-intensive manufacturing processes that would be beyond the reach of normal university resources. But with a small company as a partner, you can access additional funds from third parties – for instance the EU or Germany’s Federal Research Ministry – which helped us a great deal. In the end, we were able to demonstrate that our concept was clinically feasible and thus pave the way for the acquisition.

What advice would you give prospective company founders?
I would push out the venture capital step as far as possible, because most investors immediately seek a majority stake in the company and can then call the shots. This can jeopardize the flexibility and creativity of startups, since ultimately it’s the founders who are passionate about the invention. STAGE spent a long time applying for third-party funding in collaboration with strategic partners (such as TUM) and this meant we were able to stay in control throughout the entire development process, sometimes making decisions over the phone within just a few hours. However, in many cases, it simply isn’t possible to do without venture capital – sometimes it’s the key success factor. But it is certainly a step to consider very carefully.

Would you start another company yourself?
Yes, of course. At the moment, though, our focus is on the major research programs we are working on with Juno Therapeutics, the company that took over STAGE Cell Therapeutics. But with Markus Gerhard’s experience and my own background, we have a very strong startup culture here at the institute. There is a grass-roots awareness that the startup path is always an option. In our daily work, we often come across research findings where we say: “That has product potential.”

With all these product developments, do you still enjoy basic research?
What I especially like is the connection between basic and applied research. At this institute, we leave no stone unturned in the pursuit of basic knowledge – covering everything from crystal structures through complex mouse models to genetic models. At the same time, we are a medical institute, and the basic curiosity that drives us is always linked to a medical or clinical context. This ability to bridge both worlds is what makes this institute so special. We think clinically, but can also take a strong application back to the basic research bench or launch a new company to transition innovative research to clinical practice.

Markus Bernards

Picture credit: Astrid Eckert/TUM

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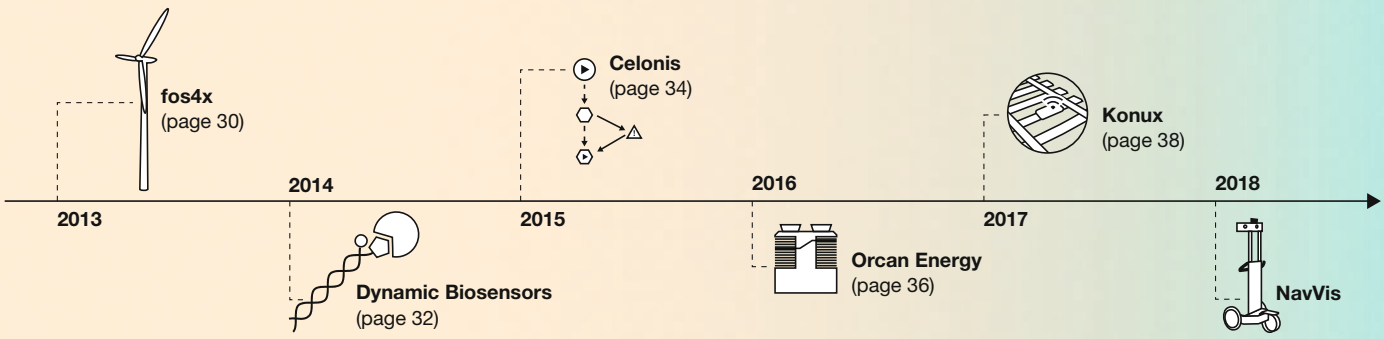
Presidential Entrepreneurship Award **Recognition and Inspiration**

The annual TUM Entrepreneurship Day invites visitors to experience the entrepreneurial spirit of the Technical University of Munich. This year, they were able to participate in the rapid prototyping workshop, watch TUM startup pitches, get in touch with TUM startups, and get the low-down on startup support.

A highlight of the event is the announcement of the Presidential Entrepreneurship Award. This EUR 10,000 prize is bestowed by the President of TUM to honor an outstanding spin-off with a largely research-based business idea.

"Young people are the ones keen to try new things, taking risks to turn their ideas into useful products, processes and services," says TUM President Wolfgang A. Herrmann. "We want to encourage their entrepreneurial spirit, in keeping with the philosophy of our entrepreneurial university."

On the following pages, Faszination Forschung presents the winners of this award since its introduction in 2013. They have all gone on to become success stories. Celonis, for instance, the winner of the 2015 award, has become one of Germany's most successful startups. A new round of investment this summer means the company is now worth more than one billion dollars. The varied range of products, processes and services showcased here reflects the diversity of TUM.



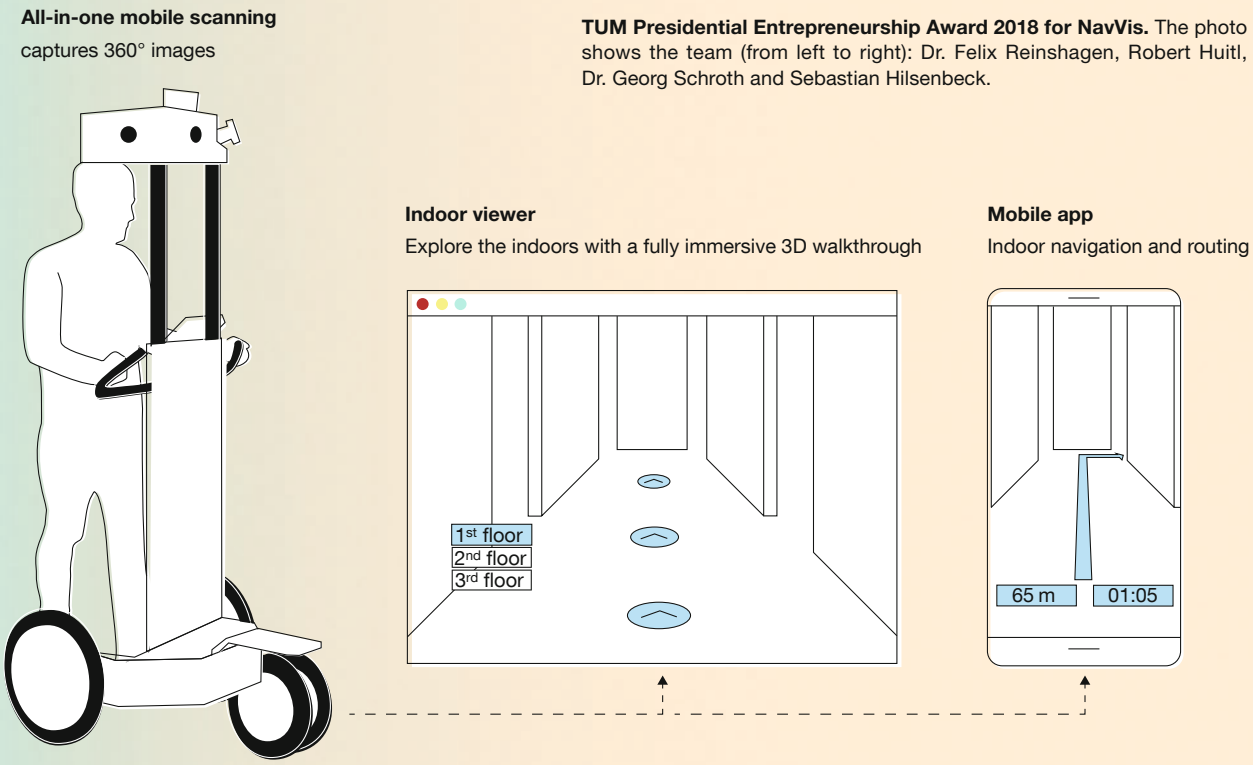
The winner of the 2018 Presidential Entrepreneurship Award is NavVis, which develops applications for highly accurate mapmaking and navigation in interior spaces. Founded in 2013 with the support of TUM and UnternehmerTUM, the company currently has approximately 140 employees working on its innovative digitalization project in Munich and New York. NavVis helps smartphone users to find their way around complex buildings such as plant halls, convention centers, airports, train stations and shopping malls. It also makes it possible to experience entire exhibitions online. To do this, the company digitalizes indoor spaces using mobile trolleys equipped with a variety of cameras. The footage is used to create photo-realistic 3D maps of buildings. This data is supplemented with a navigation system and interactive, location-specific services.

The technology for a camera-based navigation system was developed by Georg Schroth, later one of the company's founders, during his doctoral studies at the TUM Chair for Media Technology. The first to join the subsequent research project were PhD students Sebastian Hilsenbeck and Robert Huitl, followed by Economics PhD graduate Felix Reinshagen. The four men founded NavVis in 2013 with the support of TUM and UnternehmerTUM – the Center for Innovation and Business Creation – benefiting from services such as the KICKSTART startup program.

In addition to basic research and startup consulting, TUM also played a major role in many of the technical development steps. Thus, for example, the trolley prototypes and the company's corporate design were created in collaboration with the Chair for Industrial Design (see article on page 84).

Evdoxía Tsakiridou

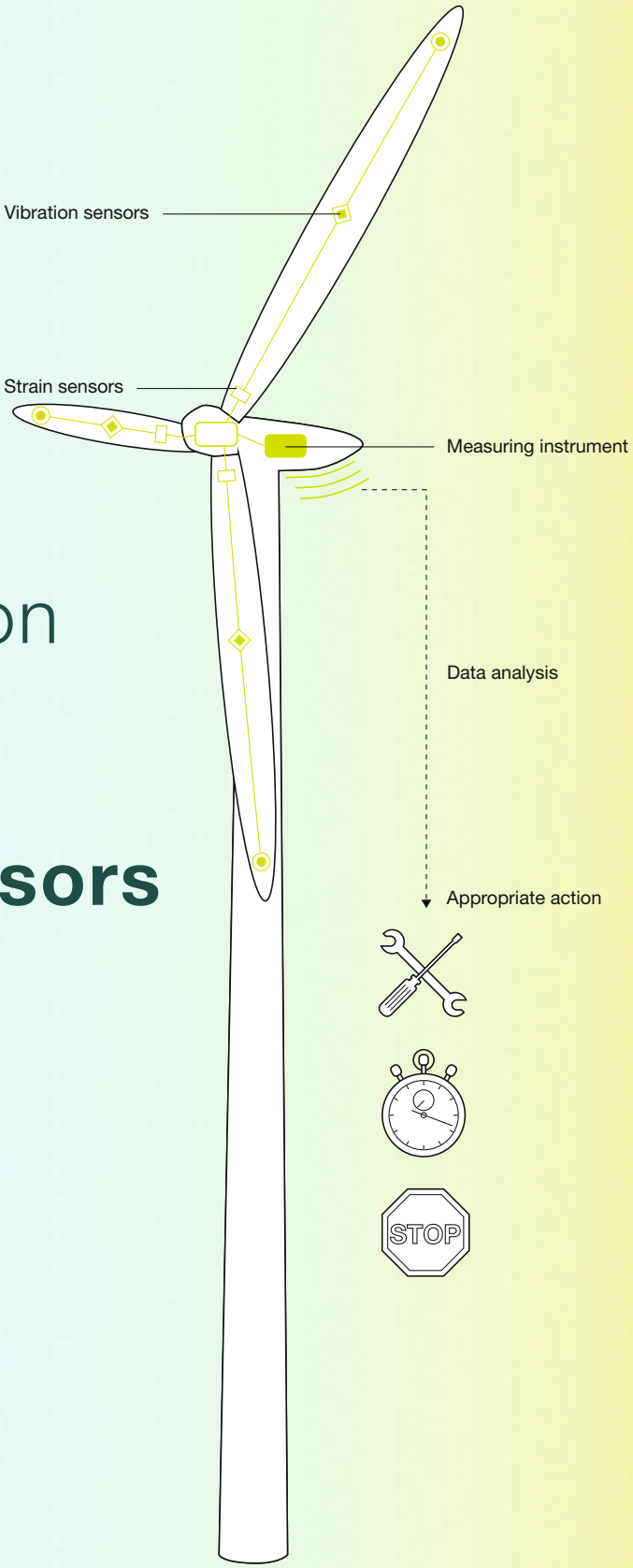
TUM Presidential Entrepreneurship Award 2018 for NavVis. The photo shows the team (from left to right): Dr. Felix Reinshagen, Robert Huitl, Dr. Georg Schroth and Sebastian Hilsenbeck.



Graphics: ediundsepp (source: TUM; NavVis GmbH), picture credit: NavVis GmbH

Gleaning information from rotor blades **Optimizing wind turbines with sensors and smart apps**

Sensors have made their way into just about every conceivable industrial system. Up until a few years ago, however, they were not to be found in wind turbines. That changed in 2010 when TUM startup fos4X developed sensors specifically for turbine rotor blades that are exposed to exceptional levels of stress.



Sensors record physical parameters directly on the rotor blades, with a control unit turning the blade out of the wind or stopping the system in case of overload.

The company's name stands for "fiber-optic sensors for x applications". Although the "x" had admittedly shrunk by the time the four founders left the TUM family in 2012 to move into their new offices and production facilities in Sendling, in the south of Munich.
Alongside the electromobility and rail sectors, wind energy was a promising market. The high-tech firm developed a modular sensor platform to track the physical performance indicators of industrial facilities. Smart apps then use these data to optimize the performance of wind turbines or wind farms.

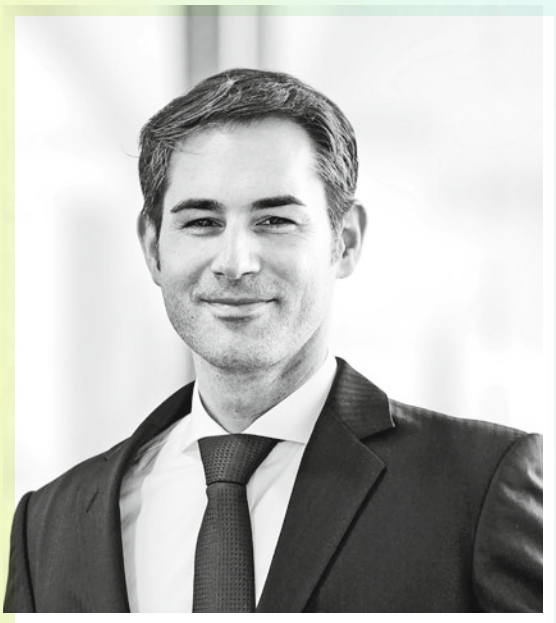
Fewer failures and increased annual yield

Manufacturers and operators are looking to this technology not just to avoid failures and downtime, but also to increase annual yield and prolong the service life of their equipment. Factors like the bending and vibration stresses that rotor blades are exposed to play a key role here. Load alternations, lightning strikes, ice formation and other stresses can all have the effect of shortening service life.

The sensor platform from fos4X consists of fiber-optic strain and vibration sensors along with a measuring instrument to read out the recorded data. The sensors are integrated in the rotor blades and connected to corresponding measuring instruments. The latter convert optical input signals into electrical output values. Strain sensors record information like material changes. In the event of an overload, a control unit steers the blade away from the wind. The system is not only able to detect structural damage to the blades, it also works out a precise preventive maintenance schedule to avoid damage.
The vibration sensors, on the other hand, measure the natural frequency of the material. The formation of ice causes this value to change. A specially developed software solution is able to determine the weight of the layer of ice. If the load is too high, the control unit stops the turbine for the time it takes the rotor blade heating system to melt the ice. The sensor system detects the change and automatically restarts the wind turbine.

Freedom to develop ideas

Lars Hoffmann is one of the co-founders of the company. Along with his peers, he was already zoning in on sensors at TUM's Institute for Measurement Systems and Sensor Technology. After obtaining his doctorate, the metrology specialist spent some time working for a consultancy firm before reuniting with his team to create the startup. The EXIST funding program also provided support for fos4X. Hoffmann is still full of gratitude to TUM for "giving us rooms, exclusive rights of use for patents and above all plenty of freedom to develop our ideas". Being singled out for the Presidential Entrepreneurship Award means a lot to him: "All five of the previous winners are successful young enterprises, so the selection process is a reliable indicator of things to come."
The other three founders have left fos4X in the meantime to pursue different projects. Since their departure, the company's workforce has grown to 70 employees and it is cooperating with nine of the top ten manufacturers of wind turbines. From its base in Munich, the company supports customers in Europe, North America and China. *Evdoxía Tsakiridou*



Lars Hoffmann is a co-founder of fos4X. After completing his doctorate, the metrology specialist worked as a consultant prior to starting his own venture.

Graphics: ediundsepp (source: fos4X GmbH), picture credit: fos4X GmbH

Swaying to and fro on a biochip

Optical sensor technology measures the dynamics of proteins

Dr. Ulrich Rant examines a biochip in a Petri dish. His company develops measuring instruments that use these chips to analyze biomolecules.

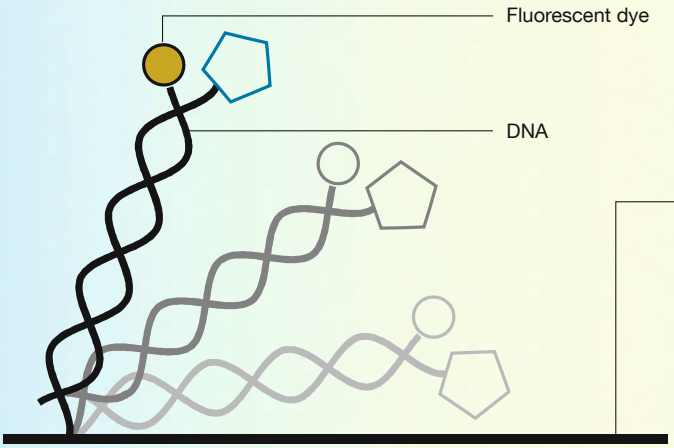
"Our measuring instruments fulfill two functions at the same time: They are able to analyze the bonding behavior of molecules, while also detecting conformational changes. The conformation of proteins is important for their function," explains Ulrich Rant, CEO of tech firm Dynamic Biosensors (DBS).

Some of his customers are from the pharmaceuticals sector and they use DBS measuring instruments to develop new drugs. Then there are the universities and research institutes who are interested, for example, in determining the size of proteins, measuring the strength of bonds or studying conformational changes.

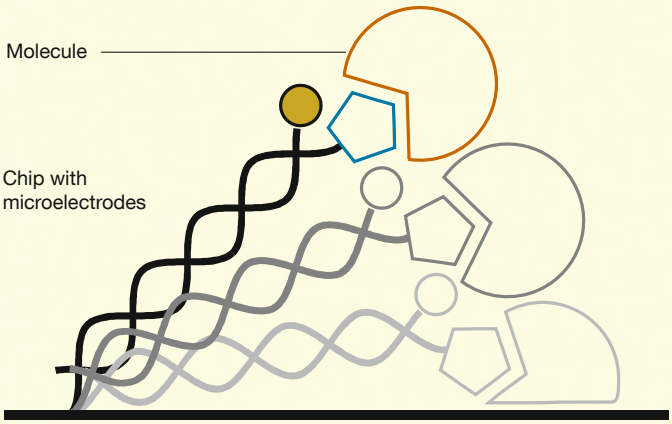
DNA acting as sensor

An important role is played here by genetic material, or more precisely nanometer-long bits of DNA acting as sensors. These sensors lie on a chip with microelectrodes and they sway from side to side when AC voltage is applied. If proteins are located on the sensors, the vibrations change. Similar to elastic rods, lightweight specimens oscillate at a faster rate than heavy ones.

The optical method used to visualize the molecular movements is based on fluorescent dyes. The luminous intensity of the light molecules varies depending on the movements of the DNA segments. This effect, which is visible under a micro-



Optical sensor technology is used to measure the dynamics of molecules, with nanometer-long DNA fragments acting as sensors. Placed on a chip with microelectrodes, these sway from side to side when AC voltage is applied.



If molecules are located on the sensors, the vibrations change, with lightweight specimens oscillating faster. Fluorescent dye renders these movements visible.

scope, can be amplified and analyzed. The patented process from DBS not only allows the molecular properties of proteins, receptors, antibodies or drugs to be measured, it also lets researchers study the interactions between proteins, nucleic acids or other molecular compounds and determine their chemical and thermal stability.

Ample research freedom

The origins of Dynamic Biosensors date back to 2013 when it was spun off from the Walter Schottky Institute, TUM's central institute for semiconductor electronics. "We felt a bit like outsiders there because of our focus on biotechnology. All the same, we received amazing support from Prof. Gerhard Abstreiter's Chair and from TUM," recalls Ulrich Rant, who holds a PhD in physics. The provision of rooms and laboratory facilities, help in preparing research proposals, seamless cooperation between departments and ample research freedom gave the young company the best possible start on the road to success.

The TUM startup received financial support from the EXIST funding program of Germany's Federal Economics Ministry and the GO-Bio initiative of the Federal Ministry of Education and Research. It has also been singled out for a couple of awards, including the TUM Presidential Entrepreneurship Award (2014). The company invested its prize money directly into laboratory equipment. A further distinction followed in 2015 with the German Innovation Award.

Dynamic Biosensors GmbH has been based in Martinsried near Munich since 2013, the year when a 10-strong core team brought the first measurement system to the market. The second version followed three years later. Today, the company has 50 employees based at several locations across Europe and, since 2017, also in the USA (San Diego, California). Four of the company's five founders are still on board and they now have their sights set on the Asian market. *Evdoxía Tsakiridou*

Graphics: Dynamic Biosensors, picture credit: Astrid Eckert/TUM

Martin Klenk, Bastian Nominacher and Alexander Rinke (from left to right) want their startup Celonis to become a global software company.

How can processes that are supported by IT systems become more transparent and efficient? What optimization measures have the potential to cut costs? Celonis developed its process mining technology to answer these questions. The company's software analyzes and visualizes process data in real time.

