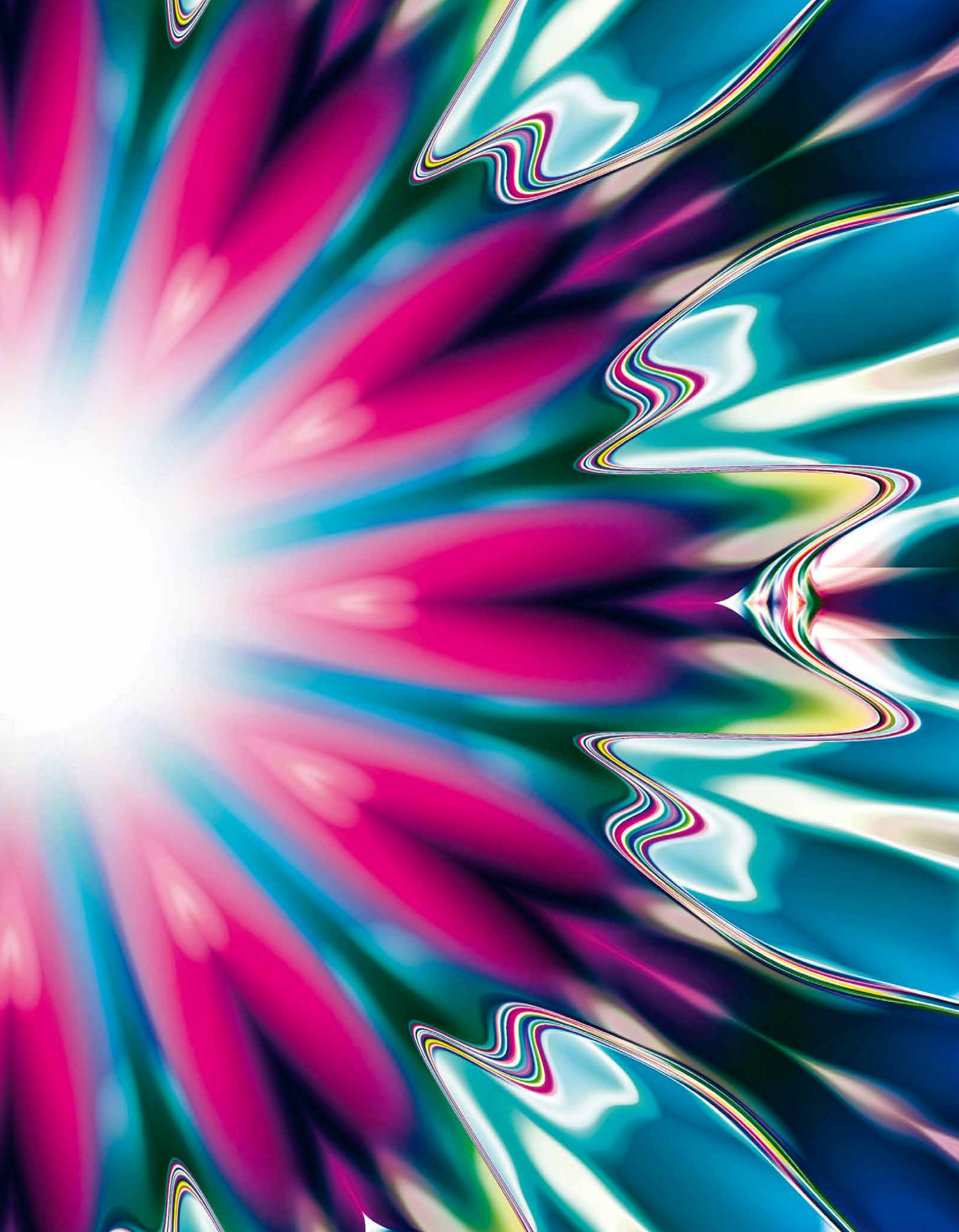
FORSCHUNG LEBEN

THE MAGAZINE OF THE UNIVERSITY OF STUTTGART

NO. 7 NOVEMBER 2016



To our readers,

„Youth will have its day,' goes a German folk song from the 19th century. But it's not all that simple for young people who embark on a career in science: success on this road requires not only a high-quality course of studies, an abiding love of scientific issues, but also a high level of stress tolerance, stick-to-it-iveness, and energetic work. At the University of Stuttgart, we help students to develop these indispensable personal qualities for their scientific careers. Our strategy and our target from the first day of study is: „Captivating talented, eager-to-perform students in science through research-oriented teaching and learning.'

Young people today are making major contributions to scientific progress. We have brought together some examples of this in the present issue of RESEARCH AND LIFE to illustrate some of the first-class scientific impulses given by young researchers at the University of Stuttgart. You will read how interdisciplinary groups of next-generation researchers in the SimTech Excellence-Cluster are using simulations to peer into the future, and how Junior Professor Maria Fyta uses gold and diamonds to pinpoint genotypes. Take a look into the brain and see how it processes business decisions, and go on a photographic trip to the exciting work locations of our doctoral students. But however fascinating the field of research may be, young persons often feel torn in their decision for a career in science - a „force field' upon which our guest author Katrin Rehak-Nitsche from the Robert Bosch Foundation casts light. It remains a fact that top-quality work by young scientists is possible only if real perspectives are offered. And this, in turn, requires personal interest on the part of mentors along with realistic, reliable planning of career tracks.

And now: we wish you much enjoyment in reading!

Wolfram Ressel
Rector of the University of Stuttgart

Photo: Uli Regenscheit

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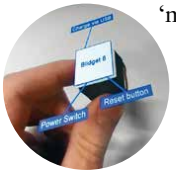

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... Heard in Passing

Stuttgart: A Research Frontrunner

The University of Stuttgart booked two major achievements this year. 'Reuters' Top 100: Europe's Most Innovative Universities' named it as one of 100 European universities with important new ideas. The list was compiled by analyzing each university's research literature and patents in ten categories in order to rate successful achievements in research, innovation, protection of intellectual property rights, and the transfer of knowledge and technology.
Secondly, the 'Times Higher Education World University Ranking 2016/17' gave the University of Stuttgart first place honors in its international ranking of 980 universities and colleges in the category of 'Outside Funding from Industry per Researcher'. Commenting on this new ranking, professor Wolfram Ressel, Rector of the University of Stuttgart, put it this way: 'The latest and most important international rankings again make it clear that the University of Stuttgart is well on its way towards worldwide distinction as a research university in the forefront of scientific and technological progress.'

Smaller than you might think

The deuteron - whose nucleus of a single proton and a single neutron make it one of the simplest atomic structures - is much smaller than previously thought. This was recently found by an international research group which included researchers at the University of Stuttgart's Institute of Laser technology (IFSW). The experiments were carried out at Switzerland's Paul Scherrer Institute (PSI), which successfully corrected previous estimates of the proton's size. The new measurement raises many questions and could lead to a revision of one of the most important physical magnitudes, namely the Rydberg Constant. At the moment the Institute is clarifying whether the measurements arrived at different results due to minute experimental inaccuracies.
Yet another possible explanation for the deviation is that a still unknown physical force was exerting an influence. In their measurements the research team applied laser spectroscopy to so-called 'myonic' deuterium: an artificial atom, consisting of a deuteron which is orbited by an exotic elementary particle called the 'Myon'. They have now published the results of their new study on the size of the deuteron in the prestigious professional journal 'Science'

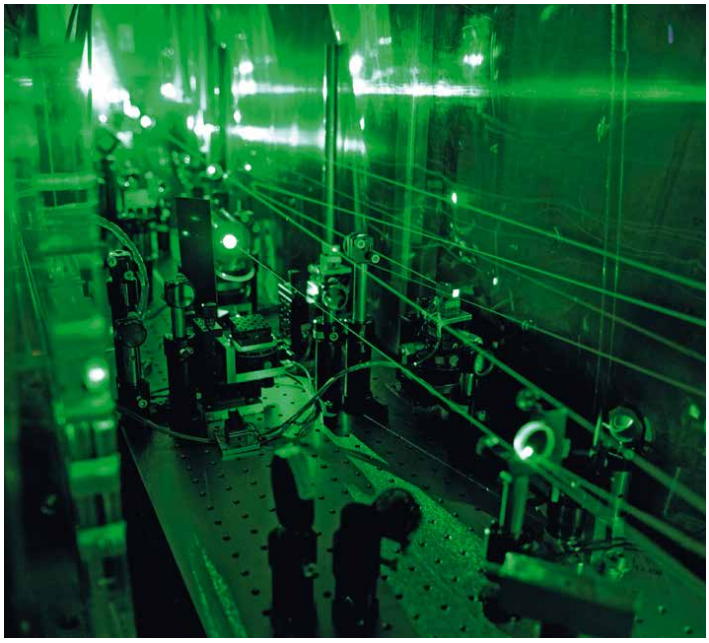

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Photo: Nicole Glass

Winning back prodigal sons (scientists who have wandered away)

Early in September, the German Academic International Network (GAIN) held its annual meeting in Washington, D.C.. Prof. Wolfram Ressel, Rector of the University of Stuttgart, was on hand with Dr. Wolfgang Holtkamp, Senior Advisor for International Affairs, to call attention to career opportunities at the University of Stuttgart. Talking to Theresia Bauer, Baden-Württemberg's Science Minister, Ressel voiced his pleasure at the intense interest shown by attendees at the conference: 'What we are seeing here in Washington is that Stuttgart is well on its way to becoming one of the world's foremost research universities. This is a strategic target we'll be pursuing even more energetically in the coming years as part of our Excellence Initiative,' said Ressel. Science Minister Bauer mentioned that with the right offers there's a good chance that the world of science in Germany can win back top-flight researchers who have left Germany for greener fields.

A Live Music Lecture

One of the most striking presentations was given by Dr. Toni Bernhart from the University of Stuttgart's Institute of Literary Sciences during the annual 'Canonical Texts' lecture series. His elucidation of the Roman 'Perrudja', in which four pieces composed by the author himself play a key role, was accompanied by a live intonation performed by students. It was a premiere, since as far as is known these compositions have never before been presented in public. No wonder, then, that 'horad', the University's own radio station and its 'Cultural Whispers' series saw this as an occasion to present a special transmission of these musicians and their violins, flutes, clarinet and piano.

A Conference for Student Researchers

Social science students from the University of Stuttgart took part in June at the 'Conference for Student Research' in Oldenburg, where Vanessa Bausch, Carola Majer and Denise Schütz presented their analysis of the possible consequences of building a solar power plant in Northern Morocco. Their conclusions were formed during a seminar on Technical and Environmental Sociology under the direction of Dr. Dieter Fremdling. They began by identifying the current status of the most important sociocultural aspects of the region on the basis of a model sketch from the German National Aeronautics and Space Research Center (DLR). Their next step was then to identify relevant system sizes and describe their reciprocal relationships. This yielded a cross-impact matrix which in turn made it possible to calculate qualitative scenarios for the years 2030 and 2050.
The conference gave students from all academic disciplines in Germany an opportunity to present research results from their areas. Their lectures and presentations on such topics as oceanic energy systems, mathematical didactics or even human medicine covered a broad spectrum of scientific research work that resulted in a lively give-and-take of ideas among those in attendance.


Photo: University of Stuttgart

OVERVIEW

Photo: STARTUP AUTOBAHN

FOUNDING SPIRIT

Re-thinking mobility

A total of 22 startups have recently applied for funds from the 'Start-up Autobahn' program. The founders presented their ideas on the future of mobility to an audience made up of the jury und spectators. The topics and techniques ranged widely, from the uses of artificial intelligence and the measurement of vital data via mobile transport management systems to personalized sound systems. Once selected, the startups will be supported and from September on by mentors in a special acceleration program. The 'Start up Autobahn' is an initiative of Daimler AG, the Plug and Play Tech Center, the University of Stuttgart, and the 'Research 'Arena2036' Research Campus. The purpose of the program is to provide young startup founders with the right environment for 'stepping on the gas' and 'rethinking the mobility of the future,' as it was put by Dieter Zetsche, CEO of Daimler AG. This will be followed by giving the member startups their own work areas in the new 'Arena2036' research building from January 2017 on.

International research center for innovations

The University of Stuttgart has collaborated with the Shanghai Institute of Smart Manufacturing (SISM) to create an international research center. The purpose: to provide impulses for developments in the context of 'Industry 4.0'. As part of this cooperative venture, joint research labs will be created at SISM where professors and teams from both partner countries can work on research topics, especially in the areas of machine design and construction and production technology. In addition, the cooperative venture will support doctoral candidates in carrying on their studies in Stuttgart and Shanghai.

The Fraunhofer Institute for Production Technology and Automation (IPA) is also participating in SISM. The center in Shanghai will start its work in the coming year. The financial resources for this will come from China: the infrastructure has already been laid at a cost volume of several million Euros contributed by the government program 'China 2025'.

Save the environment - but not without my car!

The first place to look regarding environmental issues is: ourselves. Each of us has a multitude of opportunities to help out. The question is: how far are we really willing to go, especially in our cities and heavily populated areas, to protect the world around us? Precisely this question is undergoing analysis by a group of sociologists, experts in the political and media sciences, and urban planners. Over the next five years they hope to find out what solutions are available in terms of sustainable mobility concepts. This will include a study of models that show factors which factually influence the reduction of CO_2 emissions and ideas which can be implemented in the form of sustainable, real business models. In general, there is little doubt about the value of electrically powered busses or E-autos; but questions like 'How many persons would in fact be ready to go without their own car?' are what drive Dr. Marco Sonnenberger, of the University of Stuttgart's Center for interdisciplinary Risk and Innovation Research, and his colleagues. Together with political scientist Dr. Antonia Graf of the University of Münster, he heads a research group whose special focus is on society's impact on sustainable mobility concepts in urban areas.

Photo: iStock/querbeet

Who, me? Really?
Men and Women of Science: hidden lives, uncharted paths

In 2016, according to the 'Science Barometer', more than 40 percent of all people were found to be interested in science. Nearly the same number want to be kept up to date about science or even be involved in decisions concerning science and research: they want somehow to be a part of it. But experts in scientific education now also say that while many people find research at an early age very intriguing, their faces often show surprise at the question, 'How about being a scientist yourself?' 'Who, me myself? A SCIENTIST?'

How best answer this question from young people? Can one advise them with a good conscience to go into science? The answer is yes, because science needs the best people, and because good science can only be done by good scientists. And because we are dependent upon them. And because science and research are fun and liberating. And because they turn a hobby into a profession and because the work they do is meaningful. But then it must also be possible to offer young people good perspectives. And that is easier said than done.

We at the Robert Bosch Foundation are on the lookout for people with the courage and will to make things happen; people who see in the sciences a way to help shape society; and we support them on this often bumpy path. Their needs are very diverse: there's the schoolboy who deeply desires to change the world but doesn't know how and where, and is thinking science might offer a way. Or the brilliant woman researcher who's uncertain of her own abilities and who, in spite of her quite evident excellence in scientific research, needs first to acquire enough self-confidence to compete with others. Or the inquisitive scientific thinkers who think out of the box, suddenly stand outside the normal routes to subsidies, and now keep trying to find a way to turn their ideas into reality. In the reality of today's academic Germany, they must keep a single goal in view - and this is only slightly exaggerated - in order to spend their lives in relative financial security in the German world of science: to become tenured professors.

Hopefully not just more of the same

Little has changed in recent years regarding a new generation of scientific researchers in Germany, and the situation seems to be set in stone. Every argument for attracting new blood, every statistical analysis has been worn threadbare. All the relevant persons who can have an influence have racked their brains for years about how to better the situation for young scientists. On the international stage, Germany has an exorbitant number of short-term personnel. Only slightly more than 10 percent of all scientists in Germany have permanent positions or are tenured professors (see for example 'Hazard or Career - Academic Career Structures in International Comparison', by Kreckel & Zimmermann, 2014). All others go from one temporary job to another, even though a new scientific job contract law has increased the length of such agreements. This system of academic musical chairs in which de facto only the above-mentioned 10 percent of researchers are unhampered and free to work independently has been severely criticized by the 'Young Academy', to mention only one. One solution proposed is to increase the number of university professors - a proposal which is both easy to understand and controversial.

The eye of the needle in a career of scientific research is the possibility of becoming a tenured professor. The numbers clearly show that this is a risky undertaking and that only a few can pass through. The Excellence Initiative, a bubbling cauldron of newly qualified professors, is cooled according to the Fed-

Photo: Robert Bosch Foundation

> Behind every great idea, behind every great project, stands an extraordinary person. It is these persons who change the world.
>
> **Katrin Rehak-Nitsche**
> **Area Director of Science, Robert Bosch Foundation**

eral Report on Next-Generation Scientists (2013) by depressing numbers: although some 26,000 persons gain a Doctor's Degree every year, and a total of about 3,750 persons per year qualify as next-generation scientists (e.g. as next-generation group mentors, authors of professorial dissertations, and junior professors), only about 670 of them are invited each year to join university faculties as professors. Only one out of five of these deserving scientists, and only about one out of every 40 with a Ph.D. has any chance at all of being called to join a university faculty. Even the generation change will not resolve this situation, since the number of those who qualify is three times that of the professors who go into age-related retirement. The question, therefore, is whether an increase in the number of professors will solve the problem.

We must look beyond the tips of our own noses: even a rough estimate based on a micro-census and a headcount of the work force shows, for example that even in the business world 15 percent of the work force has management functions. This is just one indication that the real problem of the universities - or at least the only one - is not a dearth of professors. Other professional sectors offer a diversity of functions, so that not every employee must become a managing director or department head in order to spend a professional career in an organization: among the positions available are those of team leaders, consultants, expert advisors, project managers, instructors, staffers, project leaders, master craftsmen, scientific research assistants, senior advisors, etc., etc. Unfortunately, the 'winner-take-all'-principle prevails in the world of scientific research, namely: professor or nothing. And that becomes crucial in the mean at the age of 42, the average age when a professor's chair is offered, and only after the career scientist has already invested immense resources in his or her career. In short: science is a high-risk career path. That is the true crux of the problem. It doesn't have to be that way; there's no lack of ideas on diversifying career paths. For example 'New Careers in Science', a joint project, examined the issue in detail and found that there is still a lack of resources and concrete implementation of long-term personnel policies at universities. This represents a structural project which, by the way, goes beyond the capabilities and legitimate purposes of foundations.

People make society

In thinking about ways to improve the situation by making a career in scientific research more attractive for qualified persons, one may ask the following questions: who will stay the course? Who make up the 10 percent? Is it the cleverest, the most creative, the best of their class, the most brilliant, the most dedicated? Is it those who will benefit us most? Is it those who will find answers to questions we haven't yet even thought of? (Let's hope so, otherwise we have an even bigger problem!) In fact, we at the Robert Bosch Foundation are looking for the ones who can make us all a better society. The reason: we deeply believe that these are the persons who change our world. When we look at Robert Bosch or Klaus von Klitzing we se the same thing: behind every great project, behind every great idea is an

extraordinary human being. That's what impels our foundation in supporting up-and-comers in the next generation of scientific researchers to take a tack that is somewhat old-fashioned and no longer 'in' in our academic publish-or-perish, H-index world: we take a good, long look at persons who come to us - at our invitation. We give a helping hand to those who generate confidence in us and the respective panel of examining experts to put their ideas into practice - for example junior professors who are at work on sustainable uses for natural resources. We know full well, however, that there is never a guarantee of success in the academic sciences - either for those we support or for us, the supporters.

Three recurrent wishes

This approach is right in line with what these next-generation researchers tell us when we ask them about their wishes or ideas for the academic system. Their answers are, of course, wide-ranging, but three wishes come up time and again: more recognition. More trust. Less 'fixing-the-women'. More recognition, for example, means receiving an answer - even if only a rejection - when applying for a professor's position, instead of plying the Internet to learn that the hoped-for job was given to someone else. More trust means, among other things, encharging someone with the use of a new method or work in a new area of an already successful project even though he or she has no previous experience with that area. Finally, less 'fixing-the-women' reflects the perception that many programs aim to educate women in the 'right' way of behaving if they want to survive in the academic world. Support for young women is good; what's not good is the 'subtext' that says something's wrong with them and they need only act like men to make everything OK. Countless academic women with top qualifications are out there - in greater or fewer numbers depending on the respective discipline. Finding them is no problem at all, and anyone who doubts this is going blindfolded through the world - and hasn't yet visited 'Academia-Net.de'! But attracting more women to positions of leadership in scientific research is not a one-way street: lifestyles differ vastly, particularly for those with children: the so-called 'woman's work' of times past must continue to be done in future as well: taking care of children, running a household, keeping a family together. Good day-care options are a prerequisite for this, but basically, a dedicated woman is more than just a professor, an institute director, a woman president: she represents an additional, dedicated partner in the family. It can no longer be taken for granted that the woman is essentially responsible for everything. That's not what equal rights mean. What that means is that if we want to gain more women for positions of leadership in scientific research we need partners who work with their scientific woman partners to build a private life and either share or take over tasks in the family. Men like this do indeed exist, and their numbers are growing. We need to support and acknowledge them - and stop trying to 'fix' the women.

That would certainly not solve all career problems in the academic world, but we have to begin somewhere. Optimism is the basic stance of our Foundation's work, and that's why we help persons to find their way and to render meaningful service to society and our world. Even - and precisely when - the prospect of success is uncertain.

