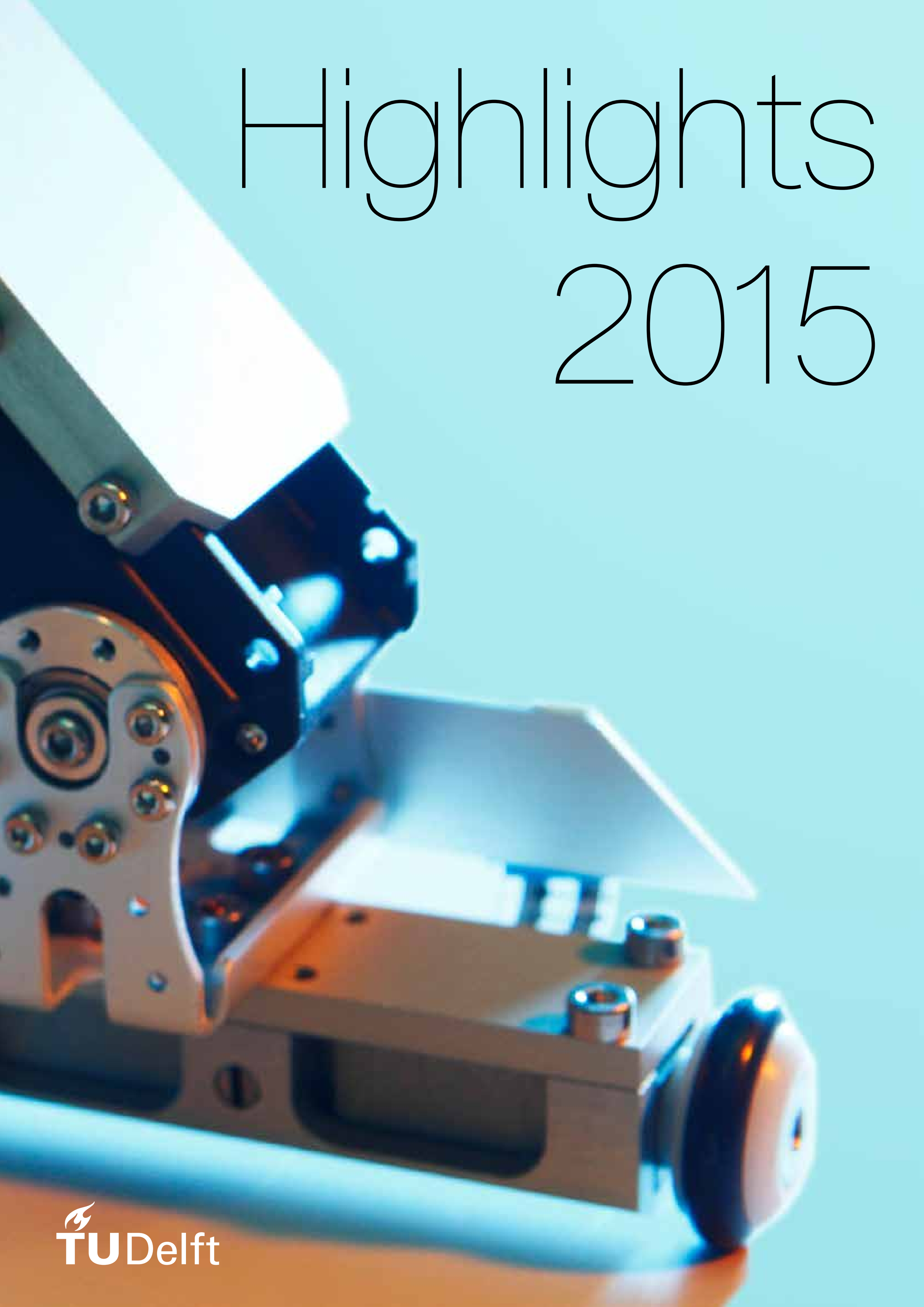
Highlights 2015



TU Delft

Highlights 2015

Delft University of Technology

TU Delft

Foreword

This TU Delft Highlights 2015 offers a beautiful insight into research, education and enterprise at our university. Once more, we rejoiced this year in ground-breaking research that was often featured in world media as well, in an influx of new students that was again higher than in previous years, and in a variety of students and employees who took a chance at entrepreneurship. In a publication like this one it is impossible to be complete, even though the name ‘Highlights’ might give the impression of a list of absolute high points over the year.

That is not the case. That we have opted to put the winning iGem and Stratos II+ student teams in the limelight this year, does not mean that we are trivialising the achievements of the Nuon Solar team, who won the World Solar Challenge in Australia for the sixth time. And although we are showcasing Professor Maarten van Ham’s important book on segregation, we are still extremely proud of the successful ‘loophole-free Bell test’ with which professor Ronald Hanson and his colleagues proved quantum entanglement, to name but a few examples.

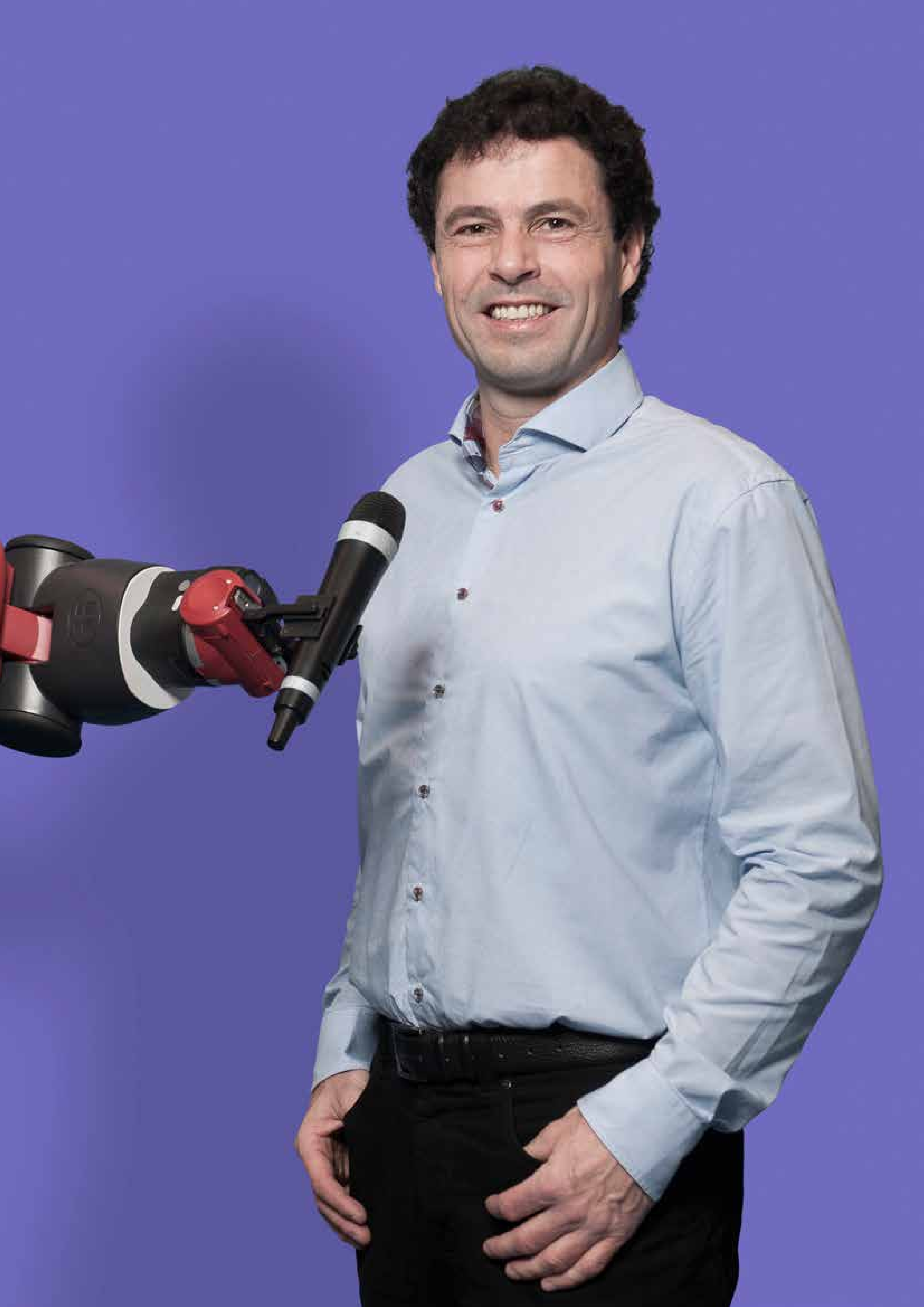
No exhaustive list then, but the twelve interviews in this publication are representative of all the beautiful things that happen at our university. This selection also succeeds in capturing all the forms of cross-pollination that are taking place. Let me give a few examples. During their Bachelor’s studies, the students of rocket society DARE enjoyed the excellent teaching of Lecturer of the Year Alexander in ‘t Veld. Nowadays, they are being asked by the Faculty of Aerospace Engineering to contribute their expertise to the setting-up of practical assignments, for example.