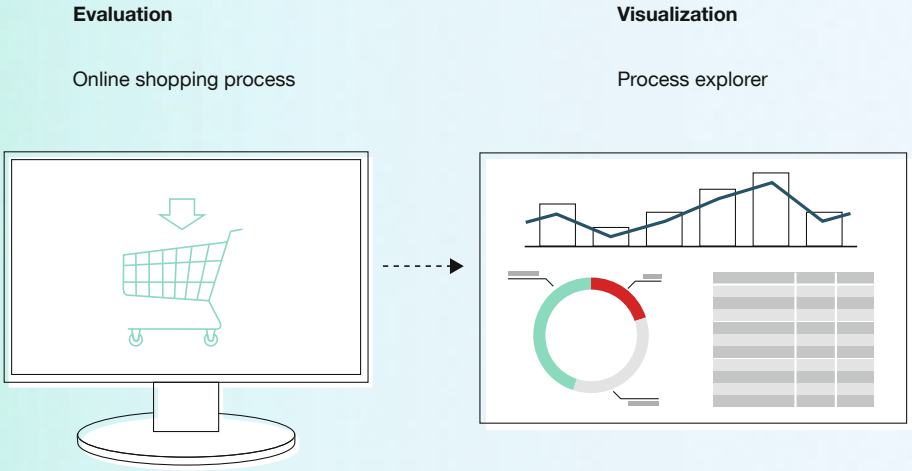
X-ray view of process data **Software to analyze process bottlenecks and highlight savings potential**

The analogy of mining – extracting valuable coal from underground – is highly apt. What Celonis does is help companies extract an equally valuable resource: data. A business process – such as purchasing – is analyzed from start to finish, extending from the prep stage through ordering to actual payment. The output visualizes where bottlenecks occur and where workarounds or redundancies can be eliminated.

Gain insights

"Machines have become completely autonomous in many sectors. This fact alone creates a stream of extremely valuable data which businesses can use to gain insights and develop innovative way of conducting their business. The underlying potential is huge: Processes can be accelerated and associated manual effort avoided. The scope for savings can be identified at first glance," maintains founder Bastian Nominacher, who got to know his two co-founders Martin Klenk and Alexander Rinke at the Academy Consult München e.V. student consulting service.

The trio, who were TUM students at the time, developed the data analytics technology on the basis of their research findings. The foundation of Celonis in 2011 was supported by TUM with workstations and a dedicated mentor. Further support was provided by TUM's startup consultation service. "This interaction was very valuable for us – there is no doubt that it put us on the fast track. We were also very grateful for the financial assistance we received from the EXIST startup grant. We are nevertheless proud to be a completely self-

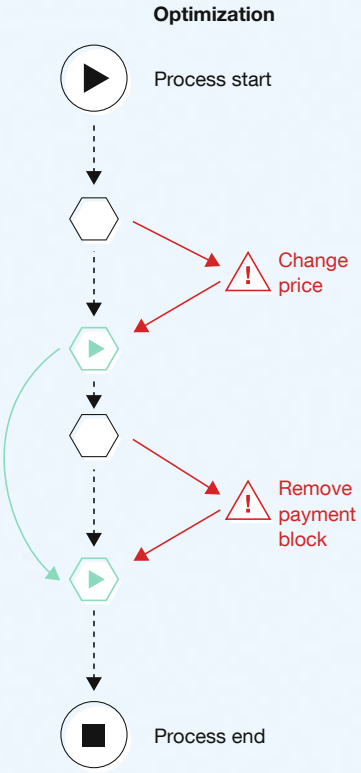


financed startup," points out the data analytics specialist. His advice to entrepreneurs is to start with a product that is not overly complex but offers a rich feature set. "It still has to be functional though, and provide benefits to customers." In the second stage, Nominacher recommends developing the product in conjunction with the customer to tailor it exactly to their needs and wishes. This is a time- and cost-saving exercise for entrepreneurs, and it minimizes the risk of off-track development.

From an entrepreneur to a manager

The 33-year-old has another recommendation to share: "As an entrepreneur, you have to learn to loosen the reins and to delegate. Make yourself less of a focal point or you will end up in a bottleneck and throttle your own success. The more the company grows, the harder it becomes to maintain an overview of all processes. That is not scalable in the long run. Your role has to evolve from an entrepreneur to a manager." Today, the startup ranks as one of Germany's fastest growing companies (Deloitte Fast 50), and a market leader in process mining, as recently recognized by a Gartner Market Study. In June 2018 Celonis raised $ 50 million in Series B funding, which values the company at $ 1 billion. "We intend to build on this position and also enlarge the market we are operating in. Our goal is not just to become a global software company, but also to reach the 1,000-employee milestone by 2020," say the Celonis founders.

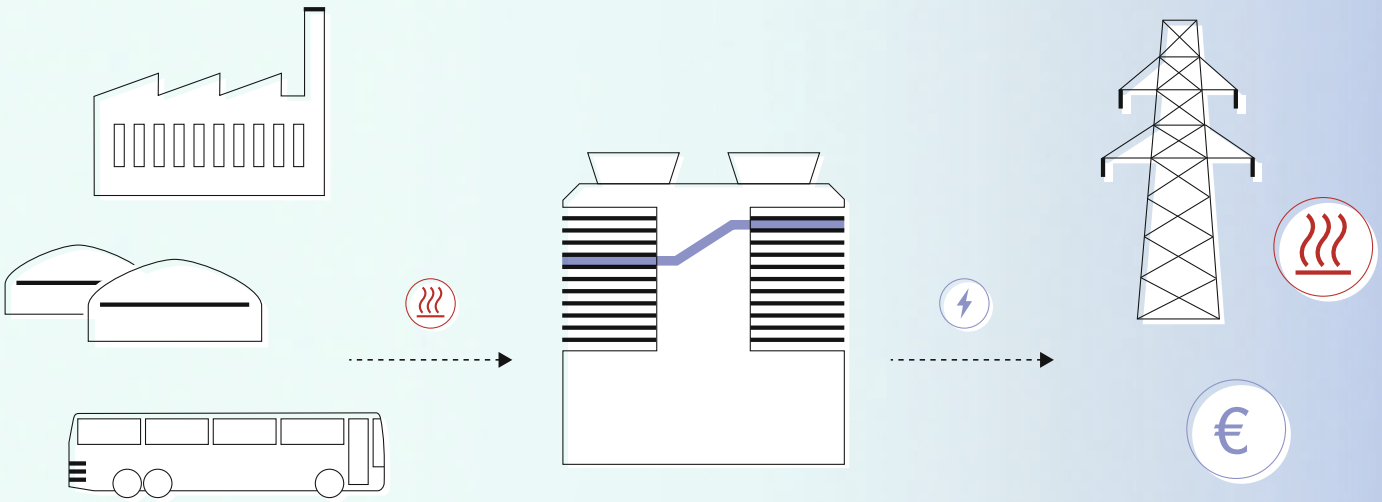
Evdoxía Tsakiridou



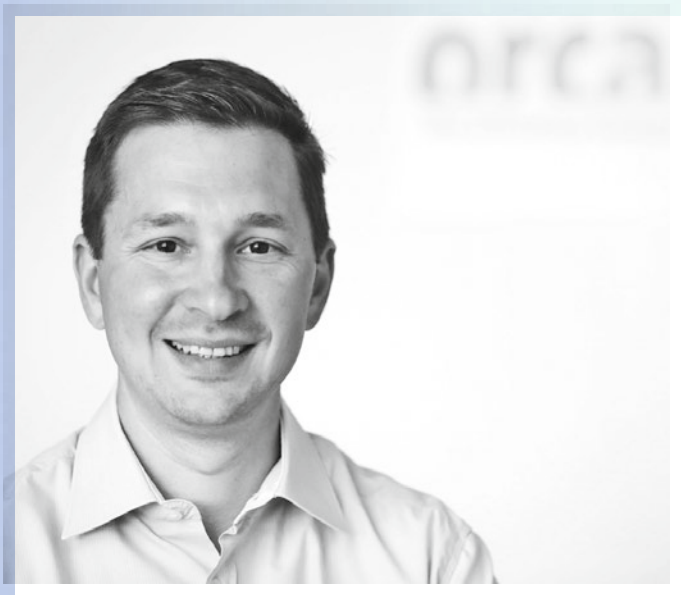
Process mining is about understanding and optimizing business processes and can easily visualize a broad variety of different processes. One example is Purchase-to-Pay: This process involves a high number of transactions; at the same time, approvals, timelines and many different procedures, requests, suppliers and their conditions drive complexity. Process mining helps procurement organizations to bring full transparency and more efficiency to their processes: It is possible to find and eliminate inefficiencies and faults in the transactional process and check for compliance and supplier performance in real time. Flexible insights allow users to increase and monitor automation rates and minimize interruptions caused by manual changes and rework activities. Dealing with purchasing processes, it is particularly interesting to compare throughput times of different parts of the process. The process explorer allows throughput times to be displayed directly in the process graph. This way, bottlenecks are easily spotted and eliminated.

Graphics: ediundsepp (source: Celonis SE), picture credit: Celonis SE

Recovering energy from waste heat
Mini power plant converts waste heat to electricity



Orcan Energy's mini power plant uses waste heat from industrial plants, biogas facilities and engines to generate CO_2-free power. Thanks to innovative control and regulation technology, waste heat sources with rapidly fluctuating temperatures can be harnessed efficiently even at frequent partial-load operation.



Orcan Energy aims to establish its second-generation ORC technology as a global standard. Dr. Andreas Sichert, one of the company's founders, feels they are on the right track.

"We have developed the second generation of ORC technology," declares Andreas Sichert, one of the three founders of Orcan Energy AG. The abbreviation ORC, which is also part of the company's name, stands for Organic Rankine Cycle. The innovation lies in shrinking the steam turbine technology by up to three orders of magnitude and delivering a standard plug-and-play product.

Instead of steam, the miniature power plant is driven by an organic fluid. It is designed for low-temperature operation from 60 °C and can generate up to 100 kilowatts of electricity. This means it can harness waste heat from industrial plants, power generation (biogas plants) or transport (ship engines) to generate not only greener but also more efficient electricity.

The cost squeeze

The miniaturized design was inspired by cost pressures. Steam power plant components are expensive. So when the three founders, Sichert and his colleagues Dr. Andreas Schuster and Richard Aumann, set out on their development journey in 2004, they quickly discovered that necessity is the mother of invention. The technology developed at TUM's Institute for Energy Systems reduces the head height of pumps from several meters to a few centimeters. "Every mistake we made during the development process helped us improve the product," points out the 36-year-old.

The company was spun off in 2008. "It took us three years to raise the investment capital for our startup. We were lucky enough to receive support along the way, however, including from the EXIST Transfer of Research program and from UnternehmerTUM. Top executives from major companies and successful entrepreneurs also provided us with advice and helped us find an investor. We learned that asking for help really pays off," stresses the doctor of physics.

140 patents filed

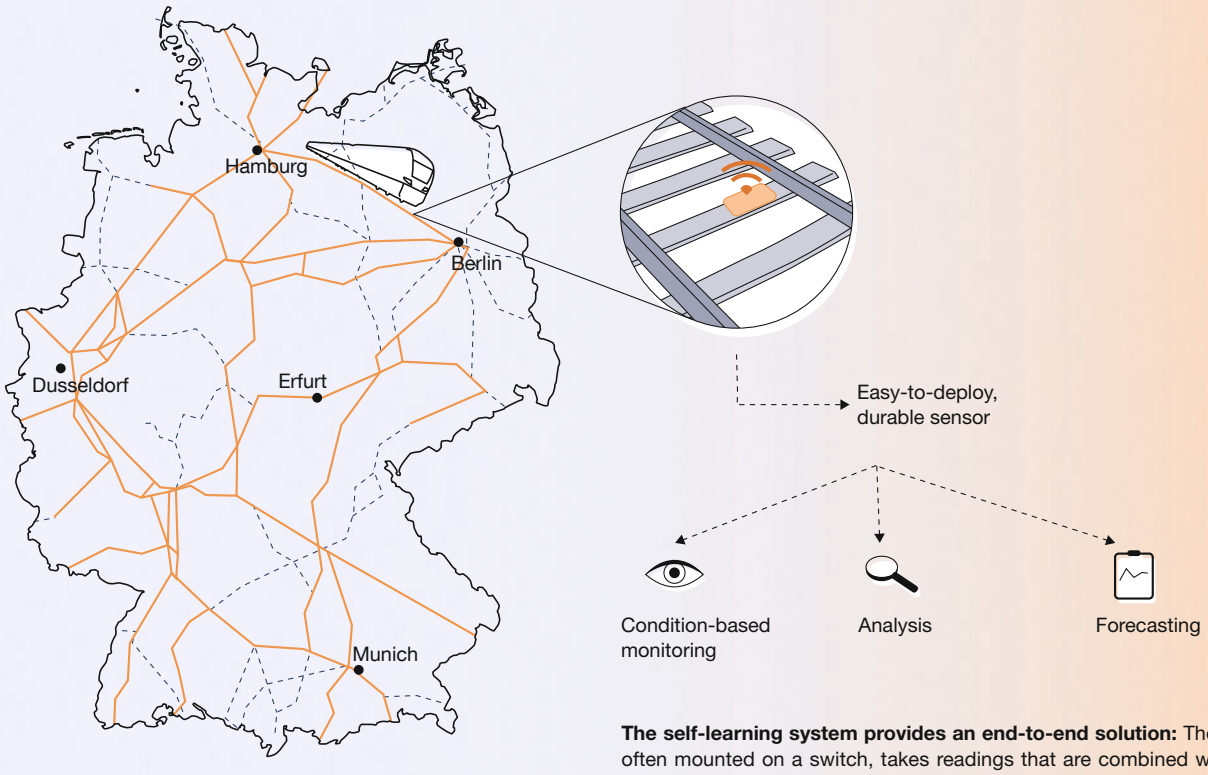
With support from TUM's patent and licensing office and Bayerische Patentallianz, Orcan's founders were able to file a patent for their first invention in 2009. The number of patents they hold has since risen to 140. At the outset, however, some of the patents originally belonged to TUM. The founders used their investment capital to buy the patents back from their alma mater and get their company ready to enter the market.

Orcan Energy's portfolio includes a series-ready solution whereby the ORC modules can be directly integrated into the waste heat source, as well as electricity generation modules that can be deployed and commissioned straight away. In 2016, the trio received the TUM Presidential Entrepreneurship Award and were ranked among the top 100 innovators in Germany.

"With a current headcount of 60 employees, we are scaling up to become an innovative mid-sized enterprise," enthuses Andreas Sichert. His company wants to establish its ORC technology as the global standard in low-temperature power generation from waste heat. There are plans to install several thousand plants in the coming five years. There is even a possibility that one day private households will be able to harness the ORC innovation with their own heating systems.

Evdoxía Tsakiridou

Graphics: ediundsepp (source: Orcan Energy AG), picture credit: Orcan Energy AG



The self-learning system provides an end-to-end solution: The sensor, often mounted on a switch, takes readings that are combined with other data and analyzed by intelligent algorithms. These then supply information about the condition, maintenance and repair requirements.

Switch technology goes digital

Intelligent sensor systems increase the capacity of rail networks

“We were very technology-focused at the beginning with notions of becoming the best sensor technology company in the world. But we quickly realized that solving customers’ problems should be our first priority,” recalls Konux co-founder Andreas Kunze.

We” includes his co-founders Dennis Humhal and Vlad Lata. As young students of electrical engineering, computer science and mechanical engineering, they met at a TUM business plan seminar and quickly hit on the idea of developing smart sensors for industrial equipment.

Large network of industry contacts

The trio abandoned their plans to do a Master’s degree, opting instead to focus 100% on their startup with the support of TUM. “With MakerSpace, TUM not only offers great infrastructure for building prototypes, but also a large network of industry contacts. That is how we as founders were able to engage with potential customers,” explains Andreas Kunze.

The early days of the company, which was founded in 2014, were a learning experience for the founders, after which they went on to fine-tune their business idea. They decided to offer an end-to-end solution encompassing sensor, data analytics and data management, adding value through the ability to combine sensor readings with other data sources and then analyze the resulting stream of information. The system thus includes an analytics program based on AI technologies such as neural networks, which can be “trained” to detect irregularities or potential failures on the basis of countless past examples. Complementing continuous condition-based monitoring, lifecycle forecasts and predictive maintenance round out the business portfolio.

Enormous savings potential

Deutsche Bahn was one of the first customers that Konux won. The German railway company oversees just under 66,500 switches. Given the number of years racked up by the rail infrastructure and its exposure to high loads, maintenance requirements are rising. If a switch fails, this can severely impact the punctuality of trains and the capacity of the rail network. In the past, DB regularly monitored the condition of its switches with manual inspections, a procedure that has become anachronistic in the digital age. “We can now record over 9,000 times more condition-based data per switch every year, and given the large number of switches involved, this translates into an enormous savings potential,” notes 27-year-old Kunze.

Konux currently has 38 employees, the oldest of whom is 62. “Age doesn’t matter to us. We simply want to hire the best people to advance our company,” underlines Kunze. And when he says “our” company, he doesn’t just mean himself and his two colleagues. Every employee is in charge to an extent, because they are all shareholders of Konux.

The company has by now completed its third round of funding, with the amount received from investors increasing each time. Initially, the founders were highly in awe of the million-euro tags, but these have become quite normal by now: “We have a plan, and the money is being channeled into realizing our goals.” Specifically, this means establishing a footprint in seven countries by the end of the year. They are already halfway toward realizing this aim and are looking to their medium-term goal of becoming “the number one data player in the railway sector”.

Evdoxía Tsakiridou

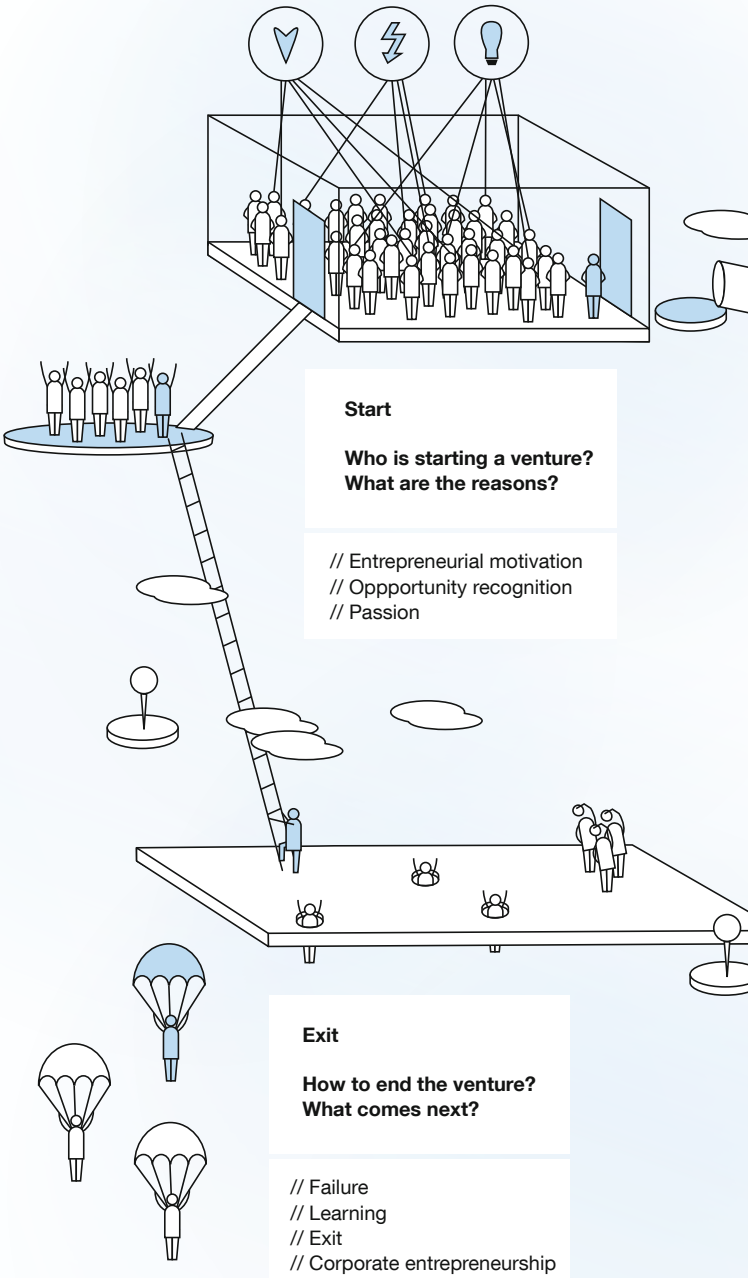
The Konux founders: (from left) mechanical engineer Dennis Humhal, computer scientist Andreas Kunze and electrical engineer Vlad Lata.

Graphics: ediundsepp (source: KONUX GmbH), picture credit: KONUX GmbH

Link
www.ent.wi.tum.de

The Science **of Creating Businesses**

A good business idea is by no means enough. But what makes ongoing entrepreneurs successful? An interdisciplinary team of scholars at TUM's Entrepreneurship Research Institute is determined to find out.