Katrin Rehak-Nitsche

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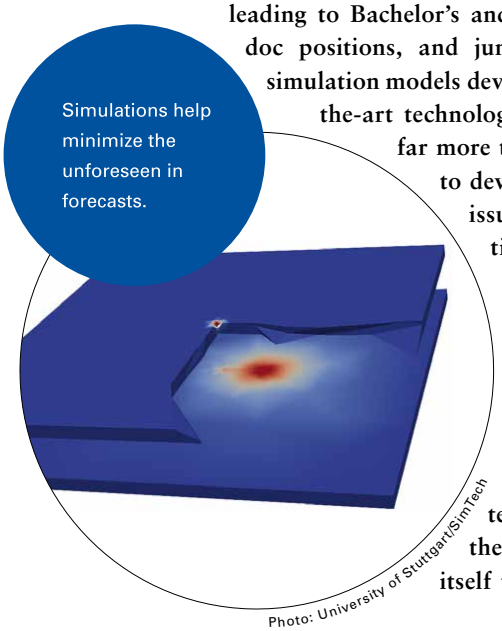
What Happens if ...?
Peering Into the Future - With Simulations

It's a complicated world, that much is certain. One great aim of science is not only to understand it but also to get behind the interrelationships - in fact, to make them predictable. The challenge is: the incalculable. In this regard, a third avenue to understanding has opened up in the last few decades as a support for experimentation and theory: simulation.

The Stuttgart Research Centre for simulation Technology (SRC) networks next-generation scientists from quite unrelated disciplines at the University of Stuttgart and the SimTech Excellence Cluster. The goal: to support gifted young scientists with a broad-based offering of courses and seminars, intensive mentoring, research and study abroad, and interdisciplinary stimulation of ideas. Just to give an example: SimTech provides interesting perspectives that include a graduate school with about 150 doctoral candidates from nine of the University of Stuttgart's ten faculties, an elite course of studies leading to Bachelor's and Master's degrees, post-doc positions, and junior professorships. The simulation models developed here with state-of-the-art technology and the know-how of far more than 100 researchers aim to develop answers to complex issues and scientific questions.



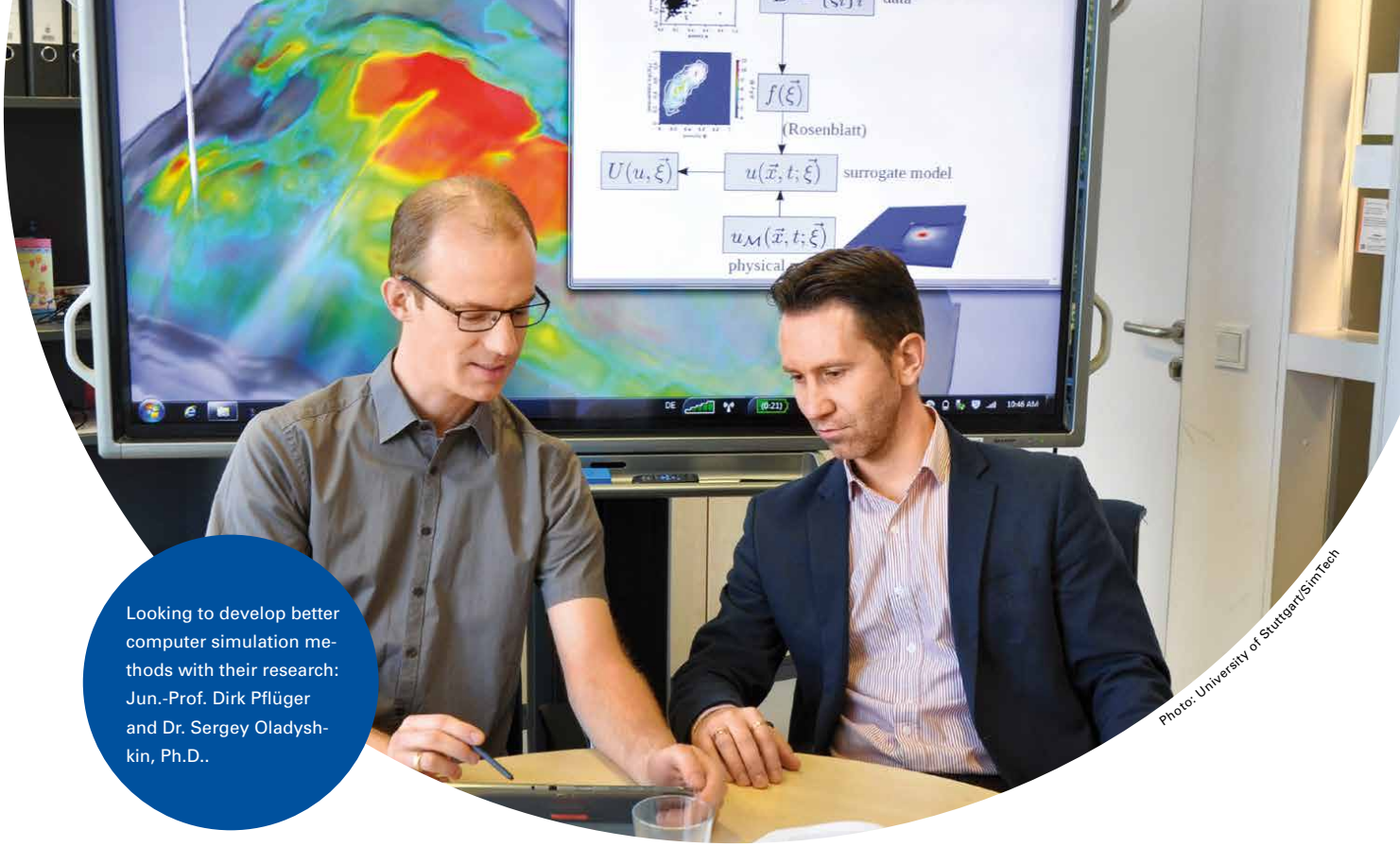
Simulations help minimize the unforeseen in forecasts.

Photo: University of Stuttgart/SimTech

Simulations have one purpose above all: to reduce the number of incalculables. Not only do they reproduce processes, they also predict them. This scientific technique for peering into the future has established itself today in all areas of life: from financial crises to environmental catastrophes that we can see coming with the help of simulations before they occur. This sometimes involves supercomputers whose immense calculatory abilities can take the user virtually through global scenarios from the future. Many simulation tasks require such great calculation capacities that they challenge even the underlying software and models. Computer pioneer Seymour Cray summed the issue up this way: 'If you're going to plow a field, which would you prefer to use: two strong oxen, or 1024 chickens?'. We naturally tend to think that it's easier to use one big, fast processor than many slow ones. The fact is, however, that computers have sped up in the last 10 years or so not because individual processors have become faster, but because there are more of them: more than 180,000, for example, in 'Hazel Hen', Germany's speediest computer in Stuttgart-Vaihingen. That makes it a challenge to use such computers. Just for comparison: if automobiles since 1970 had become faster at the same rate as computers, they would be traveling today at several times the speed of light. The result: today's scientists in this field travel between virtual and real worlds to gain new, sometimes epochal insights into the forces that move the world and will continue to do so.

Safer CO_2-storage

In climate protection, for example. Every year, we produce vast amounts of carbon dioxide - in Germany alone, some 793 million tons in the year 2014. This has made underground storage of carbon dioxide into an important point of attack in the battle against climate change, and two young researchers, Dr. Sergey Oladyshkin of the U. of Stuttgart's Institute for Modelling Hydraulic and Environmental systems (IWS) and Junior Professor Dirk Pflüger of the University's Institute of Parallel and Distributed systems (IPVS), along with the latter's doctoral can-



Looking to develop better computer simulation methods with their research: Jun.-Prof. Dirk Pflüger and Dr. Sergey Oladyshkin, Ph.D..

Photo: University of Stuttgart/SimTech

didate Fabian Franzelin, are working on a simulated system of CO_2 sequestration. Their goal: permanent storage of carbon dioxide in underground waste sites in order to reduce emissions into the atmosphere. On the other hand, some scientists question the true safety of this technique. Their reasoning: we have few data about events at a storage depth of approximately 1,000 meters below ground. This makes it uncertain, for example, just what the composition of the earth is at that depth. But it is precisely this knowledge which is essential in order to avoid the danger of stored CO_2 emerging when under pressure.

This in turn requires that more precise geological information be procured, which in turn will require a few highly expensive drilling operations in order to procure samples. 'Unfortunately, we do not have an X-ray machine that can make the entire planet transparent. That would, of course, make our simulation work much easier,' is how Dirk Pflüger illustrates the challenge in dealing with incalculables when creating simulation models. 'What we're looking for is to turn 'What don't I know?' into 'At least I know what I don't know,' or better: 'At least I know how much I don't know', adds Sergey Oladyshkin. Dirk Pflüger is a specialist in informatics, Sergey Oladyshkin in applied mathematics; but even though their disciplines are different, their research has some interesting interfaces: Pflüger works out the research methods for working with a simulation created by Oladyshkin. The parameters to be considered in CO_2 sequestration are manifold: where can CO_2 be pumped into the ground, for example, in what quantities and under what pressure? Will CO_2 leak uncontrollably out of drill holes or due to weak points in the rock layers? Conventional scientific methods quickly reach their limits when the attempt is made to take all these dimensions into account in a single model. The description used by scientists in this context is, 'the curse of dimensionality'. But now computer simulations offer new ways of inputting existing data as fruitfully as possible. To this end, Dirk Pflüger and his group are working out methods for the approximation of high-dimensional functions on the basis of 'sparse grids'. He compares this principle to that of sinking warships: 'The first thing is to sink the battleship with as little loss of time and effort as possible; then come the lesser ships, and then the smallest one.' The same holds true for simulation: the first thing is to present the key interrelationships as quickly as possible and with as little time and effort as possible.

Sparse grids can provide help in overcoming the „curse of dimensionality'.

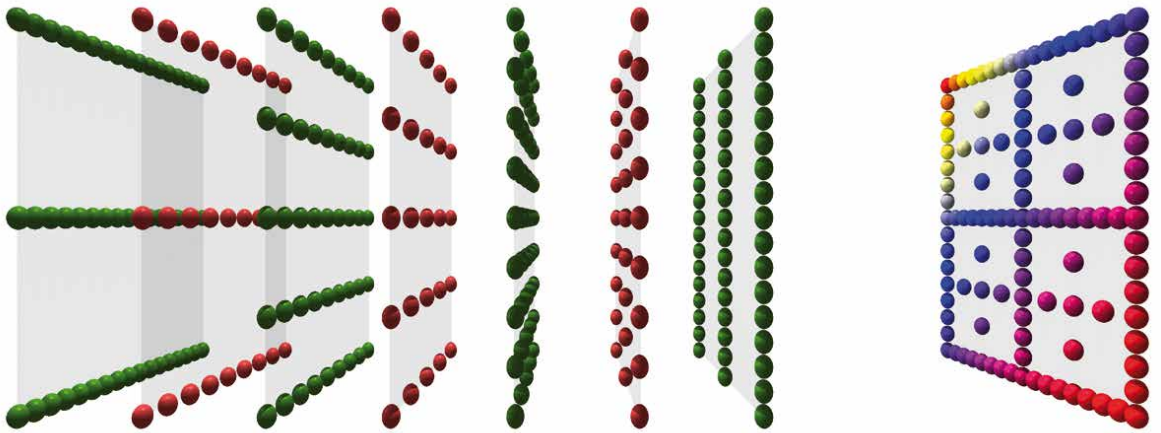


Photo: University of Stuttgart/SimTech

From basic research to application

The aim is to make the results more reliable on the basis of data-driven approaches and to make factual incalculables visible. Why is it important to quantify incalculables? That makes it possible to develop methods for reducing the complexity of computer-intensive simulation concerning CO_2 sequestration, thus making it computable within an acceptable period of time. The development of better methods of computer simulation puts the researchers on the one hand in the field of basic research. But at the same time, their work remains application-oriented inasmuch as they are dealing with real data. The results are of interesting not only to them but also for international research institutions: For example, Dirk Pflüger is also collaborating with the Sandia National Laboratories in the U.S.A. to pursue and publish the results. 'We are working above all on the question of how to master high-dimensional relations of dependency, not only with regard to the mathematics on which they are based but also regarding efficient implementation of all this and how to turn it into useful tools and software. What's nice about this project is that we constantly move back and forth between basic research and its application,' says Dirk Pflüger.

Making traffic safer

Yet another SimTech project is undergoing concrete application; it found in an area in which safety is per se preeminent: street traffic. Accident statistics have shown that far more than 90 percent of all automobile accidents stem from human failure. Passive driving safety systems - for example with safety belts and airbags - can cushion the consequences of accidents. But it's even better, of course, if the accident doesn't happen at all. The future therefore belongs to active forms of driving safety that nip accidents in the bud. Driver assistance systems warn the driver of risky situations and help him/her to react correctly. With their electronic brake assist functions, ABS and ESP and in some cases voice control and lane-change warning signals, these systems harbor an enormous potential for further development. After all: the time preceding the accident itself is in the range of seconds: precious seconds that can

save lives - as simulations make clear. 'Our vision is for ongoing measurements to take place within the auto itself and for calculations to be carried out at every moment in order to ensure the individual safety of the driver at moments of danger,' is how Jörg Fehr, Junior Professor for Multibody Dynamics at Sim-Tech, outlines the overall aim. After becoming a simulation engineer for multiphysical crash simulations at TRW (now ZF TRW), he worked with a team on the development of new safety systems for automobiles, was one of the first graduates of the Simulation Technology Cluster of Excellence, and leaped at the chance in his third year of working in industry to come back to the academic world. Now, as a next-generation researcher, his current work lets him combine research questions from industry and science in order to improve the safety of vehicles. There is a manifold range of new approaches, like considerations involving the driver's muscle activity, or longer simulation horizons, or the uncertainty of parameters which must be studied in order to better simulate human behavior during accidents.

A better understanding of the 'System Called Man'

Two aspects are relevant for this: on the one hand, the issue is to create a model of the human being and his/her behavior as well as possible and simulate it accordingly on a computer. This helps us to identify

The Total Human Body Model is used to simulate a double change of lanes. For example, it measures pressure on the ribs, or the neck vector.

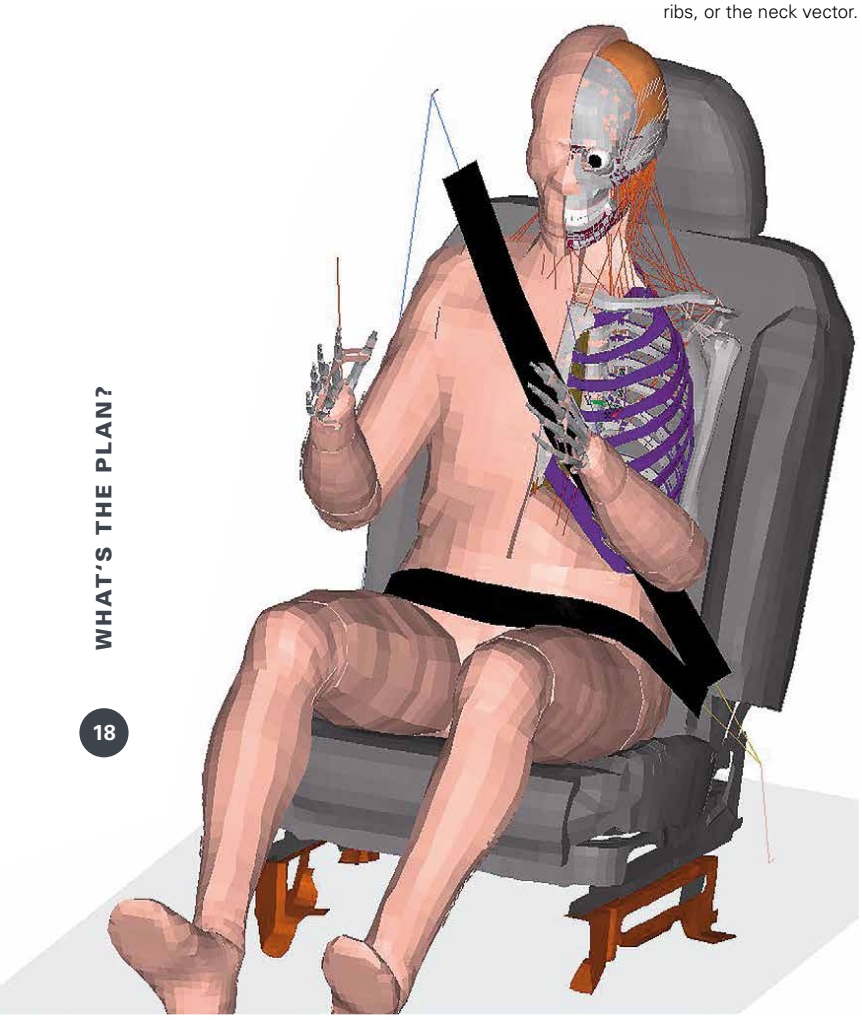


Photo: University of Stuttgart/SimTech

causes of injuries from traffic accidents more exactly and to precisely evaluate the effectiveness of various safety systems. Among other things, the research team here takes the approach of simulating muscle models. The reason: when accident is imminent, the driver changes position by means of muscle activation, and this affects the sequence of movements. The simulations here go far beyond experiments carried out with crash-test dummies, since the latter present only a mechanical approximation. In cooperation with the Institute of Sports Science (InSpo), an extensive series of trials and experiments were carried out, ideas were exchanged, and disciplines were combined in order to better understand the 'System Called Man'. Another aim is to optimize the time for calculating crash simulations by means of model reduction techniques. That in turn involves correctly defining the complexity of the models in accordance with the task at hand.

Milliseconds make the difference

The question is: How can we reduce the order of the equation system while still retaining the system's essential information? After all: the moment required for the accident itself to occur ranges between only 80 and 120 milliseconds, but the process as a whole has already begun some seconds before that, namely at the time when the active safety system is triggered. A simulation, however, must take the entire phase into account, with the result that the computer's calculations need more time. 'The speed is breathtaking; ten million equations must be solved 500,000 times throughout a single night in order to completely calculate a simulation of 120 milliseconds' duration. But a look at the entire elapsed time required by active vehicle safety systems shows that it quickly takes ten times as long,' explains Fehr. The solution is to make calculations faster by reducing the model to the most important factors, meaning that orders and dimensions must be made as small as possible, but as big. as necessary. The results make it possible to arrive at precise statements about whether the safety system in question is good or bad - and for whom. These results are directly related to the development of driving safety systems and help to make them even safer. 'It's very important to us not to do our research in a vacuum,' says Fehr determinedly; 'we want to create added value and work out solutions that have concrete applications.'

Simulation: the model of the future?

One thing's for certain: the classical image of the researcher has gone the way of the dinosaurs. Today's task descriptions are far too complex to be worked

Jörg Fehr has been a Junior Professor since 2014 at the Institute for Technical and Numerical Mechanics, part of the University of Stuttgart's Simulation Technology Cluster of Excellence.

Photo: University of Stuttgart/SimTech

out hit-and-miss by lonely persons working behind closed doors. Today's challenge is to perfect models in an ongoing, iterative process while also combining them in ever-new ways through interdisciplinary interactions. This has led to a broad interdisciplinary environment offering completely new possibilities and insights. This is where SimTech, operating as a faculty-unaffiliated network, has established a platform for a new branch of science and has brought together mathematical basic research with the informatics sciences and the world of engineering.

Katja Welte

'I know what you're thinking!' Interfacing the brain with the computer to read emotions

Assistance systems offer the potential to support users mightily in a vast range of situations - even more so when they can read the thoughts of those users. 'EMOIO', a project launched by the Fraunhofer Institute for Work Management and Labor Organization, studies such interactions between man and machine. The goal is to develop emotion-sensitive assistance systems which adapt to the respective user's emotional state and individual needs. Researchers in this world of neuro-ergonomics pursue an interdisciplinary research approach which bundles realms of competence from psychology, informatics, engineering and the neurosciences. Kathrin Pollmann and Mathias Vukeli of the University of Stuttgart's Institute for Ergonomics and Technology Management have joined this project to carry out research in the Competence Center of Human-computer Interactions in order to find how neuro-scientific techniques can be used to record and classify human emotional experiences during interactions with complex machines. The two researchers are working out a neuro-adaptive system that uses the user's brain activity to recognize whether he/she likes the system's way of doing things or not. One day this kind of brain-computer interface will make it possible to adapt the behavior of assistance systems perfectly to individual preferences and needs with no need of active feedback from the user. This has led in recent years to the use not only of active brain-computer interfaces (BCI) which are under the user's control but also to the emergence of so-called 'passive BCIs'. These BCIs are able to recognize mental and emotional states like moods, mental strain, fluctuations in performance, or sudden and unexpected reactions and communicate them directly to a technical system. The goal is a co-adaptive learning process in which the system learns from the human being and adjusts itself continuously.

kwe

Mistress of the Keys
Maria Fyta uses gold and diamonds to decipher genotypes

Just one of approximately 10,500 woman professors in Germany: Dr. Maria Fyta, a Junior Professor since March 2012 at the University of Stuttgart's Institute for computer Physics. That puts her among the approximately 23 percent of women professors recently counted by the Federal Office of Statistics. For her part, Fyta finds such questions of statistics and gender secondary. Rather, she has allowed herself from the very beginning to be guided by her own interests. And this has paid off: her research in deciphering DNA has led her and her team to a notable breakthrough with the help of gold and diamonds.