Professor Serge Hoogendoorn and Dr Alessandro Bozzon are collaborating on research that aims to increase the livability of our cities, the former from a transport management point of view, the latter from a social data science angle. Maja Rudinac, CEO of Robot Care Systems, is a former colleague of Professor Robert Babuska, and she is now in turn an employer for many of our Robotics graduates.

All of this would not be possible without our University Services, and it is with great pleasure that we present you the men from the Model Making and Machine Lab (PMB) of the Faculty of Industrial Design Engineering (IDE) who are exemplary of the dedicated and professional support staff that our university abounds with. To ensure all our students and employees enjoy a learning and working environment with state-of-the-art facilities and modern amenities, we are undertaking an extensive redevelopment of our campus. Sustainability coordinator Chris Hellinga will lift a corner of the veil on this subject.

Twelve interviews with unusual people at our university. Together they are making a difference, both at TU Delft and in our society.

Professor Karel Luyben
Rector Magnificus
Delft University of Technology



Robert Babuska

Desirable behaviour in robots

On 8 January 2016, Professor Robert Babuska will give the Foundation Day Lecture during the TU Delft 174th anniversary celebrations. Babuska is professor of Intelligent Control and Robotics in the faculty of Mechanical Engineering, Mechanics and Maritime Technology (3mE). He is also scientific director of the TU Delft Robotics Institute. 'It's not so hard to make a robot happy', says Babuska.

From a very early age I had a fascination for electricity. As a child I was always going around with a piece of cable and sticking it into the wall socket. My parents weren't very happy about that. I went on to study electro-technology in the Czech Republic, at TU Prague, specialising in technical cybernetics, which is control technology with a dash of Artificial Intelligence and robotics thrown in. So robotics was always there in the background, but I also worked on countless other applications for control technology, for example drinking water purification processes and optimisation of dredging processes.

Control technology is in everything, even if you can't see if from the outside: your mobile phone, your car, an aeroplane. I research generic systems for control technology, mainly those that are used in robotics. I love the everyday nature of it. Once you discover one method, you can apply it to all kinds of systems. I'm mainly interested in learning control systems: how you can make a system improve itself. Imagine that a robot has to carry out a difficult task, such as walking. If a human demonstrates it once, a robot will only get it right partially. You want the robot to improve of its own accord and ultimately to achieve more than a human. It is possible; it's been proven.

Anything set up by people can always be automatically optimised. A production process or climate management in the home. Yet these technologies are not often used. Where they are in use, however, is in ships. There are algorithms that are able to adapt to changing conditions at sea. The industry is incredibly careful however, as something has to behave as designed, without any surprises. So there is very little leeway for experimentation, or else you have to accept that a learning system will make mistakes from time to time, just like people. Our challenge is to ensure that these technologies don't make any major mistakes while they are learning. This research is extremely worthwhile, as you can get systems to perform far better, saving materials and energy, for example.

Reinforcement learning is one of the techniques that we use. It is based on the way in which people and animals learn, using punishment and rewards. You can't explain things to a dog or a young child, but you can reward desirable behaviour. You can pretty much apply the same principle to a computer. The reward is not a cookie, but a number. A learning algorithm tries to collect as many of these rewards as possible. Using this sort of technique, computers can start out at nothing and end up making huge achievements. There are countless examples of this in the literature and on the internet. Google DeepMind, for example, showed a computer some screens from Atari games, without explaining anything about the rules or tactics. After a couple of hours the computer was able to play well and after half a day, even better than a human. It's not world-changing application, but it does show what's possible.

We do the same with walking robots. We walk smoothly without thinking about it, but that's very difficult for a robot: it's unstable on two legs and can easily fall over. That's why it walks very carefully and looks so mechanical. You can code dynamic walking – like a human – as being the desired behaviour. So if a robot takes a good step and achieves a certain speed while not using too much energy, then you offer a reward. If it falls over, you can give punishment. In this way the algorithm can learn what the optimal operation is for the various motors, so

TU Delft Robotics Institute

How can we get robots and humans to work together effectively? That is the scientific challenge for the TU Delft Robotics Institute, where researchers of almost all of the university's faculties collaborate. Together they cover such 'hard' robots disciplines as mechatronics, embedded systems and control, as well as 'soft' robot disciplines like human-machine interaction, ethics and design. The institutes focuses on three themes. The first theme, swarm robots, concerns relatively simple robots that can jointly perform complex tasks, such as observation, measurement and data collection. The second theme is entitled 'robots that work': robots that can perform tasks for or together with humans in a human production environment. Finally, interactive robots are robots that can work together and interact with humans at a physical or social/cognitive level.

that the robot learns to walk smoothly. The rewards are points and having lots of points is good, which is programmed in. For us humans, the reward is generally dopamine: if you do something good a chemical is produced in the brain that makes you happy. It's not so hard to make a computer happy. And the nice thing about it is that the robot learns something that you can hardly programme as a person.

Robots have to be able to make decisions quickly. They operate in real-time in the real world, just like people. That's why we look at the decision-making models used by humans. We know from neuro-psychology that our brains also work using models. For example, a dream is a kind of simulation intended to process an information overload. Much of what we do is based on predictions in the brain. If you tried to catch a ball based on sensory observation, you'd be too late. Your brain calculates where the ball will end up, based on previous experiences. The predictive models in the brain are something we are constantly adding to with new data.

These kinds of predictive models can also be used to make systems and this is called predictive control. You can try to predict how the movement of a robot might look in the coming few seconds. You simulate a scenario with various different inputs from all possible movements. Then you select from the predictions the ones that are most in line with what you want. A second later you do it all again. It's just like a chess grand master who thinks several sets ahead and has to rethink again every time his opponent makes a play. Chess is difficult, but within a certain limited setting, you can calculate a hundreds steps ahead. The great thing is that within that framework you can include all kinds of requirements and limitations. Imagine that one of the scenarios that you think up results in a bad outcome, then you can make sure that the system avoids this.

This is a good application for swarm robots. A swarm of small, cheap little robots each carrying out part of a task, can achieve something really great together. You just need to make sure that they don't bump into each other unnecessarily while they're moving about, or they'll break. If they are on wheels, you can use the speeds of the left and right wheels to predict a few seconds in advance which way they will turn. If you then use a camera to see another robot coming and there's a risk of collision, you can adapt the route. Every member of the swarm has its own, albeit tiny, brain, but they don't have to constantly monitor all of

How can we ensure that things won't get out of hand with technologies clever enough to outsmart humans?

the other robots in the swarm. This sort of thing works unbelievably well in practice. Here decentral control is more efficient than central control. Another example is the manipulation of objects, think about a container hanging under a crane in a container park. The container's route can also be optimised using predictive control technology. Maybe it's really windy and some routes are more sensitive to side winds than others; then you just select the route that has the greatest chance of a safe outcome. The shortest route is not necessarily the best one.

The interaction between man and robot is where much of our research is done. Robots have to be able to anticipate humans and in return humans have to be able to understand how robots think. To this end, a robot has to be able to show a human what it plans to do, using speech or movement, light or projection, all of which is possible. The human doesn't have to accept this and the robot has to learn to be sufficiently adaptable to say: I understand; I'll do what you want. So a robot has to be able to demonstrate its intentions, be adaptive and be able to estimate what a human is planning. To achieve this we have to build in a simple programme of human behaviour. That's a lot of things to take into account, not just design, but also psychology.
It is desirable for robots to have a certain level of autonomy. Otherwise you have to constantly take the lead and tell them what to do, which doesn't get you anywhere. Sometimes a robot needs to function remotely at a great distance. So a robot has to be able to make independent decisions some of the time, some of which might be very easy: I see an obstacle and I will drive around it. Other decisions can be far harder. With self-driving cars, for example, there are all kinds of examples: should the car sacrifice its passenger to save three pedestrians? It's an ethical minefield and explains why full autonomy is not a desirable thing, because humans need to have control over robots. The robot needs to be independent, but not think up things all on its own.

So where is the boundary? How can you ensure that interaction between the almost autonomous robot and humans works well? If a car is 99% self-driving, but relies on a person for the remaining 1%, there is every chance of disaster. The person isn't used to driving any more, or is doing something else, not thinking that something could go wrong. It's a familiar scenario in air travel: if something goes wrong the pilot takes over, but he has been trained to do that. If we introduce robots into society now, we can't expect users to be entirely on the ball and understand every detail of the robot.

Looking at society, at the pace at which things are developing and the extent to which we understand what's going on around us, we can barely keep up. Take real-time trading, where companies earn huge sums of money with transactions that take place within micro-seconds. No one understands how that works or the exact consequences.

How can we ensure now that things won't get out of hand with technologies clever enough to outsmart humans? These are interesting discussions that should not be side-stepped. The complexity of the human brain is so huge that it might take twenty years, but it will happen one day. This will present us with a tough, philosophical problem, because if Artificial Intelligence is in the 'cloud', you can't just switch it off. A sensible principle is that for each step taken, in research or implementation, you must be sure that it is the right step. That you can demonstrably show that the system cannot get out of hand and that you are taking as few risks as possible when improving that system. This principle must be held on to tightly.

Alexander in ‘t Veld

A flying education

Alexander in ’t Veld is assistant professor at the Faculty of Aerospace Engineering (AE). He also flies the TU Delft research plane, the Cessna Citation. In 2015 he was voted Best Lecturer at TU Delft: ‘It helps if you know how to make dry theory come alive.’