Gitta Rohling

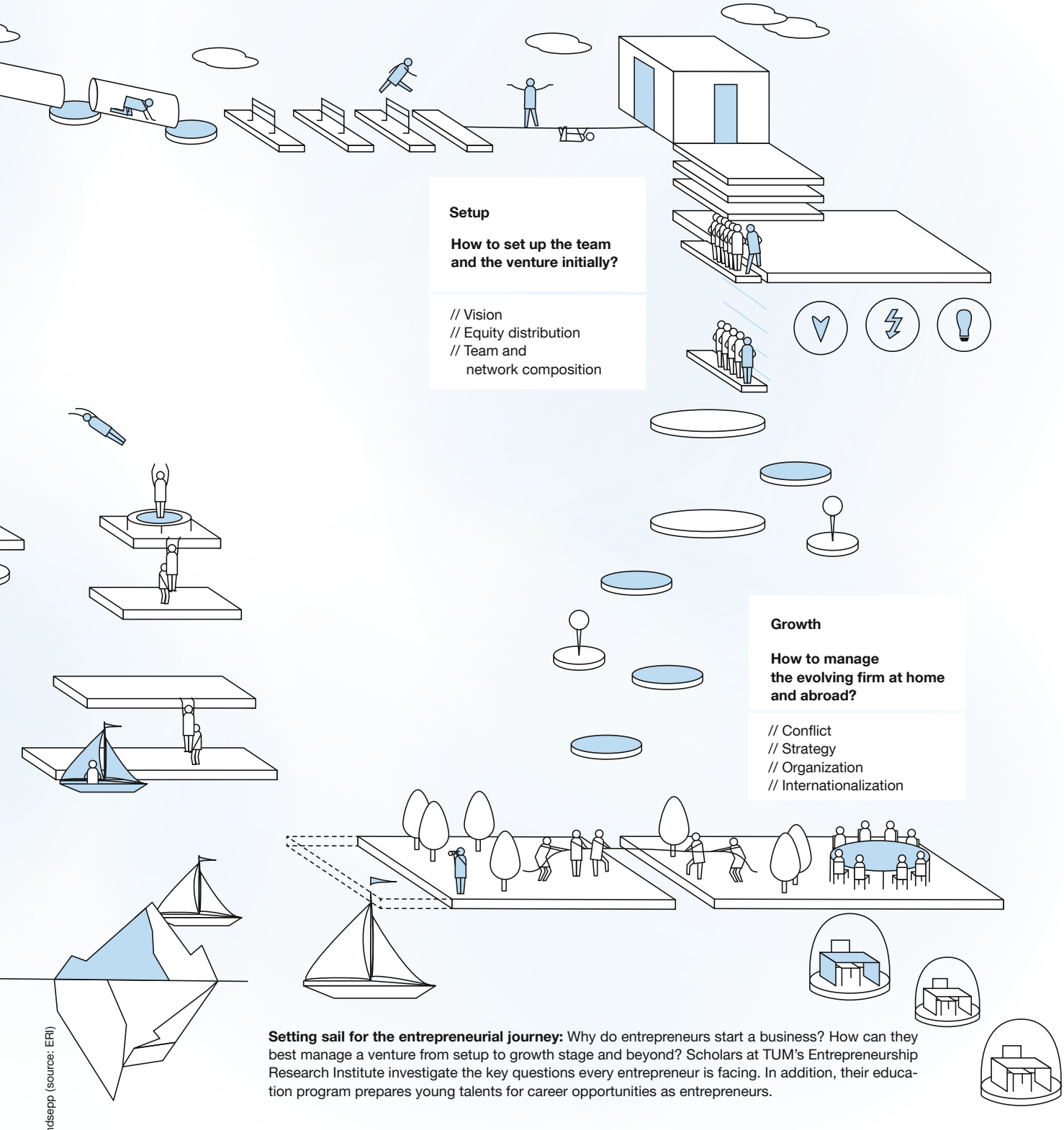
Die Wissenschaft vom Gründen

Prof. Holger Patzelt beginnt seine Erstsemestervorlesungen immer mit derselben Frage: „Wer von Ihnen kann sich vorstellen, ein Unternehmen zu gründen?" Als der Professor für Entrepreneurship 2010 an der TUM anfing, meldete sich üblicherweise ein Dutzend. Heute hebt bei dieser Frage rund die Hälfte der 600 Studierenden die Hand.

Der Molekularbiologe und Betriebswirtschaftler Patzelt forscht und lehrt gemeinsam mit der Psychologin Prof. Nicola Breugst, dem Wirtschaftsinformatiker Prof. Oliver Alexy und der Wirtschaftswissenschaftlerin Prof. Hana Milanov am Entrepreneurship Research Institute (ERI) der TUM.

Seit 2015 ist das ERI Teil eines einzigartigen Gründungsumfelds auf dem Campus Garching: Wissenschaft, Gründungsteams und UnternehmerTUM, das Zentrum für Innovation und Gründung, teilen sich ein Gebäude. Die Wissenschaftlerinnen und Wissenschaftler des ERI decken die Erforschung des gesamten unternehmerischen Prozesses ab: vom Start über den Aufbau und das Wachstum bis hin – auch das ist wichtig – zum Ausstieg. Ihr Ziel ist es, das Verständnis sowohl für unternehmerische Persönlichkeiten als auch für unternehmerische Organisationen zu verbessern.

Auf Basis der Forschungserkenntnisse können angehende Gründerinnen und Gründer lernen, von anderen gemachte Fehler zu vermeiden und Chancen zu erkennen – sowohl auf individueller als auch auf organisatorischer Ebene. „Wir wollen einen unternehmerischen Spirit in die Lehrstühle und Fakultäten der TUM hineintragen", sagt Nicola Breugst. Sicherlich entscheiden sich dann einige von denen, die in der Erstsemestervorlesung die Hand gehoben haben, tatsächlich für das Abenteuer Gründung. □



Setting sail for the entrepreneurial journey: Why do entrepreneurs start a business? How can they best manage a venture from setup to growth stage and beyond? Scholars at TUM's Entrepreneurship Research Institute investigate the key questions every entrepreneur is facing. In addition, their education program prepares young talents for career opportunities as entrepreneurs.

Graphics: ediundsepp (source: ERI)

Prof. Holger Patzelt always kicks off his first-semester lectures with the same question: "Can any of you imagine starting your own company?" When he first joined TUM in 2010 as a Professor of Entrepreneurship, only a dozen students would typically answer "yes". Today, around half of his six hundred students indicate that they can imagine doing so. The majority are studying business management, but students from engineering, computer sciences and other disciplines also take his courses.

"We want to bring an entrepreneurial spirit into the TUM departments and faculties," reveals Prof. Nicola Breugst, Professor of Entrepreneurial Behavior with a background in psychology. Together with Prof. Patzelt (a molecular biologist and business economist), Prof. Oliver Alexy (with an innovation and information management background) and Prof. Hana Milanov (with a management background), they form the core of TUM's Entrepreneurship Research Institute (ERI). The team holds lectures, seminars, and workshops for students across various faculties. "Our courses and research insights are intended to ensure that young people are open to the rich and diverse career opportunities that are out there, and are equipped with the entrepreneurial mindset they need to launch a startup," Breugst explains.

Unique environment for startups

Around seventy technology-driven, growth-oriented startups emerge from the TUM ecosystem each year. According to the German Startup Monitor (DSM), more business founders come from TUM than from any other German university.

Founded in 2012, the ERI certainly plays a role in this success. The institute forms part of a unique startup environment on the Garching campus (see graphic on p. 45). In the modern building of the TUM Entrepreneurship Center, the ERI researchers share the west wing with around twenty startup teams, all advancing their ideas in the entrepreneurship incubator. The east wing houses UnternehmerTUM – the Center for Innovation and Business Creation at TUM – which offers founders and startups a complete service from the initial spark of an idea all the way to an initial public offering. This includes a high-tech prototype workshop, MakerSpace.

"You can really sense the creative energy of technology-based startups here," reflects Nicola Breugst. She particularly appreciates the special atmosphere at the TUM Entrepreneurship Center: "Collaborating directly with startup teams inspires our research endeavors. In turn, we can then use our study findings to develop hands-on startup tools." ▷

The Entrepreneurship Research Institute is part of a unique startup environment on the Garching campus, where science, startup teams and UnternehmerTUM, the Center for Innovation and Business Creation, all share a building.

150+

curricular courses covering all aspects of Entrepreneurship Education per academic year at TUM

"Carefully weigh up potential partnerships, especially at the beginning. Your first partners continue to shape your opportunities for a long time to come."

Startup advice #1 *– Hana Milanov*

Picture credit: Astrid Eckert/TUM, graphics: edlundsepp (source: TUM)

Starting a business is just like dating!

A role-play exercise on sharing equity is a good example of such a learning tool based on research findings. It prepares entrepreneurs to navigate one of the key challenges of setting up a new venture by guiding them through equity allocation. Who gets which "piece of the pie" if one founder had the initial idea and invests more time, while another contributes more business expertise and brings in the customers? Breugst explored the journey of various startup teams and developed a role-play exercise from the results. Based on these insights, students distribute hypothetical shares, and so deal with this potentially challenging topic before even founding their startup.

Together with her colleagues, Breugst investigates the entire entrepreneurial process in her research: from founding a venture, via development and growth, all the way to the equally-important exit phase. Breugst compares the experiences of startup teams to those of a couple in a romantic relationship. At the outset, the participants discover if they are a good match and whether their joint vision has potential. When establishing a startup, they clarify who will contribute what to the partnership. In a relationship, a prenuptial agreement might not necessarily be the right route to take – but when founding a business venture, Breugst views the use of contracts as indispensable. In the growth stage, the initial excitement gradually gives way to everyday life. At that point, for instance, rituals can be helpful to keep the spark alive and sustain the partnership. And, just like a couple, a business team can split up. To avoid this escalating into a long "war of roses", a shared approach to conflict management is crucial – and external advice can also be very helpful.

"Don't patent just for the sake of patenting. Your patent is only worth as much as your ability to defend it."

***Startup advice #2** – Oliver Alexy*

Startup and growth in an uncertain environment

The ERI team aims to provide knowledge for entrepreneurial thinkers in new as well as in established organizations. In addition to the individual and team-level perspective that Breugst and Patzelt bring to the table through their research, this also calls for the business management insights contributed by Oliver Alexy.

As Professor of Strategic Entrepreneurship, Alexy investigates how companies can successfully position themselves in an uncertain environment. Why do companies make their data or algorithms publicly available? What are the benefits of open and flexible organizational models at a time of increasing digitalization? Alexy and an international research team found answers to these questions in an extraordinarily complex project: the Hyperloop. The Hyperloop is a proposed mode of passenger and freight transportation based on a fully-enclosed partial vacuum tube with a levitated capsule running inside at roughly the speed of sound. Explicitly designed as an open-source project by its initiator Elon Musk, several companies as well as interdisciplinary student-led teams, including a highly successful one at TUM, are now working on making the Hyperloop concept a reality.

In infrastructure projects of this magnitude, the work is usually first divided into small subprojects that are then handled by teams or individual staff members. "We looked at a company that took a totally different approach," reports Alexy. Hyperloop Transportation Technologies (HTT), based in Los Angeles County, California, has a core team of around 50 people and a community of about 30,000 volunteers. "For as long as the scope and structure of the work remains unclear, HTT keeps the tasks that volunteers can work on broad and vague," Alexy observes. Since many people are involved, there are many possible solution proposals, and HTT wants to remain open to all of these for as long as possible. "Only gradually does it become clear how different strands of the work need to be connected and how well – or whether at all – one solution to a particular problem fits into the picture," he says. This type of approach can prove particularly useful for startups, also enabling them to manage large, complex projects with a small core team by opening up their innovation process and integrating wider volunteer communities. "Instead of protecting all intellectual property with patents – which are often expensive – startups should likewise consider sharing knowledge with the community and so gain project partners," advises Alexy. ▷

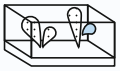
TUM's Entrepreneurship Center offers extensive services to technology-oriented entrepreneurs, from their initial ideas to the growth phase. Here, TUM and its affiliated institute UnternehmerTUM are housed together to provide a one-stop shop for these services.

Entrepreneurship Research Institute

The Entrepreneurship Research Institute conducts research into individual and organizational entrepreneurship, harnessing its findings to support young people keen to seize the opportunity to start their own venture.

UnternehmerTUM MakerSpace

UnternehmerTUM MakerSpace is a 1,500 m² high-tech workshop that enables companies and creatives to produce prototypes by offering access to equipment, tools and software, as well as a creative community.



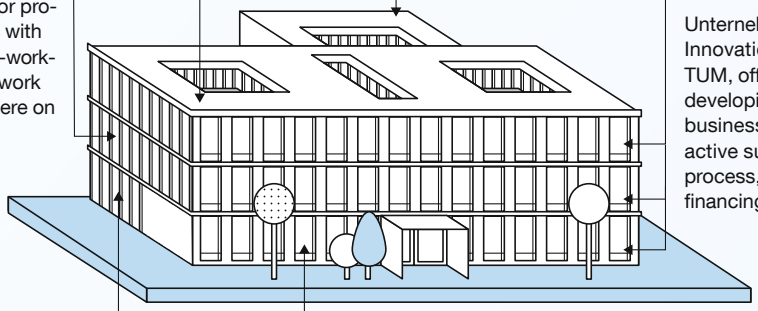
Entrepreneurship Incubator

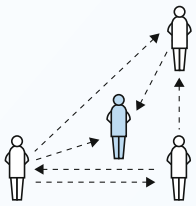
The TUM Entrepreneurship Incubator provides TUM academics and students with free startup coaching, offices and co-working space as well as access to a network of experts. Around 20 teams work here on their ideas.

UnternehmerTUM GmbH

including UnternehmerTUM Projekt GmbH and Unternehmertum Venture Capital Partners GmbH

UnternehmerTUM GmbH, the Center for Innovation and Business Creation at TUM, offers startup teams assistance with developing their products, services and business models. Here, experts provide active support throughout the launch process, as well as with market entry and financing.





Open Space for Entrepreneurship Community

The ground floor offers plenty of space for knowledge exchange, for instance through seminars, workshops and even hackathons.

Entrepreneurship Lecture Halls

At the Entrepreneurship Center, TUM and UnternehmerTUM offer a wide range of lectures, seminars and entrepreneurial training for TUM students as well as an EMBA degree program.

Graphics: ediundsepp (source: ERI)

Prof. Holger Patzelt

What makes entrepreneurs tick?

During the boom in biotech startups at the turn of the millennium, Holger Patzelt wondered: “How do business founders think? How do they make decisions?” So, when it came to writing a dissertation for his postgraduate program at the University of Bamberg, he naturally turned his attention to startup success factors. As a chemistry graduate, Patzelt earned his doctorates in molecular biology at the University of Heidelberg and in management and entrepreneurship at the University of Bamberg. He also held positions at the University of Colorado at Boulder (US), the Max Planck Institute for Economics in Jena, and the European Business School in Oestrich-Winkel. Since 2010, Patzelt has been a Professor of Business Administration with a focus on entrepreneurship at TUM. His research at TUM’s ERI focuses in particular on the motivational and decision-making processes of entrepreneurs, on handling failure, and on social and sustainable entrepreneurship.

Prof. Nicola Breugst

The people side of entrepreneurship

During her psychology studies, Nicola Breugst could find no satisfactory answer to the question of how people form companies – a topic that has driven her work ever since. She therefore wrote her dissertation on entrepreneurship at the University of Jena. After completing her doctorate, Breugst worked at the Kelley School of Business at Indiana University in Bloomington (US) and the National University of Singapore. As Professor of Entrepreneurial Behavior at TUM, her research focuses on the people side of the entrepreneurial process, in particular analyzing factors surrounding motivation and collaboration in startup teams. “Founding a business venture is an emotional rollercoaster – which makes it exciting to study,” is how Breugst explains her passion for her work.

Networking for success

Prof. Hana Milanov also investigates how companies navigate uncertainty, highlighting the role of alliances and networks, especially for startups that have yet to gain a foothold in the market. These young firms face a dual challenge – namely the need to secure vital resources and simultaneously establish recognition in the market. "This means we often see time-pressed entrepreneurs making rushed decisions on their first partnerships, which can be very costly," Milanov says. Her work in the venture capital and biotech sectors shows that the effects of early partnering decisions endure much longer than originally thought. "An alliance has a major influence on the way stakeholders assess a startup's capabilities – and a lasting one, even if the network changes over time," concludes Milanov.

At the same time, networks can be vital "pipes" to resources for startups navigating complex situations – internationalization being one of them. Here, young companies need knowledge both about the new country they wish to enter and the actual process of internationalization. "Prior research emphasized the importance of international partners for new ventures – but we know those partnerships can be difficult to manage and result in high costs," according to Milanov. Her research shows that domestic partners that internationalized their operations can be extremely helpful for new ventures trying to navigate the complexities of internationalization, especially if the entrepreneurial team lacks international experience. Her advice: "Startups should weigh up potential alliance partners very carefully, especially at the beginning, and remember that aspects of their partners' experiences – even beyond the formal purpose of the alliance – may unlock additional learning opportunities."

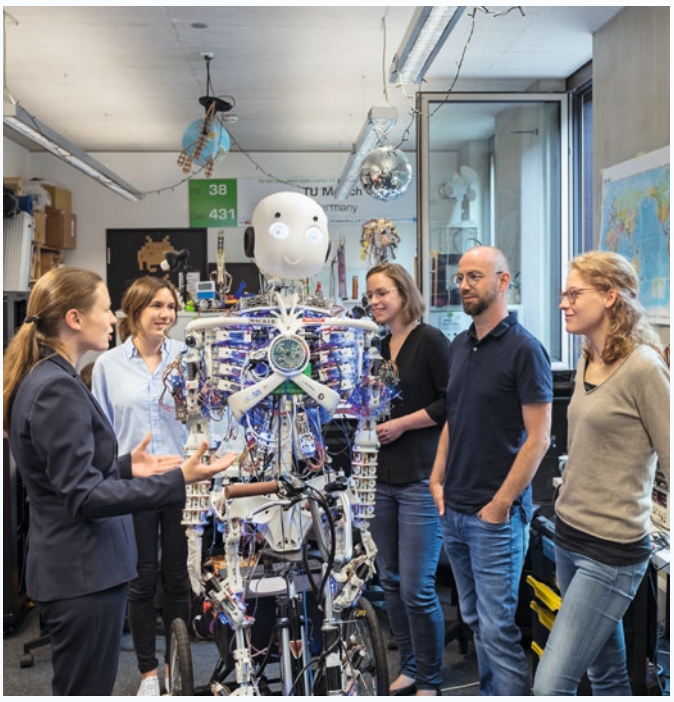
Learning entrepreneurship

On the basis of the research findings, aspiring founders can learn to avoid others' mistakes and to identify opportunities – both on individual and organizational levels. "Founders as individuals are certainly crucial to the success of a company," emphasizes Breugst. "But we can also equip them with knowledge and tools to support the entire entrepreneurial journey."

In fact, the ERI team already starts its work in the pre-founding phase, attaching great importance to hands-on experience for students. How do we identify opportunities? How do we turn an idea into a business model? How can we make effective decisions when we are overloaded with information? Interactive, hands-on exercises based on concrete questions help students working in small groups learn how to develop original ideas and find their own solutions. Certainly, some of those raising their hands in the first-semester lecture will actually begin their own startup adventure. *Gitta Rohling*

"Let yourselves get emotional, but stick to the contract and shared values which you define together as early as you can."

***Startup advice #3** – Nicola Breugst*



The Entrepreneurship Center is dedicated to experimenting with new ideas. Academics, students and entrepreneurs share this vibrant space to explore technologies, found startups and work on innovative projects, such as Roboy – an open source platform for robot development.

Picture credit: Andreas Heddergott, Astrid Eckert/TUM

Prof. Hana Milanov

It's not just who you are and who you know, but how you're known

After studying business administration in Zagreb (Croatia), Hana Milanov went to the US as a doctoral student and was immediately fascinated by the subject of entrepreneurship. She received her doctorate in entrepreneurship and strategy from the Kelley School of Business at Indiana University in Bloomington (US). Following her doctorate, she worked as a professor at IE Business School in Madrid (Spain). Her research seeks to understand the dynamics of networks and communication, and their role in entrepreneurs' (and their firms') resource acquisition, opportunity exploitation and ultimate performance – at home and across borders. "No entrepreneur ever succeeded alone – partners are a key factor in understanding the roots of startup outcomes," she concludes.

Prof. Oliver Alexy

Shaping a successful future

How can companies position themselves successfully in an uncertain environment and develop effective structures? This is an area of particular interest for Oliver Alexy, Professor of Strategic Entrepreneurship at TUM. He researches organizations that work in high-uncertainty environments – including startups as well as medium-sized and large high-tech firms. Here, Alexy's focus lies on organizational design, collaboration and knowledge transfer between companies. Originally trained in management information systems, he received his doctorate in innovation management from TUM. Prior to his appointment as a professor there, he held various positions in the Innovation & Entrepreneurship Group at London's Imperial College Business School (UK).

“Don’t tackle something new straight away, but first reflect on what’s failed. Don’t ruminate on it too much, however, or the negative emotions will gather momentum. A good balance between reflection and distraction is the key.”

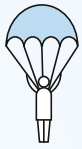
Startup advice #4 *– Holger Patzelt*

Entrepreneurship at TUM

around **70**

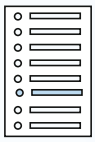
technology start-ups emerge from the TUM ecosystem each year

>1,000



technology-based, growth-oriented spin-offs in total since 1990

6th



TUM was ranked **sixth among Europe’s most innovative universities** in the 2018 Reuters Ranking.

>15k

jobs created

TUM produces **more start-up founders than any other German university,** according to the German Startup Monitor 2017

>300

TUM patents have been granted since 2000

Picture credit: Astrid Eckert/TUM, graphics: ediundsepp (sources: TUM, Bundesverband Deutsche Startups: Deutscher Startup Monitor 2017, Reuters Top 100: Europe’s Most Innovative Universities, 2018)

Promoting a “Positive Culture of Failure”

The best way for a university to support entrepreneurs in the digital age is to give them the space and the resources to experiment, as well as the opportunity to learn from failure, agree Information Systems specialist Prof. Helmut Krcmar and Dr. Helmut Schönenberger, co-founder and CEO of UnternehmerTUM, the Center for Innovation and Business Creation at TUM.