The DNA of the human body is more than just a little bit long; to be more precise, the DNA chain in only a single human cell is about three meters long. What's more, this DNA contains millions of so-called nucleo-bases: adenine (A), guanine (G), Cytosine (C), and Thymine (T). How they are lined up in the DNA building blocks determines 'Whether - to put it simply - we are talking about the genotype of a human being, a banana, or a daisy', is how Maria Fyta explains it. Techniques for identifying such chains and thus deciphering DNA have been around for some time now - the human genotype was first identified in 2003. The technique for doing so, however, is still very time-consuming and expensive. This was one more reason for Fyta to tackle the issue. She is now part of a vast community of worldwide researchers who are analyzing DNA with one major goal: to read out the entire human genome in only a few hours. That would make it possible, for example, to personalize medical care and tailor it exactly to the needs of the respective patient.
One of the most promising methods for accelerating the analysis of DNA is precisely nanopore sequencing, a technique on which Fyta is presently at work with her research colleagues Prof. Ralph Scheicher (from Sweden), Prof. Rodrigo Amorim (Brazil) and doctoral student Ganesh Sivaraman at the University of Stuttgart.

Threading the needle with DNA

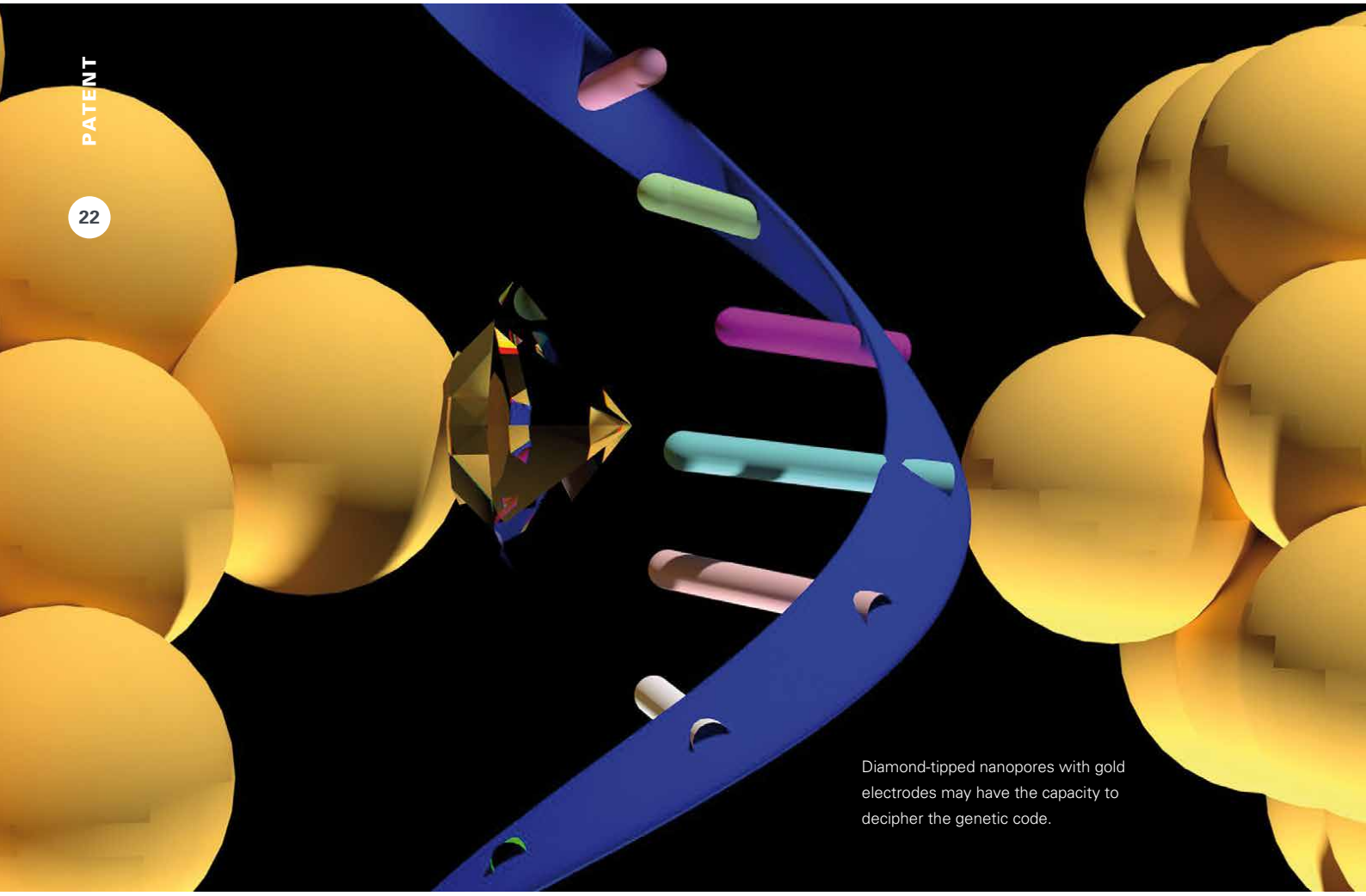
The technique requires pulling a strand of DNA through a nearly infinitesimally small hole in an artificial membrane - much like threading a needle. For their part, the membranes consist of biological or synthetic materials and have a high level of electrical resistance. Fyta works with membranes of silicon nitride or graphene in an electrically charged salt solution. In contrast to normal ion channels, the nanopores are permanently open and allow a constant flow of molecules through the membranes. The ions move from one side of the membrane to the other, generating electrical current. The amperage changes measurably each time the four different DNA bases A, G, C and T move through the nanopores. This can in turn be very quickly read out via gold electrodes positioned in the nanopores.
But it wasn't easy: 'We were looking for a way to prevent a signal overlap from the nucleobases or from the salt solution which surrounds them, since that would have falsified the results,' says Fyta. To give an idea of the overlap: it is as if individual letters of the alphabet were to merge into one another until the word is no longer decipherable. The solution, as Junior Professor Fyta explains, was: diamonds. 'To keep the signals from getting mixed up, we modified the gold electrodes with an additional layer of diamonds. It turned out to be the breakthrough we were hoping for, because it changed the interaction between DNA and nanopores. We found that the signal changes radically, depending on which nucleobase is being pulled through the nanopores at any given moment.'
It took physicist Fyta and her team a good three

‘Tireless curiosity, a love of combining things to see what works best - those are character elements that must be firmly anchored in the DNA chain of every scientist.’

Junior Professor Maria Fyta

Photo: Uli Regenscheit

years of research to announce their first successful trials in June of 2016. 'But we're nowhere near the end of our research', she says. 'This discovery has remained purely theoretical in nature up to now. Now we must fine-tune our observations on the computer and then turn our ideas into practical reality. But that's science, after all: always step by step!' Step by step: that's a good way of describing Fyta's own personal career after her birth in Germany and growing up in Greece. But no matter where she was, she always liked mathematics and physics; and so, after her school graduation she decided to get a university degree in physics. She herself has the very qualities she describes as part of every scientist's DNA chain: tireless curiosity and a love of combining things to see what works best. Those are essential elements



Diamond-tipped nanopores with gold electrodes may have the capacity to decipher the genetic code.

Photo: University of Stuttgart/SFB 716

'in the DNA chain of every scientist,' she says again, but now, as a 39-year-old mother of three children, with a gleam of humor in her eye. Her Master's Degree was followed by a doctorate at the University of Crete, whence her studies took her to Boston in the U.S.A., where she began her research on nanopores in 2005. But success has spoiled neither Maria Fyta's curiosity nor her interest in other issues. She is also fascinated by the sciences of solid body and material physics, where, for example, she is pursuing the question of how to determine the characteristics of materials and what happens when she changes their structure or their chemical features. For Fyta, the exploration and discovery of new topic areas is part and parcel of her career: 'Time and again they provide the inspiration for other projects.' Just one example: her interest in research into small diamonds ultimately led her to experiment with the characteristics of nanopore sequencing. The upshot is that there's no saying what new fields of science this Junior Professor will hit upon in future for herself. What does she herself say? 'A true researcher dies in his boots. All my projects have the same general direction, but what comes next is always a surprise. And so I try to react flexibly.' Isn't that fatiguing and frustrating at times? 'Not at all!' says Fyta emphatically. 'After all, there's no fun in doing the same thing forever or always knowing what will happen!'

Michaela Gnann

Creative and Focused

Every year, a good 400 candidates from all over the world successfully conclude their doctoral degree studies at the University of Stuttgart and in doing so make major contributions to the growth of science with their creativity in research and teaching. For many, the Doctor's Degree is the springboard to an academic career; others acquire valuable abilities for careers in the business world or with non-profit organizations. Along the way, these young persons experience both an enormously variegated research landscape in the engineering, natural, liberal arts and social sciences and a highly stimulating area of work. Some doctoral and post-doc students talk on the following pages about their adventure.

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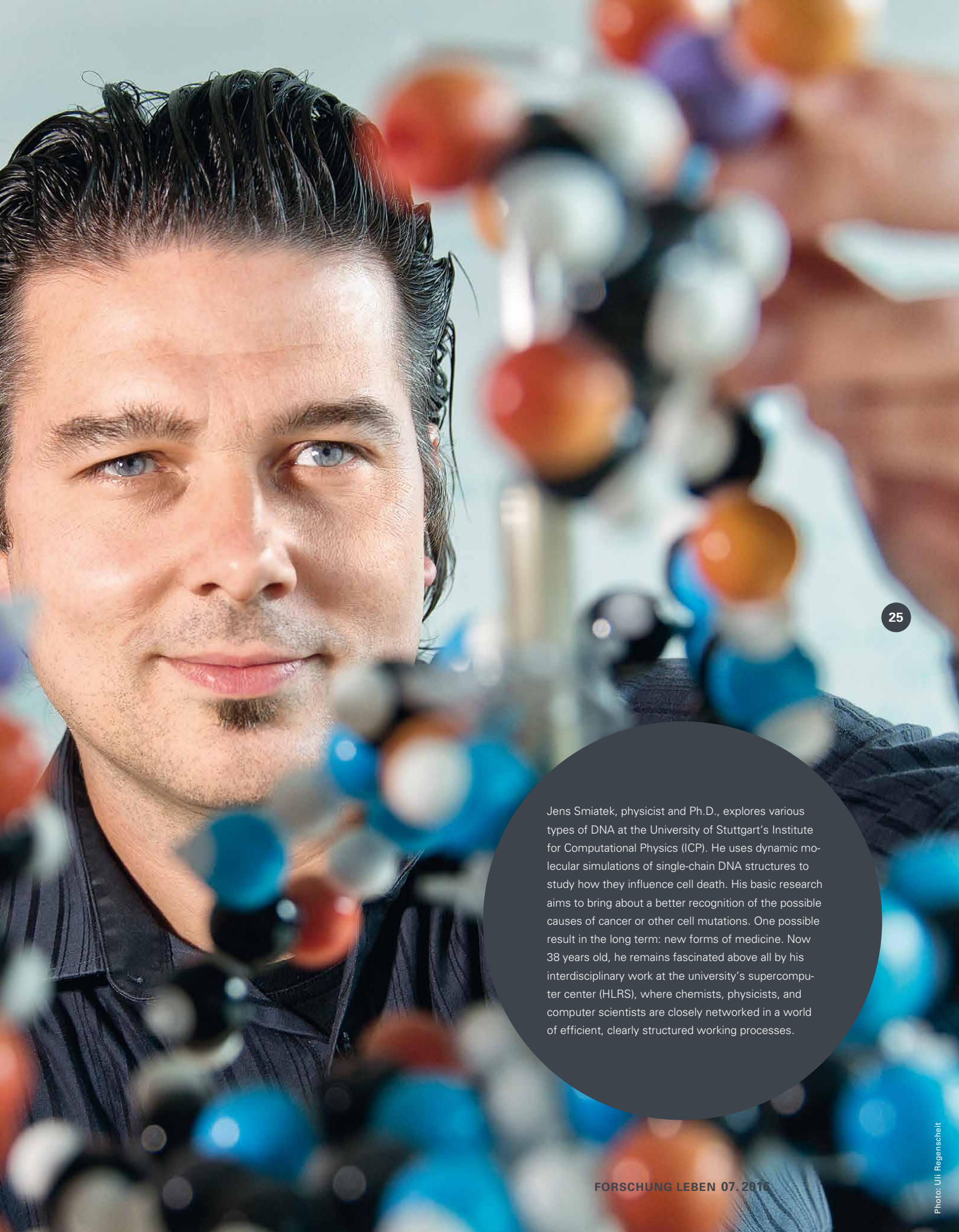


Jens Smiatek, physicist and Ph.D., explores various types of DNA at the University of Stuttgart's Institute for Computational Physics (ICP). He uses dynamic molecular simulations of single-chain DNA structures to study how they influence cell death. His basic research aims to bring about a better recognition of the possible causes of cancer or other cell mutations. One possible result in the long term: new forms of medicine. Now 38 years old, he remains fascinated above all by his interdisciplinary work at the university's supercomputer center (HLRS), where chemists, physicists, and computer scientists are closely networked in a world of efficient, clearly structured working processes.

Photo: Uli Regenscheit

Annika Liebgott and Thomas Küstner of the Institute of Signal Processing and Systems Theory (ISS) are specialists in the preparation and processing of magnetic resonance tomography (MRT) images. Together they are developing a software that will help physicians and medico-technical assistants to evaluate MRT scans more easily. It will compensate for movements or special patient characteristics like body fat which can otherwise reduce both the quality of images and their diagnostic usefulness. For example, movement artefacts cause blurred lines in the image. The new software will not only evaluate scans directly in the making but will also provide tips about parameters which must be adjusted to achieve informative results. This in turn will largely obviate the need for arduously made follow-up images.

One optimal advantage in this for Liebgott is that the University of Stuttgart's Institute of Signal Processing and System Theory (ISS) has cooperated for years with the University of Tübingen's teaching hospitals, offering the rare opportunity to link together two exciting fields of research: electrotechnology and medicine. This 27-year-old scientist sees her home town of Stuttgart as the ideal place to carry on joint research with high-level industrial partners and universities.

The University of Stuttgart

Photo: Uli Regenscheit

Since 2013, David Hartich has been a doctoral candidate at the University of Stuttgart's Institute for Theoretical Physics. His work takes him into the world of molecules, where he uses thermodynamics to find how much energy is needed by bacteria, for example, to reliably process signals by means of their receptors. Since thermal fluctuations constantly hamper them in doing so, these organisms require energy in order to counteract such external influences. Hartich's calculations, which can also pinpoint the maximum speed of computers, indicate that the quality of information processing is directly dependent on the amount of energy available.

The University of Stuttgart

Photo: Uli Regenscheit

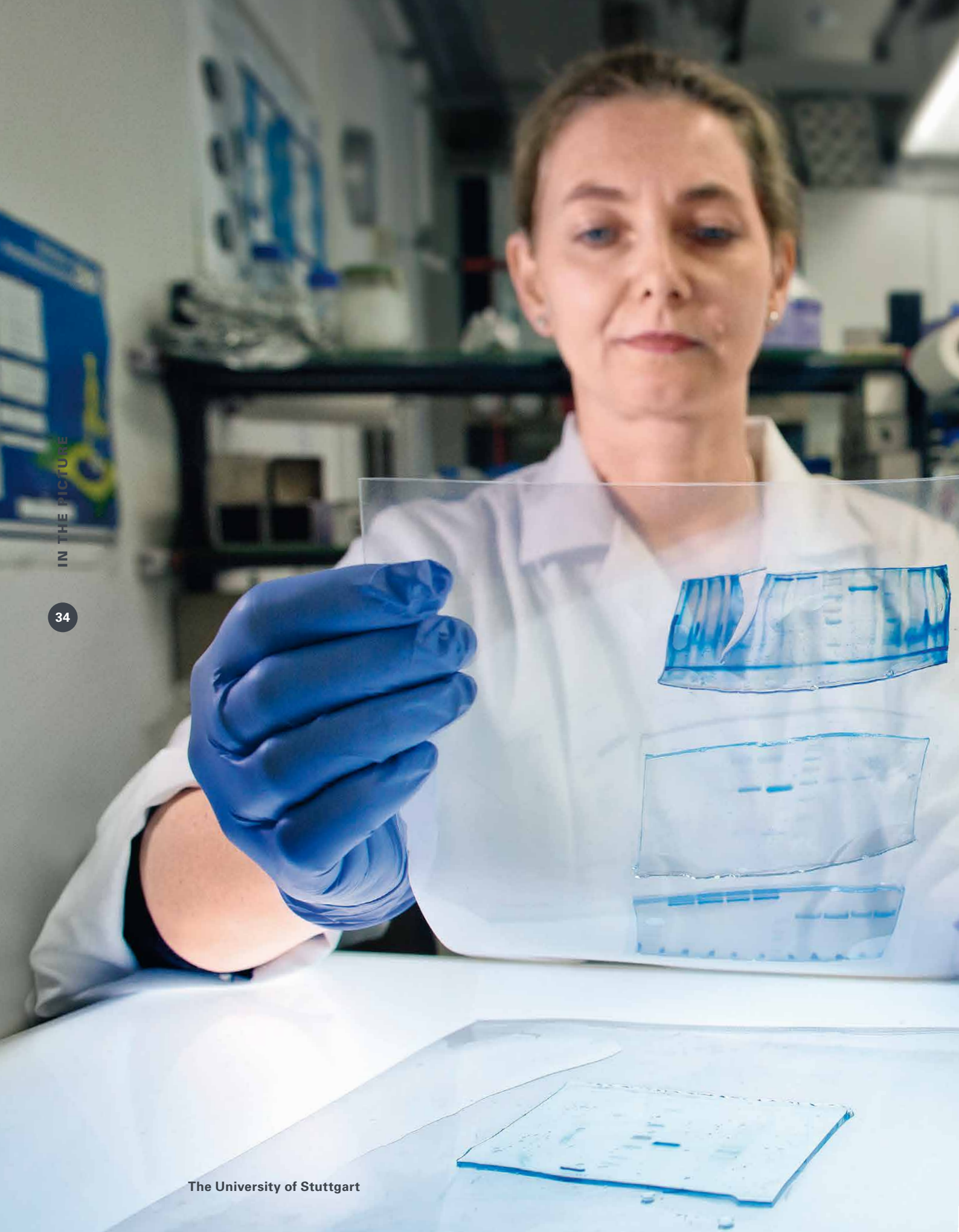
Better sealants by means of lubricants? That is the question for Dr. Peter Schuler, who carries out basic research on every aspect of elastomers at the University of Stuttgart's Institute of Machine Components (IMA). What Schuler wants to show is how sealants can be improved by the use of more suitable substances which bring more to the seal than just their material compatibility. Now 34 years old, Schuler is working out different experiments with his student Nina Laumer in order to test the surface behavior of a nearly endless range of production materials. What Schuler prizes above all in his work is the wide-ranging freedom given him for scientific research, independently of any particular industrial projects. His work also gives him freedom to parcel out his time in such a way that he can spend time with his three children.

Photo: Uli Regenscheit

The University of Stuttgart

During the molding of still partly fluid materials, it is important to heat as homogeneously as possible. That is why Kim Rouven Riedmüller is studying whether thick-walled tubes provide better final results when used as initial mold tools than cylindrical full-form tools. He finds help in simulations of molding processes, where he demonstrates how „skin effects', that is, innate, inhomogeneous material structures can be avoided by means of irregular heating. When carrying out his trials he relies on the excellent equipment provided by the Institute for Metal Forming Technology (IFU), which even makes it possible to recycle metallic waste shavings into new preliminary shapes.

Photo: Ulf Regenscheit



The University of Stuttgart

Cancer continues to be one of humanity's greatest health problems and is the second-most common cause of death in Germany alone. That has moved Dr. Dafne Müller of the University of Stuttgart's Institute of Cell Biology and Immunology (IZI) to study how the human immune system can be influenced in such a way that it battles tumors efficiently on its own. Müller applies genetically engineered proteins to test their impact on cell cultures in a preclinical phase. To do so, she introduces the proteins directly into the tumor and then studies their ability to bind, that is, whether an antitumoral immuno-response occurs. A further step is to test the results in mice. Müller is fascinated by the idea of inducing the human body's own immune system to respond more effectively to cancer. The University of Stuttgart gives her optimal conditions for her work.

Photo: Uli Regenscheit

Timo Koch has successfully blended two of his interests - medicine and the environment - at the University of Stuttgart's Institute for Modelling Hydraulic and Environmental Systems (IWS). His research project is focused on the dissemination of medicines in blood capillaries, with particular attention to the transition from vein to tissue. In contrast to the standard clinical research approach with imaging techniques, Koch has chosen a different method: micro-scale simulations that show on the basis of physical processes how medicinal agents behave in the blood circulatory system. His work yields important insights concerning, for example, how to transport medicine directly to the desired area, for instance a tumor. The Simulation Technology (SimTech) Excellence Cluster offers him a multitude of interdisciplinary opportunities for exchanging ideas and an outstanding technical basis for his work.