As a little boy I already wanted to become a pilot. Or a bricklayer. A neighbour once built a wall in his garden and I remember watching him open-jawed. My parents advised me to become a pilot; they said I could always build walls in my free time. By the time I was completing my VWO (‘pre-university education’), I had decided to study Aerospace Engineering and become a pilot. I thought this would give me with lots of opportunities for working in aerospace.

Simultaneously with my degree programme I also obtained my pilot license; I already had a couple of hundred hours of flight experience in small planes, aerial advertising, etc. I dreaded the approach of my graduation date: I knew I would have to make a choice then. I really wanted to prepare a doctorate - I had even been offered a PhD position at MIT, the Massachusetts Institute of Technology - but I also knew that if I didn’t do something with my pilot training, I would lose my license. At my graduation, I not only got my grade, but I was also asked whether I was interested in becoming a pilot engineer at TU Delft. This meant obtaining my doctorate and flying. How could I refuse? It also meant that I would have to teach; it was just part of the deal. So teaching was not really a vocation of mine, although it turned out to be great fun.

Our plane is actually a business jet, but without the classy interior. It has been completely revamped into a flying laboratory, with measuring systems that can be adjusted for the specific objective of each flight. Our flights can have any number of objectives. We sometimes fly with cameras on the nose of the aircraft, with additional antennas, or even with torpedoes with measuring equipment under the fuselage. We run this plane together with the Netherlands Aerospace Centre (NLR). I am manager of flight operations of our shared flying services and responsible for all projects carried out with the plane. In particular with TU Delft-related projects, I may at times spend as long as two years on the preparations.

Together with the NLR, we also have our own design organisation, certified by the Human Environment and Transport Inspectorate (ILT). This means that we are authorised to modify, approve and implement the plane design ourselves. This places us in a unique position, since such rights are usually reserved for manufacturers. For example, we have also made the plane fly-by-wire, so that it can be flown using a joystick via a computer. We just have to connect a laptop and we can immediately test new programs, for example for better approach routes to the airport. Of course we can always intervene if something goes wrong, or even adjust the software during the flight.

A great deal of this research is not necessarily linked to my own research. We did a number of studies of air quality in various places in the world for the UN. And during the volcanic eruption in Iceland in 2010 we were one of the few research aircraft permitted to fly into the closed European airspace to collect samples. We were asked to measure the concentration of volcanic ash in the air. This required adjusting the Cessna by adding special ‘sniffer’ equipment and particle counters. More recently we conducted a study on new environmentally friendly approach procedures. This study incidentally did touch on my own PhD research.

My doctorate dealt with ‘continuous descent operations,’ which are procedures for guiding planes to the runway via constant gliding flights. Every pilot knows how to do this basically, but when it’s busy the air traffic controller takes over. Everyone is told to fly at a fixed speed and height, which is quite inefficient. You can handle a lot of planes in this way, but it costs extra time and fuel, and low altitude flying is very noisy while noise pollution is precisely what we are trying to reduce. There are different ways of resolving this problem. I looked at whether planes can calculate the distance to their predecessor themselves, so that the air traffic controller no longer has to do it. This requires the pilot to fly in an optimal profile himself while keeping an eye on his predecessor. In my scenario this achieved by flying with minimum engine power. This is quite difficult to do, because the only things you can still control are the ‘flaps’ and the precise moment when you release the landing gear. The landing gear creates a lot of air friction, so if you lower it too soon, you will not make it to the runway. If you lower it too late, on the other hand, you will end up too close to your predecessor. But if you do it exactly right, you will make it to

Aerobatic pilot

'In my free time, I like to fly upside down' says Alexander in't Veld, assistant professor and teaching pilot. 'I have been doing stunts for years. To me, this represents ultimate freedom. Civil pilots are trained to fly not too slanting and not too fast from A to B. Then they have to do this with large aircraft, in the middle of the night, with bad weather and under difficult conditions. They get really good at it, but they are still only using a tiny portion of what a plane can do.
People who train to be pilots always think that they will be as free as birds. But you have to fly a precise course at a precise altitude, otherwise you'll get air traffic control on your back. If you want to experience real freedom, you have from time to time to fly straight up or straight down, or spin on your own axis a few times. This kind of freedom is only possible in aerobatics, air acrobatics. It brings you right back to the basics of flying. All that matters is your altimeter, your speedometer, and your hand-foot-eye coordination.'

the runway without having to step on the gas pedal.

In terms of content, my lectures have nothing to do with my research. I teach the third-year Bachelor's course Flight Dynamics. Flight Dynamics deals with stability and movements, in other words the control characteristics of a plane. This does dovetail seamlessly with my background as a pilot. My predecessor, Professor Bob Mulder, was also a pilot and my teacher. I enjoyed this course as a student because it explains the theory behind what you experience when you pilot a plane. If you just read the book, though, it's all dry theory, with lots of mathematics and physics. It helps if you can make the theory come alive. You can sometimes link it to a plane crash; the sum the students solve shows what went wrong. Then it's not just a sum any more: it actually gives us information about what the plane does, which is worth its weight in gold.

But the students still have to solve the equations. After all it is an engineering course. In Delft we are really good at theoretical education, and students tend to pick this up fast. But it can certainly do no harm to show them how the theory impacts the practice. For example we often begin with comprehensive equations. Then we start crossing things out: we assume that this is zero, and that that is a constant, etc. The sum that remains is never a problem for the students. But I want to present them with a case study, so that they can make these simplifications themselves. They need to get a feeling for it. I also want them to understand how design impacts performance. I want them to understand that if a plane is unstable, you can alter its design. And that this is something that can be done by placing the wings at a wider angle or more to the rear. They don't have to become full-fledged aircraft designers, as long as they understand that certain design choices have an impact on the handling characteristics of the plane.

The laboratory course plays an important role in this context. In small groups of six, we take all students on a research flight. This is something I do together with my colleague: one of us flies the plane, while the other one explains. On the basis of the theory, the students are required to create a model beforehand and to use this model to calculate what the plane will do during the flight. If what they expect to happen happens, it's great. It gives them confidence that their funny-looking sum actually describes what the plane does. The thing is, you can calculate it all with a programme like Matlab, but it's only once you are up in the air that you experience

‘We know that they know how to do these calculations. But it’s all about understanding what you do and what it means’

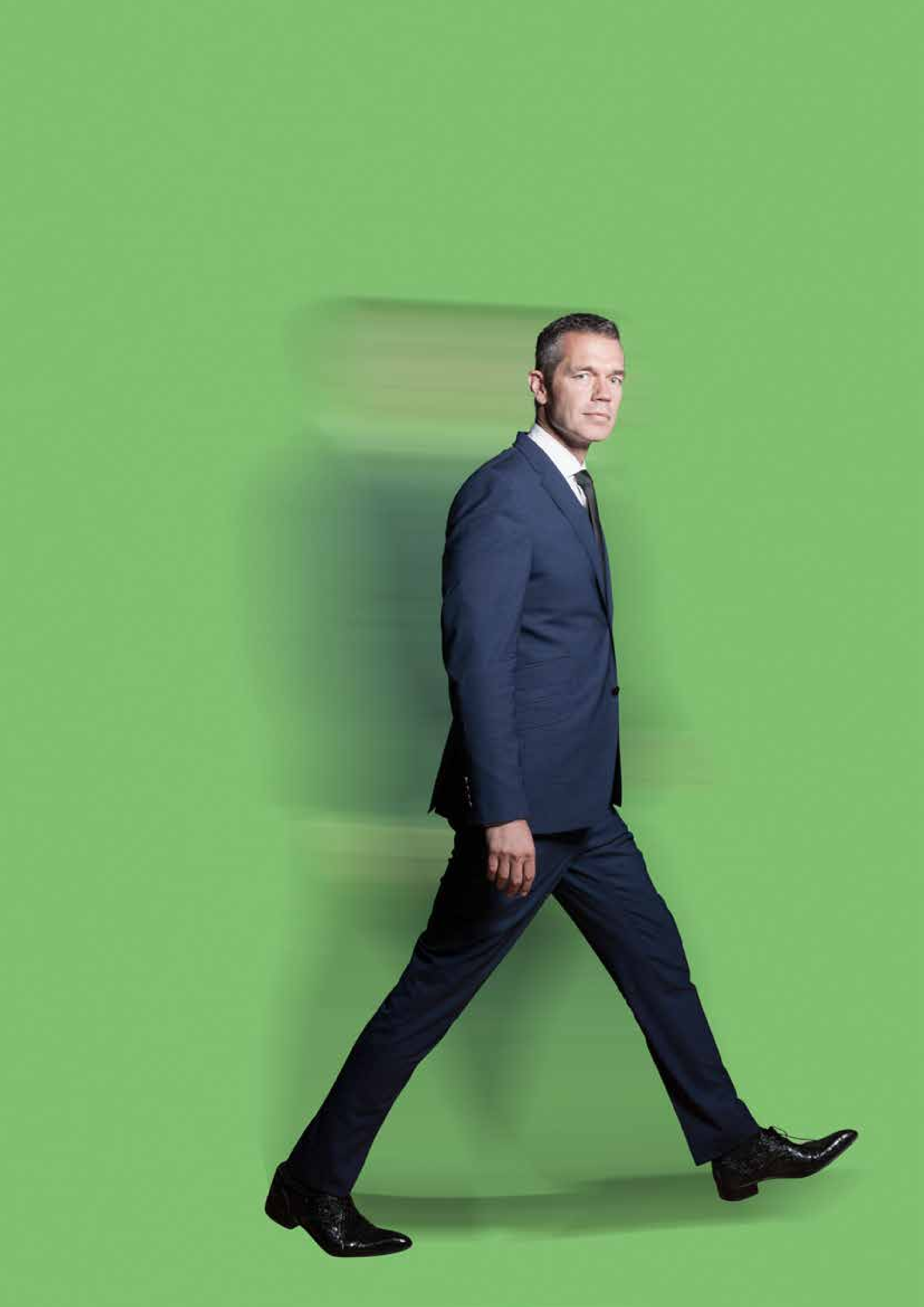
what this kind of diagram looks like in practice. Students also learn to work with measuring systems. In the lectures, they are mostly asked to work with clean sums that always come out right. In practice, some things you can know with great accuracy, others not. This is also something you have to develop a feeling for.