Klaus Manhart

Eine „positive Kultur des Scheiterns“ fördern

Die Digitalisierung verändert die Wirtschaftswelt: Unternehmen digitalisieren zunehmend ihre Geschäftsprozesse, Produkte werden individualisiert oder in Dienstleistungen transformiert. Vor dem Hintergrund technologischer Umbrüche wird die innovative Bedeutung von Start-ups besonders deutlich, stellt Dr. Helmut Schönenberger im Interview fest. Er ist Geschäftsführer von UnternehmerTUM, dem Zentrum für Innovation und Gründung an der TUM.

Mit einem umfassenden Angebot begleiten TUM und UnternehmerTUM technologiebasierte und wachstumsorientierte Ausgründungen bei der Entwicklung neuer Produkte und Dienstleistungen – vom erfolgreichen Geschäftsaufbau über den Markteintritt bis in die Wachstumsphase.

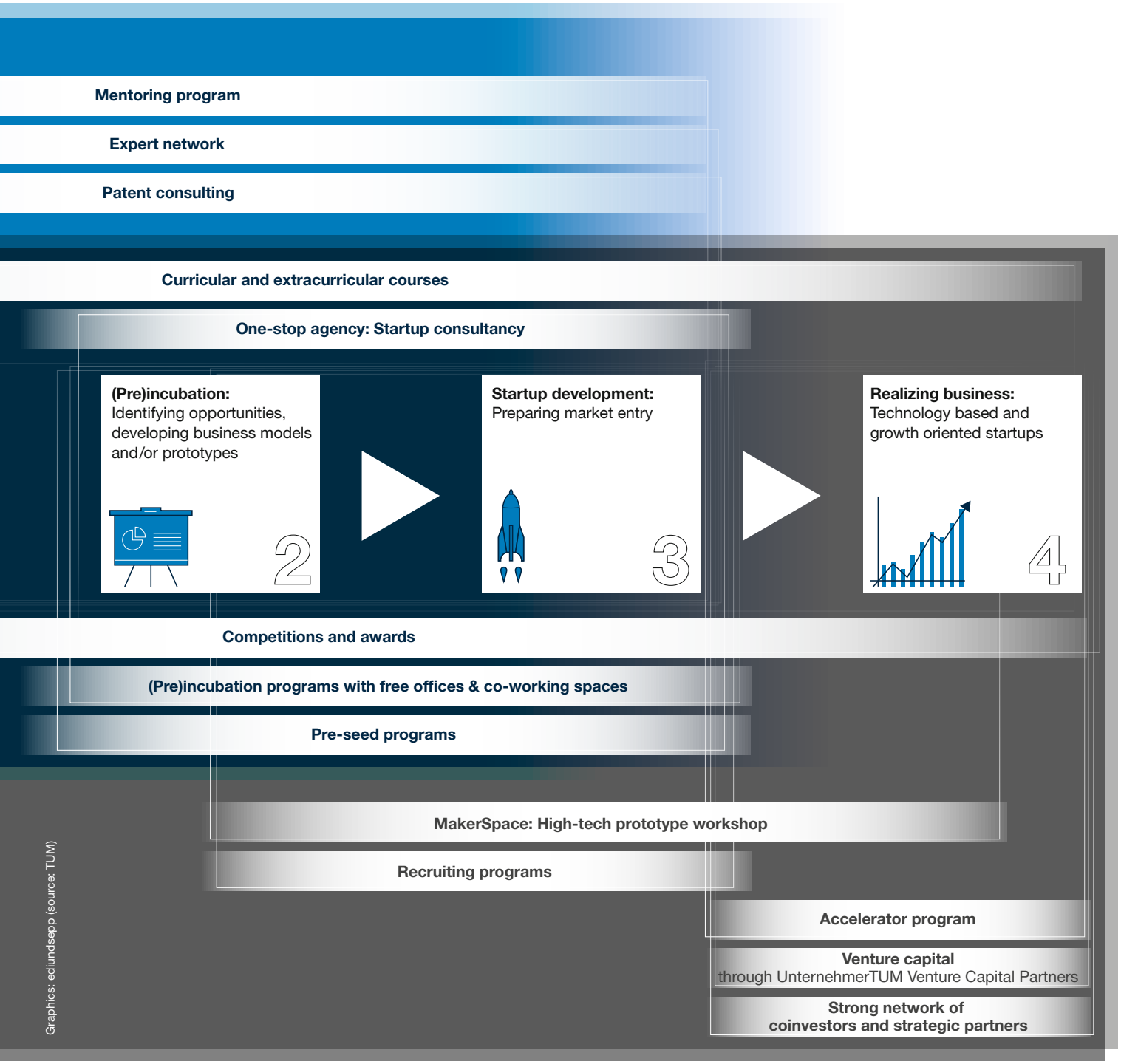
Die Gründungsteams aus dem Umfeld der TUM finden laut Schönenberger „einen geschützten Rahmen vor, in dem sie experimentieren und Dinge ausprobieren können“. Die Wissenschaftlerinnen und Wissenschaftler an den Lehrstühlen fungieren zudem als „Inspirational Advisors“, wie Prof. Helmut Krcmar berichtet: „Wir ermuntern die jungen Leute, gute Ideen zu entwickeln und diese auszubauen“, sagt der Wirtschaftsinformatiker und betont: „Wir geben ihnen ein bisschen Mut zur Größe mit“.

Wichtig ist beiden Experten, dass Universitäten eine Kultur fördern, in der das Scheitern positiv bewertet wird. „Wenn man an hoch innovativen Produkten arbeitet, wird immer nur ein kleiner Teil Erfolg haben. Wer wirtschaftlich auf die Nase fällt, kann das nächste Projekt angehen – und es vielleicht zu einem weltweiten Markterfolg bringen“, fasst Schönenberger zusammen. □

Graphics: ediundsepp

This is how we foster **entrepreneurial talents:**

Research – Education – Startups



Graphics: edlundsepp (source: TUM)

Faszination Forschung: Where do you see the biggest impact of digitalization on the business world?

Prof. Dr. Helmut Krcmar: The way I see it, the defining change comes in the form of product and service combinations, the ↦ "everything as a service" concept. This essentially means viewing "things" as service providers. These days, for instance, very few people are likely to buy a foldable city map. "Everything as a service" means you can now access a map on your smartphone when and where you need it – and for the exact city you are touring. Another example would be a company developing a sensor system. If it analyzes and evaluates the data streams from these sensors, that company can then also provide a high-value offering blending both product and service elements.

Since this brings service providers closer to their customers, they naturally need completely different processes and a lot of knowledge – in other words, data. After all, a rich knowledge base translates into products and services that are both better and more individualized. In my opinion, it is this individualization, enabled by technology, that is really driving ↦ digital transformation.

The term ↦ "disruption" is often used in this context. What does that mean?

Krcmar: Disruption is often confused with destruction. But disruption doesn't automatically mean destroying everything that was previously in place. It simply adds a new contextual layer. So the car is no longer seen as just a material product with its own image, for instance, but also as a provider of mobility services. So disruption means embracing a new value concept, with different service characteristics becoming more important.

Dr. Helmut Schönenberger: Disruption in particular shines the spotlight on the crucial role played by ↦ startups. They power innovation processes and are one of the biggest drivers of change. Digital technologies are comparatively easy and affordable to access, and entry barriers for entrepreneurs are low. That is why there are so many startups in the digitalization arena, all trying to develop new business models and reach as many customers as they can.

↦ "Everything as a service" see glossary on p. 59

Encouraging young entrepreneurs is a priority for both of them: Information Systems specialist Prof. Helmut Krcmar (left) is involved in numerous networks, which provide support for business founders as well as being a co-founder of companies himself. Dr. Helmut Schönenberger is co-founder and CEO of UnternehmerTUM, the Center for Innovation and Business Creation at TUM.

How do these business models differ from conventional ones?

Krcmar: Startup business models operate according to the "deconstruct and recombine" principle. These ventures dismantle a ↦ value chain and reassemble its links in a new and ingenious way – or they isolate one small piece of it and focus solely on that. Take the finance sector, for instance, with its ↦ fintech startups. International bank transfers are just one step in the value chain – and not a particularly profitable one you might assume. But if you bundle a whole series of transfers, that then becomes lucrative. As part of the offering of a major established bank, a mini-service such as transfers doesn't count for much. But if a fintech startup concentrates on this and cleverly markets it worldwide, it can "steal" a link in the value chain from the banks – and use it to make good money.

Schönenberger: By now, entrepreneurs have learned how to deconstruct value creation systems and extract the exciting parts. This creativity relies on three main skills: Firstly, startup teams quickly master new technologies, since they usually come from a university setting, have access to cutting-edge technologies and are keen to experiment. Secondly, they are extremely fast when it comes to implementation as they are used to agile working methods. And thirdly, compared with established companies, startups can also execute their projects very cost-effectively – particularly because these teams tend to pay themselves comparatively low salaries and hope to increase the value of their company in return.

A lot of startups are focusing on topics like machine learning and artificial intelligence at the moment. Why is that?

Schönenberger: Startups mainly position themselves in areas of technological transformation. And in the ↦ artificial intelligence (AI) arena, a window is opening right now. Many investors are keen to buy into this market and are putting up significant funds. And the technology for AI is now in place. So this is a highly attractive field for startups at present.

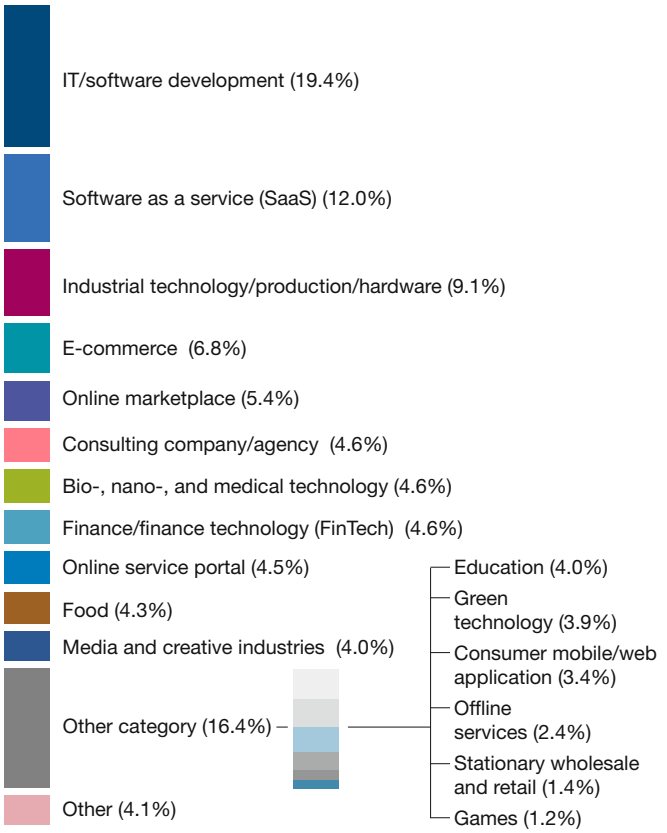
Krcmar: We have about 70 startups emerging from TUM each year – many of them with a data-driven business model. Applications range from ↦ machine learning through pattern recognition to visual detection methods – all branches of AI. The great thing about projects of this type is that the technology can be deployed across a huge number of sectors – from sports to manufacturing. ▷

appliedAI Initiative

With its mission "We accelerate the adoption of AI", UnternehmerTUM joins forces with leading public sector, industry and tech players in the "appliedAI Initiative". Combining corporate experience, entrepreneurship, the latest research and a creative mindset – the initiative accelerates the adoption of artificial intelligence (AI) in industry as well as society. UnternehmerTUM provides a broad spectrum of products and services, all focused on the understanding, development and implementation of the latest AI.

https://appliedai.de

Startup sectors and business fields



The results of the German Startup Monitor 2017 show the impact of the digital economy when it comes to new ventures: Around 19 percent of the startups surveyed stated that their venture belongs to the IT/software development sector, followed by software as a service (12%), as well as by several other sectors related to digitalization such as e-commerce and online marketplaces.

Graphics: ediundsepp (source: Bundesverband Deutsche Startups: Deutscher Startup Monitor 2017), picture credit: Kurt Bauer/TUM

What is the relationship like between established companies and startups?
Schönenberger: Collaboration between the experienced and established on the one hand, and the new and agile on the other, strengthens both domains. The BMW Startup Garage, for instance, selects young companies from around the world focused on innovations in the automotive sector. They then receive three months of support from BMW, engage with their technical departments and can build strategic partnerships.
Krcmar: In many cases, I think established companies have forgotten how to embrace new angles and new ideas. That is why partnerships of this kind are also very important for them.

How are startups from the TUM ecosystem positioned on the international stage?
Schönenberger: Both Munich as a whole and the TUM ecosystem in particular are regarded as major startup hubs. Here at TUM and UnternehmerTUM, we focus on technology-based ventures that are looking to grow. We are particularly strong in this field. With all our specialists in IT and the natural and engineering sciences, we have a strong technical foundation – while our TUM School of Management brings the business development expertise to the table.

Link
www.i17.in.tum.de

Prof. Dr. Helmut Krcmar

Research focus on digital transformation

Helmut Krcmar has been Professor of Information Systems at TUM since 2002. His research focuses include digital transformation, information and knowledge management, and engineering and management of innovative IT-based services. He is particularly interested in the role of digital platforms.
Krcmar studied business management at Saarland University in Saarbrücken, Germany, also receiving his doctorate there. He then began his research career in the US, working as a postdoctoral fellow at the IBM Los Angeles Scientific Center and as Assistant Professor of Information Systems at New York University and the City University of New York. Back in Germany, he held the Chair of Information Systems at the University of Hohenheim, Stuttgart, from 1987 to 2002, before moving to TUM.
Krcmar is involved in numerous research institutions and networks on digitalization, including as a board member of the Center for Digital Technology and Management (CDTM) and as spokesman of the Board of Directors for fortiss, the Bavarian research institute for software-intensive systems and services, affiliated with TUM. He is also Chairman of the Research Committee of the Münchner Kreis, Co-Chairman of Germany's National E-government Competence Center (NEGZ) and founder of the Initiative for Digital Transformation (IDT), as well as a Fellow of the Association for Information Systems (AIS).

"Academics can act as inspirational advisors – by encouraging young people to come up with good ideas and take them to the next level."

Helmut Krcmar

What concrete support is available for entrepreneurs at TUM?

Schönenberger: TUM students have a protected environment here, allowing them to experiment and try things out. They also have access to resources such as ↦MakerSpace and can engage with customers.

At the same time, they can benefit from a wide range of funding opportunities. Germany's Federal Economics Ministry has introduced the ↦EXIST program, for instance, where business founders can apply for a year's startup grant to ensure basic funding. TUM and UnternehmerTUM also help startup teams to regularly secure this type of support.

Krcmar: Academics from TUM's departments can also act as inspirational advisors. This means encouraging young people to come up with good ideas and take them to the next level. We encourage them to think big, for instance suggesting that digital transformation means more than just digitizing a manual.

Schönenberger: Professors and academic staff who lead by example and inspire students play a very important role. They have an entrepreneurial mindset and some of them have started ventures themselves too. Their experience and – above all – their passion are something they can pass on. This also contributes significantly to the entrepreneurial culture here at TUM.

Where does a startup begin, and how does it then develop?

Schönenberger: The beginnings of a spin-off can be traced back to the teaching and learning process – for instance to the ↦entrepreneurship training offered by the TUM Entrepreneurship Research Institute (ERI) (see also p. 40) and UnternehmerTUM. The next step is to give students a basic understanding of how to develop a product and how to start a venture. The joint startup coaching provided by TUM and UnternehmerTUM supports prospective company founders in developing their idea and taking the next step. If they then decide to proceed with a startup, office space and advisory services are also available at TUM's ↦incubator. ▷

UnternehmerTUM – Center for Innovation and Business Creation at TUM

UnternehmerTUM is TUM's center for innovation and business creation. This institute assists startups and established companies in developing new products and services, also helping to build the business, prepare for market entry and drive growth, which includes the securing of venture capital. UnternehmerTUM's high-tech workshop, MakerSpace, offers an extensive range of equipment over 1,500 square meters to enable prototype construction and small-scale production.

UnternehmerTUM GmbH was founded in 2002 by the entrepreneur Susanne Klatten. More than 50 high-growth spin-offs emerge each year from UnternehmerTUM alone, with over 2,000 people taking part in training courses. In 2017, Germany's Federal Economics Ministry designated UnternehmerTUM a "digital hub" to drive digital transformation in the mobility sector.

www.unternehmertum.de

Picture credit: Kurt Bauer/TUM

“It is a major opportunity for universities to promote a positive culture of failure.” *Helmut Schönenberger*

Any startup also carries the possibility of failure. How can these ventures stand the test of time?
Krcmar: It’s fundamentally important that we support young people who want to start their own business. And that also means helping them work out how much time they want to invest and where to cut back. If a project does go down the tubes, we hold a “wake”, emphasizing the fact that we had fun and we learned something, but just because we started implementing an idea three years ago doesn’t mean we have to continue pursuing it now.
Schönenberger: This is a major opportunity for universities to promote a positive culture of failure. When you’re working on highly innovative products, only a few of them will ever be successful. But that is not a problem, since the projects themselves provide a valuable learning experience. And even if you do fall flat on your face from a commercial perspective, you can dust yourself down and get back in the saddle – perhaps even making the next project a global market success.
Klaus Manhart

Dr. Helmut Schönenberger

Leading startups to success

Helmut Schönenberger is co-founder and CEO of UnternehmerTUM, the Center for Innovation and Business Creation at TUM. His passions lie in inspiring people in the areas of innovation and entrepreneurship and leading promising startups to success. During his studies in management at TUM, the aerospace engineer already started a consulting business with fellow students and developed a strategic concept for the university’s management team to strengthen its startup culture – the origins of UnternehmerTUM. Schönenberger has played a major role in the design and ongoing development of UnternehmerTUM’s services for startup teams, scientists and companies.

Glossary

Artificial intelligence (AI)
"Artificial intelligence" is a branch of computer science that seeks to simulate human cognitive functions, such as thinking, problem-solving and reasoning, in computers. Its core focus lies on the development of programs and machines intended to function along similar lines as human intelligence.

Digitalization
Whereas "digitization" refers to the conversion of analog processes to digital formats to enable computer processing, "digitalization" has a broader sense, describing the digital transition or shift to a digital business model in which all processes are computerized.

Digital transformation
"Digital transformation" is the trend among organizations to use digital technologies throughout their operations and digitalize all business processes, develop new business models and tap into modified value-adding arrangements. Digital transformation is driven by digital infrastructures and applications (e.g. apps).

Disruption
In this context, "disruption" means a high-speed shift from the familiar to something new and revolutionary. Examples of disruption include the upheaval in the taxi industry caused by driving service Uber or changes in the entertainment industry in the wake of streaming services such as Amazon and Netflix.

Entrepreneurship
"Entrepreneurship" refers to the foundation of companies based on innovative business ideas. Entrepreneurship is characterized by the ability to recognize and seize market opportunities and turn them into profitable undertakings. This entails the coordinated deployment of resources and the willingness to embrace a calculated level of risk.

Everything as a service
"Everything as a service" or "anything as a service" (most commonly abbreviated XaaS or EaaS) describes a scenario where everything is provided and consumed as a service. Tangible and intangible assets are no longer bought but rented; either converted into services or flanked by them. Thus the customer no longer owns a product, such as a car, but procures the benefits of the product as a service.

EXIST program
Germany's Federal Ministry for Economic Affairs and Energy (BMWi) has been offering support through its EXIST – University-Based Business Start-Ups program since 1998. Targeting students, graduates and scientists, this aims to increase awareness, motivation and skills in the startup field, as well as providing initial funding for the launch phase.

Fintech
"Fintech" stands for "financial technology" and is a collective term for technologically advanced financial innovations that result in new financial services. In a narrower sense, the term is often applied to startups offering digital or technological financial innovations.

Incubator
In the business context, an "incubator" helps new and startup companies to develop. At TUM, the incubator provides office space and workstations for entrepreneurs, as well as startup coaching. Building on this, UnternehmerTUM also offers a dedicated incubator program, XPRENEURS.

Machine learning
"Machine learning" describes the acquisition of new knowledge by a computer system and is thus a branch of AI. Like a human being, the computer generates its own knowledge from experience and can find solutions to new problems autonomously. This is achieved by a computer program analyzing examples and attempting to identify certain patterns and rules in the data with the aid of self-learning algorithms.

Makerspace
"Makerspaces" are open spaces where people work creatively on new ideas, projects and physical objects. Spanning 1,500 square meters on the Garching research campus, UnternehmerTUM's MakerSpace offers introductory courses and access to software, machines and tools – from laser cutters to 3D printers.

Startup
A "startup" refers to a team preparing to launch a venture or to a recently founded company, bringing its own – ideally highly innovative – business idea to market and striving for rapid growth.

Value chain
A "value chain" describes the interlinked activities or steps that combine to enable a company to create value or manufacture products of value. It shows the path of a product or service during its transformation: from input or starting material to output or use case.

Picture credit: Kurt Bauer/TUM

Three questions for **TUM's Data Protection Official...**

Faszination Forschung: Why is data protection such a hot topic in connection with digitalization?
Prof. Uwe Baumgarten: Large amounts of data are collected in the course of many digital projects. This often includes personal data such as an individual's whereabouts, habits or profiles and even fitness information. This is where data protection comes into play: Whoever gathers such personal data has to take the legal framework into consideration, and above all the right to self-determination in regard to information. This right has been strengthened with the EU's new General Data Protection Regulation. The person whose personal data is processed must have a clear understanding of what happens with their data and give their express consent. A good approach here would be to use consent forms, which provide easy-to-understand information about the purposes of data processing.

How does research contribute to the topic of data protection?
An important aspect is the improvement of anonymization techniques. This means changing the data so that no conclusions can be drawn about individuals. Then you have machine learning and artificial intelligence processes, where algorithms are "trained" with large amounts of data – personal data in particular – and learn how to make decisions. Their reason for making a particular decision is often not so easy to understand, however, hence the interest in research aimed at exploring and explaining these processes.