Photo: Uli Regenscheit

Katharina Heck studies how porous tissues absorb water. Her work takes her down to minute scales of measurement to find how plant roots take in moisture. Her solution involves focusing on the immediate surroundings of plants, known as the „Hizosphere'. These surroundings often contain gels (forms of mucilage) secreted by the roots to influence the absorption of water. In her different simulations, Heck is developing a pore-network model that will one day help to create water-saving forms of technology for agriculture. Now 26, she finds special enjoyment in creating models of complex systems. The standard software used by the University of Stuttgart's Institute for Modelling Hydraulic and Environmental Systems (IWS), along with the many opportunities offered by the SimTech Excellence Cluster, give her the ideal basis for this.

Photo: Uli Regenscheit

The University of Stuttgart

Jannik Haas (above left) of the University of Stuttgart's Institute for Modelling Hydraulic and Environmental Systems (IWS) is searching for the optimum mix of existing energy storage systems. His focus is on renewable forms of energy and on water power in particular. In order to calculate the best possible storage techniques, Haas draws upon different sources: incalculables, the robustness of technical systems, cost factors, and environmental compatibility. The plan for his method is to make it part of a planning tool that will enable governmental agencies to better estimate and steer the impact of energy policies. As an added benefit, energy companies will receive a tool for determining what services can be provided when, where, and at the best price. Haas, who studied for a time in Chile, is full of praise for the German doctoral system, with its early introduction to mentored research. He is also motivated by the pertinence and relevance of his research topic and the opportunities given him to collaborate with other institutions. At right above: Prof. Wolfgang Nowak, director of the Department of Stochastic Simulation and Safety Research for Hydrosystems at the IWS.

Photo: Ulf Regenscheit

Today's latest photosensors can show individual pixels or rows of pixels successively instead of simultaneously. But if a scene or a camera moves when a picture is taken, a so-called „rolling shutter effect' may result: the resulting picture is blurred. Today's drones too are steered by means of similar sensors, which prevents them from correctly pinpointing their own spatial position. But that will change, if Dr. Jan Maximilian Montenbruck of the University of Stuttgart's Institute for Systems Theory and Automatic Control (IST) has anything to say about it. Starting with a systems-theoretical approach, he has worked out an algorithm that makes it possible to reverse image distortions. What fascinates him about his work? The interface between technical solutions and pure theory. He enjoys the full support provided him by the University, not only in terms of his freedom in choosing a research topic but also because he received special aid as a young doctoral candidate in the University of Stuttgart's SimTech Graduate Program.

Photo: Uli Regenscheit

Internet Community Rescues World Cultural Heritage Site

Treasures destroyed by the IS remain virtually intact as 3D reconstructions

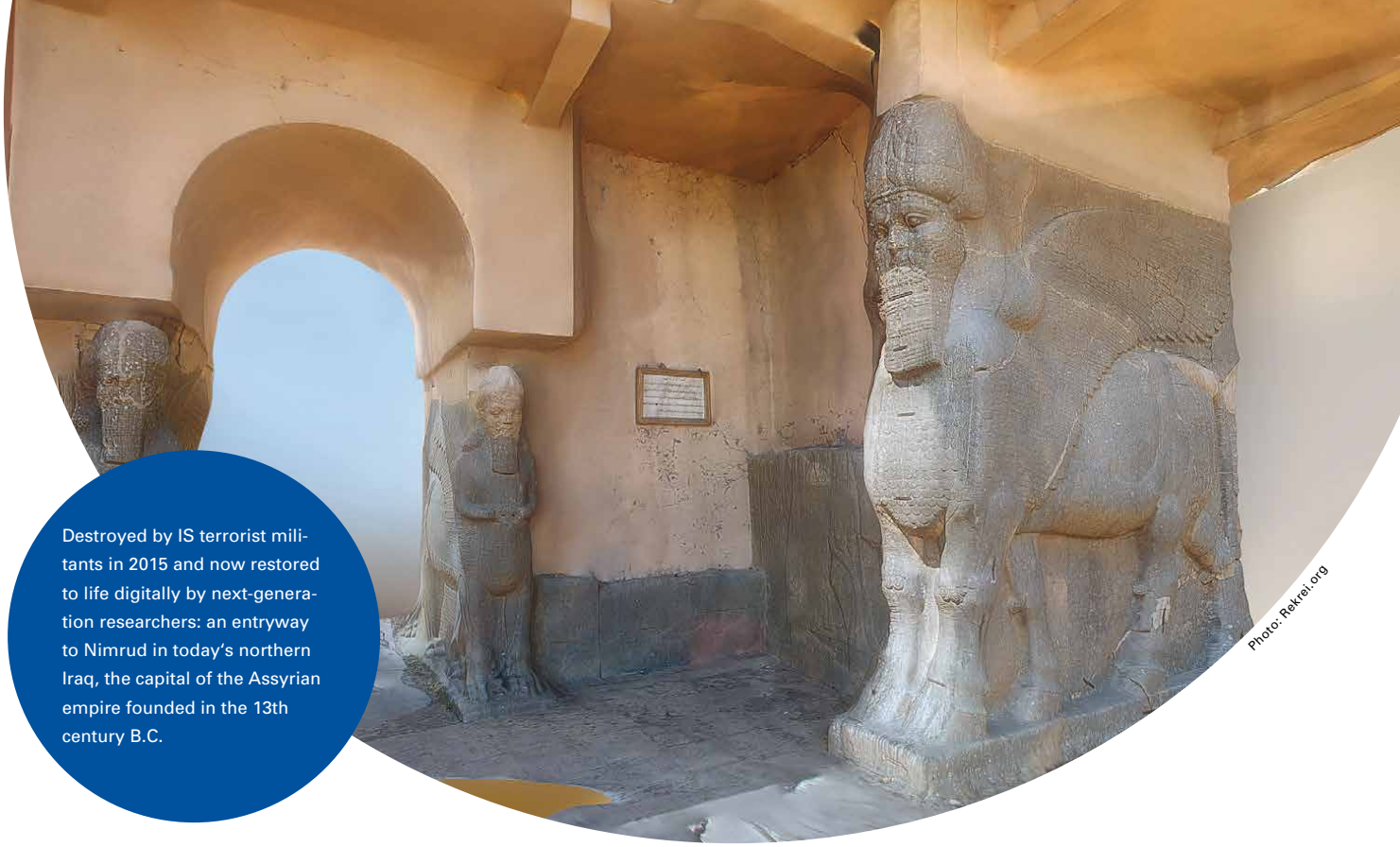
On February 26, 2015 life changed for Chance Coughenour, a doctoral candidate at the University of Stuttgart's Institute for Photogrammetry (IfP). That was namely the day on which terrorist militias of the 'Islamic State' (IS) published a video on the Internet in which its fighters were shown destroying Iraq's museum of Mossul, with its millenium-old statues. That act triggered a new method of preservation of cultures.

32-year-old Chance Coughenour sat at his computer until late that fateful night, communicating with a facebook-group of colleagues from the European Union's 'Initial Training Network for Digital Cultural Heritage' (ITN DCH) Project. Since October 2013, it has brought together 16 next-generation researchers in eight countries to study how to preserve the cultural heritage of humanity in digital form. 'Why not use photos in order to reconstruct the statues virtually with photogrammetry and exhibit them in a virtual museum?' wrote Matthew Vincent of the University von Murcia. Coughenour answered: 'That would be a fabulous answer to IS: reconstructing anything they destroy. Before they knew it, both were caught up in this project of their own making. Within two weeks, they had created from 16 photographs a three-dimensional reconstruction of the Lion of Mossul, plus an Internet website on which this statue was presented as the first exhibit of the virtual museum. International media like the major Spanish and French dailies 'El Pais' and 'Le Monde', along with the British broadcaster BBC reported about it. What started initially under the name 'Project Mosul' is now 'Rekrei'. When translated from Esperanto, it means roughly 'rebuild'. That's important, because other cultural monuments elsewhere have also been caught on film. Coughenour's original aim in carrying out his EU-project and writing his dissertation at the IfP was to work with automated 3D and 4D data acquisition using laser measurement and photogrammetry. After finishing his Bachelor's Degree in history at West Virginia University, the young American completed two Master's Degree programs: one at the University of Leicester in England and a second one in Spain in virtual archeology. The latter also brought him to the IfP, because 'Photogrammetry is very important for archeology and for our virtual heritage.' To deepen this insight, he looked for an institute that can deal with the further development and digitalization of a technology invented in the 19th century in which the spatial form of an object can be reconstructed from photographs.

Before long, however, the 'Rekrei' project grew to such dimensions that it took up - and still takes up - most of Coughenour's time. Speaking as a scientist, he says, 'Rekrei gave us a way to set a small counterpoint to the barbarianism of the IS.' His Internet platform does this by linking crowd-sourcing with photogrammetry: from anywhere in the world, anyone can upload photographs of historic monuments or process them into 3D models. From there, they are taken into the project via the 3D-platform 'Sketchfab'. 'This kind of 3D reconstruction has been made

Photo: Rekrei.org

Shards remaining after IS-destruction of the famous 'Lion Statue' from the Allat Temple in the Syrian oasis city of Palmyra.



Destroyed by IS terrorist militants in 2015 and now restored to life digitally by next-generation researchers: an entryway to Nimrud in today's northern Iraq, the capital of the Assyrian empire founded in the 13th century B.C.

Photo: Rekrei.org

possible at all only through the immense popularity of digital cameras and mobile phone cameras,' says Coughenour.

Even today, the two 'Rekrei' founders are solely dependent on donations for their project, since it is not part of their research for the ITN-DCH project. On the other hand, their work with 'Rekrei' to preserve mankind's cultural heritage in the age of the Internet has led to an insight of central importance: the voluntary participation of persons all over the world is so overwhelming that there is no need to hire a team for gathering data. At the beginning, up to 100 emails a day came in, 'including some from 3D artists who normally work on Hollywood films!' At present, 364 persons are collaborating in 'Rekrei'. This highlights the idea's greatest advantage: no archeologist is needed on location in order to preserve a historic monument. Anyone looking to preserve such a piece of cultural heritage need only upload his photographs to rekrei.org, at which point others can then create the related animation. '3D models from crowd-sourced images may not match the original exactly,' says Coughenour, 'but if the original has been lost, we at least have a good reproduction of it.' In fact, UNESCO has now included the 'Rekrei'-reconstructions on its website reclaimhistory.org, as part of its campaign to preserve cultural heritages. Only as his dissertation neared completion did 'Rekrei' finally become part of Coughenour's work at the IfP. As a result, for example, he now mentors students in their work, including one project to reconstruct the Temple of Palmyra, which was also destroyed. Chance Coughenour and Matthew Vincent continue steadily today in their ongoing development of 'Rekrei'. For example, they have created a tool which integrates all the relevant images from the 'Flickr' photo community after they are released for publication. 'All the photographs we need are already on the Net,' says Coughenour, now an expert for digital archeology and photogrammetry. He estimates that in only a few years automated software will be available for gathering photos for 3D objects. If so, it will not only enormously accelerate the digital preservation of world cultural heritage sites but will also be useful in other areas as well. For Coughenour, this means that both public and industrial funding sources should find it attractive to support projects like 'Rekrei'. 'Photogrammetry was invented in Germany, and it would be terrific if we could find funding here too!'

Daniel Völpel

Looking Below the Surface
How business decisions evolve in the human brain.

The image of the purely rational hero is long since passé in the economic sciences. We see this, among other things, in the area of Controlling, where the impact of allied fields of knowledge is ever more visible. Doctoral candidate Ann Tank at the University of Stuttgart has studied neurobiological processes and their role in the appraisal of commercial key indicators. She did so by employing magnetic resonance tomography, a standard technology in medical analysis. One may well ask: What does this method have to do with Controlling, which deals with the analysis of dust-dry data?

In every company, decisions are made each day that have an impact on employees, customers, and owners. In turn, these decisions are nearly always based on key indicators that show the company's current status. While the decision-making process often displays a similar pattern, it is carried out by persons with very different makeups, and only in recent years has science directed its attention to thought processes in the brain that lead to such decisions. This new area is the territory in which Ann Tank has written her dissertation. Her aim: to cast light on neurobiological processes that play a role in the appraisal of commercial key indicators. In pursuing this path, 30-year-old Tank has chosen an unusual topic, part of the field of neuro-economics. This is a discipline which has grown up at the meeting point where economics, biology and psychology come together. 'What I want to do is to make processes which take place in the body during business decisions objectively and directly measurable,' says Tank. She takes her theoretical basis for this above all from 'neuromarketing' - a branch of research promoted by businesses which hope to understand what makes people decide to buy.

Looking for the right partner

When writing her dissertation at the Department of General Management Accounting and Control at the University of Stuttgart, Tank found few publications in the literature about her topic. Although some experiments had been carried out to study human behavior in economic decision-making situations, the human brain's role in these situations

Overview of brain regions which go into action during business-making decisions.

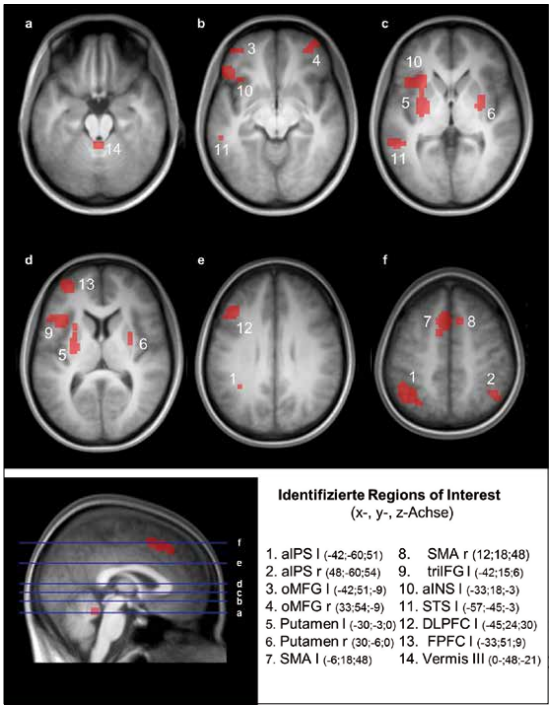


Photo: University of Stuttgart

was unexplored territory, and she found she needed partners. After a woman scientist in her circle of friends told her about the University of Tübingen's Center for Neurology, she contacted Dr. Axel Lindner there. He heads up a task force studying the neurobiology of decision-making at the Hertie Institute's Department of Cognitive Neurology for

Doctoral candidate Ann Tank uses MRT technology to track neuronal processes in business decisions.

Photo: Max Kovalenko

Clinical Brain Research. The very first meeting was a meeting of minds: Lindner was enthusiastic about Tank's idea. Together they resolved to join forces in tracking neuronal processes in business decisions. Tank then discussed with Lindner and her thesis advisor, Prof. Burkhard Pedell, how to design the project.

The experiment was divided into two phases. In the first, each of 125 student volunteers had the task of acting as controller for a toolmaking company owner who must decide on the basis of complex commercial key indicators whether to continue or discontinue a development project. Then the volunteers reported their feelings about the exercise. They also answered questions about their own background of experience and their responses to risk. 'This information allowed us to draw some initial conclusions about processes which take place in the brain during this decision-making process,' says Tank.

Participants in the first part of the experiment were allowed to apply for the second phase, namely a study using functional magnetic resonance tomography (fMRT). It's a method usually familiar to non-professionals only from visits to the doctor. But in neurobiology it provides not only important but also easily understandable data. First a magnetic scanner records metabolic processes in the brain. Areas there which become active consume more oxygen from the blood. This changes the density of the blood at that location, triggering magnetic changes which are then recorded by the scanner. The results can then be shown as if in a video. This represents a major step forward over the electro-encephalographic method (EEG) previously used for such experiments. It merely recorded changes in brain flows, viewed from the surface of the head.

The second phase of the experiment was more selective about participants. For example, artificial metal joints, bone screws or tooth stabilizers were grounds for exclusion. The reason: metal in the body is incompatible with MRT. 'We also wanted to avoid even minimal health risks for those in the study,' says Tank. After being selected, the 30 participants carried out their tasks lying flat in the MRT tunnel, where the scanner recorded their brain activities. When areas become active, it is reasonable to conclude that they are affecting the decision-making process.

An hour of looking at the tube

The study took a long time: participants were asked to remain motionless for four times 12 min-

Ann Tank's basic research also provides first neurobiological evidence in the field of controlling for an interaction between commercial decisions and emotions.

Photo: Max Kovalenko

utes, while their heads were gently held in place by cushions. During processing of the key indicators, a special MRT-camera recorded eye movements to provide further information about how the test persons arrived at their decisions. Was all relevant information taken into account? What information was central? The tasks were presented in the MRT tunnel through a system of mirrors which made curves and numbers easily legible for the participants. Their job: to use this information as if they were controllers, as in the prior experiment, to arrive at decisions about a development project. The test persons answered by means of a pushbutton in their hand.

Empirical studies have already indicated that emotions also play a part in commercial decisions. For the first time, Ann Tank's work has provided neurobiological support for this interaction in the field of Controlling. For example, she found that the quality of the recorded decisions was related in many cases to activation of the affected brain area. This includes not only areas which are responsible for cognitive processing of information but also areas which may be related to the emotional assessment of information. The experiment also provided evidence that an affinity for risk can affect the quality of decisions in certain cases.

The results may be unspectacular for non-professionals, since they do not directly give rise to concrete solutions for companies. At least, not yet. But that was not Tank's aim. Rather, her dissertation describes basic research which aims not to give answers but to generate as many new questions as possible. The importance of this is that they allow a still-young field of research, like neuro-economics, to continue growing.

Heimo Fischer

100 Years of Hybrid Production Materials

A new project casts light on the history of materials research

New composite materials like glass-fiber reinforced aluminum, aramid fiber honeycomb, and carbon fiber-reinforced plastic (CFK) have already provided major impulses for development in various areas of industry.

Photo: Archiv des Instituts für angewandte Naturwissenschaften Dresden

Fiber-reinforced plastics are now the trend in materials used by engineers and natural scientists. How did the development of such materials come about? Dr. Andreas Haka of the Department of History of the Natural Sciences and Technology intends to go into this question and has initiated a research project to do so.

Photo: Archiv des Instituts für angewandte Naturwissenschaften Dresden

Modern technology: In the year 2002 Volkswagen coordinated the development of a carbon fiber-reinforced floor module for small cars.

In researching hybrid materials, Haka ranges through a century of production material studies and development strategies. His first results show how differently the development of new composite materials in the 20th century has influenced various branches of industry like aviation and the automotive industry. His work gives Haka not only unexpected views into secret industrial research projects and science laboratories but also contact with trailblazers of the new technology. The resulting insights are already part of his classes.

Tim S. Schmidt


Photo: Kai Melde / MPI für Intelligente Systeme

3D-drawings with musical notes

Together with the University of Stuttgart, researchers at Stuttgart's Max-Planck-Institute for Intelligent Systems have found a way to generate "acoustic holograms" with little effort. Using a 3D-printer, they made a plastic relief image that conducts sound faster than a surrounding liquid. The more they slowed sound waves, the thicker the printer applied the material. Using this method, the researchers drew Picasso's Dove of Peace as an "acoustic hologram". Even more important, however, they have expanded the possibilities for manipulating infinitesimal particles. This could lead to greater precision and quality in ultrasound diagnostics in the fields of medicine and materials diagnostics.

A bridge to sustainable mobility

Although wood is regarded as a sustainable building material, it was inadequately weather-resistant up to now for bridges. But a prototype at the University of Stuttgart's Institute for Materials Testing is showing how it is now feasible to build long-lasting wooden bridges on the basis of new structural principles as traffic routes for the mobility of the future. The 40-meter-long "Stuttgart Bridge", the only one of this kind in the world, is the result of two research projects. Their aim was to develop innovative construction principles and a catalogue of specifications for long-lived and low-maintenance bridges made of the sustainable, CO2-storing material wood. To this end, the team of scientists dreamed up a new construction method for the transition points between the superstructure and the thrust bearings, in order to avoid damage from water, foliage, gravel or snow. They also worked out a surface covering that ensures long-term preservation of the wooden bridges.

Freedom of thought is what Germans find most important

German citizens regard freedom of thought as the most precious good provided by law. This was found by a forsa-study of the University of Stuttgart's Institute for the Social Sciences. After all, 66 percent of those queried said that they would view restrictions of their right of free speech as negative. The right of a person to free thought and opinion is regarded as more valuable, for example, than the right of self-determination, personal data, or freedom of religion. The result of the study: a majority of the population would accept higher taxes in order to increase safety within the country. Most rejected a cutback in social services in order to finance safety measures. In addition, many Germans would welcome a more seamless system of videocameras as a preventive against crime. But many would reject more rigorous control of home PCs.