Bob Ross is a recurring feature in my lectures. He was a landscape painter who painted landscapes live on television in the 1970s. He didn’t use delicate paint brushes, but two-inch brushes and putty knives. He would just stand there and throw paint against the canvas, but the end result was always a very detailed landscape, with mountain tops, pine trees and babbling brooks. He did this in a very soothing, almost therapeutic way. So relaxed, and with such a calm voice. This is the kind of experience students have in a lecture. They are sitting in a nice warm room, with a cup of coffee, and there is a man there talking to them about equations. You can see them thinking: ‘Hhmmm, angle of attack divided by V squared... Yes, that seems about right.’ But the problem with Bob Ross is that if you feel inspired and you go to the shop and buy some paint, you will quickly find out that you are probably quite unable to reproduce his performance at your first try. This is my wake-up call: that they have to get hands-on experience with this material themselves.

I also understand that students will not always have prepared all the chapters before they come to the lectures. My course falls in a busy period in the curriculum. This is something that we’ve tried to change, but it remains a busy time, with other courses with strict deadlines. And it’s not as if you can just read this stuff once and understand it. So I have to drag them through the material and show them how to plan their approach, where they should start to solve these problems. The risk is that they will start thinking: ‘Oh, well, he will explain it all.’ So there is always this tension.

To the great disappointment of educational innovators, I am a dinosaur who stands in front of a blackboard with a piece of chalk in my hand. The advantage of this is that students tend to think: ‘He will erase it in a minute’ or ‘If I don’t show up I will never find out what he said.’ In a way this is the original form of motivational education. If you solve the equation yourself, it works much better than if you just show students a slide. I also make mistakes sometimes, and that keeps them on their toes. At the end of the day, I am covered in chalk; I have turned into one of those dusty teachers that I never wanted to become. Of course it’s very useful that everything is online and I don’t have to hand out things or send emails around. Some of the lectures have also been recorded and are online, a resource that I am very grateful for. But not everything that is new is automatically better. Of course those overhead sheets we used to use have made way for PowerPoint. It’s great as long as you use it to support your narrative, and not as a crutch.

I also always bring planes to class. I have one of those nice big Playmobil planes, even though my two-year-old daughter doesn’t like me borrowing it. In the context of visual education, that plane works ten times better than trying to draw things. Students are also allowed to bring their own model plane along to the exam. Some of them bring beautiful models, others just use a set square/protractor with a pen attached. This course is chock-full of coefficients that have to be positive or negative. There are probably some people who can learn this stuff by heart. But once you can figure it out with your little model plane, then you really understand it and you will never get it wrong again. We know that they know how to do these calculations. But it’s all about understanding what you do and what it means.



Serge Hoogendoorn

Slow traffic needs knowledge fast

Professor Serge Hoogendoorn is Professor of Traffic Management at the Faculty of Civil Engineering and Geosciences (CEG). In 2015 he received an ERC Advanced Grant for five-year research into traffic theory for pedestrians and cyclists. 'Pedestrian and cyclist traffic is becoming ever more important in our cities. In Amsterdam it is already the most important mode of transport,' according to Hoogendoorn.

As a 17-year-old, I thought of studying science, as I was good at maths and physics. It was either that or visual arts. The academy of arts attracted me immensely, but in the end I decided that studying something with better financial prospects was the wiser option. After a visit to the TU Delft open days my choice was easy: applied mathematics.

It suited me very well. I was most fascinated by the subjects that had more of an applied character. I found the system theory subjects truly inspirational. There you learned how to measure systems, capture them in mathematical terms, and then analyse and optimise them. I found that both an inspiration and a challenge. I chose my graduation subject after a course in optimum control of distributed parameter systems. After three lectures I had completely lost track of the subject and I couldn't stand that. Following my graduation I was supposed to enter mandatory military service, but shortly before that, my graduation professor phoned: would I be interested in a PhD on modelling and optimising traffic streams? I was never conscripted in the end.

My field of research concerns the observing, understanding and modelling of traffic flows in networks. The aim is to use the resulting knowledge and models to improve the design, planning and flow of traffic. Improving the flow of traffic can be done in many ways, for example with assisted driving systems or by influencing traffic with the help of traffic lights or ramp metering systems. My main interest are the control mechanisms that allow you to optimise this. For example, I would like to understand the best way to divide the flow of traffic in a network in order to minimalise congestion. I don't think the essential question here is whether you do that with the help of variable messaging signs along the road or with systems in the car, but I've noticed that this discussion of in-car vs. roadside is getting a lot of attention.

What we do is fundamental research from an applied perspective. This usually begins with the gathering of data, from practice or sometimes through driving simulators or questionnaires. These data provide insights into the behaviour of road users and these insights in turn lead to new theory and mathematical models. During my NWO-Vidi research project, we registered the driving behaviour of motorists on motorways from a helicopter. A thorough analysis of the data showed us how to capture this in accurate models. The models can then be used to predict for example what will happen if the share of lorry traffic increases by twenty percent or if we lower or increase the maximum driving speeds. Next, you can think of ways to optimise the traffic system. You can do this with simple scenarios such as an overtaking prohibition or an extra traffic lane, or with elegant mathematical optimisation techniques.

You want to test such optimisations in practice of course. The Praktijkproef Amsterdam ('Amsterdam Practical Trial') is a good example. It is the first large-scale pilot with coordinated network traffic management in the world. Commissioned by Rijkswaterstaat, we are collaborating in this project with the Ministry of Infrastructure and the Environment, the municipality of Amsterdam, Province of Noord-Holland, City Region of Amsterdam, and various companies. The aim is to improve the traffic situation in and around Amsterdam. This can be achieved by attuning the available measures such as traffic ways and ramp metering as best you can. Done sensibly, it will achieve a definite improvement in the flow of traffic in the network.

The trial does not only help decrease traffic jams, but also provides us with

Crossing borders

Professor Serge Hoogendoorn and his team are not only crossing disciplinary borders in their research, but actual ones as well. 'In Melbourne we are currently setting up a similar practical trial to the one in Amsterdam,' says Hoogendoorn. 'I'm doing this together with Professor Hai Le Vu of the Swinburne University of Technology in Melbourne, where I am an honorary professor. The issues are different in Melbourne, so I expect to learn a lot. Central to the problem is that the motorway network is not finished: the motorway becomes an urban connection road and then becomes a motorway again. This leads to problems, as traffic has no easy access to the city. We are now in the process of adapting our methods of measuring and controlling to this situation. This is bound to be quite a challenge, because local traffic data are of a lesser quality than in the Netherlands.'

many new insights. It turns out that some of the accepted ideas on the control of traffic are not as important as previously thought. For example, predicting the exact moment a traffic jam will arise is not only impossible, but it is not really necessary here either. It is better to react effectively than to anticipate wrongly. The exact location and length of tailbacks are much more important for coordinated network traffic management, and so is information about the routes that motorists choose. In this practical case, the question is how we can get a clearer view of actual and expected traffic situations. Possibly so-called floating car data, i.e. information from navigation systems and smartphones in cars, can help here.

My ERC Grant means recognition for the quality of our work, and the funds enable us to perform more exciting and pioneering new research. I believe that slow traffic as a research subject will only gain importance over the coming years. Not just from a scientific standpoint, but also because walking and cycling are more often the preferred modes of transport in overcrowded cities. This is already the case in Amsterdam, and it has clear advantages for accessibility, liveability and health. Hence, we should take care that cycling and walking in the city remains attractive. Bicycle traffic jams are a hot topic, and problems with bicycle parking near train stations are regularly on the news, but the interaction of bicycles and pedestrians with other modes of transportation can also lead to problems with safety and traffic flow. Not just right now, but also in the future when self-driving cars will be making their entrance. We need more knowledge to cope with these problems and to come up with smart solutions for them.