What advice would you give startups with a data-driven business model?
The first thing entrepreneurs need to reflect on is whether they really need personal data for their business model. If they do, they must ensure transparency about what and whose data they are collecting. The users' right to ask for information about their stored personal data has been strengthened. They may also request that inaccurate data be corrected, withdraw their consent for future data processing, and even demand the deletion of their data. Companies have to be well prepared for this eventuality: It is relatively easy to accumulate and store data, but not so easy to delete it on a selective basis.

Undine Ziller

Prof. Uwe Baumgarten

Following his undergraduate and doctoral studies in Informatics at the University of Bonn, Uwe Baumgarten qualified as university professor in Informatics at Carl von Ossietzky University Oldenburg. Baumgarten has been Professor of Informatics at TUM since 1994. The focus of his research lies in the field of mobile distributed systems. He has held the position of Data Protection Official at TUM since 2010. In this position, he takes care of informing and advising people about data protection regulations and the resulting obligations and monitors compliance with these regulations.

Link
www.datenschutz.tum.de

Picture credit: Astrid Eckert/TUM

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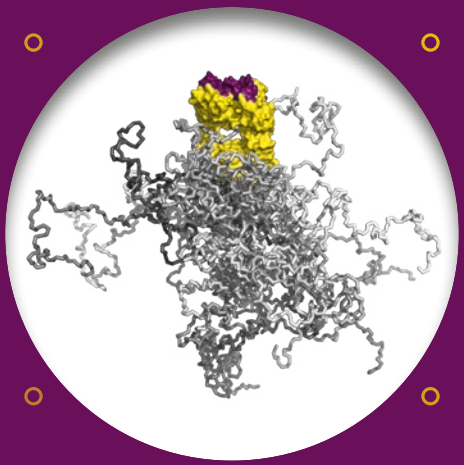
Small Molecules, Big Impact

Arne Skerra is one of TUM's most prominent entrepreneurial scientists. He knows exactly what it takes to create a company spin-off and why a winning streak can sometimes be a double-edged sword.



Graphics: ediundsepp

Prof. Arne Skerra

Pioneering protein design

Arne Skerra holds the Chair of Biological Chemistry at TUM, having been in post since 1998. He is also one of the university's most successful company founders. The protein designer originally studied chemical engineering at the Technical University of Darmstadt, Germany, and was awarded his doctorate (Dr. rer. nat.) in 1989 by Ludwig-Maximilians-Universität München (LMU). His thesis at the LMU Gene Center focused on the genetic engineering of antibodies in the laboratory bacterium *E. coli* – an important invention already at this early stage in his career, which swiftly found worldwide application. Today, Arne Skerra is (co)inventor of more than thirty international patent families.

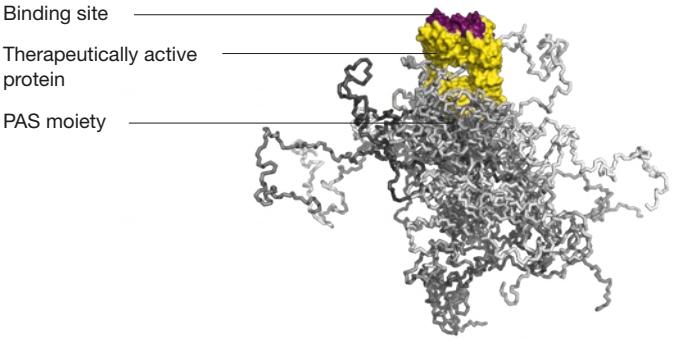
As a postdoc, his career first took him to Cambridge, UK, to the prestigious MRC Laboratory of Molecular Biology. He then returned to Germany as a group leader at the Max Planck Institute of Biophysics in Frankfurt, directed by Nobel Prize winner Dr. Hartmut Michel. He completed his qualification (Habilitation) at Goethe University Frankfurt in 1995 and held a professorship in protein chemistry at the Technical University of Darmstadt from 1994 to 1998. With his appointment at TUM, he established the new Chair of Biological Chemistry at the life science center in Weihenstephan. Thus far, his Chair has been a springboard for two well-known international spin-off companies: Pieris Pharmaceuticals, Inc. and XL-protein GmbH. Skerra is a full member of the German Academy of Science and Engineering (acatech) and a recipient of TUM's Heinz Maier-Leibnitz Medal. In 2005, he was also awarded the Karl Heinz Beckurts Prize for his achievements in applied science.

"You have to have a certain entrepreneurial spirit to steer a startup over all the hurdles on its path." *Arne Skerra*

Brigitte Röthlein

Kleine Moleküle ganz groß

Arne Skerra, Professor für Biologische Chemie an der TUM, ist einer der weltweit führenden Protein-Designer. Immer wieder entwickelten er und sein Team Innovationen auf dem Gebiet der Protein-Biotechnologie, mehrere davon wurden in Ausgründungen vermarktet.
So erfand Skerra beispielsweise ein Verfahren, um die Aufenthaltsdauer von pharmazeutischen Wirkstoffmolekülen im Körper zu verlängern. Dazu konstruierte er eine Kette aus den drei kleinen, natürlichen Aminosäuren Prolin, Alanin und Serin (PAS), die mit dem Proteinwirkstoff gekoppelt wird. Wie ein molekularer Wattebausch umgibt diese das therapeutisch aktive Protein und verhindert so, dass dieses zu schnell durch die Nieren aus dem Blutkreislauf filtriert wird. Diese Innovation wird PASylation-Technologie genannt und kann das bisher übliche Verfahren der PEGylation ersetzen, welches mit einigen Nachteilen behaftet ist. Die Entwicklung führte zur Gründung der XL-protein GmbH durch ein Team um Skerra im Jahr 2009. Bereits acht Jahre zuvor gründete Skerra zusammen mit Weggefährten die Firma Pieris. Im Jahr 2016 ging diese Firma als Pieris Pharmaceuticals, Inc. an die US-Börse Nasdaq. Sie beschäftigt sich mit der Herstellung von Anticalinen, künstlichen kleinen Bindeproteinen, die für verschiedene therapeutische Zwecke nützlich sind. Auch bei dieser Plattform-Technologie, die an seinem Lehrstuhl von den wissenschaftlichen Grundlagen bis zur Anwendung entwickelt wurde, war Skerra der Erfinder.
Eine weitere Ausgründung ist von Skerra und Mitarbeitern für die kommenden Jahre bereits geplant: Diesmal geht es um Proteine, die durch Licht schaltbar sind. □



Like a ball of cotton wool, a chain of the amino acids proline, alanine and serine (PAS) wraps around the therapeutically active protein. This voluminous structure causes delayed kidney filtration – keeping the active substance in the bloodstream for longer.

The idea struck the researcher at a conference in Berlin in 2005. The discussion revolved around ways of making active biopharmaceutical proteins, which usually get excreted quickly by the kidneys, stay longer in the human body so they could better unfold their therapeutic effect. Arne Skerra, Professor of Biological Chemistry at TUM since 1998, first became aware of this issue in connection with his groundbreaking research on Anticalin proteins. Designed by him years before, these biomolecules act like antibodies but are significantly smaller, making them both simpler to produce and easier to distribute inside the body. One option for prolonging their circulation in the blood was a process known as PEGylation. This involves coupling the active protein to polyethylene glycol (PEG), an artificially produced macromolecule (polymer). PEG can be attached to the active ingredient as a highly flexible chain, increasing the molecule's apparent size so that it no longer fits through the fine pores of the kidney and thus remains in the bloodstream for a longer period of time. ▷

Picture credit: Magdalena Jooss/TUM, graphics: ediundsepp, Arne Skerra

“At the Berlin conference, several presentations reported difficulties with production, and, also, there were observations from animal experiments that PEG can accumulate in the kidneys, liver and even the brain, because the body cannot break it down,” Skerra remembers today. “Having heard about all these problems with PEGylation, I started to think there must be a more elegant way to resolve this challenge. And the first thing I thought of was replacing PEG with polyglycine.” During subsequent laboratory testing, however, it turned out that this design was not ideal. So, in a second attempt, Skerra constructed a biopolymer from a sequence of three other, naturally occurring small amino acids: proline, alanine and serine (PAS). His experiments showed that this biological polymer behaves in a surprisingly similar way to PEG and, when coupled to a therapeutic protein, dramatically prolongs its in-vivo life span. This biological polymer also has the advantage that it can be genetically engineered and produced together with an active protein molecule, and, importantly, it is totally biodegradable.

Dream team – uniting business with technology

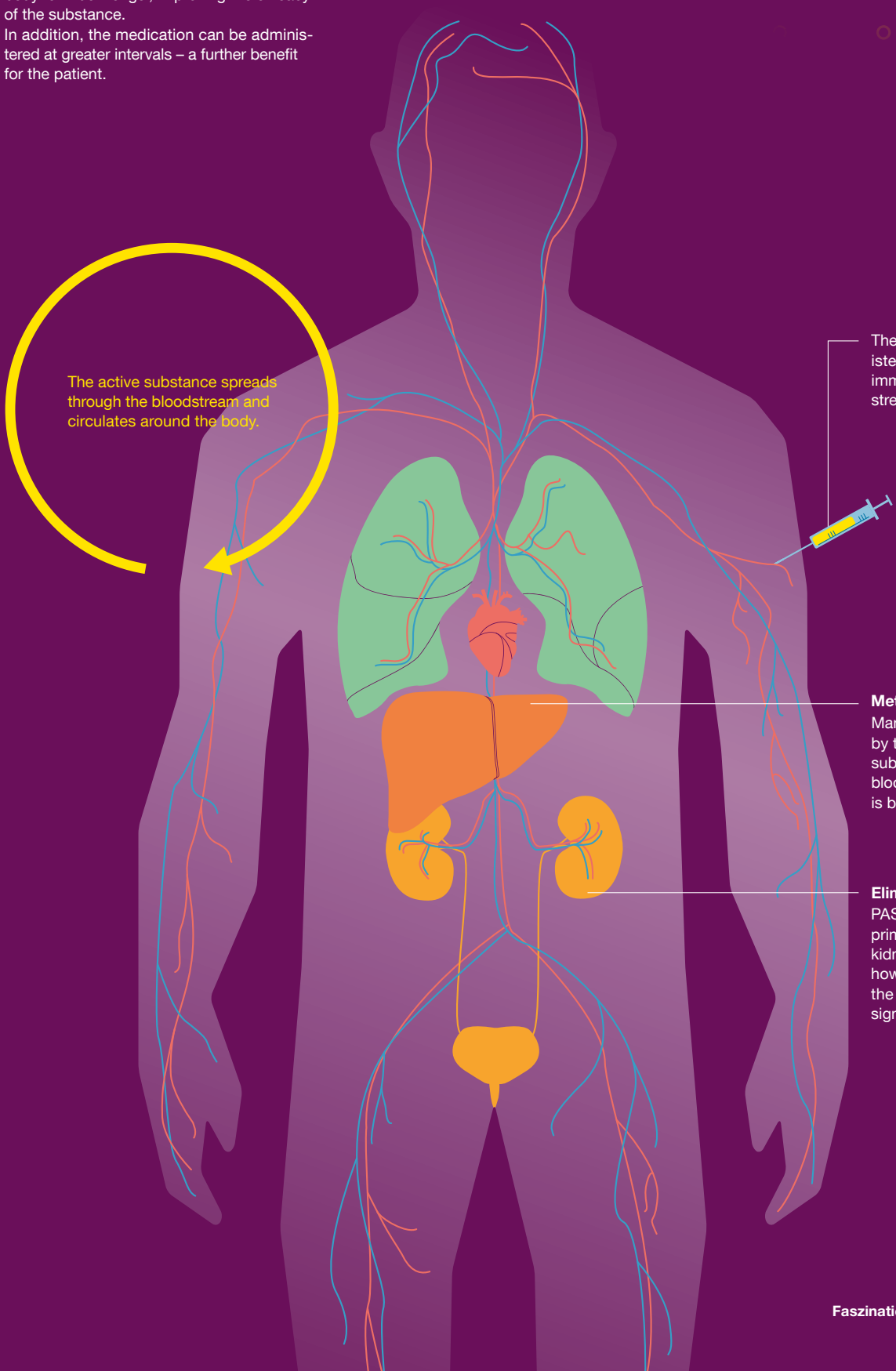
It was evident to Skerra and his co-inventors that this innovative PASylation technology, which was patented through TUM, had significant market potential. Consequently, in April 2009 they decided to start a company for its commercialization: XL-protein GmbH. The company acquired the exclusive licensing rights from Bayerische Patentallianz (BayPAT), the technology transfer office that markets TUM’s patents. “XL-protein pays annual license fees, which were moderate at the start and increase over time, reflecting the fact that it takes a while for a new biotech venture to gain a strong financial footing,” Skerra explains.

Entrepreneur Claus Schalper has been an important ally and business partner throughout. “The two of us make a pretty good team – as we already saw in the past when we together founded the company Pieris,” confirms Skerra. “Besides the technology and finances, psychology plays a very important role when you’re developing a company. You have to negotiate constantly – with licensors, investors and potential partners or customers. In our case, a visionary scientist and a business-savvy entrepreneur is a win-win combination.” The duo quickly found a pharmaceutical company as a customer in a strong financial position that was interested in XL-protein and its PASylation technology, and the first business project kicked off.

Headquartered in the Innovation and Startup Center for Biotechnology (IZB) in Weihenstephan, the company now employs about ten people. It has concluded a number of cooperation agreements with prominent pharmaceutical and biotech companies keen to leverage the PASylation technology. XL-protein pursues a two-pronged business model. Initially the company constructs PASylated drugs and produces small amounts of test substances for feasibility studies. If these are successful and the partner decides to embark on advancing development, XL-protein issues a sublicense. ▷

Prolonged circulation in the bloodstream

Biopharmaceuticals often comprise small proteins that are quickly excreted from the body. Molecules enlarged with the help of PASylation technology circulate in the body for much longer, improving the efficacy of the substance.
In addition, the medication can be administered at greater intervals – a further benefit for the patient.



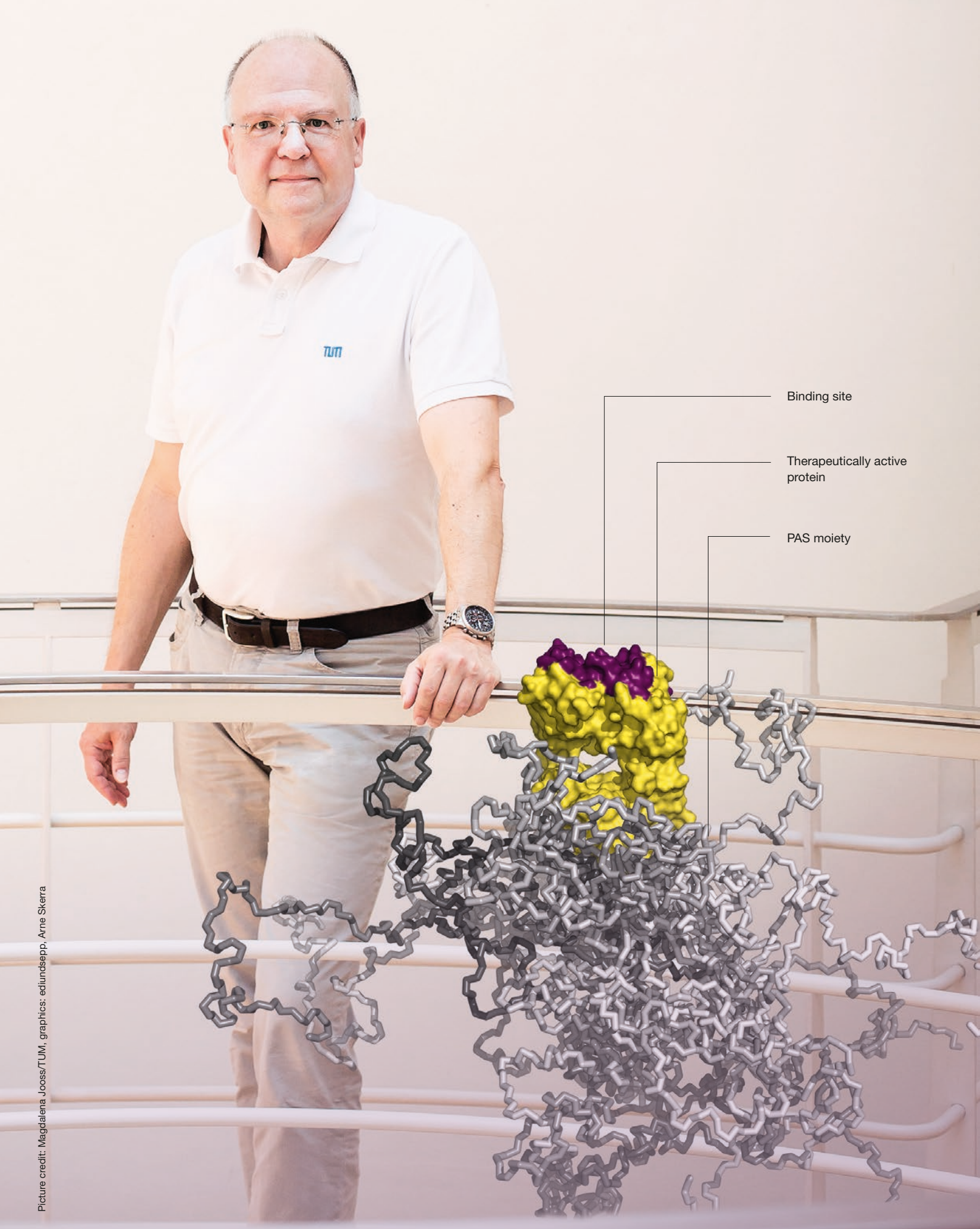
Graphics: ediundsepp (source: TUM)

Arne Skerra is one of the world's leading protein designers. With two successful startups behind him, he is currently preparing for a third.

Competitions and competitive thinking

For the spin-off XL-protein, Skerra was able to draw on experiences gained eight years before, when he founded Pieris to market his Anticalin technology. That venture capital funded company went through various stages and, meanwhile listed on the stock exchange as Pieris Pharmaceuticals, Inc. (Nasdaq: PIRS), now occupies a solid market position.

Although Skerra is passionate about his fundamental work as a researcher in protein science, he is also no stranger to business acumen. "Some find it daunting, but I have always been fascinated by the prospect of thinking research through to the real-world application. Back during my studies at the Technical University of Darmstadt, I was challenged to scale chemical processes to multi-ton quantities. And it goes without saying that cost considerations also influence the application potential," he reflects. "I always had a head for financial figures, and I credit my parents for my awareness of monetary value and sense of economy." ▷



Picture credit: Magdalena Jooss/TUM, graphics: ediundsepp, Arne Skerra

In 2000, when the Pieris spin-off was still in the planning stages, Skerra saw posters about the Munich business plan contest (MBPW) and decided to participate. “Their events offered coaching and advice and it was there that I first found out in detail what a business plan entails,” he recalls. “The MBPW also provided a variety of networking opportunities and, among other things, a bulletin board with a contact forum. That’s how I got to know my co-founder, Claus Schalper, who took responsibility for the commercial and business development side. We were on the same page right from the start.” The four-strong team, including two other scientists, won the first prize at the MBPW in July 2000.

As Skerra sees it, such competitions can certainly be supportive. XL-protein has had its fair share of success in that arena too, including at the Science4Life Venture Cup, where the startup was awarded the first prize in 2010. “That was a key learning experience,” he underscores, “allowing us to talk not only to coaches, but also to investors. At the same time however, I came to see that a winning streak can be a double-edged sword as it can fuel resentment among colleagues and jury members.”

Still, this does not deter Arne Skerra from continuing to ensure promising research results make it to market. Indeed, plans for his next spin-off are already under way. This one focuses on proteins that can be switched on and off by light. The German Federal Ministry for Economic Affairs and Energy (BMWi) is currently funding the research project as part of its EXIST initiative, with the aim of bringing it to market.

Skerra is somewhat hesitant to hand out general advice for young researchers looking to follow in his footsteps, since his position as an established professor and Chair holder means he is not the typical university-based startup entrepreneur. Yet he is quite happy to draw on his experience to help with specific issues. And for him one thing is clear: “You need to have a certain entrepreneurial spirit in order to steer a startup over all the hurdles on its path. And finding the right contacts is crucial – outside but also within the university. I recommend face-to-face conversations if at all possible. That is often the key to finding a successful compromise.” *Brigitte Röthlein*

"Some find it daunting, but I have always been fascinated by the prospect of thinking research through to the real-world application."

Arne Skerra

Picture credit: Magdalena Jooss/TUM, graphics: ediundsepp

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A Feel **for the Flow**

When Albert Sepp shared his idea ten years ago, most people were skeptical: A hydroelectric power plant you can't see because the turbine and generator are hidden in a riverbed shaft? That allows fish to pass safely and freely downstream? Fortunately, Sepp's boss Peter Rutschmann wasn't one of them. "Let's try it," he said and now the idea is becoming reality – on the river Loisach in Bavaria.

Daniela Becker

Herrn Sepps Gespür für Strömung

In der Loisach, nahe der Gemeinde Großweil in Bayern, entsteht das weltweit erste Schachtkraftwerk. Bei diesem ökologischen Wasserkraftwerk befinden sich Turbine und Generator in einem Schacht, der vor einem Wehr im Flussbett eingebaut ist. Auf diese Weise sind nur minimale Eingriffe in die Landschaft erforderlich. Durch die Führung der Strömung über dem Schacht sind Fische in hohem Maße vor Verletzungen geschützt und können über ein „Abstiegsfenster" – eine Aussparung im Wehr – flussabwärts wandern.