Water on stone

A scientists from Russia, Chechnya and Germany have now succeeded for the first time in binding water molecules with gemstones in such a way that ferro-electric signs are observable. The nanochannels of the crystals store water molecules and keep them far enough from one another to prevent them from forming hydrogen bonds but close enough for them

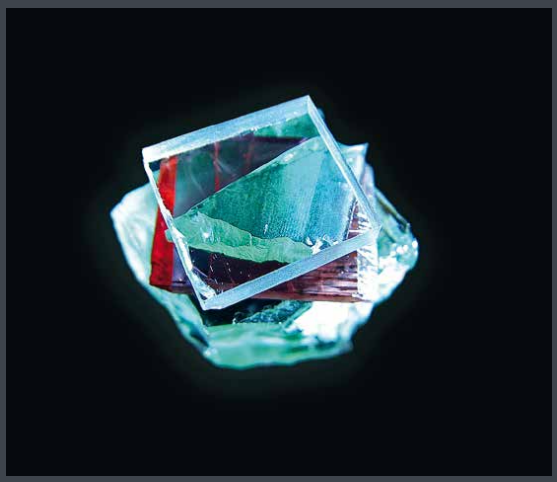


Photo: University of Stuttgart/PI I

to "sense" each other electrically. Optical studies over a broad spectral range were able to observe the H2O molecules directly, and the scientists noticed that all electrical dipoles orient themselves when the temperature drops to absolute zero, i.e. minus 273 degrees centigrade.

The physicists at the University of Stuttgart's 1st Physical Institute believe that the ferro-electricity of these isolated water molecules also plays an important part in biological systems. Their research thus opens the way to new insights into the function of proteins and cells. This in turn could be applied, for example, in fuel cells, data storage units, light sources, and other electronic devices.

Environmentally friendly: Climate control for trucks

Big trucks keep a cold wind blowing in the cabin on hot summer days by leaving their engines running. But comfort for the drivers is burdensome for the environment: not only do the mighty diesel engines require 4 liters of fuel per hour to keep the interior cool, but they also pollute in terms of noise and exhaust gases. Because the potential for savings here is gigantic, the University of Stuttgart's Institute for Thermodynamics and Heat Technology was commissioned two years ago by the HAPPICH Company in Wuppertal to find an environmentally-friendly alternative. The first prototype is already in operation: when the engine is turned off, the new cooling technology continues working – without compressor, refrigerating aggregates, or coolant. It is noiseless, emission-free, and uses only water, exhaust gas heat, and zeolite, a porous, high-capillary vulcanic mineral which is environmentally friendly even in its synthetic form, as a water vapor storage material. Dr. Henner Kerskes and his team in Stuttgart succeeded in demonstrating at year's beginning that the adsorption technique refrigerates effectively. A patent application has been submitted for this new cooling technology.

Photo: promobil

Plant Viruses - beyond Good and Evil
Researchers show their work to Nobel Prize winners

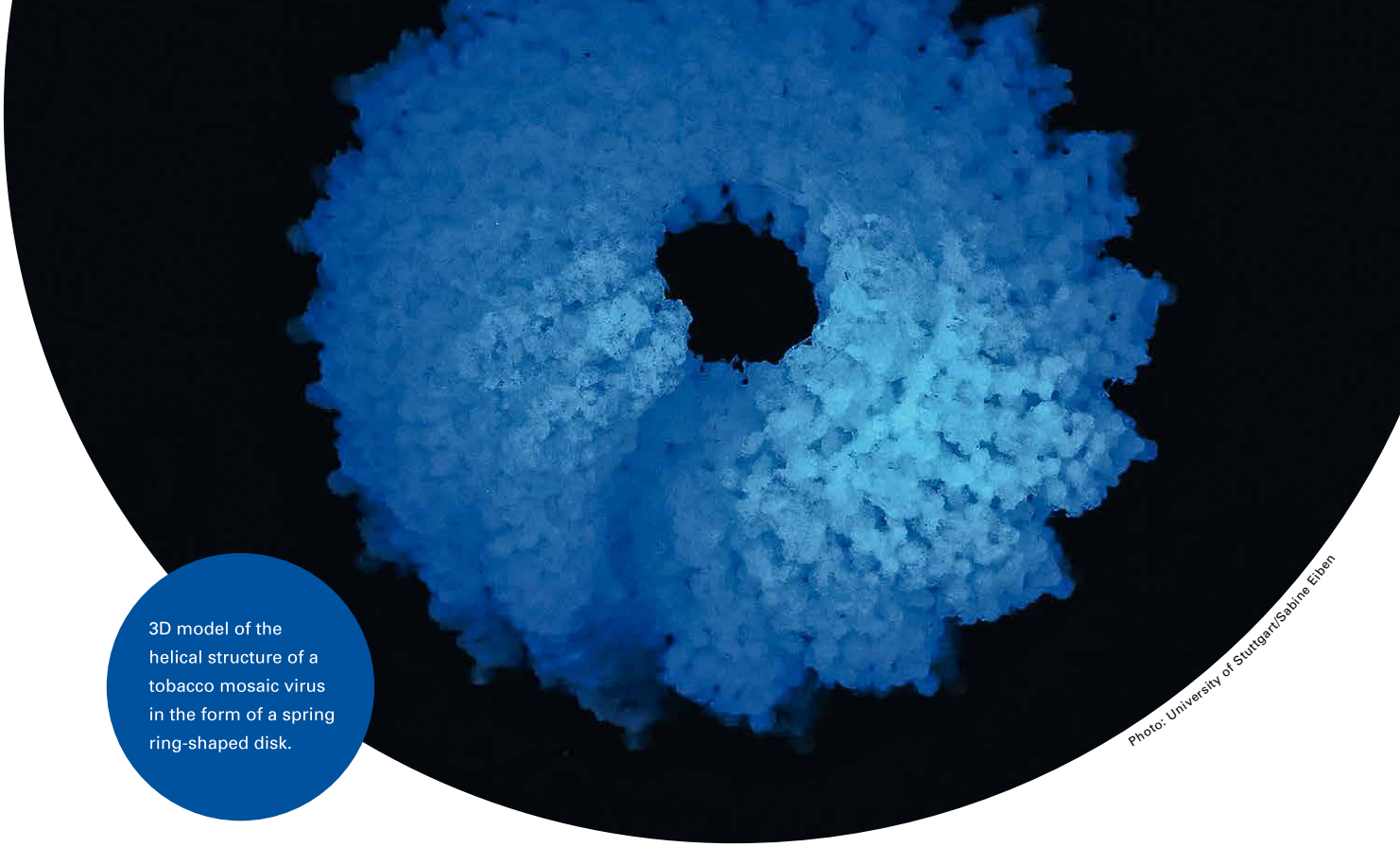
They're tiny, erect shells that make architects green with envy, and can still destroy their surroundings. A study in contrasts: plant virologist Dr. Katharina Hipp of the University of Stuttgart's Institute of Biomaterials and Biomolecular Systems (BIO) and its Department of Molecular Biology and Plant Virology studies the African cassava mosaic virus, a cassava plant parasite, while her colleague Dr. Sabine Eiben finds some good qualities in the tobacco mosaic virus. Viruses may lend wings to nanotechnology in future as a basis for sensors, a support framework for tissue substitutes, or even in cancer diagnostics.

Katharina Hipp has been fascinated by geminiviruses, since the day when she listened as a young student to a lecture at the Department of Molecular Biology and Plant Virology at the Institute for Biomaterials and Biomolecular Systems. Her eyes glow as she gently rotates and tilts a model of the cassava mosaic virus, a member of the geminiviruses, between her fingers. The model, a parting gift from a former doctoral student, was printed out on a 3D printer according to the high-definition structure the two had worked out from many blurred electron microscopic projection images of a virus particle. 'What sets geminiviruses off from all other viruses is their protein envelope, which forms two incomplete icosahedra - whence the Latin name 'gemini', for 'twin'' explains biologist Hipp, who is now a post-doctoral researcher in the department headed by Holger Jeske. 'Normally, we would expect these twin pairs to break apart easily, but that doesn't happen here.' This still surprises Hipp. Viruses normally appear as rods, nearly spherical polyhedra, or - as here - as individual icosahedra. Even though the geminiviruses are only about 20 to 35 nanometers in diameter (one nanometer = one millionth of a millimeter) and are thus pygmies among the viruses, and get by with only a minimum set of proteins, they cause considerable damage to many crop plants, primarily in the earth's tropical and subtropical zones. The African cassava mosaic virus initially betrays its presence by a 'mosaic' pattern of light and dark-green areas on the leaves of the infected cassava plant, after which the entire plant wastes away. To make her point, Hipp says, 'The cassava root is part of the basic diet of many in Africa and Southeast Asia, where it's as important as the potato once was for us.' Many small farmers cultivate cassava behind their houses to feed their families. If the harvest fails due to a virus, the situation is dramatic for the people there.'

Understanding how it works

Whiteflies, which are endemic in warm zones, transmit the cassava virus from one plant to another by sucking their juices. As 39-year-old Hipp warns, 'If climatic warming continues, these insect transmitters of geminiviruses could spread to the more temperate latitudes and bring many viruses with them.' Even today, crop damage is found in Spain and Italy, for example, from the 'tomato yellow leaf curl virus', a geminivirus which attacks tomatoes and paprika plants. Like the African cassava mosaic virus, it is one of the 'top ten' most important plant viruses.

Hipp also points to a solution: 'We can only prevent the virus from spreading if we understand how it works.' As a biologist she wants to know how the 110 identical envelope proteins of the cassava mosaic virus interact with each other in order to form stable particle twins for transporting the viral genotype. Her tactic is to use a computer to analyze at which location on an electron microscopically reconstructed 3D-structure the individual amino acid building blocks of the envelope proteins are located.



3D model of the helical structure of a tobacco mosaic virus in the form of a spring ring-shaped disk.

Photo: University of Stuttgart/Sabine Eiben

Hipp explains: 'If I can find out which areas of the envelope proteins are important for this, I might be able to strategically infiltrate mutations that would prevent the virus from forming and transmitting particles.' Another point of attack against the virus might be to replicate the genetic information which it introduces into the plant cell. In doing so, the virus is dependent upon the host cell. Virologist Hipp has conducted experiments with yeast cells and found that a certain area of replication-associated proteins from the cassava mosaic virus trigger the cell to multiply the foreign genotype. But many questions about the structure and dissemination of geminiviruses remain to be answered. Hipp has a goal: 'It would be wonderful if our basic research could help in developing a way to counter these viruses.' In future, Hipp will be heading the electron microscope section of the Max-Planck Institute for Developmental Biology in Tübingen.

From parasite to nano-tool

In contrast to geminiviruses, tobacco mosaic viruses are among the best researched of all viruses. In fact, the first proof that viruses exist came at the end of the 19th century with the finding that tobacco mosaic disease is triggered by germs which pass through bacteria-proof filters. Today, Sabine Eiben even finds a lot that's good, precisely in the tobacco mosaic viruses: they can be useful nanobiotechnological tools. Eiben is a post-doctoral student and team leader in the 'NanoBioMater' Project House of the Carl-Zeiss Foundation and the University of Stuttgart and works in the research group of Prof. Christina Wege, in the same department as Katharina Hipp. Eiben's group tests tobacco mosaic virus-based nanostructures for different applications - a difficult task, since such structures are technically difficult to produce from biological material.
It sounds like a simple kitchen recipe: mix the genotype, a ribonucleinic acid strand, with the envelope proteins of the tobacco mosaic virus, and presto! Protein rings appear almost magically and package the genotype into a 300 nanometer-long tube. Then the virus substance can be manipulated to create new kinds of structures: tobacco mosaic viruses of different lengths which can be bent like boomerangs or made to branch out like stars. 'We can even put together virus-like particles in a test tube that no longer have an infectious viral genotype,' reports Eiben. As always, however, the most effective producers are the tobacco plants that flourish in the greenhouse on the roof of Natural

Sciences Center II on the University of Stuttgart's Stuttgart-Vaihingen campus, where Sabine Eiben studies how viruses infect the plants via defects in their leaves. Eiben is working here with basic elements of nature's nano-toolbox by triggering bacteria to produce tobacco mosaic virus envelope proteins or genetically modifying these proteins so that enzymes, peptides or nanoparticles bind to

Katharina Hipp with a model of the African cassava mosaic virus. A 3D reconstruction of it, produced from electron microscopic images, is shown on the screen in the background.

Photo: Helmine Braitmaier

them, which allows biologist Eiben to assign new functions to these virus-like particles. For example, her work team recently showed that when coupled with enzymes, virus particles can greatly improve the action of biosensors in detecting glucose. As Eiben explains, 'The viruses stabilize the enzymes and increase the surface area, resulting in a high level of sensitivity.'

Different functions

Theoretically, a functional group, such as an enzyme, can bind to each of the more than 2,000 envelope proteins of the tobacco mosaic virus. 'What's more, we can combine different envelope protein variants in a virus particle in such a way as to spatially separate different functional areas from each other,' says Eiben triumphantly. Whether this will someday take the place of the conventional blood sugar measurement swabs used today remains to be seen, says Eiben; but new, more sensitive biosensors will be eagerly welcomed in other areas too. This might include, for example, virus-based sensors which can detect drug residues or toxic agents in foodstuffs or environmental samples. And for field effect transistors like those found as switches in every computer, Eiben has also produced virus particles upon which electrically conductive metal oxides are deposited even at room temperature. Previously this required temperatures above 400 degrees centigrade, so that only temperature-resistant materials were feasible as transistor boards. The gas-sensitive metal oxide layer might make it possible in future to use such virus-bearing field effect transistors to detect, for example, methane in the surrounding air.
Eiben is working in the interdisciplinary NanoBioMater Project House with materials scientists, technology specialists, and chemists to learn more about the uses of tobacco mosaic viruses in hydrogels with regard to biocompatible materials - for example, to produce tissue substitutes. It might be possible to use the viruses as a support framework for cells and growth factors or to precipitate calcium phosphate, the basic substance in our skeleton.

A virus like a rock star

The tobacco mosaic virus continues to inspire Sabine Eiben with new ideas for its application, but also in the form of artistic images, like those hanging above

Photo: State Ministry of Baden-Württemberg/ Uli Regenscheit

Sabina Eiben (left) and Christina Wege present their research work at the Nobel Prize winners' meeting.

her office desk. This year, Eiben was privileged to present, together with her boss Christina Wege, her task force's research at the year-end Nobel Prize Winners' Meeting at the invitation of the Competence Network for Functional Nanostructures of the Land of Baden-Württemberg, which gave the two their own booth at the round trip by ship on the Lake of Constance on July 1. Eiben fondly remembers the friendly, pleasant atmosphere on that occasion: 'Although the conference was devoted this year to physics, we were visited by a great many people who were interested in our biological work in the border area between physical, chemical and technical applications.' For her part, she stands out as nearly unique in the world of research as one of the world's few plant virologists in the area of nanotechnology.

Helmine Braitmaier

A ‘Brain’ for the Internet of Things

‘meSchup’: the platform that links devices together - quickly and without fuss

How can we network many different devices, each with its own respective characteristics and interfaces, in such a way that each makes use of the sensors and functions of the others?’ This basic question of the Internet of Things is what Thomas Kubitza, a doctoral candidate at the University of Stuttgart’s Institute for Visualization and Interactive Systems (VIS), wants to find an answer for.

Ideas that strain the imagination about the ‘Internet of Things’ (IoT) have intrigued the public mind for years: the refrigerator, for example, that orders its own foodstuffs when supplies are low, or the tablet computer that offers recipes for leftovers. ‘The smartphone with its networking capacities is only scratching the surface here, says Thomas Kubitza. ‘Our vision is to have hundreds of networked devices around us, each with its own individual abilities. If we can combine them, it will open up completely new vistas for organizing our daily life.’

Up to now, developers have needed weeks to teach different items of technical equipment to communicate with one another. That has impelled Kubitza and his group during the last three years to concentrate on developing their ‘meSchup’ platform, that can bring such devices into line with each other in only minutes. The respective software is located in a housing that is only a little larger than a carbonated beverage can. But once it is connected to an electric power source, it becomes a hub that uses its own standard radio and cable connections to create its own WLAN and needs only an Internet browser to access the user interface. Its ‘Smart Things Pool’ displays all the devices which the system has found. Just one example: to integrate a smartphone into the system, the user need only lay it briefly on the ‘can’ for it to be recognized automatically. The platform itself uses the standard programming language of JavaScript. Upon request, Kubitza demonstrates a bit of what is possible with this system: he need only tap his cell phone for ‘meSchup’ to recognize the action and transcribe it automatically as a program line. Then Kubitza shakes a small cube stationed on his desk, and presto! It is immediately linked via WLAN with his cell phone and begins to light up each time he taps the phone.

Speedy. Smart. Networked. The ‘meSchup’ platform brings different devices together within minutes via WLAN.

Photo: Kubitza meSchup

All of this, however, is only window dressing. In practice, the system knows practically no limits in carrying out a complex networking of things. What makes it different from today’s typical IoT applications is that the software need be entered only once into ‘meSchup’ for each type of device. That represents an enormous relief from stress in using IoT networks in the office and industry or just simply at home, since it is unnecessary to re-adjust the unit every time a change is made on location. And when a user connects the hub to an existing network, it automatically makes use of that network’s infrastructure. ‘meSchup’ is the brainchild not only of Kubitza, but also of four Master’s Degree dissertations. A large community of student helpers also assisted in the cre-

Photo: Kubitza meSchup

ation of this platform - like Norman Pohl, a colleague who helped to develop the mobile sensor hardware. Kubitza's own dissertation took up the question of how end users who have little or no programming experience can install IoT applications on their own. Even though still young as a VIS-researcher, Kubitza has been in charge of the Stuttgart contribution to the EU project 'Material EncounterS with Digital Cultural Heritage' (meSch) since 2013. He originally followed his thesis advisor, Institute Director Prof. Albrecht Schmidt, from the University of Duisburg-Essen to Stuttgart, the State Capital of Baden-Württemberg, after the completion of his Master's Degree program. For its part, 'meSch' was a joint project in which scientific research institutes and museums from six European countries developed interactive techniques for exhibitions. VIS was commissioned to provide both the software and hardware for this. 'meSchup' then proceeded to demonstrate its usefulness in everyday life at 'Museon', the popular science museum in Den Haag: at the Atlantic Wall exhibit there, visitors were able to select their own perspective on a 'smart' object, that is, one with digital technology, and then start their own individual interactive viewing programs.
Since 'meSch' will be phased out at the end of January 2017, Kubitza is now searching for co-founders who will help him put 'meSchup' on the market as a startup. That would put the 'Internet of Things' only a few clicks away.

Daniel Völpel

Just A Little Miracle
How 3D-printing is revolutionizing mini-optic production

An optical lens, less than one thousandth of a millimeter in diameter, produced with a laser whose pulses are shorter than a millionth of a second, and used in endoscopes which are thinner than a human hair. Sound like a sequel to the movie 'Honey, I shrunk the kids' from the year 1989? Now, more than three decades later, it has become reality. Harald Giessen, Director of Physics Institute 4, and his young research team move in a world of other dimensions when working in their high-tech laboratory at the University of Stuttgart's campus in Vaihingen. And what they have worked out there is a 'tiny' scientific research sensation: micro-lenses from a 3D printer.

The naked eye can barely make them out, but they themselves see everything. The resulting applications are endless: autonomous robots with mini-sensors, cell phones with 360° cameras, spy spectacles, and 20-20 digital eyes for vehicles or infinitesimal flying objects. Mini-lenses constitute a breakthrough above all in medical technology: in minimal-invasive diagnostic procedures and surgical interventions where medical technology quickly reached its limits in the past, 'impossibly' thin endoscopes now open up new horizons. They can examine organs and areas of the body that were formerly inaccessible. Just a few examples: the tear duct of the eye, the interior of a tooth root, or middle ear diagnosis via an eardrum hole with a diameter of only 100 micrometers. The endoscope lenses are produced in a single process by printing out the lens together with its frame directly on a tiny glass fiber.