Since the late 1990s we have been successfully pioneering the monitoring and control of pedestrian crowds. We have become one of the most important research groups in the field of pedestrian flow theory and management. In traffic engineering however, car traffic is still receiving more attention than pedestrian traffic, let alone cycle traffic. That has probably to do with the impact of cars and car traffic (and traffic jams) on people and society. I think of things like the economic cost of congestion and the frustration caused by it, or the freedom cars seem to offer people and the social status they derive from their cars. In view of the continuing urbanisation it is necessary to shift focus to urban mobility, including motor traffic and public transport, but also including pedestrians and cyclists. This will certainly be my focal point in the coming years.

A car is not always the most attractive mode of transport anyway: in many busy cities it is easier and cheaper to travel from A to B on foot or by bicycle. Moreover, as our cities, including our train stations and other public spaces, are becoming progressively busier, the available space for cyclists and

‘We have become one of the most important research groups in the field of pedestrian flow theory and management’

pedestrians is getting scarcer too. The call to improve the use of our public spaces is getting louder; this to ensure continuing safety, accessibility and comfort. Thus cycling and walking are getting more and more attention. The car as a holy cow might lose some of its sanctity in the coming years. Owning a car may not be as important to the younger generation as it was twenty years ago.

We are ultimately concerned with the scientific challenge. This field of research is still in its infancy, as it were. There is a distinct lack of mathematical models and theory describing cyclists’ behaviour. We have taken good first steps in the past for pedestrian flows and crowds, but here too we are still far away from a generally accepted theory. It is not that surprising. On the one hand it is simply difficult, as it involves the behaviour of many individuals each with their own motivation, who – often subconsciously – communicate with each other, interact and move in all directions. On the other hand there are so few data available. Data are now becoming available in dribs and drabs, allowing us to develop methods for modelling the behaviour of cyclists and pedestrians. The ERC grant is a great opportunity to be at the forefront of this development.

We do not work in a vacuum. Mobility is a multidisciplinary field by definition. We have been collaborating with scientists from various domains for many years. My Vici project, for example, was aimed at modelling and managing traffic and transport under unusual circumstances and in disaster scenarios. The research team comprised psychologists, civil engineers, mathematicians, modelling experts and information scientists. This collaboration allowed us to make real progress, not only in understanding human behaviour in extreme situations, but also in formalising that knowledge into mathematical models. Behaviour is important, of course. Traffic jams or pedestrian flows along a busy shopping street; it is the eventual result of human behaviour. Human behaviour at different levels at that, from the split-second decision of braking for a pedestrian crossing the street, to the long-term decision you take when you consider cycling to work tomorrow instead of going by car.

This multidisciplinary collaboration can also be seen in the Amsterdam Institute for Advanced Metropolitan Solutions (AMS). As Principal Investigator I try, together with my AMS colleagues, to combine the urban mobility research with problems or solutions in other fields whenever possible. We view the city as a Living Lab, so we intend to test out things, allowing us to learn by doing, rather than trying to figure things out sitting behind our desks. We really need such a lab to develop robust solutions for an unruly reality. AMS is also important for the ERC research project. Our close relationship with the municipality and other partners enable us to gather data and conduct experiments in the city. This can involve a large project like the setting up of the Urban Mobility Lab, but also a smaller initiative like equipping AMS employees’ bicycles with GPS. Moreover, AMS is a group of very enthusiastic and driven people who I really enjoy working with.

For larger projects such as the Amsterdam Practical Trial it is vital to collaborate with businesses and governments. Working closely together with a company like INCONTROL Software Solutions also provides you with insight into what problems are encountered in practice and hence what is really needed. I often see scientists making assumptions about what is needed in practice without really getting in touch with people out there. That gap is too wide, and I honestly feel that this is not acceptable in a field like ours. It is for this reason that my group undertakes a lot of applied research in addition to fundamental research, and we are all engaged in disseminating knowledge to the professional sector. Besides, our intensive collaboration with businesses and governments also makes it easier for our students to find an external graduation project or an exciting internship.

Sky high

In October 2015, the Delft Aerospace Rocket Engineering (DARE) student association set a new European record when their Stratos II+ rocket reached an altitude of 21.5 kilometres. Winning team members Christ Akkermans, Rob Hermsen and Jeroen Wink know all about the long road to an altitude record.

A huge pan of paella, a campfire, lots of sangria and no curfew: the Stratos team chose a fitting approach to celebrating their European record on a Spanish beach. The moment had been preceded by years of hard work. Christ Akkermans, Rob Hermsen and Jeroen Wink took over from the team that launched the Stratos I in 2009, which reached an altitude of 12.3 kilometres and set the European record for amateur rocketry at the time.
'Following the success of Stratos I we wanted to go higher. The ultimate goal is to reach outer space; that is, not within orbit of the earth but 100 kilometres high, beyond the atmosphere,' Christ Akkermans says. Fifty kilometres was set – arbitrarily – as an intermediate goal. 'In order to do that, we had to switch to either a much more powerful fuel or a different type of engine. It was still very much an open question.'
Jeroen Wink was on the team tasked with answering that question: 'They used a solid propellant for Stratos I. Basically, it's a kind of flare with the fuel and the oxidiser in a package. It's not very efficient.' Consequently, a hybrid engine with solid fuel and a liquid oxidiser was chosen in the end. 'It was a safety issue more than anything else,' Rob Hermsen explains. 'You can make the solid propellant more powerful, but that means switching to highly explosive and toxic substances; we didn't want that.'
A different kind of technology, in other words, with all of the inherent bugs. 'We started out on a very modest scale, and the first prototype we tested was one giant leak. You learn from your mistakes,' Wink says. 'In the beginning, the engines had only ten to fifty kilos of propulsion; we could test that on campus. After a couple of years we were able to scale up to 1,000 kilos. Suddenly there was so much involved.' To clarify: you can lift a car with 1,000 kilos of propulsion. For safety reasons it was no longer possible to conduct the tests on campus, but after some searching TNO Rijswijk made its research facilities available. 'Strict safety regulations applied. We had to provide a lot of information in terms of risk analysis. This forced us not only to critically review and improve our design but also to think about overseeing people.'
'We had to explain all kinds of procedures, too,' Hermsen adds, 'such as the order in which you have to connect everything in order to be able to safely fill the rocket with fuel.' The fuel itself also posed a logistical challenge. 'It used to involve a couple of small gas cylinders; now we needed a lot more, and not just in Delft, but later in Spain, too. Every day something came up that no one had any prior experience in dealing with.' That was in 2013; the first launch took place in 2014 in Spain, on a launching site near Huelva.
'A first launch attempt never goes off without a hitch, even though we hoped it would, of course,' Wink says. 'We still had a lot to learn about operations. Although we had it sorted out for the static tests, much more is involved in a launch.'
The Flight Termination System, for example, is an essential component. 'That's the system you can use from the site to terminate the flight because the rocket would otherwise land in the wrong place,' Akkermans explains. 'It shuts down the engine, and you can also activate the parachute to slow it down. We still had to design the FTS.'
Wink adds: 'There will be a designated area in the sea for it to land safely. The rocket is tracked using radar and you are continuously calculating where it will land when you switch off the engine. If it's too close to the edge of the safe area, you have to terminate.' In other words, the system must communicate not only with the other systems in the rocket, but also with the launching site. 'It was very difficult to design a system that runs really fast and simultaneously must be able to receive radio signals. We spent months racking our brains. Fortunately, the Space Exploration department helped out with the calculation of the rocket trajectories,' Akkermans says.
The FTS could not be tested until the actual launch. Various shortcomings were revealed. 'In reality, we tried to launch a prototype. All of the systems had been designed separately and put together later. There was still considerable room for improvement,' Wink says. The launch failed, but the experience gained was crucial. 'We decided afterwards to try again; after all, we had come very close.'
Back to the drawing board. A month's worth of analyses produced a list of fifteen items for improvement related


3M
AIRBUS
DARE
TUDelft

Who are they?

Christ Akkermans is pursuing a Master's degree at the Faculty of Aerospace Engineering (AE). He has been involved with DARE for four years now and has been responsible for the sponsoring and PR from 2014 onward. His final project involves his work on the rocket engine igniter using liquid oxygen and liquid methane for the Stratos project.
Rob Hermsen is also an AE Master's student. He was the Stratos II team leader. After an internship with Airbus he returned to Stratos II+, where his experience was gratefully applied. He, too, is in the final project phase, which in his case involves the rocket engine's mains system using liquid oxygen and liquid methane, i.e. the cryogenic propellant feed system.
Jeroen Wink is a fellow AE Master's student and has been a member of DARE for four years. He started by designing the hybrid propellant for Stratos II and took over from Hermsen as team leader. His final project likewise involves the rocket engine, specifically the liquid injection and the corresponding combustion stability.