Erdacht wurde das Schachtkraftwerk von Dipl.-Ing. Albert Sepp und Prof. Peter Rutschmann vom Lehrstuhl für Wasserbau und Wasserwirtschaft der TUM. Über viele Jahre verfeinerten die Ingenieure gemeinsam mit ihrem Team die Technologie. Die TUM hält daran inzwischen zahlreiche Patente in verschiedenen europäischen Ländern sowie in den USA, in Kanada und Brasilien. „Wir haben etwas Neues entwickelt, das der gesellschaftlichen Forderung nach mehr Naturschutz Rechnung trägt", sagt Rutschmann.

Das einfach zu konstruierende und kompakte Kraftwerk mit geringem Bauvolumen ist für kleine und große Wasserkraftstandorte gleichermaßen geeignet. An größeren Wehren können mehrere Schächte nebeneinander angeordnet werden. „Wir können die Turbine und den Generator aber auch in einem Container vorinstallieren und solch ein Minikraftwerk in Gegenden fernab vom Stromnetz transportieren", sagt Rutschmann.

Wenn das erste Schachtkraftwerk im Frühjahr 2019 in der Loisach in Betrieb geht, sind Sepp und Rutschmann ihrem Ziel einen großen Schritt näher: Die klimafreundliche Wasserkraftnutzung naturschonender zu gestalten. □

Graphics: ediundsepp

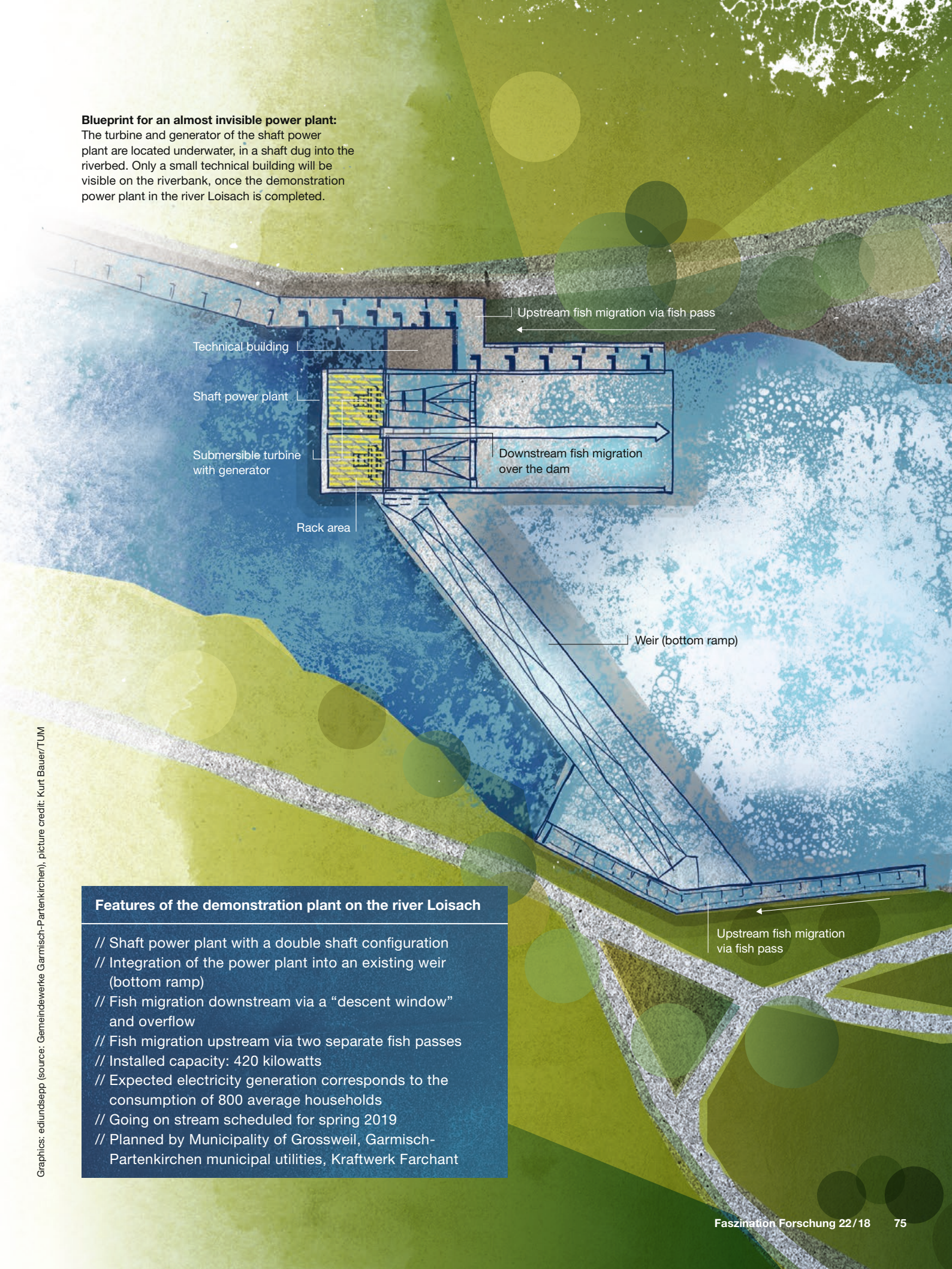
The first shaft power plant is to be built on the Bavarian river Loisach, using an existing weir.

It's a spring morning and the air is chilly. The peaks of the Bavarian Alps towering in the background are still covered in snow. Albert Sepp and Prof. Peter Rutschmann stand on the banks of the Loisach river near the Bavarian village of Grossweil and survey the construction site.

They are looking at a pit the size of a classroom in the riverbed. Since the 1970s, this has been the location of a bottom ramp – layers of stones and boulders between a series of sheet pilings. The ramp maintains the groundwater level and protects the Loisach's riverbed. And now, this is where the municipality of Grossweil – together with the Garmisch-Partenkirchen municipal utilities and a local power plant operator – is busy constructing the hydropower plant Sepp and Rutschmann have spent so many years researching. Implemented here for the very first time, the power plant is concealed in a shaft in the riverbed. The aim is to generate climate-friendly electricity with as little impact as possible on fish and their habitat. The so-called "shaft power plant" is scheduled to go on stream in spring 2019. ▷

Engineers Albert Sepp (right) and Prof. Peter Rutschmann have developed the so-called "shaft power plant". Construction of the demonstration plant at Grossweil could be an important step toward widespread use of this new hydroelectric power concept.

Blueprint for an almost invisible power plant:
The turbine and generator of the shaft power plant are located underwater, in a shaft dug into the riverbed. Only a small technical building will be visible on the riverbank, once the demonstration power plant in the river Loisach is completed.



Graphics: ediundsepp (source: Gemeindewerke Garmisch-Partenkirchen), picture credit: Kurt Bauer/TUM

Features of the demonstration plant on the river Loisach

// Shaft power plant with a double shaft configuration
// Integration of the power plant into an existing weir (bottom ramp)
// Fish migration downstream via a “descent window” and overflow
// Fish migration upstream via two separate fish passes
// Installed capacity: 420 kilowatts
// Expected electricity generation corresponds to the consumption of 800 average households
// Going on stream scheduled for spring 2019
// Planned by Municipality of Grossweil, Garmisch-Partenkirchen municipal utilities, Kraftwerk Farchant

“I think it’s important not to get ahead of ourselves. But when an idea finally takes shape, it certainly does feel good.” *Albert Sepp*

Eco-friendly hydropower

Albert Sepp has spent his entire career working with water. The civil engineer conducts his research at TUM’s Laboratory of Hydraulic and Water Resources Engineering, led by Rutschmann. Sepp, who lives in a passive energy house and drives an electric car, is on a mission to make hydroelectric power more eco-friendly.

In conventional hydropower plants, water from a dammed river is channeled either directly or via a conduit to a power house, where it flows through the turbines and is then fed back into the river. This is problematic for river wildlife because their natural migration routes are disrupted by the dam and power station structures. Although technical solutions to enable the downstream migration of fish are legally required, their effectiveness is often debatable. If fish swim into the turbine, there is also a risk that they will be injured or killed.

Sepp has investigated many power plant concepts over the years. “I just wasn’t satisfied with the status quo,” he explains. The engineer set about doing some calculations and building physical flow models. In 2008, he put his idea down on paper for the first time: His aim was to dig a shaft – complete with turbine and generator – into the riverbed, removing the need for outlet flow and backflow altogether. This, Sepp believed, would improve flow dynamics while reducing the impact on fish migration and the river ecosystem as far as possible. And so the idea of the shaft power plant was born.

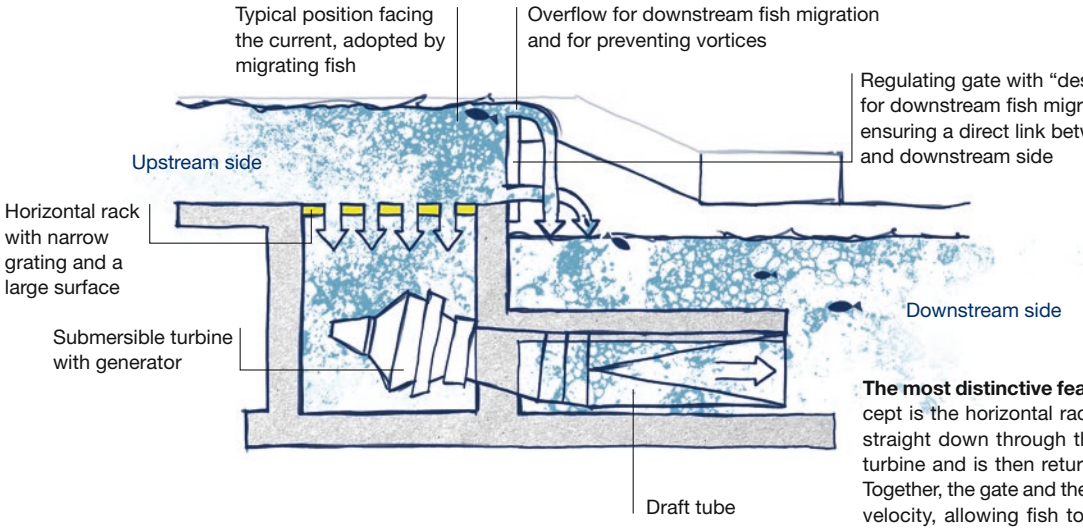
Protecting the river habitat

The standout feature of the shaft power plant is its rack configuration. This metal grate prevents debris such as stones, branches and leaves from getting into the turbine. In Sepp’s concept, it is positioned horizontally across the shaft in the riverbed. The water for the power plant pours straight down through the rack into the shaft, drives the turbine and is then returned to the riverbed downstream. Water also flows over the dam through an adjustable gate above the shaft. This regulating gate can also be opened to divert floating debris and floodwater.

The distances between the bars of the rack are small, but the overall rack area is large, ensuring low flow speeds over the shaft. Together with the overflow, this prevents larger vortices from forming on the water’s surface. In this way, fish can move freely over the shaft and migrate downstream. “My hope was that the fish would swim with the horizontal current to special openings – descent windows – in the regulating gate, rather than following the downward shaft current,” Sepp explains.

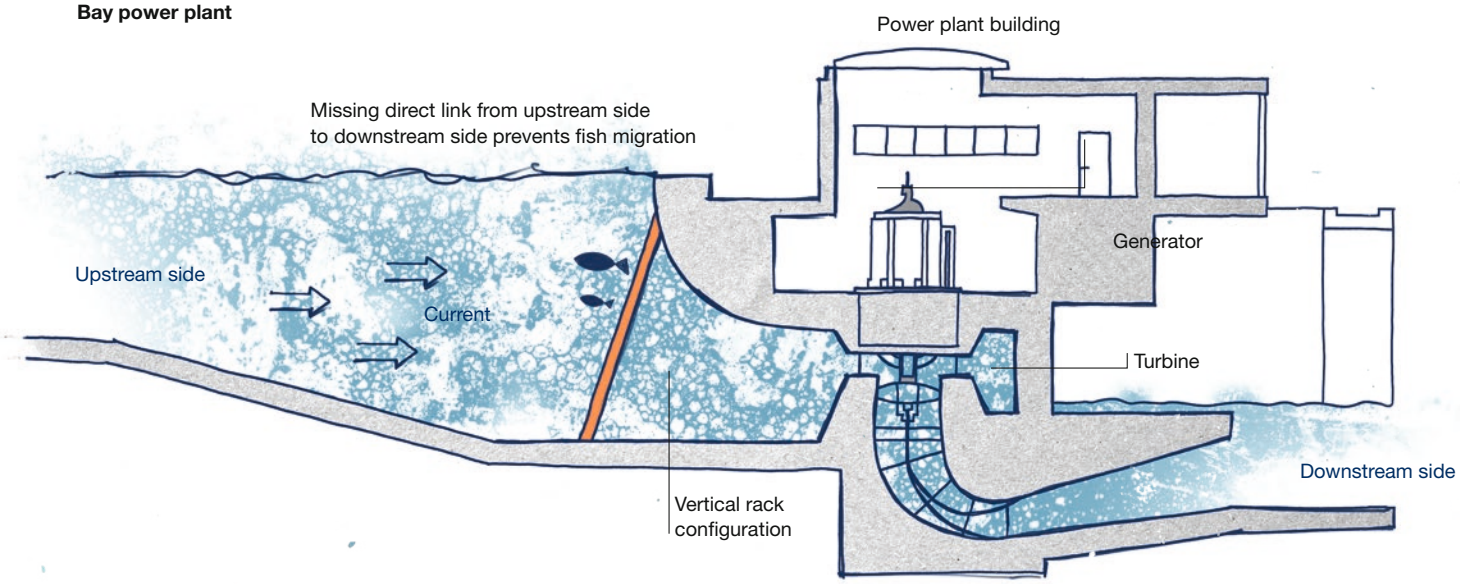
This idea of his caused quite a stir in certain professional circles. Many people in the hydropower industry found it difficult to believe that the horizontal rack idea would actually work, while others were skeptical about the new design because the turbine in a shaft power plant is not accessible around the clock. “But this is not in fact necessary, since the technology used is particularly low-maintenance and stable,” outlines Peter Rutschmann, Chair of Hydraulic and Water Resources Engineering at TUM. ▷

Shaft power plant



The most distinctive feature of the shaft power plant concept is the horizontal rack configuration: The water pours straight down through the rack into the shaft, drives the turbine and is then returned to the riverbed downstream. Together, the gate and the rack ensure a low, controlled flow velocity, allowing fish to swim safely and freely over the shaft and pass downstream.

Bay power plant



In conventional bay power plants, the rack has a vertical position, "barring" the way for fish to pass downstream. At the rack, migrating fish continuously fight against being entrapped. Once exhausted, they are at high risk of passing through the turbine and being injured.

Benefits of the shaft power plant concept in comparison with conventional bay power plants

// Only a small technical building above ground required; plant itself completely underwater, avoiding noise emissions and alterations to the landscape
// Effective technology for fish descent
// Flow continuity for bed load and floating debris
// Flood safety
// Can be retrofitted at existing weirs
// Improved river continuity
// Reduced construction work; prefabrication possible

Graphics: ediundsepp (source: Albert Sepp/TUM)

Dipl.-Ing. Albert Sepp

Harmonizing power production with environmental protection

Albert Sepp is a graduate engineer FH from the Munich University of Applied Sciences. He has been part of the team at TUM's Laboratory of Hydraulic and Water Resources Engineering in Obernach since 1980, focusing mainly on physical model testing. He also works as a freelance engineer in the fields of hydropower and energy technology.
As the inventor of the eco-friendly shaft power plant, he was a joint recipient of TUM's Heinz Maier-Leibnitz Medal along with Prof. Peter Rutschmann in 2016. This award was presented by University President Prof. Wolfgang A. Herrmann, "in recognition of pioneering engineering achievements in the design, planning and technical implementation of a new type of hydropower that provides an optimum balance between economic and environmental interests."

A feel for the flow

Sepp picked the quiet time between Christmas and New Year in 2008 to divulge his idea, wanting to know if Rutschmann also saw potential in the shaft power plant. "You bet!" thought the professor. "Few people have as intuitive a sense of how water flows as Albert Sepp," he confirms. So, from then on, the inventor had an experienced expert from the scientific community on board, who helped drive the idea even when they encountered resistance. "To me, being an engineer doesn't just mean continually improving an idea from fifty years ago," emphasizes Rutschmann. "More to the point, it means looking at the challenges that society currently faces. We have developed something new to meet the need for more effective nature conservation."
TUM filed two initial patent applications for the shaft power plant concept with the German Patent and Trade Mark Office (DPMA) in 2009, followed by further applications. Today, the university holds patents in numerous European countries as well as the US, Canada and Brazil.

"To me, being an engineer doesn't just mean continually improving an idea from fifty years ago – it means developing something new."

Peter Rutschmann

A promising prototype

In 2010, the two engineers teamed up with doctoral student Franz Geiger to build a physical model of the shaft power plant at TUM's research laboratory in Obernach. They went on to build a first outdoor prototype, which they fed with water from the river Isar to create realistic operating conditions. This enabled them to investigate the behavior of different types and sizes of fish in relation to the shaft power plant.

Numerous experiments confirmed Sepp's original hope: The narrow grating of the rack does indeed act as a barrier. Thanks to the diverted current and low flow velocity, the fish adopt a slanted position and appear to swim effortlessly over the shaft. Larger fish, highly valuable for reproduction, are completely protected. Although smaller fish, less than 15 centimeters in length, fit physically through the narrow grating, only a small proportion of them actually slip through the rake. And the vast majority of these were able to pass through the turbine unharmed in the experiments led by Rutschmann and Sepp. "There is no power plant concept able to guarantee a hundred percent protection," explains Sepp. "But we do expect the shaft power plant to give the fish a very high level of protection," he adds.

Pilot plant in a challenging location

"When we heard about the idea of an environmentally friendly shaft power plant in 2011, it came at just the right time for us," recalls Günther Rösch from the Garmisch-Partenkirchen municipal utilities. At that time, together with the Mayor of Grossweil, Manfred Sporer, and Markus Pöttinger, a local power plant operator, he was looking for a plant concept that would ensure a high level of protection for fish and be suitable for ecologically sensitive sites. After all, the flora and fauna habitat in the section of the Loisach comprising the bottom ramp is protected under the European Union's Habitats Directive. And, like many other weirs or transverse structures in rivers, the ramp must be made more readily passable by fish in accordance with the requirements of the EU Water Framework Directive.

The shaft power plant was just what Grossweil's hydropower plant operators were looking for. They thus submitted a building application for a shaft power plant in the Loisach, which was approved in December 2014. Initially, several nature conservation and fishing associations filed objections to the planned construction but the various stakeholders involved were able to reach an agreement.

Together with other innovative hydropower plants, the Loisach site is part of a Bavarian-wide monitoring program commissioned by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) and the Bavarian State Office for the Environment (LfU). A team led by Prof. Jürgen Geist from TUM's Chair of Aquatic Systems Biology will be responsible for monitoring the pilot plant's impact on the local fish population and their habitat. ▷

Graphics: edjundsepp, picture credit: Kurt Bauer/TUM

Solutions of all sizes for worldwide deployment

The team has since received numerous inquiries about shaft power plants – both from within Germany and abroad. The engineers are able to adapt the concept to different requirements. In a case study for a power plant in the Mekong River, for instance, Rutschmann outlines how the shaft principle can also be applied to larger dams by constructing several shafts next to one another. Such a multishaft power plant would incorporate a channel between blocks of adjoining shafts, providing a near-natural habitat for fish and allowing them to swim downstream. “There are plans for countless hydropower plants in Asia and Africa, as well as in Southeast Europe,” Rutschmann reports. “These projects should be implemented in an ecologically sustainable way.”

The shaft power plant can also be deployed on a smaller scale. “We could pre-install the turbine and generator in a container and transport this ‘plant-in-a-box’ to remote areas where people have no access to the power grid,” reveals Rutschmann. The World Bank is already showing an interest in this project.

In collaboration with technology consultant Dr. Christian Hackl, Rutschmann and Sepp founded the company HYDROSHAFT GmbH to advise plant operators and investors on the construction of shaft power plants. A licensing agreement gives the company the necessary rights to use TUM’s patents and allows it to pass on the appropriate rights of use to future plant operators.

“We could pre-install the turbine and generator in a container and transport this ‘plant-in-a-box’ to remote areas.”

Peter Rutschmann

Prof. Peter Rutschmann

Devising win-win solutions

Born in Switzerland, Peter Rutschmann pursued his studies and received his doctorate at ETH Zurich, where he worked in applied research for over twenty years. He was then appointed to the University of Innsbruck (Austria) in 2002. Since 2007, he has held the Chair of Hydraulic and Water Resources Engineering at TUM.

Rutschmann’s research focuses on environmentally sustainable hydropower, flood protection, river morphology and ecohydraulics. Since 2016, he has coordinated the European research project Fishfriendly Innovative Technologies for Hydropower (FIThydro). The project brings together 26 partner organizations from 10 different countries. “We aim to create an online tool that can be used to plan and evaluate hydroelectric power plants,” explains Rutschmann. “This will enable us to find solutions that are scientifically sound while factoring in all interests – both economic and environmental,” he continues.

Together with Albert Sepp, Rutschmann was awarded the Heinz Maier-Leibnitz Medal by TUM. Rutschmann has also been commended by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) for his services to the environment.

Constructing the first shaft power plant

In November 2017, the time had finally come for the project to officially launch. Almost ten years on from the initial idea, Sepp and Rutschmann joined Grossweil's Mayor Manfred Sporer, Günther Rösch from the Garmisch-Partenkirchen municipal utilities, and the then Bavarian State Minister for Economic Affairs, Ilse Aigner, for the official groundbreaking ceremony for the first shaft power plant at Grossweil. The Free State of Bavaria is contributing around 1.9 million euros in prototype funding to the demonstration project that is scheduled to go on stream in spring 2019. It should then generate roughly the amount of electricity that 800 average households consume. Yet Grossweil's citizens will see and hear very little of the power plant hidden in the riverbed. "This is why we are planning a viewing platform so people can look at the shaft," reports Mayor Sporer.