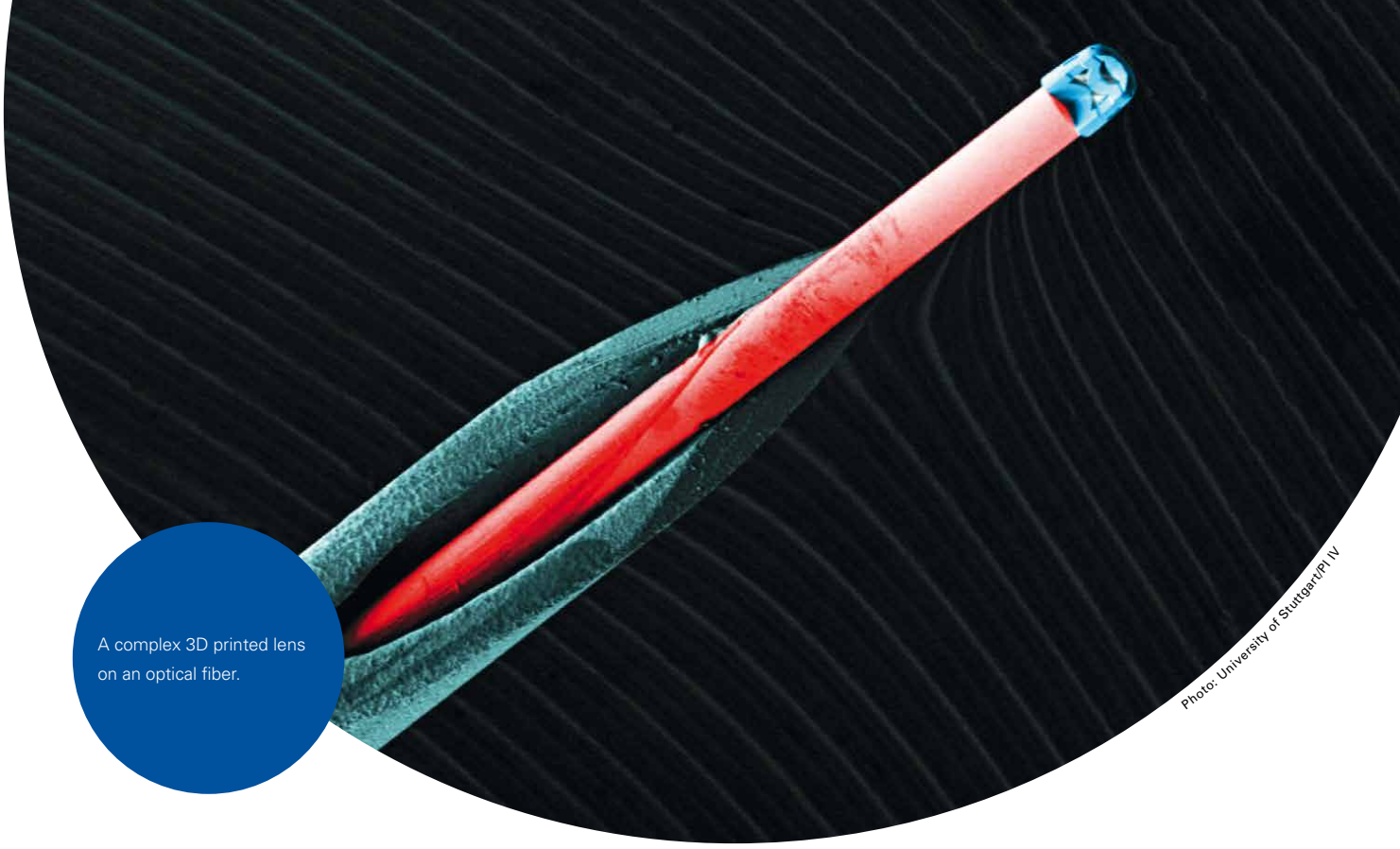
The 3D printer used to make such optical lenses has little in common with the conventional printer. The basis of the lens is a type of liquid photoresist coating which is poured onto a glass slide or a glass fiber. This is then hardened with the aid of a technique jestingly named the 'dentist's trick' by Harald Giessen, namely with UV light in the red (not blue) spectrum.

2 x red = blue

Since blue UV light hardens everything found within its light cone, an extremely precise method is required. The solution: the femto-second laser, which emits light impulses lasting only a thousandth of a millionth of a millionth of a second. 'That's about as long as an electron needs to orbit 100 times around an atom,' says Harald Giessen. The technique requires using a microscope to focus the laser, with a pulse duration of less than 100 femto-seconds, on the liquid photoresist coating. Two photons of the red laser beam meet at the focal point, cast light upon it, and cause the coating to harden. Giessen explains it in layman's terms this way: 'When the polymer (the coating) sees the two red light particles, it thinks, 'They're just as good as one blue one!' So two times red equals blue.' A series of hardening laser 'shots' brings the lenses into the desired shape, one point after another, with more than 1,000 layers per hour. This technique makes it possible to create even incredibly complex devices quickly, easily, and with a precision that even makes it possible to create free-form surfaces.

From the bull to the lens

The cornerstone for all this was laid long ago: the method is based on the two-photon absorption process discovered back in 1931 by Nobel Prize winner Maria Goppert-Mayer. Then, around the turn of the millenium, the Japanese researcher Satoshi Kawata used a femto-second laser for the first time to harden photoresist coatings and showed that an infinite number of shapes could be produced in this way - from bulls to naked women. But when asked how he and his team were the first to get the idea



A complex 3D printed lens on an optical fiber.

Photo: University of Stuttgart/PI IV

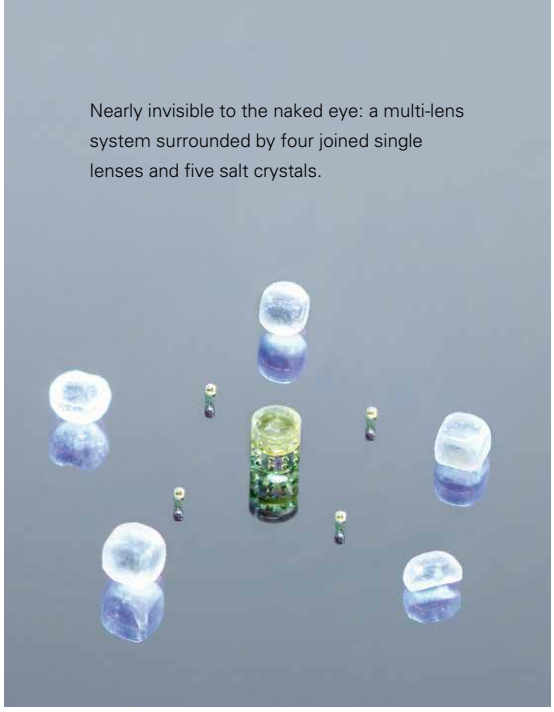
of printing out lenses and positioning them on glass fibers, Giessen answers: 'We simply asked ourselves why nobody had done it up to now. Sometimes the solution is right in front of our noses!'
Only a select, privileged few are allowed to view the 'holy halls' where the lenses are printed. After all, as Giessen points out: the machines there are worth millions. Just one example: the high-precision 3D printer with its integrated femto-second laser from Nanoscribe, the Karlsruhe startup company, costs half a million Euros. 'You won't see anything like this in any other laboratory in the world,' says Giessen, visibly enthused about his room of other-worldly treasures. Up to now, several hundred lenses have been printed out here with the 3D technique.

Interdisciplinary team

It all began with Giessen's former doctoral candidate Timo Gissibl, whose work is now being carried on by Master's Degree student Simon Ristock. The structural designs for the lenses are created by doctoral candidate Simon Thiele, a member of Alois Herkommer's task force at the Institute for Technical Optics. There was a moment when the team of researchers reached a point in Giessen's view where no further progress was possible with the resources of his own discipline, and so he turned to Thiele, at the allied institute. 'They can all be calculated,' announced Thiele, and true to his word, the first design was worked out and printed in only a single day. That was enough to convince Harald Giessen. 'Simon knew how to make good optical designs, and that put us in business.' As a whole, the team now includes ten researchers working on the project interdisciplinarily at the Stuttgart Center for Photonic Engineering (SCoPE). Their abilities range from optical design and 3D printing expertise to the areas of materials science, measurement, and control, and the team includes mechatronics and electronics specialists.

Revolutionarily fast results

The results are small. Tiny, in fact. The researchers test the resolution of the lenses with the so-called 'Air Force Test Target Scale' and an image created by the U.S. Air Force in order to test the resolution capabilities of optical instruments. A look into the laboratory's microscope shows what 'Simon's 35th lens' is capable of: the image is so clear that even tiniest lines are recognizable. The quality is thus similar to that of a professional microscope lens but costs only a fraction of the latter's price. As Giessen points out,



Nearly invisible to the naked eye: a multi-lens system surrounded by four joined single lenses and five salt crystals.

Photo: University of Stuttgart/PI IV

however, the really revolutionary thing about it is not the size or the low cost, but the speed. 'We need only a day to go from idea and optical design to the CAD model. That means a lot to us as natural scientists and physicists. Never before have we arrived so quickly at applications' When asked how often they print out these new lenses, the answer comes like a shot from three mouths at once: 'As often as possible!' A lens is used up in one to three hours, so that up to 10 may be needed in a single night. For a 'bigger' lens, in contrast, about 10 hours are required. And lenses yielding ultra-high-quality images due to multiple focal points have now become feasible for the first time, along with free-form optics. 'It amounts to computer-aided manufacturing for optics,' is how Giessen sums it up.

Small lenses in gigantic demand

The project is subsidized by the Baden-Württemberg Foundation as part of its 'Top Research Initiative'. Once the data were 'hard and fast', different aspects of the project were discussed nearly simultaneously in diverse publications. 'It was like a lightning bolt,' says Giessen; 'the telephone was ringing off the hook!' So many inquiries came in from all over the world that Simon Ristock was forced to created a database for them. This has led, among other things, to close collaboration with numerous companies, including such high-tech enterprises as Trumpf, Carl Zeiss in Oberkochen (with advisory services to all areas of optic research), and Storz, the medical technology and world endoscopy leader in Tuttlingen. One set of technical specifications in a commission by this company, for example, required the team to produce an endoscopic lens that can illuminate all surrounding areas. The answer was ready a week later: uniformly illuminated, high-resolution images. A project for which the company itself would otherwise have needed at least half a year. 'We were pleased - and Storz too, of course!'

Many perspectives

But the research team is by no means finished: both the method itself and the areas of application harbor a huge potential for development. For example, the team is currently working on a way to print the lens out directly onto a microchip. If it were to be positioned on such a CMOS chip, compact sensors could be produced for such devices as minidrones. Another challenge for the research team is to create long-lasting, reflection-free images in true-to-life colors. Here they need 'a few tricks,' as they currently admit. This project has become a trend-setter for interdisciplinary collaboration between engineers and physicists in research and industry, a fact which induced the German Federal Ministry of Education and Research (BMBF) to subsidize the researchers and their industrial partners with more than two million Euros in a new joint project coordinated by four physics institutes. 'Without the others, none of us alone could have reached this result. An interaction like this exists only here, in the region of Stuttgart,' sums up Giessen. It is realistic even now to speak of a new era in the production of miniature optical devices.

Katja Welte

A Happy Mistake
From photonic building block to sensor

An SQI chip lies on a reactor tray with interferometer structures. Two fibers connect the grid coupler on the chip with optical input-/output coupler elements.

Photo: University of Stuttgart/INT

Penicillin, Teflon, super glue, or the discovery of America: first seen as mistakes, but later as keys to great steps forward. The word used in this context is 'serendipity', a chance observation or a by-product that turns out to be a new and surprising discovery. That's precisely what happened to a group of doctoral candidates at the University of Stuttgart's Institute of Electrical and Optical Communications Engineering. The 'serendipity' in that case: a sensor that can be used to detect the presence of any kind of substance.

Their 'real' mission was to research photonic building blocks of optical elements in the field of communications engineering. That led this group of scientists and researchers to develop complex, optical transmission and receiver structures on silicon disks - an important feature for controlling energy consumption during data transfer on the Internet and in the telecommunications industry. But they were bowled over by what surfaced in their research measurements: 'In the ideal case, simulations and measurement match during an experiment. Some deviations are, of course, only natural. But in this case, we stumbled on some very, very unusual measurement results,' recounts Dr. Wolfgang Vogel, Senior Academic Advisor at the Institute of Electrical and Optical Communications Engineering (INT). The researchers became detectives: step by step, they uncovered a recurrent system in the strange measurement results. They found that it depended on many factors: material and surroundings, the height of the waveguide, the placement of optical fibers on the grid coupler, even the time of day and the outside temperatures, that is: mornings, afternoons, warm, cold, or even whether someone was just passing through the laboratory. What followed were countless measurements, trials, and discussions that even enveloped the doctoral candidates' seminar at which Niklas Hoppe, a scientific researcher at the Institute, presented the whole issue. 'It's only natural to prefer hearing about successful results to an hour-long lecture about something that went wrong. But it was just those discussions that broke the conundrum open,' says Vogel.

Learning from mistakes ...

The insight sounds simple at first: structure your test - in simplest terms - to send light into a chip and get it out again. To do it, use so-called 'grid couplers', i.e. periodically structured elements which absorb light and emit it again, and link all this to a waveguide. Since the latter grew to dimensions not originally envisioned, a second light mode became meaningful. That was the key: the collision of these different rays of light led to interferences. 'We were amazed to find how much trouble an apparently uncomplicated waveguide can cause but also what can be done with the results ...,' says Vogel. The doctoral candidates went on to find not only the cause but also the phenomenon behind the distorted measurement results and that it can be used to construct a sensor. After developing their idea, they contacted the University of Stuttgart's Institute of Interfacial Process Engineering and Plasma Technology (IGVP), which also works with functional sensor coatings. 'We design the sensitive coatings, and the INT reads them out,' says Dr. Monika Bach, Director of Chemical Interface Technology. It was methods engineering student Pascal Scheck who, in his Master's thesis, brought together the disciplines of two institutes: a materials-oriented and an electrotechnically aligned one. In countless discussions, the INT research team

A graphic view of an interferometer whose functional coating absorbs specific molecules, and a simulation of an electrical field distribution of the 'light mode' as it passes through the waveguide.

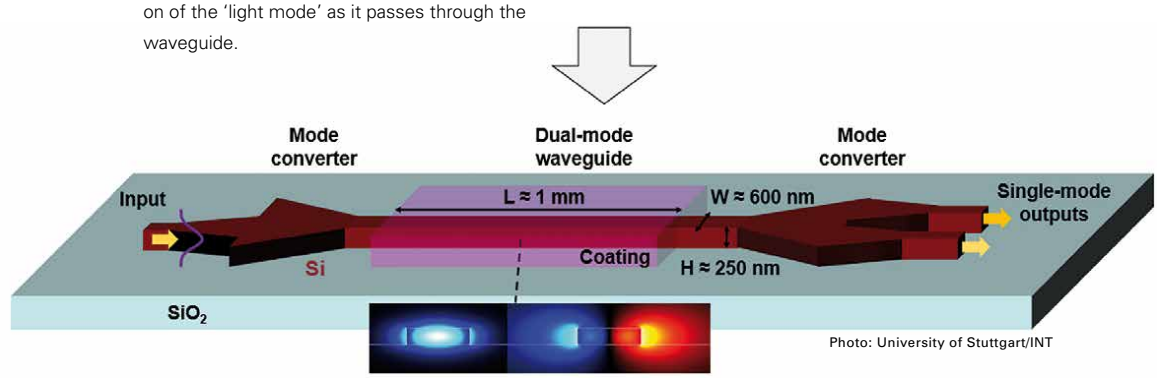


Photo: University of Stuttgart/INT

used the background knowledge presented in his work and the measuring equipment magic of Niklas Hoppe in the INT laboratory to gradually bring about successful exploitation of the above-described phenomenon in order to develop the new sensor

... and build it

The sensor functions like a key in a lock: the chip is enveloped in a polymer coating. In turn, the coating contains molecule-specific sensor points which function on the principle of molecular imprints by reflecting certain chemical structures in the form of a negative impression in the hardened polymer. When other molecules 'wander' over these points during the measurement process, some specific ones deposit themselves in the polymer coating. This changes the optical characteristics of the polymer, which in turn shows up in the measurement results. As a result, the sensor is able to show the presence of any particular substance in even a nearly non-existent concentration. This makes it conceivable that a complete laboratory could be located on a minichip (the 'lab-on-a-chip') by placing numerous sensors with different coatings on the chip so as to demonstrate the presence of hundreds of different substances with only a single measurement - in the medical area, for example, or in environmental analytics, and from hemograms to chemicals. The sensor also stands out because it is not only extremely tiny but also extremely robust and can even be re-used. The research team's next step will be to work with potential industrial partners to develop prototypes for specific applications and to apply for research subsidies in order to conduct experiments leading to a better understanding of the principles involved.

Research, trials, combinations

The 'serendipitous' sensor principle upon which the young scientists stumbled is not completely new, and has been mentioned in the literature. But the way to finding it can only be described, as Vogel says, as 'remarkable'. 'With time, we humans tend to grow a bit short-sighted in our own work worlds and stick to the research course we have set for ourselves.

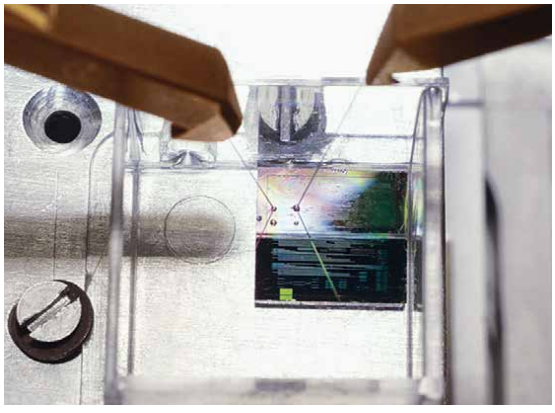


Photo: University of Stuttgart/INT

View from above into the reactor tray, showing fibers which extend into a fluid and coated chip upon which integrated waveguides and building blocks shimmer.

That's why it's so surprising that two completely unrelated institutes here in Stuttgart were able to collaborate so successfully in blazing a new trail, and in such a short time!' Above all, it shows how an idea can emerge and become reality when all of the university's many possibilities are interlinked and exploited. 'I can only hope that even more vistas and formats will open up for working with other institutes on such exploratory ideas. That wouldn't even require much money. Here in Stuttgart we have optimum conditions for it but still use only too few to the most. We are already front-runners within our disciplines; the issue now is to expand our areas of competence at the interfaces with other disciplines,' says Bach. A journal article about the results of the above-described 'think tank's' work has now been accepted by the prestigious IEEE 'Journal of Selected Topics in Quantum Electronics' and will appear shortly there. Should research be target-oriented or unrestrained? Complexity researchers have found that progress comes a combination of many small steps and a few highly speculative leaps of thought. Thus both are needed.

Katja Welte

Nature Sets the Pace
From the cricket to the hirsute airplane wing

It's the grand vision of engineers: maximum fuel efficiency in airplanes, automobiles and railway trains thanks to nearly turbulence-free surface currents. But that will require a great deal of basic research with today's very time- and work-intensive research methods. Gabriel Axtmann of the University of Stuttgart's Institute of Aerodynamics and Gas Dynamics (IAG) is working on a solution that would not only simplify current measurements but would also be easy to use. The doctoral candidate's secret is nature itself, more precisely: the lowly cricket.

The cricket uses fine hairs Ⓐ on its nether body appendages to perceive and interpret acoustic waves from its surroundings. It's a matter of survival: depending on the direction in which pressure waves bend the sensorial hairs, the cricket can estimate, for example, how groß and dangerous a coming object is. This is the principle used by Gabriel Axtmann for his research work.

The basic idea can be illustrated by an aircraft wing. The researcher's interest is on the threshold at which a laminar current becomes turbulent Ⓑ. The first major step is to make this 'point of transition' visible and to interpret it. Engineer Axtmann conducted all of his experiments at the computer - a big advantage over time-consuming current measurement methods like 'particle image velocimetry' (PIV). In Axtmann's research design, the hairs show up in the form of a mathematical grid matrix, which he then subjects virtually to eddying currents. Depending on the form, speed and dissemination of the eddies, the hairs bend in a specific manner Ⓒ. That is, their sensory reactions reflect the current event. The algorithms programmed in this manner are able to recognize differences in current and thus determine the 'point of transition'.

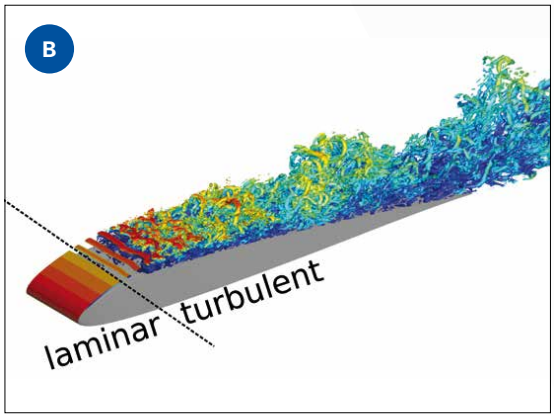


Photo: University of Stuttgart / Gabriel Axtmann

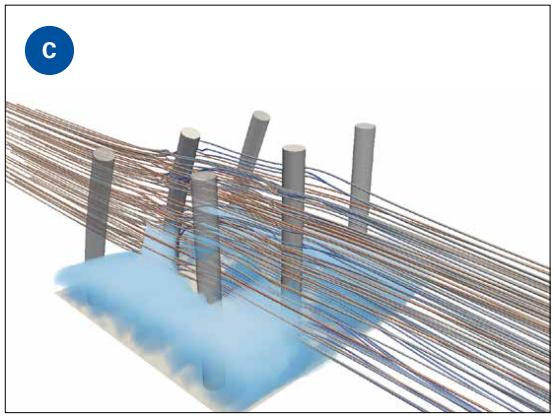


Photo: University of Stuttgart / Gabriel Axtmann

The young researcher's next step is then to study possible laminar wing designs. His idea is that the hairs are not merely reactive, but also proactive, that is, they affect the current depending on whether, for example, they are more rigid or more vibrational in design. They can then give back an impulse that charges the current with energy and makes it remain longer on the surface. As a result the 'point of transition' shifts its position. When applied practically, this could mean that a sort of 'hair toupee' would be glued at pre-defined points to aircraft wings and would then modify air currents, making the wing

Bionics deals with the creative transfer of natural phenomena to technology. The idea behind this interdisciplinary field of research is that life as found in nature has worked out structures, processes and solutions through evolution which man can use systematically for applications involving technical objects and methods. Bionics also plays an important role in many research areas at the University of Stuttgart.