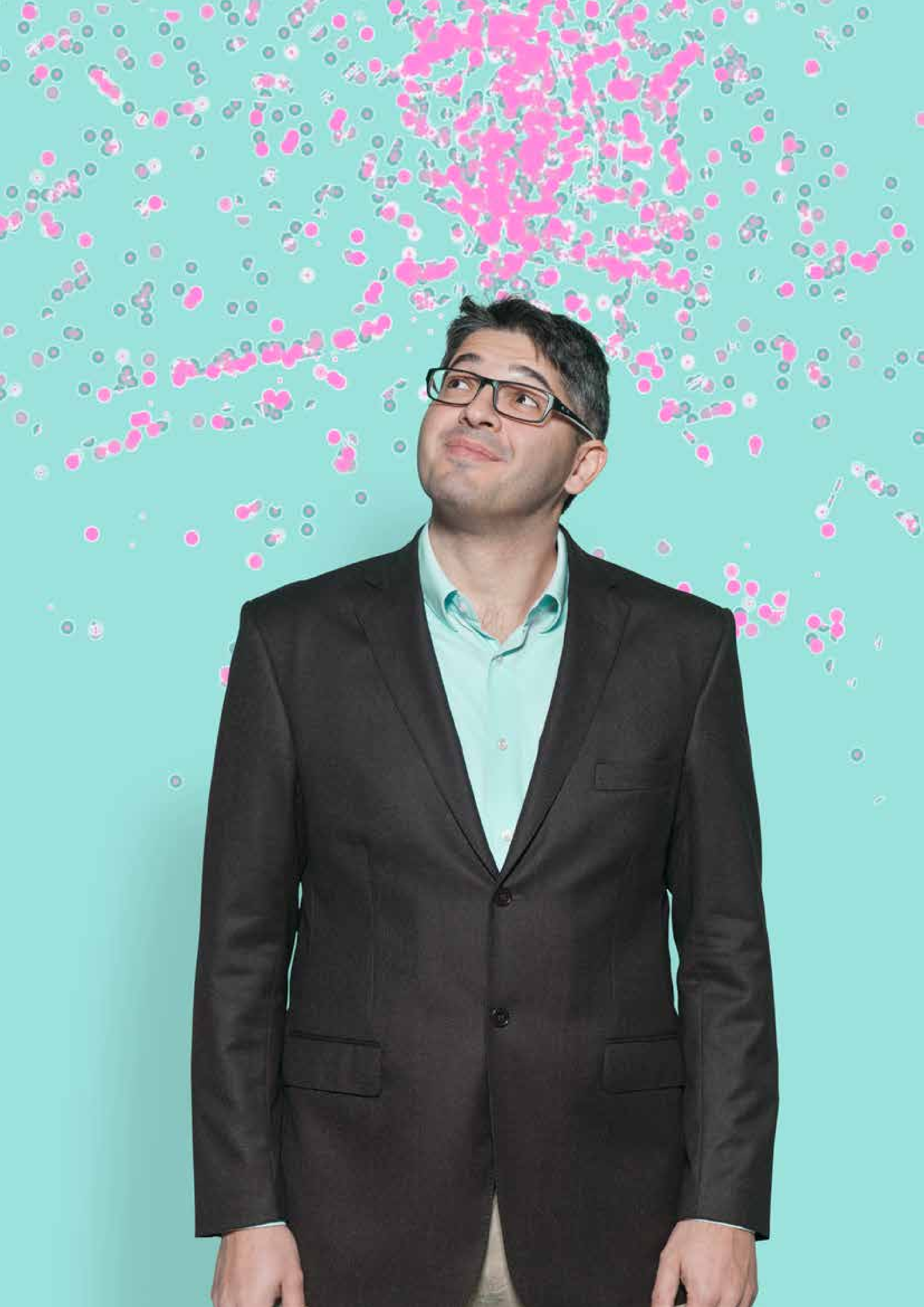
to the technical systems, logistics and operations and project management. Hermsen: 'We ended up calling the new and improved version Stratos II+ because even though the basic design was the same, it was still a new rocket for the most part.'
The Stratos II+ was sent to the south of Spain this autumn for a new launch attempt, and the team boarded an aeroplane. Aside from some delayed luggage carrying last-minute parts, everything seemed to be going smoothly. Until the first launch day. 'It takes you almost an entire day before you can press the button,' Hermsen says. 'And when it was time, a bunch of smoke came out and that was it.' For a moment the team was gripped by doubt, and wondered whether the project was in fact too ambitious for a group of students after all. There was not much time for contemplation, however. The weather forecasts were not looking good, and the safe zone could only be closed for a limited number of days. 'We had a margin of no more than a couple of days. In a rush, we took the rocket out of the tower and immediately started trying to figure out what was going on. Luckily, it was clear within two hours, and after another couple of hours we had a solution.' The problem turned out to be a fuel line issue that fortunately was easy to resolve.
The new launch attempt took place on Friday 16 October, at 16.30. 'When you see it start up, you think 'yes!' but the engine has to run for 23 seconds, which is also the window for the FTS system,' Akkermans says. Wink adds: 'In the tower, you have one second to cheer, but then you have to be quiet, because you have to determine whether you will keep flying, or terminate. After 23 seconds the engine switches off, and you can no longer do anything.' Hermsen: 'The flight lasts a total of eight minutes, compared to five years of work. And the suspense doesn't end there, either. How high will it reach, will the parachute work, how will it land, will it be recovered?' Fortunately, they were able to follow the safe landing through the camera feed, and a half hour later they heard from the tower that the capsule had been recovered. Not to mention the important news that the record-setting attempt had been successful. But their work was not over yet. 'Around seven, the capsule arrived back at the launching site and we opened it straightaway,' Hermsen says. All of the data and video footage had to be removed and backups had to be made. 'We put everything online as quickly as possible, including camera images from the site. It's a lot of follow-up work, but the stress is gone by then and you're on a euphoric high.'
The data revealed that the engine and all of the other systems had worked practically perfectly. Then why did the rocket fail to reach fifty kilometres? 'That's a complicated story,' Wink says. 'Maybe we were too heavy because we used a little too much oxidiser, due to a defective sensor. You come out of the tower a tad slower and you're less stable, which makes you turn against the wind more. As a result you fly flatter and remain longer in the dense atmosphere, where

'The aerospace sector also wants to cut costs, and as students we're bound to a low budget. That compels us to think creatively in order to make effective use of means, time and hardware'

there's more resistance.' Hermsen: 'If you compare those 21.5 kilometres with the 50 kilometres, it seems like you only made it forty per cent of the way, but in terms of energy we fell short only by ten or fifteen per cent. Altitude isn't a good gauge, actually.' Of course, that means that they might have to relinquish the record in the future. 'There are more and more universities that think it's cool,' Wink says.
What's so 'cool' about building rockets? 'I always loved aeroplanes and everything that went really fast, which makes aerospace an obvious choice,' Akkermans says. Rockets in particular hold a special fascination for most of the members. That is basically a given, considering the time commitment, which is compensated with few if any study credits. Still, you can get a lot out of it as a student. 'You certainly become a better engineer from the practical experience you gain here.' It can help your career, but it is not the only reason why aerospace companies follow the DARE students with interest. 'You see commercialisation in aerospace, too. The dynamic in those companies is changing, and the requirements for technology and personnel are changing along with it,' Wink says. 'The aerospace sector also wants to cut costs, and as students we're bound to a low budget. That compels us to think creatively in order to make effective use of means, time and hardware.'
One of those creative ideas was to use fuel made from harmless sorbitol, paraffin and aluminium powder. Stratos II+ earned the nickname 'the sweetener rocket' in the media on account of the sorbitol. Whether Stratos III will make it to space on sweetener and candle wax remains to be seen. 'Stratos II is finished; now we're looking at how we can reach outer space in all sorts of projects. How it will come together in the future is no longer up to us,' Hermsen concludes. They can steer their successors in the right direction, however. Akkermans: 'One of the problems is that the rocket turns to the wind too much, and remains too long in the dense atmosphere. A way to combat that would be to actively stabilise the rocket using flexible fins; that way, the wind isn't a problem. It's yet another open question.' Who will accept the challenge?

Aerospace test platform

DARE has been an independent association from 2005 onward. 'As a student association we set our own goals. Neither TU Delft nor any company tells us what to do,' Rob Hermsen says. At the same time, the association enjoys close ties with the faculty. 'Lecturers help us with knowledge and advice and contacts with companies.' The relationship is becoming increasingly reciprocal. 'We have extensive experience with certain hardware and operational systems. More and more, we're being consulted on laboratory courses or experiments in teaching,' Jeroen Wink says. 'This cross-pollination works really well.' Christ Akkermans: 'The interaction is also evident by all of the people who do their final projects with us. We've long since proven that we are more than a hobby club.' DARE's activities are increasingly becoming an aerospace test platform both at TU Delft and beyond. 'Stratos II+ carried a payload from Radboud University for a radio astronomy experiment. You can gain experience with us in a cost-effective way,' Wink says.



Alessandro Bozzon

Data science with a twist

Dr Alessandro Bozzon is an assistant professor at the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS) and an expert on social data science. He is in charge of the Social Glass Project, which aims to achieve a better understanding of urban environments with the help of social media.

Internet and the web have revolutionized the way we create and access information. The web now hosts huge amount of data covering all aspects of human activity. However, being created by people, data are often influenced by their creator's views and biases. 'To make better computer systems that are personalized and inclusive, we need to understand more about the relationship between people and the data they produce. To achieve this at scale, often means moving out of our comfort zone as computer scientists,' says Dr Alessandro Bozzon. 'My vision is of a new generation of web data management systems that combine the cognitive and reasoning abilities of individuals and crowds, with the computational powers of machines, and the value of big amounts of heterogeneous web data'.