On that spring morning in May 2018, Sepp and Rutschmann look quite content as they gaze into the sunlight. The shaft for their power plant will soon be installed in the construction pit at the bottom of the Loisach river. But Sepp still has his feet firmly on the ground: "Water levels on the Loisach river can rise dramatically, carrying a lot of driftwood. We are demoing our new technology under extreme conditions," he explains. "So I think it's important not to get ahead of ourselves. But when an idea finally takes shape, it certainly does feel good."

Daniela Becker

Peter Rutschmann (left) and Albert Sepp aim at reconciling hydropower and environmental protection. For the purpose of advising plant operators and investors on the construction of shaft power plants, they have founded the venture HYDROSHAFT GmbH.

In spring 2018, there is still only the construction pit of the future shaft power plant to be seen. It is scheduled to go on stream at the beginning of 2019.

Graphics: ediundsepp, picture credit: Kurt Bauer/TUM

Peter Rutschmann (left) and Albert Sepp standing above their first prototype of the shaft power plant, installed at TUM's Laboratory of Hydraulic and Water Resources Engineering in Obernach.

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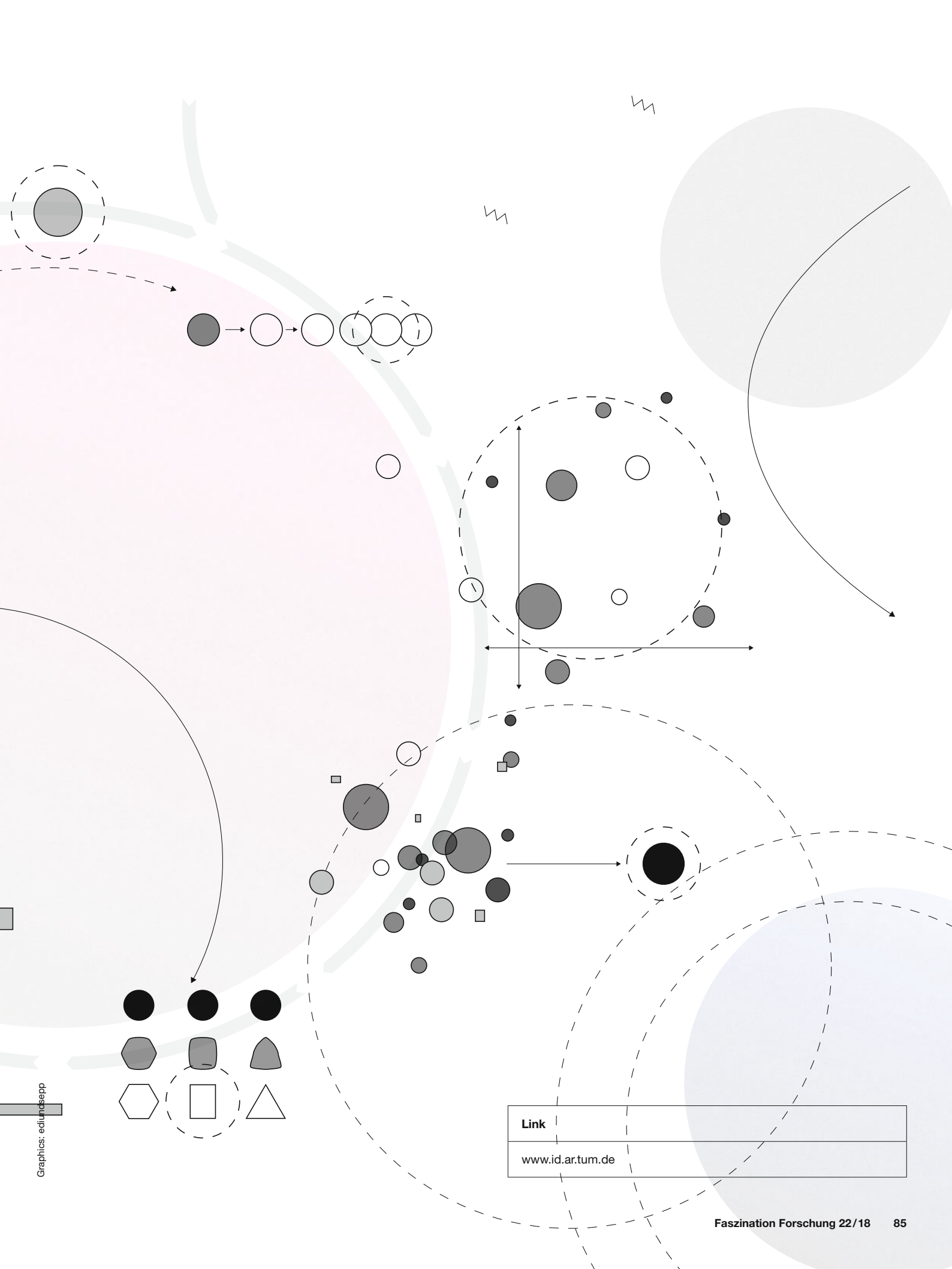
Need-based **Innovation**

As a designer, Fritz Frenkler is dedicated to products that inspire by combining form and function. TUM's Professor of Industrial Design brings budding designers together with young startups under the umbrella of the "Design Enterprise" program. This meeting of minds results in technologies and products that are aligned with real needs.



Graphics: ediundsepp

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www.id.ar.tum.de

Thomas Edelmann

Die Erfindung des Notwendigen

Fritz Frenkler, Professor für Industrial Design an der TUM, bringt angehende Designerinnen und Designer mit Start-ups in Kontakt. Er hat das verpflichtende einsemestrige Modul „Design Enterprise“ initiiert: Studierende im Masterstudiengang Industrial Design unterstützen junge Gründungsteams dabei, aus einer innovativen Idee heraus Produkte oder Dienstleistungen zu entwickeln, die gebraucht werden. Für Frenkler bedeutet das, ein Design zu schaffen, das die Funktion repräsentiert und eine Verbindung zur existierenden Produktwelt herstellt. Wird beispielsweise ein Produkt entworfen, das im Labor benötigt wird, sollte dem Designer zufolge auch bedacht werden, wo es dort Platz findet. Und ob es Probleme lösen kann, die auch im Kontext der Anwendung der Technologie bestehen. „Dann entsteht etwas wirklich Notwendiges“, so Frenkler.

Mit seinem Team hat der Wissenschaftler im Rahmen von „Design Enterprise“ mittlerweile über 80 junge Firmen begleitet. Sein Anliegen ist es dabei, ein unternehmerisches Verständnis von Design zu vermitteln. „Studierende und Gründungsteams haben einen gemeinsamen akademischen Hintergrund und begegnen sich auf Augenhöhe“, erklärt Frenkler. Manchmal fassen die Studierenden Fuß im Team des jeweiligen Start-ups. Mitunter werden sie in den neuen Unternehmen gar zu Partnern. „Die meisten Start-ups, die zu uns kommen, erkennen Design als notwendig und wichtig an“, sagt Frenkler. □

“Functional design, which is use-driven, remains a prerequisite for market success.”

Fritz Frenkler

Faszination Forschung: What makes a design both successful and useful in the eyes of a customer?

Prof. Fritz Frenkler: The aim of design is to make meaningful products for people. And that is why functional design, which is use-driven, remains a prerequisite for market success. Nevertheless, design was packed under the marketing banner in the past. Not only that, but marketing massively influenced design – which did the companies involved no favors.

Why was that?

The product development focus usually boiled down to revamping existing products and coming up with variants – it was rarely about strengthening brands or values. Only in the last ten to fifteen years has design been considered in a broader context again, with companies such as Apple setting a strong example here.

What role does industrial design play in the innovation process?

As designers, we maintain an awareness of the social context and connect the challenges of our time with technological developments. Our approach these days is more scientific, so we can substantiate the design process more methodically. Sometimes our work is about making it clear to a company that the product it wants to bring to market is not necessary at all. For instance, because it is socially questionable, ecologically problematic or risky for the company in terms of sales. That is all part and parcel of industrial design. ▷

Prof. Fritz Frenkler

An entrepreneurial approach to design

Challenges associated with environmentally sound mass production, changes in society due to shifting demographics, and universal design are the research focuses of Fritz Frenkler's Chair of Industrial Design. Together with students and doctoral candidates, he is taking an entrepreneurial approach to design. In other words, embedding design to a greater extent into corporate decision-making processes.
Frenkler studied industrial design at Germany's Braunschweig University of Art (HBK). He was Managing Director of frog design Asia and part of the team responsible for designing the NeXT Computer for Steve Jobs. He was also Head of Design at German railway company Deutsche Bahn AG. In 2000, he founded f/p design, a design studio that now has offices and representatives in Munich, Berlin and Kyoto (Japan).
In 2005, Frenkler was made an honorary professor at the Braunschweig University of Art, before gaining a full professorship with his appointment to TUM's Chair of Industrial Design in 2006. He is committed to developing design as a career, for instance through his role as Regional Advisor for the World Design Organization (WDO). Frenkler has also been Jury Chair for the iF Product Design Award since 1995 and co-founder and board member of the iF Design Foundation since 2018. In 2013, he was appointed a member of the Architecture Section of the Akademie der Künste (Academy of Arts) in Berlin.

Graphics: ediundsepp, picture credit: Magdalena Jooss/TUM

"The role of industrial design is to facilitate the product development process on an equal footing with all other stakeholders," says Prof. Fritz Frenkler, who has gained design experience both as an entrepreneur and as a university professor.

You travel a lot for work, especially in Asia. Are there differences between Asia and Europe in how industrial design is perceived?

In China and Singapore, you encounter the traditional approach, which emphasizes detailed solutions and differentiation. The challenge there is to create differences between products with a high degree of convergence due to the underlying technical developments. In Japan, Sony exemplifies how you define a brand through industrial design. Brands that did not systematically focus on design did not survive the economic crisis there. In South Korea, they put Peter Schreyer in charge of design throughout the entire Hyundai-Kia Group. Kia's market success underscores the importance of design in determining which companies will win through.

Design thinking – an approach where people are trained to think and act like designers – is playing a growing role in companies. It is applied to structural and organizational processes, as well as to product development. So does that mean the design profession is becoming redundant?

We shouldn't underestimate our role. Design thinking is rooted in tried-and-tested design methodologies based on prototypes. Design is an iterative process. In the course of trial, error and optimization, we circle back around, questioning what has already been achieved and bringing in new criteria to arrive at a meaningful outcome. As soon as this method is applied to other areas, as is the case with design thinking, that adds value to design. The only thing is, designers need to make sure they also harness this added value. We must reintegrate ourselves into the process we developed. The role of industrial design is to facilitate the product development process on an equal footing with all other stakeholders.

At TUM, you initiated “Design Enterprise” – a one-semester module in which Master’s students support young startup teams in developing their product and corporate identity. How does the program work?

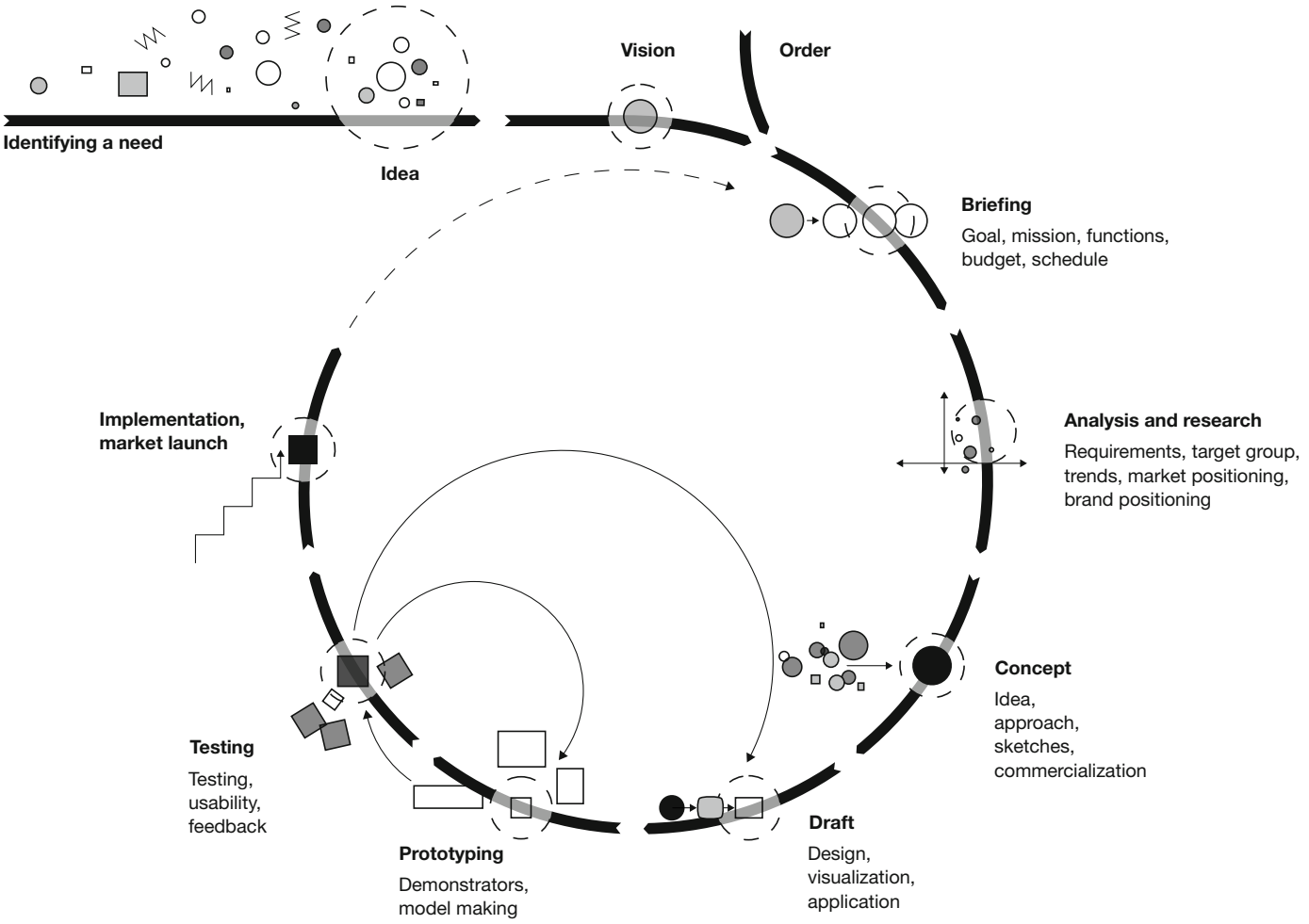
It is difficult for Master’s students in industrial design to gain access to existing companies other than as employees. “Design Enterprise” is therefore a mandatory module that every student must complete. It brings them together with TUM scientists and engineers who have invented something or have an idea – the aim being to develop this into a product or service. We have now assisted more than 80 new ventures.

So where does design come in?

To take an idea further, you have to give it a concrete physical form. It needs to become tangible. A new technology must be practical and fit into our world of things. So entrepreneurs come equipped with their ideas and meet our design students. What my team and I try to do is bring both sides together in dialog. That means facilitating and providing intensive support. There are usually several entrepreneurs, due to the complexity of today’s research topics. The goal is to come up with a name and consider questions such as: How should the company position itself? What does the brand look like – and what about the product? This goes all the way through to packaging. ▷

Design process

The design process is made up of different stages – from the initial idea through development and testing of a prototype to market launch. These steps refer not only to product and service design, but can also be applied to organizations.



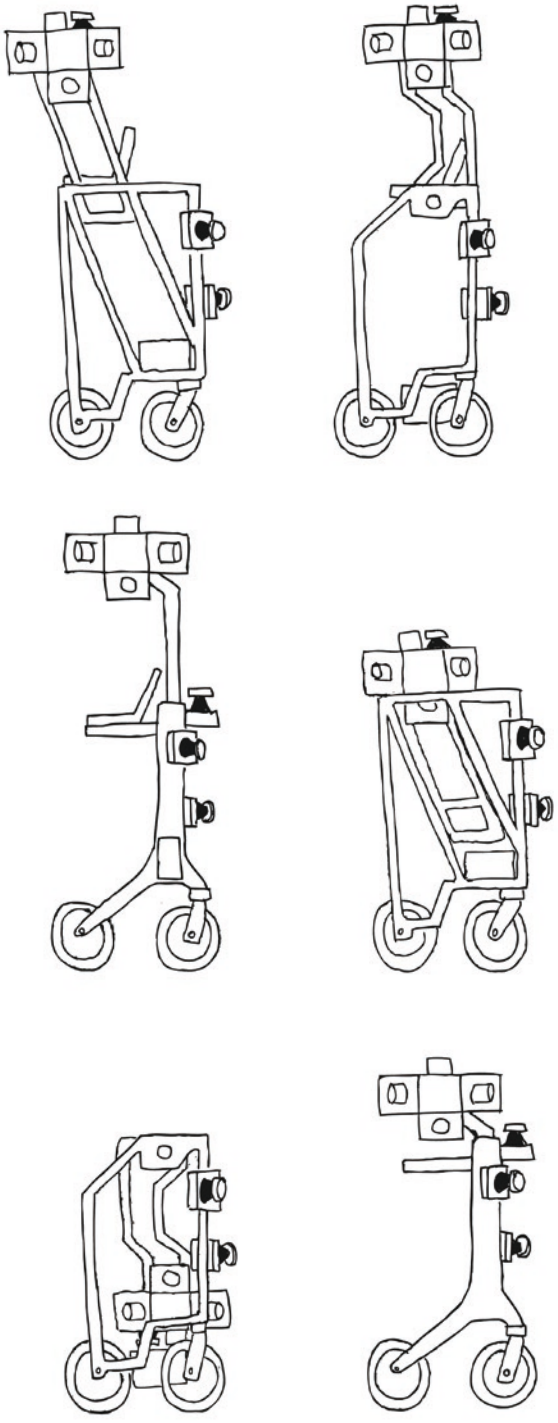
Graphics: ediundsepp, picture credit: Magdalena Jooss/TUM

How does that change the original product idea?

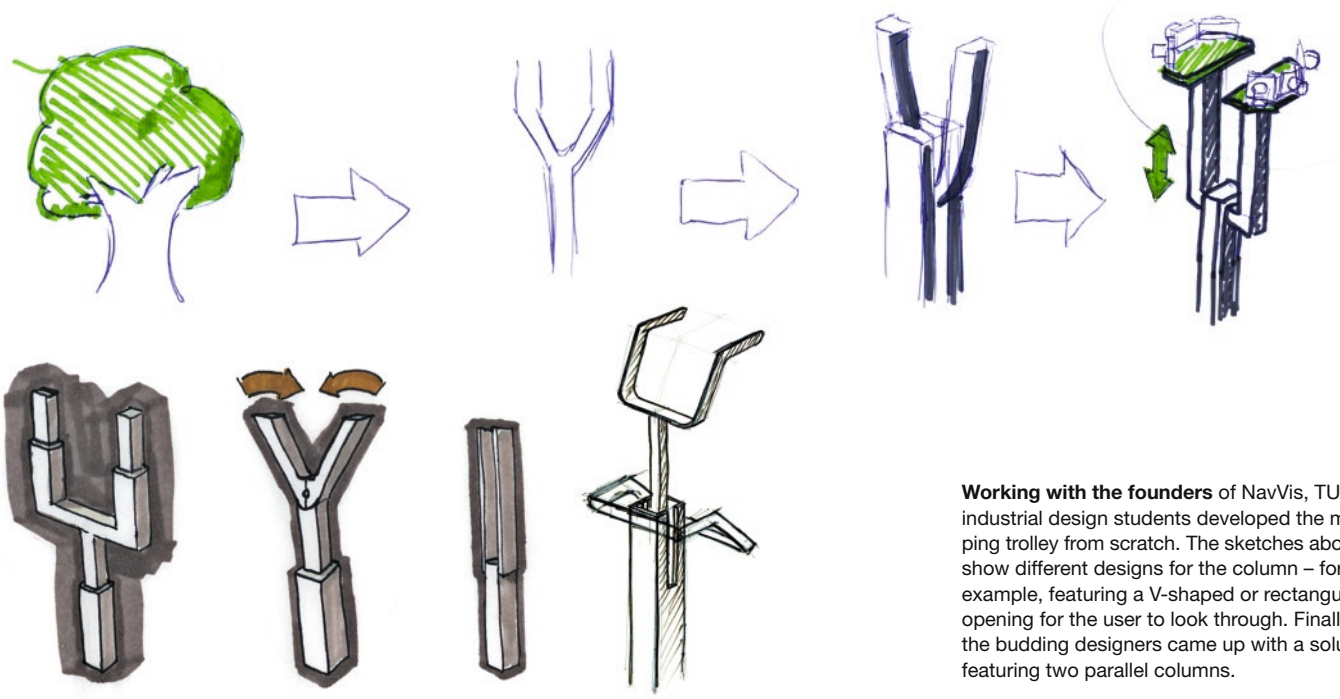
As you go through the different steps and stages of the design process, you can see whether there is more to a project or whether it should perhaps strike out in a different direction. For instance, one of our teams was focusing on software for indoor navigation. But we realized as we went along that there were only rudimentary solutions available for the necessary hardware. In this way, we identified a gap and came up with an initial product in response. The “Design Enterprise” development process then gave rise to NavVis – a company that now offers hardware, software and services. If this design process is well implemented, the engineers will also learn from it. So it might be that something completely different – but more fitting – emerges than was originally envisaged. In a young company, the opportunity is there.

And what about established companies?