Photo: Fotolia

A

much more fuel-efficient. The idea could also be applied to railway trains, automobiles, fans, stationary gas turbines, and wind energy plants. All these applications would then be a product of nature – modelled on the lowly cricket.

Linny Bieber

HUMANKIND
Employees are the key to internationalization and corporate change

Achieving and maintaining success on the international stage is one of today's greatest challenges for companies. Yet another is reacting quickly and flexibly to changes in the business world. How to master such challenges is in turn one of the challenges faced by Dr. Corinna Elosge and Christian Mahringer, two young business economists at the University of Stuttgart's Institute of Business Administration (BWI) and Institute of General Business Administration and Organization (ABWL). One thing they find time and again in their research is that the role of the individual is decisive for the success of the whole.

The world of business is always in movement. One company buys up another, another spins off areas and opens up new branch offices. Established companies and startups develop new technologies and change to cope with the changing competition. We see it in today's automotive industry, where traditional giants do battle with 'outsider' competitors like Apple and Google, but also in the IT branch, where innovations appear too fast to follow. The ability to survive in global trade has become the most important success factor in Big Business.

Individual actions

Young researchers at the University of Stuttgart's business institutes are currently studying what conditions companies must meet in order to develop this ability. The research focus is not only on market analyses, strategy papers, or company statistics but also and above all on the role of the people working in a company. The question is: how does the behavior of the individual affect the versatility of his/her company?

The force is at the top

Dr. Corinna Elosge is a scientific research assistant who wrote her dissertation at the University of Stuttgart's Institute of International and Strategic Management. She is part of the team of Prof. Michael-Jörg Oesterle, which studies how and with what methods companies penetrate foreign markets, what countries they focus on in doing so, and why. This area of study, the framework for their work, contains virulent issues: after all, German companies achieve about 70 percent of their turnover in foreign countries. Even medium-sized German companies in branches of industry like machine design and construction and plant engineering receive a large share of their earnings outside their home markets. Elosge's doctoral thesis presents her study of the impact of a CEO change on the international development of a company. Even though the top person is not omnipotent, he or she has a decisive influence on strategy. Even in German companies, where the principle of collegiality is so important, CEOs are in a position of might. 'Their experience and values make them appear as the major doers and shapers,' was the observation of Corinna Elosge.

Her dissertation compared, among other things, the frequency of CEO-changes with the degree of company internationalization. To quantify the latter, she calculated the overall share of foreign turnover for all companies studied.

Mastering this task required, of course, data. Very much data. So her work started with a comprehensive work of research, in which Corinna Elosge concentrated on more than 100 major German companies. Fortunately, she was able to access a set of data complied in earlier years for another scientific research project. The 'catch', however, was that the information contained there had to be updated. So, after finding that annual company reports often failed to help her move forward, the

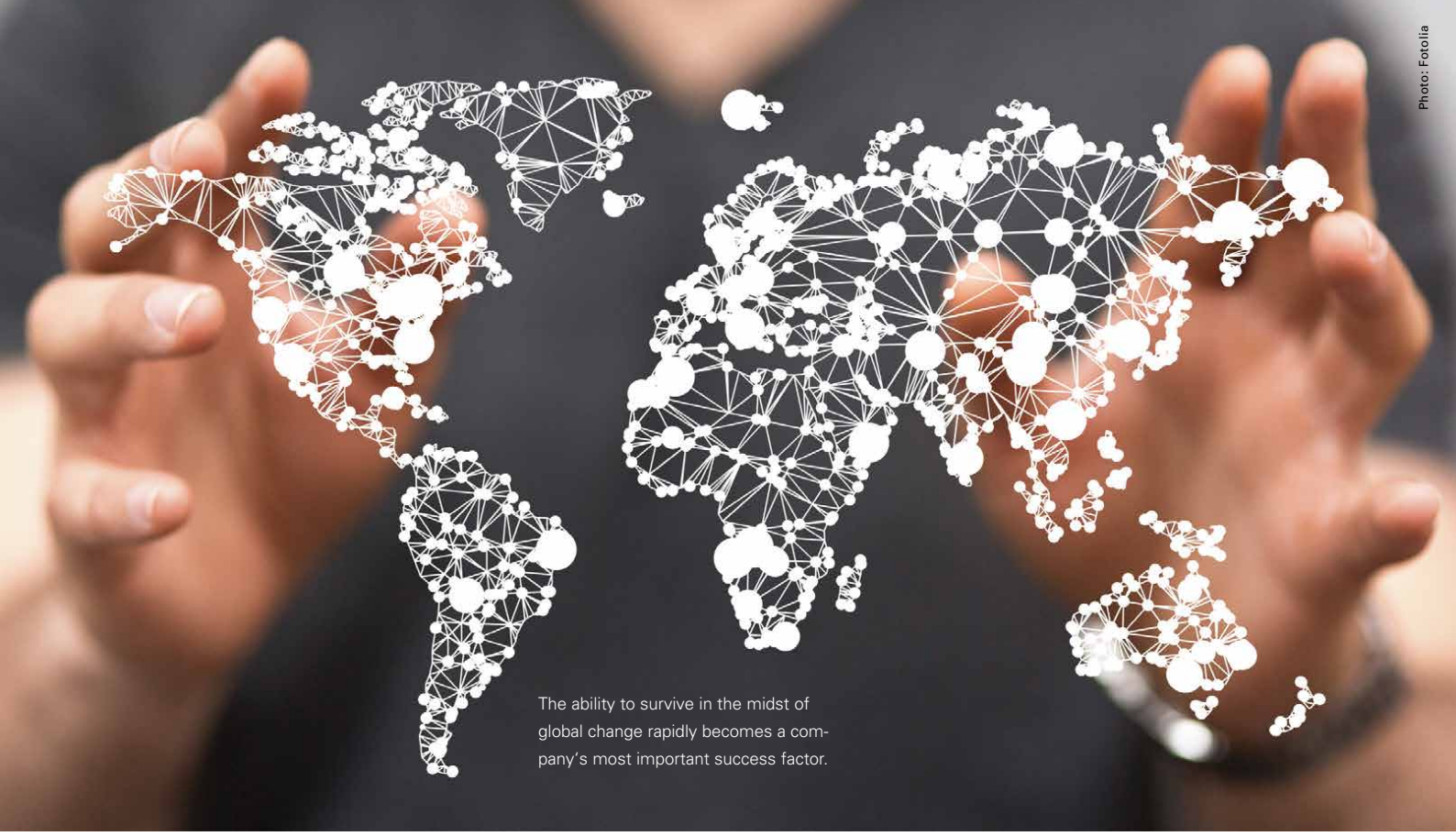


Photo: Fotolia

The ability to survive in the midst of global change rapidly becomes a company's most important success factor.

young scientist buried herself in databases and archives. 'It was an excursion into the recent history of business,' she reports: not all companies in her first sampling had survived over the years. Great companies of the past like Hoechst, Mannesmann or Degussa are no longer around in their former shape. 'Panel Mortality' is the buzzword of experts for this effect.

At the conclusion of her research work, she possessed data for the 102 largest German production companies from 1990 to 2012. Elosge then analyzed this data by means of different statistical methods to see whether they matched various hypotheses. For example, she asked whether a CEO's time in office affected the international development of his company. She also studied the frequency of change and its impact, and how much it matters whether a new CEO comes from the company's own ranks or from elsewhere.

A new wind in internationalization

Companies today are interested in these questions, knowing how much influence a CEO has. When a change of CEO is on the horizon, the potential successor is either broken in and introduced to his future tasks within the company itself or is recruited discreetly from the outside. Both procedures are well-known in commercial research. 'But they have been only rarely studied in the international context,' says Elosge. Her dissertation showed that there is a connection between the overall number of top-management changes and the degree of internationalization of a company. This can be illustrated in the form of an upside-down letter 'U'. That is, companies often go international when a new person is at the top. Fresh wind seems to billow out the sails of doing business abroad. But, as economist Elosge also warns, 'This effect has its limits.' When there are too many top-level changes, internationalization tends to grind to a halt.

And internationalization is also affected when outside managers from other branches come to the top chair in a company. The share of business abroad often displays inconstant growth, changing at different tempos, often with major ups and downs. One possible explanation for this is that external managers may bring new experience that is good for internationalization but also introduce incalculables. As Corinna Elosge put it, 'The impact of too many changes is negative.'

One reason for turbulence may lie in the top-level manager's behavior. Examples of practical evi-

dence for this thesis can be found in cross-branch fusions. Even when a company finds an outstanding enhancement for itself in a business fusion, the two partners often fail to merge seamlessly because the top-level managers on both sides cannot work together. These human drawbacks are dangerous for business firms; they keep companies from adapting quickly to changing market conditions.

New insights and change

What applies at the management level is also true for the company as a whole. That's why management needs to know how each employee can strengthen his company's ability to adapt - for example by keeping up with what's happening and being alert to new opportunities. In short: by acting entrepreneurially. Christian Mahringer is a person who studies such issues. He is a 27-year-old scientist working with Prof. Birgit Renzl at the University of Stuttgart's Institute of General Business Administration and Organization. Mahringer's research takes him into an area called 'dynamic capabilities' by business economists: how companies can continuously renew themselves and continue to develop in times of change. For one thing, it requires that employees continually bring new insights into the company. Implementing these insights effectively, however, also requires that they know for whom this information is relevant.

The human aspects of applied economics have fascinated Mahringer since his first day at the University. After entering upon his studies at the University of Hohenheim, he soon specialized in the area of business psychology. 'I was always intrigued most by the actions of individuals in the business context.' Later, after he received his doctorate near Salzburg, his professor, who had been called to the University of Stuttgart, asked him if he wanted to join her. He said yes and now, not even 30 years old, he has already marked up his first successes: he regularly presents some of his research results at international scientific conferences, and was recently honored by the prestigious European Academy of Management (EURAM).

Knowledge exchange on the golf course

The following example shows what a typical research project in his discipline sometimes looks like: it starts with a survey at a company which provides packaging machines for pharmaceuticals. This is a highly specialized market, with little competition and only a few customers. The loss of only one customer immediately affects sales volume, and a single error in sales and marketing can have painful results.

Employees in the company were asked about events which they viewed as outstanding successes. The resulting input, it was thought, would show how companies can integrate knowledge from the outside. The statement of the question was intentionally left somewhat vague. 'We hoped in this way to be open for new issues while formulating questions for future research projects,', says Mahringer. The answers of the employees brought interesting details to the surface. One, for example, related how his customer made improvements in his own packaging machine because the version he wanted was unavailable. 'That was very important information for the supplier,' says Mahringer. But the salesman in the field got that information only because he had developed a relationship of trust with that particular customer. 'Just one example to show how important personal contact is,' says Mahringer. Other respondents in the study confirmed this. Some insisted that the often-scorned golf course meetings are the best opportunity for a give-and-take with partners, customers, and suppliers.

Mahringer's research work extends to more than the way in which companies gather information. That information must also be put to efficient use - by

precisely those persons who need it most. Today's information technology offers resources for this. For example, information can easily be presented in comprehensible form digitally. 'But it's not enough just to send it out by email and trust that the right people will receive the relevant information,' says Mahringer. On the contrary: experience has shown that it is precisely complex data which is least often correctly assessed. But there's hope: data fulfills its purpose 'when it serves as the basis for discussion.' Discussions - and Mahringer's work makes this clear time and again - are of central importance for successful processes of change. One condition, however, is that they be honest and target-oriented. 'If they are only pro forma, they are useless,' says Mahringer. The goal must be to find out what the respective employee really thinks and needs and how he assesses a problem. For their part, employees can only give wings to change if they have the feeling that they can in fact make a difference. 'If not, it is very likely that the change process will come to nothing.'

Heimo Fischer

Helping Others Help Themselves - At Any Time
Students cast light on 200 years of charitable organizations in Baden-Württemberg

Can the 200-year history of a charitable organization include a core idea that defies most contemporary political currents and social expectations? This question intrigued the team of Prof. Sabine Holtz at the University of Stuttgart's Department of Regional History, part of the Historical Institute. The result is a volume created by five students together with Ph.D.s and professors from the University for publication on the occasion of the 200-year anniversary of Baden-Württemberg's Public Welfare Service.

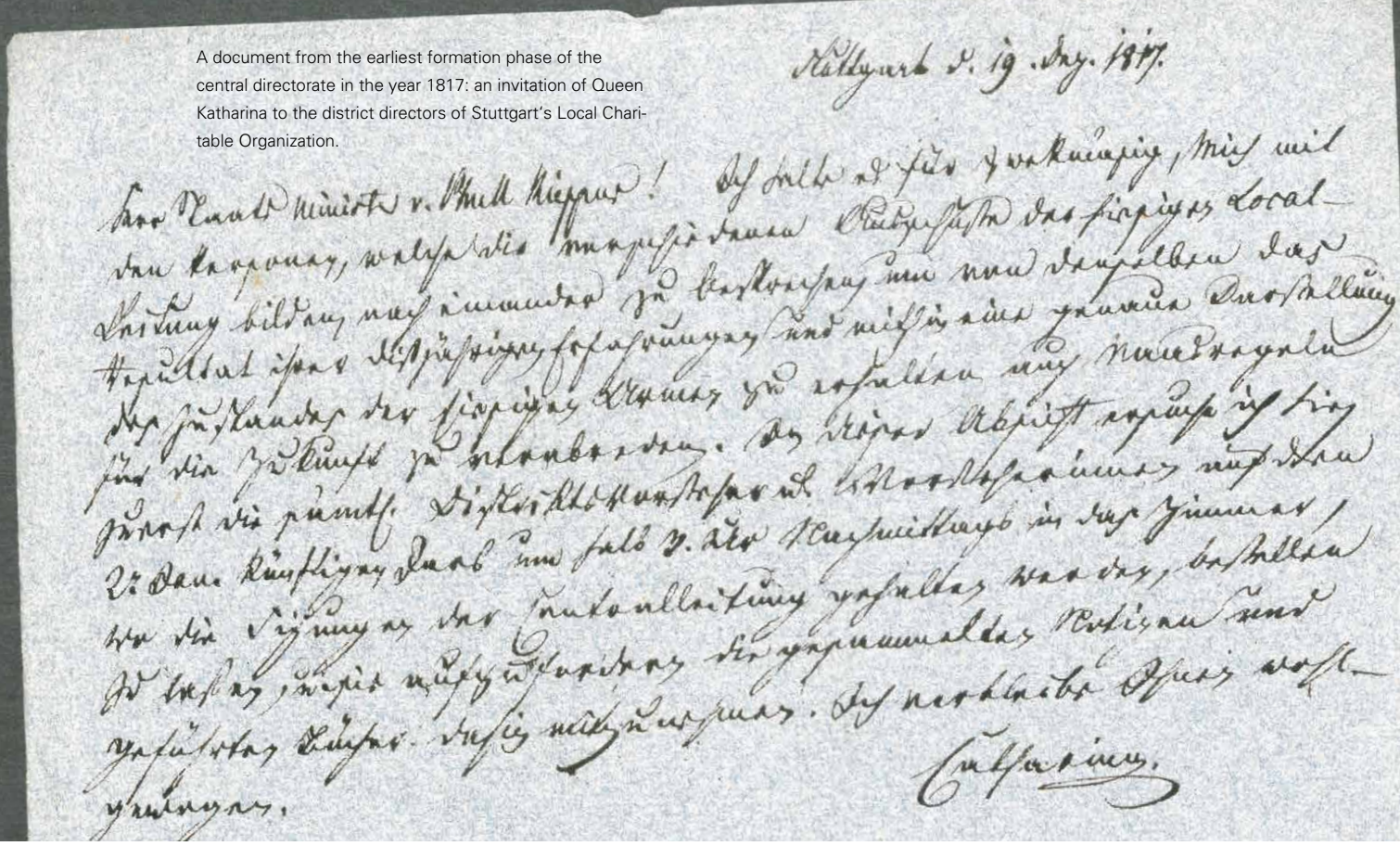
Historical overviews often take the form of a chronology. But in this book, entitled 'Helping Others Help Themselves. 200 years of Public Welfare Service in Baden-Württemberg,' Sabine Holtz casts light on the individual stages of a 200-year history. Also unusual was the method of instructive research and learning used to assemble this commemorative work: 'Essentially, the method consisted not only of presenting information for readers' reception but also of jointly generating the contents on the basis of archival sources previously left untouched on dusty shelves,' explains Sabine Holtz. 'This is our way of leading students to carry out active research on their own, and the idea of working independently and as an individual also surfaces in the contents of this publication - thus mirroring one of the basic foundational ideas of the Public Welfare Service.

Modern thought back in the 19th century

Representatives of the Public Welfare Service approached Holtz in 2013 with the request that she put together a commemorative volume. Historian Holtz took the idea to her graduate seminar on 'Social Mores and Social Welfare Work in the Kingdom of Württemberg'. Five enthused students from the 27 seminar participants immediately volunteered to help with the project. The biggest challenge facing them: all available sources dating from the 19th century are handwritten. 'The arduousness of working with these old documents shouldn't be underestimated: deciphering them is much more laborious than working with printed sources or collating existing research work,' says Holtz. The graduate seminar was the seedbed for three Bachelor's and two Master's degree theses. Their core ideas reappear in the individual essays which form the guiding themes of the book. For example, Dominiq-

„Under the Queen's Protectorate:' Queen Katharina of Württemberg was a benefactress, among others, of the Swabian Women's Association – whose various ways of honoring her included postcards.

Photo: City Archives of Stuttgart, Postcard No. H 137



A document from the earliest formation phase of the central directorate in the year 1817: an invitation of Queen Katharina to the district directors of Stuttgart's Local Charitable Organization.

State Archive of Ludwigsburg, No. F 240/1 BO 81

ue Corinne Ott's text takes up the gender-specific behavioral structures of the 19th century within the 'Charitable Organization', as it was called then. The reason for the name: Queen Katharina, the founder, was already a very modern thinker back in 1816 and originally wanted the association to consist only of women. And Amelie Bieg talks in her essay about the 'Sanctuary House Movement.' The concept, which originated in Basel, consisted of offering orphaned or disadvantaged children both refuge and active support. Bieg presents five biographies to show how children with no hope of a future became young, professionally trained adults. 'The history and the different forms of today's public welfare service work have a common core that reappears time and again: helping others to help themselves, without ever losing sight of current events or acute needs,' says Holtz. And in spite of all the vicissitudes during 200 years of history, this has remained unchanged.

Michaela Gnann

The year without a summer: the origin of the public welfare service

Today's public welfare service work started in 1817 as a charitable organization founded by Queen Katharina of Württemberg. its birth marked a time of political upheaval in Germany's southwest: the economic situation was extremely precarious. The financial crisis reached its peak in the 'hunger years' of 1816 and 1817. Due to an exploding volcano in Southeast Asia, the German summer was a period of endless rain and storms. The consequences were dramatic, with horrendous crop failures, exorbitant prices for scarce foodstuffs, famine, disease, and poverty. The impact on social structures was dramatic: for example, the numbers of beggars increased, and the crime rate rose rapidly. The reaction of the young kingdom of Württemberg to all this was to found the Charitable Organization.

‘Daring to Jump’
FlixBus boss Jochen Engert is right where he always wanted to be: at the helm of a company

Business consultant Jochen Engert, a graduate of the University of Stuttgart, was working on his Ph.D. when he learned that the market for long-distance bus travel was about to be thrown open. He lost no time in seizing the opportunity together with two friends and founded a startup. Today his long-distance bus company FlixMobility GmbH, better known to many as FlixBus, is the market leader, offering digital strategies, economically priced tickets, and a lot of feeling for the lifestyle of its young customer base.

The Stuttgart University graduate doesn’t look very adventuresome at first glance. ‘Sheltered’ is how Jochen Engert describes his childhood in Gosmannsdorf am Main, a town of 1,000 near Ochsenfurt in Germany’s Unterfranken Area, in a close-knit family, and his active membership in the soccer club. School was followed by military service, after which he thought for a long time about his future course of studies. Now 34 years old, he reminisces, ‘I wanted a mix of economics and technology’. The University of Stuttgart offered precisely that in its ‘Technical Applied Economics’ curriculum. ‘It was a full-scale economics degree course with a technical flair - exactly what I was looking for.’

Smooth as silk

His choice of courses was deliberate, strategic, and target-oriented; he wanted to ‘get as much content as I could.’ In particular, he delved at the University - interspersed with two semesters abroad at the University of Ottawa - into Controlling and Finance and learned how to manage company-type organizations. Business consulting in particular aroused his interest, and even as a student he gained practical experience. Following his graduation, Jochen Engert joined the Boston Consulting Group (BCG) where he worked for two and a half years as a consultant for customers all over the world, enjoying the diversity of projects and issues which he encountered. It went ‘smooth as silk’, and with his degree in Business Administration he was well on the way to an assured professional future. In 2010 he took a sabbatical in order to write a doctoral thesis at the Otto Beisheim School of Management in Vallendar on ‘Industrial Service Pricing’. But even then, quite another idea was simmering just beneath the surface.

The moment of decision

‘I always had an urge to start up my own company,’ he says, as if this were self-understood. For years he worked out the ramifications of different business ideas with his present business partners Daniel Krauss and André Schwämmlein. ‘And then, just when my Ph.D. thesis was underway, we heard about this issue of market liberalization.’ That was the moment of decision.