Existing theories about how people interact with the world can help. Personality psychology, for example, but carried out with computational methods. 'How to ascertain the personality traits of individuals without having to ask subjects to sit through hours of questionnaires? If we can automate that process at scale, with comparable results and accuracy, we can create systems that are able to adapt to your personality based on your behaviour and on the data you produce, and thus make your experience with them more fulfilling and engaging.'

One way to do this is to look at writing style. For instance, American psychologist James Pennebaker has shown that everyday language can reflect personality traits. Simply put, the frequency with which you use certain words can say something about your gender, your age or whether you are confident or insecure, for example. 'This is not as straightforward as counting words,' explains Bozzon. 'We know that people behave differently in different environments, and this reflects in the way they produce data,' he says. 'People have an official persona and an informal one. You have to take this systematic bias into account, especially in domain-specific settings. We are after robust and reliable methods to understand the properties of web data and of the people creating them, and to apply that understanding to create better systems.' Bozzon's work is currently applied in three societal and industrial domains: the urban environment, cultural institutions and the enterprise. He is involved in exciting projects in all three of them.

Social Glass

The Social Glass project looks at the urban fabric through the lens of social media. Every day, people generate huge amounts of data on social media about life in the city. By tapping into that source of information, it is possible to identify and study both incidents and structural problems, such as demographic pressure and tourism trends. Through social media, citizens can take an active part in improving life in the city, and ultimately their own well-being. 'With Social Glass we want to help making the city more liveable, and we are creating computer science tools for that purpose,' says Bozzon. The Social Glass approach goes beyond the way social media are currently being used by municipalities. 'Twitter is now used widely for interaction with the public, but we are not exploiting the full value of social data yet.'

Last summer, Social Glass experiments were carried out during the Sail Event in Amsterdam, where Amsterdam was the temporary centre of the nautical world, attracting 2.3 million visitors over five days. 'The Sail experiment was all about crowd management,' says Bozzon. 'In cooperation with the research group lead by Professor Serge Hoogendoorn, we monitored flows of people with the help of different techniques, such as cameras, sensors, as well as human sensors on social media. The project showed the added value of social web data, which can help complementing cold and dry numbers with explanations. Why do cameras detect a long queue forming in a certain area? Is it just because an event is popular, or is there something else going on?' In such a case, more information is needed. 'You want that information as fast as possible and as accurate as possible. We are now testing this at event scale, but we are working towards solutions at city scale.'

Some 60,000 Twitter and Instagram users were engaged online by the Sail event, producing a total of 226,000 posts. 'To help interpreting the event, we looked for user activities that gave an idea of how crowded people thought it was, looking for instance for words like

About Alessandro Bozzon

Dr Alessandro Bozzon studied Computer Science & Engineering at the Politecnico di Milano, where he also obtained a doctorate in Information Engineering in 2009. He joined the TU Delft in 2012, where he is a member of the web Information Systems group at the EEMCS Faculty. He is part of the Delft Data Science Initiative, an investigator at the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), and a Faculty Fellow with the IBM Benelux Centre of Advanced Studies.

'My background is in database and information retrieval, topics that I teach in Delft,' says Dr Alessandro Bozzon. 'I provide the next generation of engineers with the knowledge required to process and valorise large amount of data at scale.'

His research is centred on social data science. 'That is data science with a twist, the twist being that we acknowledge the central role that people have in their relationship with data.' Bozzon studies data-driven user modeling and engagement methods to create inclusive systems that improve the well-being of people. 'By understanding you and your goals, we can create systems that adapt to you, thus giving you a fulfilling and engaging experience.'

"full" or "busy".' Bozzon then applied user modelling techniques to determine if users were residents or visitors. 'In this way we could tell more about the difference in perception of crowdedness between residents and non-residents.' As it turned out, residents were less vocal. 'Perhaps tourists are not used to the big city, whereas resident experience such an event as a novelty, something outside normality.'

User modelling is essential to give meaning to web data. 'The city belongs to the people, so understanding who they are, how they live, and their cultural background gives you the key to interpretation. For example, if you are looking at Twitter, you have to know who actually is on Twitter. If that turns out to be mostly men in their forties, you still have go to Instagram to get the opinion of teenagers, for example.' That still leaves other groups unaccounted for too. 'You have to find ways to gather data that are inclusive. Not just observing data, but making sure you include the population that is of interest to your purpose. We call this process social sensing, an important part of the Social Glass project.'

Using social data also has the advantage of getting information fast. 'Nowadays municipalities still send out questionnaires to citizens, or compile a report on tourism once a year. By that time things have changed again. We want to shorten the time between the need for information and its actual availability.'

There are now plans to apply the Social Glass method to larger areas and bigger events, such as the Gay Pride or King's day in Amsterdam. Bozzon is thinking even bigger. By next year he hopes to be working not on an event basis but continually, with the help of tools for the study of long-term dynamics and trends, possibly across cities. 'What I envision is an open repository, a kind of urban knowledge collider, where the needs of all stakeholders in cities are incorporated and all knowledge is made accessible, so that everyone can make use of it.'

Rijksmuseum

Cultural institutions are increasingly aware of the intrinsic value of their collections, which goes beyond the objects to include their usage. 'If collections are accessible and well-described, many more people can make use of them than museum visitors alone. So how do you do that at scale?,' wonders Bozzon. This question arose at The Rijksmuseum when it started digitising its print collection. It is one of the largest collections in the world, comprising over 700,000 prints. It was estimated that it would take professional annotators more than 20 years to go through the entire collection. 'Indeed, the Rijksmuseum will still be here in 20 years' time, but how can we speed up the process while guaranteeing annotation quality?' Moreover, the required knowledge is not always available at the museum. Art experts are not usually botanists or ornithologists as well. 'What we

‘Anyone can recognise a rose,’ but you still need an expert in botany to name the exact species’

need are tools for the acceleration of knowledge creation. How can we employ the cognitive ability of people to create knowledge in a systematic and reliable way?’ Human computation and crowdsourcing are key here. Bozzon explains: ‘It is extremely difficult for a machine to recognise a species of birds in a photograph; in a drawing it is almost impossible, because of style and interpretation, for instance.‘

The Accurator platform has been developed, to help the Rijksmuseum – and other museums later on – with annotating its collection. The platform is also used for research into so-called niche sourcing: the identification of those with specialist knowledge within a crowd. ‘Anyone can recognise a rose,’ says Bozzon, ‘but you still need an expert in botany to name the exact species.’ Once you have identified these experts, you also want them to stay involved until the project is finished. ‘Here we come back to personality. People are driven by different motives. That can be money, but also passion or your status within the group. If you are part of a community of passionate amateurs, perhaps the best way to keep you engaged is by having your contribution recognised by other members of your community.’

Inclusive Enterprise

In 2014, IBM and TU Delft joined forces in a Collaborative Innovation Center (CIC) on Big Data Science. ‘We are collaborating on several research projects; one of them is the inclusive enterprise. We want to use social data to increase the well-being and engagement of workers,’ says Bozzon. Naturally, companies want to avoid employees stagnating through lack of motivation. ‘Demotivation is often due to a lack of communication. The bigger the organisation, the harder it is for information to percolate through the organisation. You hardly know anything about your colleagues in the next office, your manager knows little about you, and his manager nothing at all.’ So how can data science help here? ‘You can find a lot of useful information about employees and their expertise within the data they produce. About existing networks, regardless of organisational structure, about how they reach out to the world. You can use this information to make people feel appreciated and valued, for example by engaging them in projects they are passionate about.’

Understandably, not all employees are eager to share too much with their employer. ‘That is where we, as computer and data scientists, can come in and make sure that all the safeguards with regards to data protection within the enterprise are met.’ At IBM, Bozzon and his colleagues can study the inclusive enterprise concept at scale, potentially involving the whole population of 400,000 IBM employees. ‘That is quite a challenge. In addition to ‘traditional’ computer science problems, we need to devise engagement techniques that are inclusive, and safe. So participation should be voluntary, and information should only be shared selectively, when it is beneficial to the employee.’

In an exemplary project, it was studied how employees can best be engaged with a gamified learning experience, where they can learn more about the company, its technology and their colleagues. ‘Through rigorous scientific work, we have shown the suitability of this approach, and discovered how different personalities are attracted to different kinds of incentives. A common misunderstanding about gamification is that all you have to do is give people a badge at the end. It is not; it is about being adaptive and inclusive.’

Bozzon believes the inclusive enterprise is the way forward. ‘Newer generations give great importance to their relations with the company, feeling good about what they do, and about the company’s understanding of their potential and strengths. They care about personal growth and influence. This new perspective brings novel challenges, and excellent opportunities for great research with societal impact.’

Hands-on manufacturing

The Model Making and Machine Lab (PMB) is vital for Industrial Design students. Manager Don van Eeden and colleague Roel Franken of the PMB see countless students come and go each year. They help create a link between the design as it is on paper or a computer screen and the actual reality of the manufacturing process. 'You can't learn everything from a computer screen.'