It’s a lot more difficult then. They come with a brief and all stakeholders will try to take the project in the planned direction, whether that really makes sense or not. Objections raised by the design team are often fruitless because there are certain production structures in place, along with fixed ideas about the market. By comparison, most startups are focused not on the existing market, but on a future market they are seeking to shape with their product. Their product has not yet reached maturity and they understand the importance of design. So there is a high degree of flexibility when dealing with future entrepreneurs. ▷



NavVis develops applications for mapmaking and navigation inside complex buildings like hospitals, airports or universities (see also p. 29). Several sensors and cameras mounted on a mobile trolley capture the data and footage necessary to create photo-realistic 3D maps. The main challenge for the design of the trolley (see sketches above) was to avoid its operator appearing in the image recording.



Working with the founders of NavVis, TUM industrial design students developed the mapping trolley from scratch. The sketches above show different designs for the column – for example, featuring a V-shaped or rectangular opening for the user to look through. Finally, the budding designers came up with a solution featuring two parallel columns.

In the current mobile mapping system commercialized by NavVis (left), most of the distinctive prototype features developed by the team of students have been maintained. Point clouds, such as the dataset recorded in the entry hall of TUM's Bestelmeyer Süd building (right), provide the basis for numerous applications, such as routing and navigation in buildings and building information management.

Picture credits: Designprojekt im Masterstudiengang Industrial Design: Bartosch Cylkowski, Philip Döbele, Andreas Goebel, Julius Graupner, Philip Heinrich, Marina Kalinina, Mandolin Maidt, Simon Nicklas, Peter Schlickenrieder, Thomas Stiehler, 2013; NavVis 2018

The aCar (above) is an electric car, custom-designed for the needs of a rural population in Africa. The vehicle was conceived by an interdisciplinary team of students and scientists from TUM. The design of the car and its various transport modules (right) stems from Fritz Frenkler's "Design Enterprise" program. With their startup EVUM Motors GmbH, TUM graduates Sascha Koberstaedt and Martin Šoltés now want to take the aCar to series production.

TUM spin-off Lilium GmbH is looking to develop an ultralight electric aircraft that takes off and lands vertically. It was inspired by an idea from TUM alumnus Daniel Wiegand and his team, namely a flying taxi that will whisk passengers to their destination at 300 kilometers an hour, avoiding all traffic and using climate-friendly energy. A team of industrial design students contributed to the original design.

So this interplay is the best way for companies to interface with design?

Yes, and it is generally successful with these young entrepreneurs. They are usually open to input because they recognize design as being necessary and important. Students come together with entrepreneurs and are able to draw on a common academic background and interact on the same wavelength. Sometimes new ventures emerge from these projects with our students as partners, or they join the team of the startup they're assisting.

What advice would you give students and academics who have a business idea?

As soon as you determine that it really is a good idea, you should try to develop a useful product from it. The key is to arrive at a design that reflects the function – there should be a certain logic to it. And it's important to reach out to the existing product landscape. The context always matters. Maybe I can create a new system around my product? If I design something for use in the lab, for instance, I also need to know how it will fit in there. I need to be familiar with the issues that users face in my target environment. Maybe I can solve two or three other problems with my product that might not be specific to my technology but to how it is used. That way, something truly necessary takes shape.

Thomas Edelmann

With his "Design Enterprise" program, Fritz Frenkler and his team have assisted more than 80 new ventures.

Graphics: ediundsepp, picture credits: Chair for Industrial Design/TUM; Lilium Aviation GmbH; Magdalena Jooss/TUM

Expanding Horizons **with High Technology**

TUM's lecture halls, labs and research internship programs inspire a steady stream of startup ideas. Here, we introduce three teams translating research findings into business ideas and embarking on their own ventures.

IRUBIS

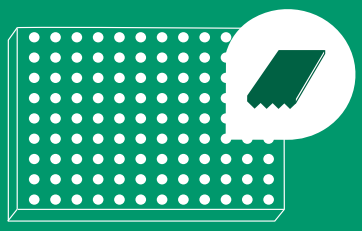
With sample carriers made of silicon instead of diamond, the IRUBIS team aims at making infrared spectroscopy faster and cheaper. Lorenz Sykora graduated in physics from TUM. His co-founders are physicist Anja Müller from the Technical University of Berlin and TUM business economics graduate Alexander Geißler (from left to right).

Munevo

Munevo has developed a control solution for electric wheelchairs based on smart glasses. The Munevo team consists of TUM students and graduates Aashish Trivedi, Konstantin Madaus, Deepesh Pandey and Claudiu Leverenz (from left to right).

retorio

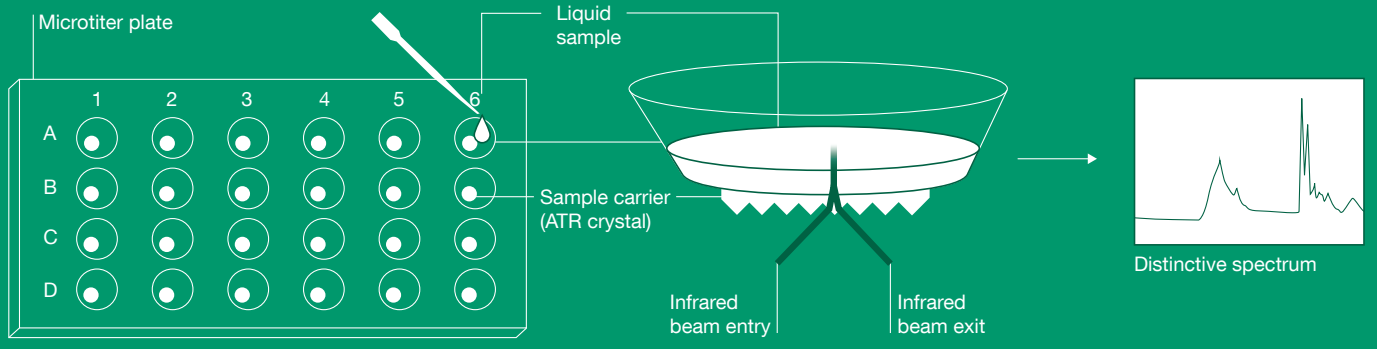
With the help of artificial intelligence, retorio aims at helping users to improve their communication skills. Dr. Christoph Hohenberger and Patrick Oehler previously worked as PhD students at TUM's School of Management, while co-founder Abdurrahman Namli graduated from Istanbul Technical University (from left to right).



Swift
Sample Analysis

Infrared spectroscopy is an often time-consuming method for analyzing a wide variety of samples. With a cheap and disposable sample carrier made of silicon instead of diamond, IRUBIS aims to speed up this process.

From milk through motor oil to medication – just about every substance you can think of can be analyzed using infrared spectroscopy (IR). "This technique is standard practice at analytical laboratories," confirms Lorenz Sykora, physicist and co-founder of IRUBIS.
The method involves passing infrared light through a sample, which causes the molecules inside to vibrate. Part of the light is absorbed, producing a spectrum. This spectrum is so distinctive that it can be used to pinpoint precisely which molecules the light has encountered. IR spectroscopy can thus reveal the exact composition of a substance. This can be used to detect impurities in milk, for instance, or to expose labeling fraud in medicines.



The core component of the ATR (attenuated total reflectance) infrared sprectroscopy technique is the crystal, which is used as a sample carrier and reflects the infrared light. The IRUBIS team has developed a low-cost silicon crystal with high sensitivity. Integrating many crystals into a well plate can make it possible to investigate up to 96 measurements simultaneously.

Infrared light is passed through a sample, causing the molecules inside to absorb part of the light and thus produce a spectrum.

The spectrum is so distinctive that it can be used to pinpoint precisely which molecules the sample is composed of.

Graphics: ediundsepp (source: IRUBIS), picture credits: Astrid Eckert/TUM, Munevo

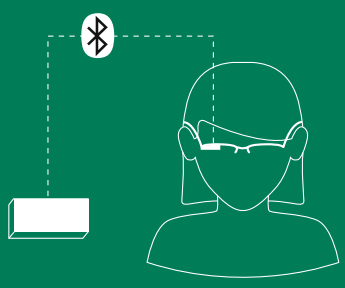
Laborious manual cleaning

To date, however, performing several consecutive measurements has been a highly time-consuming task. This is due to the sample carriers, which are usually made of diamond and cost around 5,000 euros each. To justify this outlay, they need to be used many times over – which means manually cleaning the carriers after each measurement.
This is something Lorenz Sykora set out to change. Together with business economics graduate Alexander Geißler, whom he met at a business plan seminar hosted by Unternehmer-TUM, and fellow physicist Anja Müller, he developed new sample carriers made of silicon – the material used in microchips. "Our sample carriers deliver measurement results on a par with conventional carriers, at a fraction of the cost," declares Geißler – now Managing Partner of IRUBIS. The single-use carriers enable up to 96 measurements simultaneously. "In the long term, we are aiming for production costs of less than a euro per unit," adds Geißler. In 2017, the team received the TUM IdeAward for their business idea, which comes with 12,500 euros in prize money as well as individual consultancy services for their startup.

Blood as the ultimate challenge

The silicon sample carriers fit all commercially available infrared spectrometers. Biotech companies are the first customers, keen to use IRUBIS' carriers for protein analysis as part of drug development. "In the future, we plan to enable blood analysis using our system too," reveals Geissler. "But blood has thousands of different components – so that's the master challenge of analytics."

Claudia Doyle



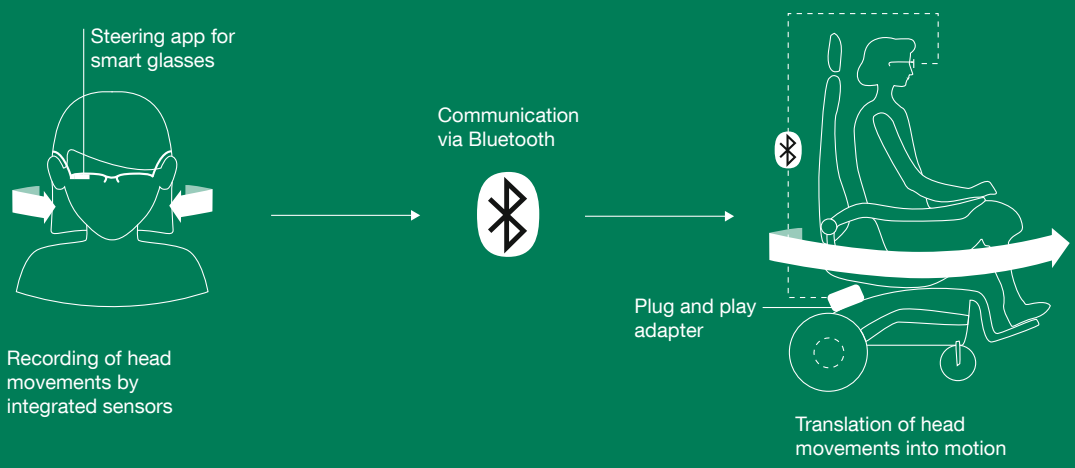
Intuitive **Wheelchair Control**

The Munevo team has developed a smart glasses solution that enables people to steer their wheelchairs hands-free, just by using head movements.

First put on the glasses, then nod your head briefly, and the electric wheelchair begins to move. If you tilt your head to the right or left, the wheelchair turns in that direction. "The steering system is intuitive and adapts to the individual user," outlines Claudiu Leverenz, who studied business informatics at TUM. Together with Konstantin Madaus, who holds a Master's in Mechanical Engineering from the university, he founded Munevo to bring a new control system for electric wheelchairs to market.

Currently, electric wheelchairs are usually steered with a joystick. People who cannot use their arms can steer with their chin or have sensors installed in the wheelchair's headrest.

The idea originally stemmed from a research internship through Prof. Helmut Krcmar's Chair of Information Systems in 2015, with Leverenz initially pursuing it as more of a part-time project. However, since 2017, he and Madaus have been focusing full time on Munevo, supported by informatics students Aashish Trivedi and Deepesh Pandey. Initially advancing their concept from TUM's incubator with the added bonus of startup coaching, the team is now on the lookout for new premises.



Munveo's control solution can be easily adapted to electric wheelchairs. It uses smart glasses to detect the wearer's head movements. The data is sent via Bluetooth to a special adapter, which then translates this information into motion commands.

"These solutions do work, but our control solution based on smart glasses makes it easier to move smoothly," explains Leverenz.

Nod and off you go!

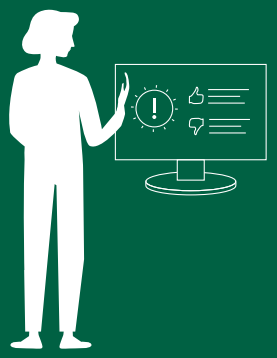
High-tech smart glasses are wearable computer glasses that integrate sensors. Using a software app developed by the Munevo team, these sensors can detect the wearer's head movements and send the data via Bluetooth to a special adapter, which then translates this information into motion commands.

Medical device approval pending

The invention is set to be approved as a medical device by the end of the year. A clinical trail is underway to demonstrate the safety and efficacy of the new control unit. "Here, subjects are using our system to navigate a wheelchair through an obstacle course," discloses Leverenz. The amount of positive feedback he has already received from test users and medical supply stores keeps him motivated. "Our goal is to increase people's independence and quality of life," he confirms.

Claudia Doyle

Virtual
Communication Coach



At TUM, budding entrepreneurs benefit from the startup incubator on the Garching campus, which provides them with office space, workstations and coaching free of charge. The retorio team has made the most of this opportunity, developing a coaching program based on artificial intelligence.

It's a scenario most of us can relate to – standing by yourself in a packed auditorium, clutching a microphone with clammy hands and finding your mouth has gone dry. Performance anxiety affects many people when they give presentations and Patrick Oehler is no exception. "As a research associate, you often have to speak off the cuff in front of large numbers of people, and I suffered a lot from nerves at the start," recalls Oehler who holds a Master's in Management and Strategy and who until recently worked at Prof. Isabell Welpe's Chair for Strategy and Organization at TUM. Together with his colleague, Dr. Christoph Hohenberger, and technical co-founder Abdurrahman Namli, they developed "retorio". This software is intended to help people improve their communication skills and reduce their anxiety about public speaking.

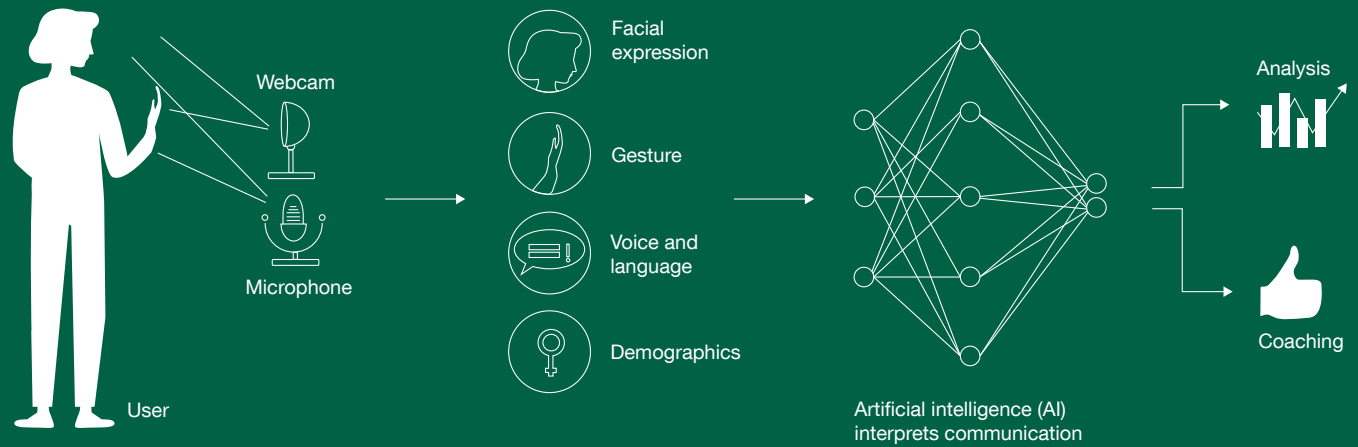
Training software to be responsive

Artificial intelligence steps into the coach's shoes here, filming a user's presentation via webcam and analyzing their voice, facial expressions and gestures. It also provides the user with real-time feedback, for instance alerting them if they are speaking too fast. At the end of the presentation, it then gives a detailed evaluation of what is already going well and what the user still needs to improve.

For this feedback loop to work, the algorithm first has to be supplied with data. "Machines can already analyze voices, facial expressions and gestures," explains computer scientist Namli, "but we have to teach them how other people respond to these elements and whether they find the presentation authentic." The retorio team achieves this by drawing on a database of 10,000 videos, showing people speaking in a wide variety of contexts – from a mother describing her familiy to a young man giving a talk on cosmetics.

Flanking human feedback

The retorio team asks participants to watch the videos and answer questions such as: "Would you like to work with this individual?" or "Would you trust this person?". The algorithm derives patterns from this information and applies them to new situations. So the machine-based feedback for people using the virtual coach can become more and more accurate. The three company founders view their software as a valuable addition to human communications training. When it comes to market, users will be able to practice anytime, anywhere, from their own PCs. After all, as Oehler points out: "Many people are only really motivated to do this when a presentation is coming up soon." *Claudia Doyle*



Graphics: ediundsepp (source: Munevo, retorio)

Anytime, anywhere coaching: With retorio's coaching software, users could soon practice presentations and get feedback at home on their PCs.The software is designed to record the presenter's language, voice, facial expressions and gestures and uses artificial intelligence methods to analyze the data.

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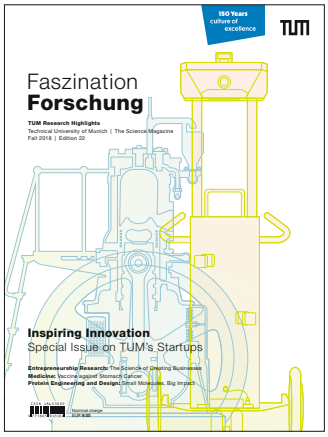

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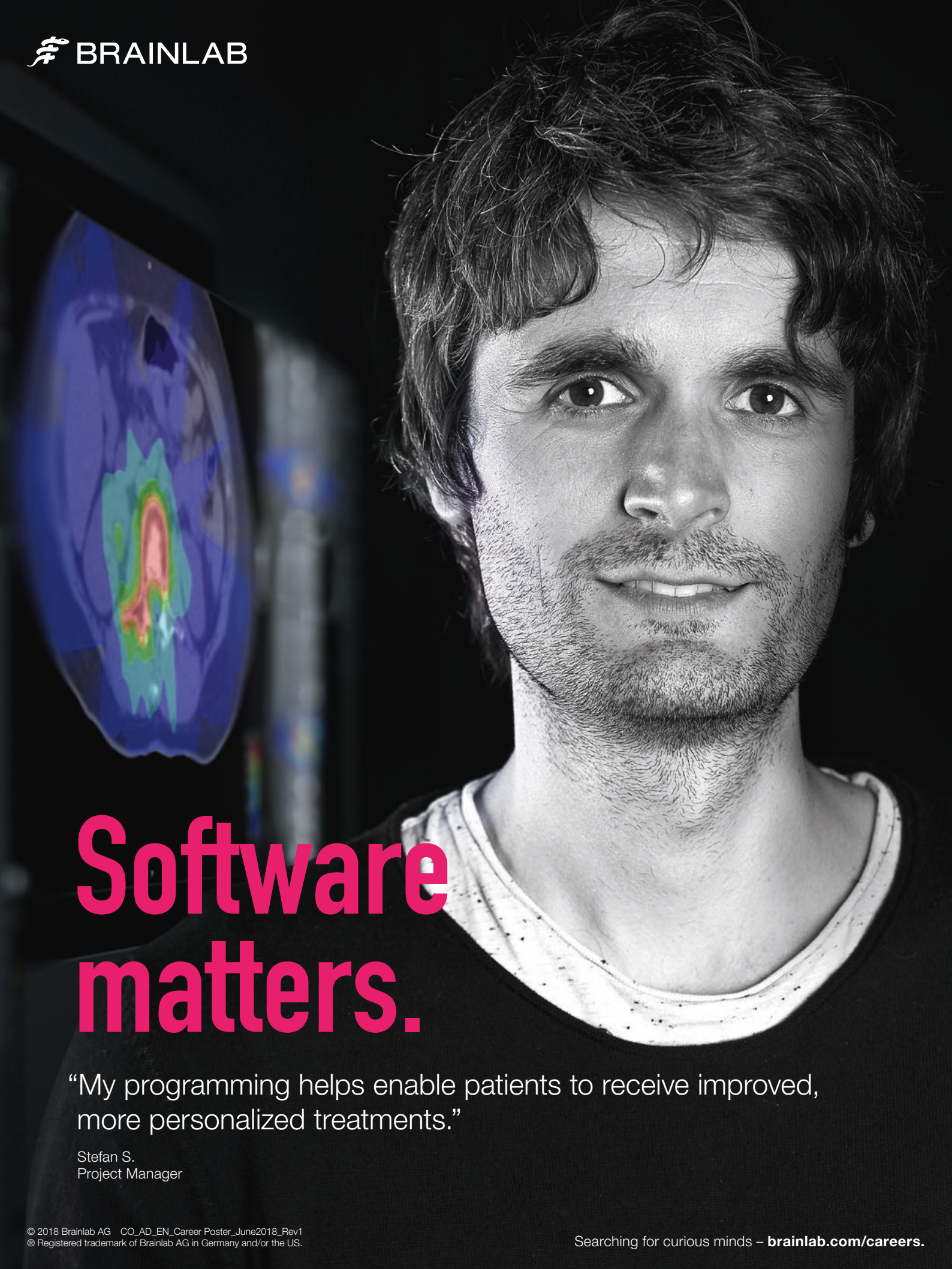

Software matters.

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