After 75 years during which the German Bahn had a monopoly on long-distance travel, the German government at that time debated whether to open up the domestic German long-distance travel market in the interest of economically priced alternatives. A new market segment was possible. Although whether and when were still speculative, the three friends pricked up their ears. ‘It doesn’t happen very often that a market in front of our doorstep is liberalized,’ smiles Jochen Engert. It was a once-in-a-lifetime opportunity - but the three young men let it go by at first.

Why leave a secure job?

‘We took it for granted that the German Bahn would come and do this itself,’ says Engert. ‘The Bahn is the biggest transport company in Germany, with the biggest impact and the most options.’ But then the unexpected happened: the Bahn turned up its nose at the idea. ‘They didn’t find the market attractive,’ says company boss Engert today. ‘Once again,

When the long-distance bus travel market opened up in 2011, Jochen Engert and two friends seized the opportunity to found a startup. Today FlixBus is on the road all over Europe.

Photo: Foto: Flixbus/Jan Röder

we started paying attention, and then we thought through various business models, with the question: 'Where is there added value for us? Which idea might work?'

A time of intensive work began. At first, the Ph.D. thesis and the startup proceeded parallel to each other. Engert's BCG colleague André Schwämmlein was also working on his doctoral thesis at the time, and business informatics specialist Daniel Krauss was working for Microsoft. 'And then we reached a point where we had to decide: do we finish our Ph.D.s and then go back into consulting? Do we stay with our secure jobs? Or do we make the jump and start up a company?' Everybody knows the answer: The long-distance travel market opened up on January 1, 2013, and the three were at the starting line with FlixBus GmbH.

Actually more of a technology company

The three-man startup, founded in Munich in 2011, with its first busses on the road on February 13, 2013, has now become a Europe-wide long-distance bus travel company with about 1,000 employees. More than 1,000 FlixBus brand busses are now rolling for FlixMobility GmbH to more than 900 destinations in Europe. FlixBus has build up more than 100,000 points of connection and carried 20 million passengers in the year 2015. At the moment, FlixBus dominates the market with more than 80 percent in Germany, not least because it has bought up various competitors - just recently Postbus. The company is now also the market leader in France and Italy.

What is special about the concept is the 'partner model'. FlixBus does not own its own busses and drivers, but prefers to work Europe-wide with more than 250 mostly medium-sized bus companies. The heart and soul of the company, which describes itself as more of a technology company than a bus company, is the 'FlixBus App', a technology platform offering a booking system, delayed scheduling management, and GPS live tracking. There is also a marketing approach under the motto 'green mobility' which specifically uses targeted online marketing to make the 'old-fashioned' bus industry attractive for a younger interest group. This involves a uniform look for all partners, with green busses, intuitive booking of tickets via an app, no-cost WiFi, electric outlets for smartphones, Infotainment during the trip, friendly bus drivers, and very reasonably-priced tickets. Now there is even an online charter platform.

Linny Bieber

How to retain skills on long-term missions

The world is not enough – that's what we see when man's innate desire to know makes him fly in manned spaceships to distant planets. Mars is the currently planned destination. The trip will take six to nine months - one way. Both physically and psychically it will be a situation of extremes for astronauts, and will require minute preparation. The question, however, is: does this preparation in fact take the entire human factor into account? What will happen if the astronauts forget after a half-year how to carry out a landing and/or docking maneuver? We know this from the past: abilities of human beings that lie dormant for a long time become lost. This is where SIMSKILL, a research project of the University of Stuttgart's Institute of Space Systems (IRS), takes its cue. A five-person team which includes engineers Andreas Fink and Miquel Bosch-Bruguera and Valerie Schröder from the University of Stuttgart is working with universities in Brussels and Rome to find out how to preserve skills under exceptional, long-term conditions like extreme isolation, weeks without daylight, or reduced oxygen in the air. To this end the young scientists went to the permanent stations Halley VI and Concordia in Antarctica at the end of 2015 and set up two mobile cockpit simulators modelled on the interior of the Sojus spaceship. They then used these simulators to try out different conditions and go through flight exercises that varied in frequency. The research team is now comparing this 'flight' data, gathered up to the beginning of November 2016, with control data gathered at a 'base station' at the IRS with volunteers. The results will be used, among other things, in planning the training and the operation of long-term projects in manned space flight.

Martina Hönekopp

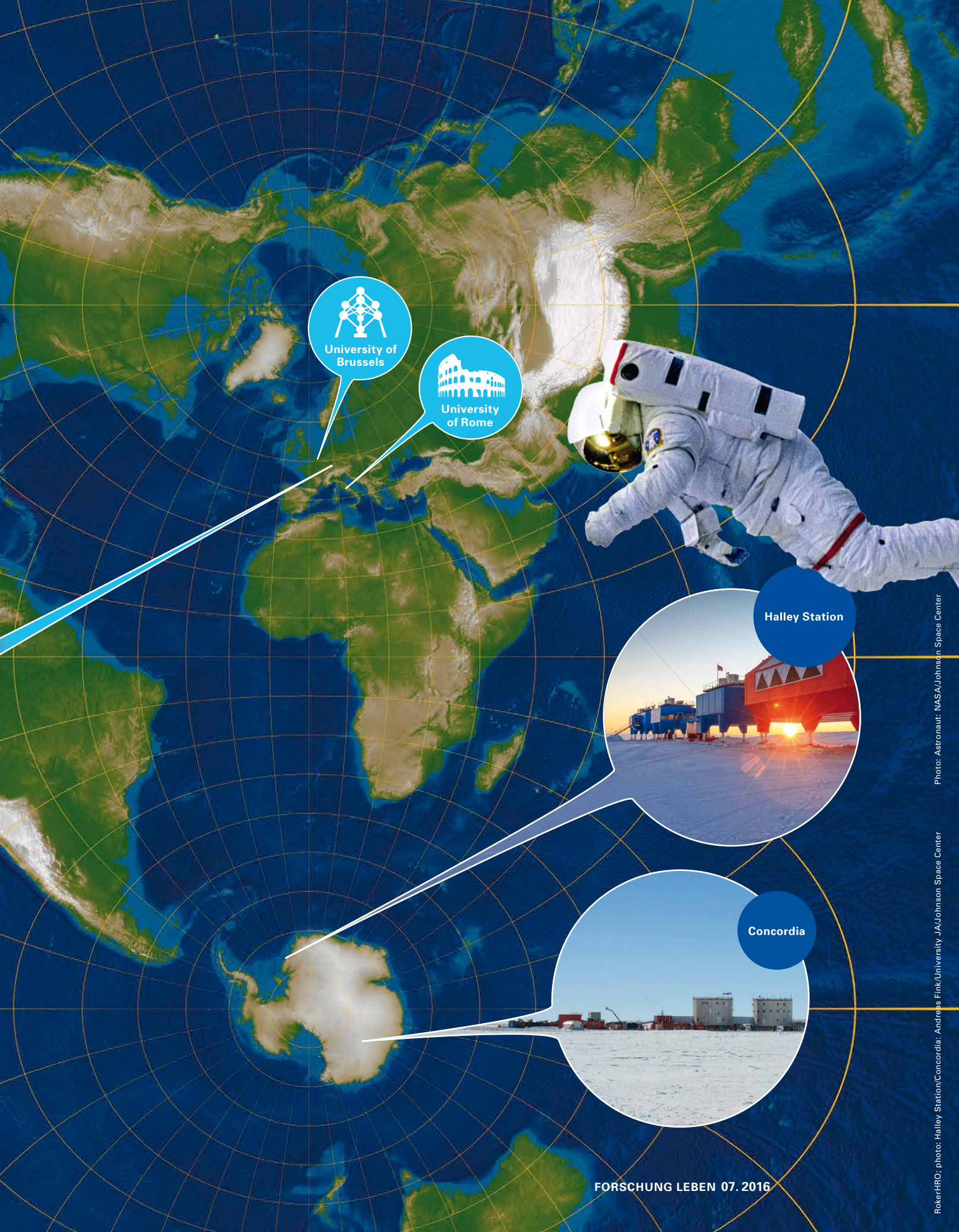


Photo: Astronaut: NASA/Johnson Space Center

RokerHRO; photo: Halley Station/Concordia: Andreas Fink/University JA/Johnson Space Center

Saving Lives - Affordably
Li Zhang is working on low-cost earthquake forecasts

Precise monitoring of landslide-endangered areas can save many human lives, but it is expensive. But now reasonably priced early warning is becoming a real possibility thanks to the research work of Dr. Li Zhang, a scientific research assistant at the University of Stuttgart's Institute of Engineering Geodesy (IIGS)

About one million cubic meters of rock thundered down into Southern Tirol's Pragser Valley in August 2016 during a landslide. Fortunately, there was no damage to human life. But on a worldwide scale, landslides occur time and again and eradicate entire urban settlements under layers of mud and boulders. Such forces of nature are practically unstoppable: man is helpless when millions of tons of earth and rock go into motion. But early recognition of infinitesimal movements in such danger zones could help to perceive the threat of danger and allow settlements to be evacuated in time.

Measurements in millimeters

Li Zhang can only smile when asked whether it wouldn't make sense in such danger zones to simply set up a network of GPS receivers like the ones pre-installed in smartphones or navigation devices. Li Zhang, 32 years old, has been working in her office on the sixth floor of the University of Stuttgart's Institute of Engineering Geodesy since 2009 on precisely such early-warning systems. One result of her work was the finding that normal commercial GPS receivers like those in private use do not meet the requirements. 'A 'navi' is relatively unconcerned about deviations of a few meters; it can still find the destination,' says Zhang. 'But we need a precision of millimeters in order to supervise deformations - the more accurate the better.' If a slope moves only five millimeters, that could be a critical signal. The measurement must therefore be that much more accurate. Navigation devices, on the other hand, function with a maximum precision much the same as visual evaluation, that is, about one to three meters. So-called 'geodetic' GPS receivers have long been used for professional purposes of this kind; they not only receive the same 'code signals' as navigation devices but also process much more accurate 'phase signals'. The drawback: such receivers cost about 20,000 Euros apiece, and that is without the added cost of supply current from solar panels, backup batteries, and data transfer. The costs of investment needed to ensure extensive operations is thus very expensive for developing and emerging countries. When Li Zhang came to the IIGS in 2009, she therefore approached her institute director, Prof. Volker Schwieger, about the possibility of reasonably priced deformation monitoring - and that turned out to be the topic of her dissertation.

Language barriers a thing of the past

Li Zhang was born in 1984 in the East Chinese province of Zhejiang. She first studied teledetection and Geoinformatics at the University of Wuha. An exchange program brought the young researcher to Baden-Württemberg and the University of Stuttgart in 2003, where she first had to pass the German language test. 'I must admit,' she says with a laugh, 'that I didn't understand my class lectures completely, because not every teacher speaks as slowly as my language instructor!' But now the language barrier has long been surmounted: Li Zhang herself now holds classes, for example about deformation analysis. She studied Geodesy and Geoinformatics in Stuttgart from 2004 to 2009 and at the same time gathered practical experience at the Urban Surveying Office of Stuttgart and as a student worker at Robert Bosch GmbH. Zhang finds it easy to sum up the focal point of her research work: 'I'm very interested in finding whether much less expensive equipment can yield high-precision results.' Now that her

dissertation is finished she can answer this question with a resounding 'Yes!' But she had to traverse a long gauntlet of challenges before reaching this point. At the beginning, she found it quite easy to find inexpensive receivers and suitable antennas for only a few hundred Euros. It was also not difficult to read out the integrated software results and analyze them. As scientist Zhang says, 'Signal reception involves a plethora of sources of error.' For example, the signals from GPS Satellites 20,000 kilometers above the earth often do not reach the ground receiver directly but are reflected, for example from city building facades and other objects. And even when the signal is emitted from the ground and then arrives at the antenna, it has traveled a very long way. Such multi-path effects can result in inaccurate determination of positions.

Photo: Jens Eber

'Choking off' sources of error

'I made models of these effects for my dissertation and then tried to minimize them,' recalls Li Zhang. She now uses a 'choke ring' of her own design to reduce reflective ground waves; it is a circular plate with metal rings of different diameters positioned below the antenna to stop signals from below. Zhang minimized other error sources by identifying their typical patterns and then correspondingly optimizing the receiver software with algorithms she developed herself. The inexpensive receivers, previously unsatisfactorily precise, now have an accuracy of only a few millimeters - quite comparable to that of high-priced geodetic receivers.

'Our idea is to install such systems everywhere in endangered regions,' says Zhang. Ideally, it might be possible to automate the monitoring process by transmitting the measurement data of the receivers automatically via WLAN in real time to a primary central location for assessment. 'A few years ago we already built and tested a low-cost GPS monitoring system with an autonomous solar panel power supply and backup battery, automatic data transmission, and real-time evaluation. It functions flawlessly.'

At least two receivers are required to monitor, for example, a slope which is in danger of sliding. To achieve millimeter precise accuracy, the distance between both receivers should be less than about ten kilometers. Area-wide monitoring in endangered regions is a cost issue, which is why Zhang's' research work in Stuttgart immediately drew worldwide attention. 'I work in a team at the FIG, an international union of geodesic engineers. We also have a task for there for cost-efficient monitoring, and

Photo: Jens Eber

„Choke rings' make it possible to ward off ground reflections which could cause inaccuracies in GPS measurement results.

this is very interesting above all for our colleagues from poorer countries,' says Zhang. Admittedly, however, she has been unable up to now to develop a multipurpose monitoring device. 'The equipment and the related software must be adjusted for the purposes of each individual task,' says Zhang. Even in future, therefore, it will be impossible to purchase such high-precision GPS systems in the do-it-yourself store around the corner.

In future, it might be possible to employ the low-cost monitoring devices for other uses than early warning of landslides, as Zhang explains. Her system could also help in monitoring bridges or dams. It is well known that the gigantic concrete walls of dams bend according to the amount of water behind them, and every bridge has its own natural vibration frequency. Should such deformations exceed a specific level, this could serve as an alarm signal. Li Zhang and her colleagues at the IIGS have already formed plans for testing her system at a dam with an artificial lake.

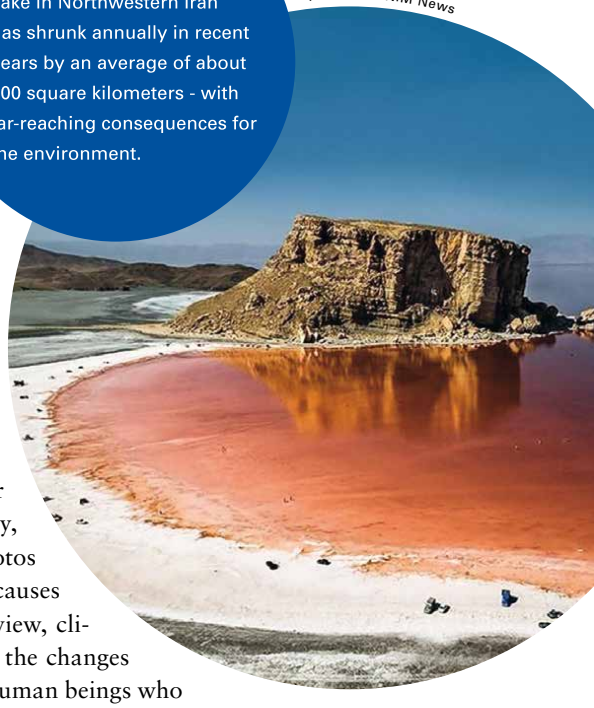
The next target: moving objects

Zhang spent a good five years working on her dissertation. Interested feelers have already come from industry. But she is still not finished with the issue of GPS monitoring, quite the contrary. She feels at home in Stuttgart, but can still envision working someday in China again. Until that happens, however, she intends to tackle other related challenges. 'My interest lies in precisely tracking the movement of objects using reasonably-priced GPS devices.' It can be assumed that there is a huge number of possible areas of application for this, especially in the era of Industry 4.0 and its ever-more digitalized production processes. Zhang also believes that the automotive industry with its current interest in 'autonomous driving' will be interested in such high-precision, low-cost GPS receivers. However, that will require finding a way to counter the many sources of interference of communication between satellites and receivers.

Zhang is therefore also experimenting with GLONASS, the Russian counterpart to the U.S. GPS system. 'We have procured new receivers that can process the signals of GLONASS, GPS, and the Chinese satellite navigation system Bei Dou,' says Zhang. It is important to be able to access more than one satellite precisely when moving objects are to be monitored. Since there are still only a few receivers for Bei Dou signals in Europe, some experts are already thinking about a cooperative venture with University of Wuhan.

Jens Eber

Follow the Water!
Satellites help follow water movements around the world



The water surface of Urmia Lake in Northwestern Iran has shrunk annually in recent years by an average of about 200 square kilometers - with far-reaching consequences for the environment.

Photo: TASNIM News

Global water flows form a highly complex system and are for that reason difficult to track. But Dr. Mohammad J. Tourian of the University of Stuttgart's Institute of Geodesy has found a way to make them more transparent by linking three satellite-supported observation techniques.

One cubic kilometer of water is so much that it is hard to imagine it - as if a cube 1,000 meters on a side were to be filled. Another way of putting it: five billion bathtubs would be required to hold the same amount. This is the volume that Dr. Mohammad J. Tourian of the University of Stuttgart's Institute of Geodesy arrived at when researching Urmia Lake in Northwestern Iran. It was once about 10 times as large as the Lake of Constance, but now its surface has been shrinking annually by an average of about 220 square kilometers, so that the lake has lost the above-mentioned cubic kilometer of water. The water level has sunk annually by an average of 34 centimeters a year with far-reaching consequences for the environment. 33-year-old Tourian, who studied in Teheran and then applied for a doctoral candidate position at the University of Stuttgart, is not the type of researcher who measures water samples in a glass. Quite the contrary: he gathers his data from satellites. In the case of Urmia Lake, however, he found that the analysis of satellite images was not enough for him to arrive at a comprehensive understanding of the causes and impact of water losses. 'We now link three observation techniques in order to get an overall picture,' says the Iranian who has now been carrying out his research in Stuttgart since 2008. Among other things, he uses satellite altimetry, in which radio impulses are sent vertically to the earth, to determine the level of the water surface. And he uses satellite gravimetry to measure changes in the earth's gravity field, which fluctuates when, for example, large areas of ice in the arctic melt or Lake Aral shrinks. Finally, he appraises satellite photos to gain insights into the causes of change. In Tourian's view, climate has less to do with the changes in Urmia Lake than the human beings who drain off massive amounts of groundwater for agriculture and dam up some of the lake's tributaries, thus cutting off more and more of the lake's water replenishment. The Iranian government has now adopted a plan of action which aims to prevent illegal water removal.

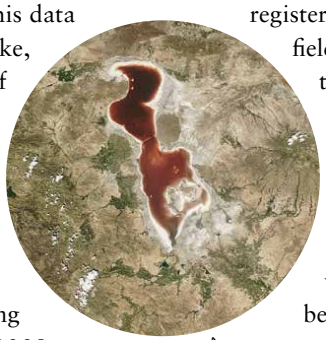


Photo: NASA

These and other results provide new incentive to Tourian and his colleagues. 'We're working to break down the data better in order to study specific regions in greater detail.' For example, the satellites would have to carry out more precise measurements in order for research to be carried out on changes in the cyclical circulation of water in permafrost regions. Gravimetry in particular has problems in registering infinitesimal changes in the gravity field. Tourian is nevertheless confident that the study of global water circulation flows can help mitigate the consequences of climatic change. 'Above all, political decisions are required on a worldwide scale,' says scientist Tourian. 'But even today, much can be done in individual regions if causes and effects can be precisely identified - as at Urmia Lake.'

Jens Eber

Imprint

Publisher: The University of Stuttgart

Address: The University of Stuttgart, Keplerstraße 7, 70174 Stuttgart
Telephone: 0711 685-82211, Fax 0711 685-82291
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Editorial Board: Dr. Hans-Herwig Geyer, Andrea Mayer-Grenu, Sympra GmbH (GPRA)

Concept: Tempus Corporate
www.tempuscorporate.zeitverlag.de

Design and realization: Zimmermann Visuelle Kommunikation
www.zimmermann-online.info

Advertisements: ALPHA Informationsgesellschaft mbH
info@alphapublic.de, www.alphapublic.de

Print: W. Kohlhammer Druckerei GmbH & Co. KG, Stuttgart

Printed copies (German version): 7.500

ISSN: 2198-2848

Internet: www.uni-stuttgart.de/forschung-leben/

MIX
Papier aus verantwortungsvollen Quellen
FSC® C016267

klimaneutral
natureOffice.com | DE-159-798467
gedruckt

Printed on Circle Silk Premium White, certified with the EU-Ecolabel of Quality (Reg.-No. FR/11/003).
Printed on 100% recycled paper.

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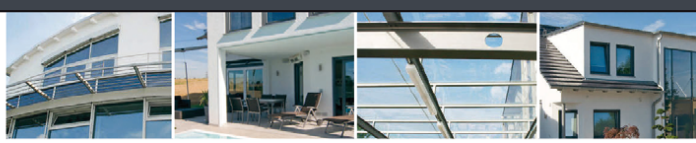

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