The Model Making and Machine Lab (PMB) is at the very least what you would call a noisy place. With sounds of machines and hammering echoing across the huge workshop, you know people are at work here. A tour of the equipment shows that the PMB is fully equipped with everything from a simple handsaw to the most up to date 3D printers, laser cutters and computer operated band milling and foam machines. Don van Eeden has been in charge here since 2013. He started 25 years ago at what was then the Central Workshop. 'There was a rental pool and one day I was assigned to Industrial Design; I just never left,' he explains. That was in 1997. Colleague and co-educator, Roel Franken joined the PMB nine years ago. 'I was studying mechatronics and ended up here via the school's intern agency. It was a mutual success.' Along with their colleagues, Van Eeden and Franken support the lab teaching, for example making prototypes and models. 'We also give instruction on specific machines so that students can operate these themselves.'

Scary

'The workshop can be a bit of scary place for students at first,' says Van Eeden. 'They are used to being able to just pick up a book and get everything they need from that,' adds Franken. 'But here, they have to ask all kinds of questions about things that they can't find out about any other way. Of course it is a big step for them to show us what they have thought up, because then we start to shoot it down.' 'We have to,' says Van Eeden: 'We have to find out exactly what it is they want a design to do and whether or not it is feasible, so we need to discuss it in-depth.' Students can also sometimes be very wary about showing their ideas because they might want to win a competition, or might want to start their own company. It's not really anything for them to worry about. 'We have a duty of confidentiality; we can't just chat at a party about all the things we're involved with at work,' explains Franken.
Safety is of course a high priority in the workshop. Everyone has to wear dust-coats, steel-toe shoes and safety goggles in the workshop.' 'It's the shoes in particular that the students try to get out of wearing; they say they're not working with heavy stuff.' "No, but the person next to you is", is what we tell them,' says Franken. All of the machines also have instruction sheets and staff monitoring the work. Healthy & Safety officers also visit regularly. 'For them this kind of workshop is fascinating,' explains Van Eeden. 'We know by now how things should be done, so any recommendations for improvement are generally just to do with small details. But they do come and have a look at any new equipment.' And not just to check out if it's safe for students. 'Recently we got a new 3D printer that uses a plastic powder. That stuff gives a lot of dust, so we were keen to know if it was safe to breathe it in,' explains Franken.

Safety instructions

Students are only allowed to work once they have been properly instructed. All first-year students are given a tour and safety instructions, after which they are allowed to use the band saw and sanding disk. If they want to use the mills and lathes, they have to undergo a half day of training first. They need it. 'They don't really known what the tools are, only that they need them,' says Franken. 'In their head, the piece is already finished, it just needs to be made,' adds Van Eeden. 'So you need to get right back to the core of the idea. For example, does it need to be mounted on something? Can we weld that or mount it mechanically? That sort of thing.'
Before they start work on their own things, students are familiarised with the lab. 'The course contains practical making assignments. For example, they might be assigned to make a rotating-symmetrical shape and work at the lathe or the 3D printer,' says Franken. Those are busy times, especially at the end of the semester. 'Sometimes there can be a week-long wait for the milling machine.' Luckily the timetable makers are pretty helpful. 'They try to stagger the submission dates, so that not everything has to be handed in at the same time. That's a huge help to us,' says Van Eeden. However, there


TUDelft

Lathes for dummies

The mills and lathes are the real workhorses at PMB. While lathes are used to make rotation-symmetrical shapes - like a cylinder or table leg - a mill can be used to make all kinds of shapes and profiles from the materials. With the lathes, the lathe equipment is still as the material moves around it; with a mill, the tool moves rather than the item. They are both what we call machining processes, in which the mass of an item decreases by a controlled material-removal process (subtractive manufacturing). This is contrary to, for example, a 3D printer, or processes like welding or casting, in which the mass increases, or techniques like cutting or slicing where the mass decreases without machining. These days, most of these machine tools are computer operated.

are times when not everyone gets a turn, especially if students don't sign up in time. 'Sometimes they quit, if they can't meet their deadline because of the waiting times. Then they they have to do things by hand, or they go to another faculty.' The workshops at the faculties of Architecture and the Built Environment and Mechanical Engineering, Maritime Technology and Materials Science are particularly popular for this. Conversely, the PMB also gets students from other faculties. 'We'd love to help everyone, but we do have to set priorities.'

Personal

Six years ago there was just one large workshop, but then it was split up. Along with four other colleagues, they now support the practical teaching at IDE. On the photo from left to right you see Don van Eeden, Carlo Buhrer Tavanier, Roland van der Velden, Roel Franken and Rene van de Schuur. Ismail Bozdag, who is not on the photo, mans the store, another unique facility in the faculty, according to Van Eeden. 'You can get individual nuts and bolts, or a small plate of material. It's like an old- fashioned hardware store.' They see the smaller, split-up organisation as an improvement. 'It's much more personal now and less huge. In the past, we'd get groups of forty students coming in; now we know them all by name.' They also see that graduates are often attracted to a particular instructor. 'They like having the same person to go to week after week. It's not strictly necessary, because we are all all-rounders here.'

Apart from prioritising students within the faculty, there is a further reason to keep an eye on who is in the workshop. 'For example, if there is a design competition in 3mE then they only have a limited number of hours to access the workshop. So if we were to give them more hours here, it wouldn't be fair to the rest,' says Franken. That also touches on another question that they deal with daily: to what degree should they help students, for example when it comes to their exam pieces? 'In principle they must do it themselves. In the first instance we assess how they put together a design and how feasible it is. Then we look at what the students are able to do themselves. So, if there is a lot of lathe work, they will first need a morning or afternoon learning how to use the lathe. This is the basis for learning how to operate the machine safely. Then the students progress by doing things themselves, trying them out or asking us.' The feasibility of a design is really important, but they mustn't be tempted to make too many changes. 'That can be a real pitfall. We have to be careful not

‘They are used to being able to just pick up a book and get everything they need from that but here, they have to ask all kinds of questions about things that they can’t find out about any other way’

to project our vision on to the student,’ says Van Eeden. ‘It’s not always bad when something goes wrong, it can be part of the learning process. But when it comes to final exam pieces, we do try to give them a hint sometimes. “Have you thought about this...” That sort of thing.’ What really plays a role is what stage the design is at. Van Eeden explains: ‘If we see that they are going to use it for something, then it’s important that it’s done right. You have to always give them safe margins to work within. You can’t let them make a chair that will collapse when someone sits on it, for example.’ One important insight for students is that they shouldn’t see their design as a whole. ‘It’s better to do things in stages and put them together once you know that everything works. Otherwise you often can’t go back and fix it. So you should first create the inside separately and see what happens before you build a casing around it.’

Hands-on

These are all important lessons that they can only learn in practice and that they can carry with them into the rest of their career. ‘Look, what they are doing here is real hands-on work. Most of them probably won’t get the chance to do this again. Even if they do go on to make their own products, then it will probably be done in a factory,’ says Franken. ‘So if they don’t get things quite right in the workshop, while it’s annoying now, the experience will stand them in good stead for the rest of their professional career. The faster they come up against practical issues here, the better they can deal with them.’ Van Eeden adds: ‘We see that they need it. You need to feel and experience what you have drawn. For example, they can print a handle here and it might turn out to be very thick. You can’t do everything from a computer screen.’ Over the course of the years, they’ve seen all kinds of projects pass by. ‘Wytze’s bike was made here,’ says Franken. That was the Lady Duchess, the bike that Wytze van Mansum designed in 2009 for Cannondale. ‘It was all over the news. He works in the bike world now. The basis for this was probably his final exam project, even though that never went into production.’ The famous Ambulance Drone by graduate Alec Momont also passed through the workshop. ‘The housing for it was turned on the CNC bank here.’ The DreamTeams, the student projects that score highly in international competitions, are also regular visitors to the PMB. ‘It’s mainly the new teams. The established teams can manage for themselves, often businesses are interested in helping them. But any time there’s a real panic, they show up.’

Every years they also get participants from the HEMA design competition; IDE students tend to do really well. ‘They often work with fabric and we have two sewing machines here. We can also make vacuum shapes in plastic sheets. We don’t just do coarse machining and welding,’ he jokes. And we get on really well with researchers. ‘They often have test pieces that need some changes and we can help with that,’ explains Franken. Van Eeden adds: ‘Conversely, we can also go to them when we are stuck with something and need measuring equipment.’ The best times are when someone graduates. ‘We are always invited and we always try to make sure that one of us is there. They often tell us, “I learned so much from you; I wish I’d known that earlier.”’

Jan Leen Kloosterman

Second chance for thorium

Jan Leen Kloosterman works with the Radiation Science and Technology department at the Reactor Institute Delft, part of the Faculty of Applied Sciences. He was appointed Professor of Nuclear Reactor Physics in April 2015. His speciality: molten salt reactors that use thorium as fuel. He is part of a major European research project that hopes to demonstrate that these reactors are inherently safe during the coming years. 'If we want to, we will be able to build a demonstration reactor in Europe in ten years' time,' says Kloosterman.

Professor Kloosterman has been conducting research on thorium nuclear reactors for ten years now. Why thorium? 'Existing reactors use uranium-235 because it is easy to split. However, this isotope occurs very rarely in nature,' he explains. 'Uranium-238 may be a suitable alternative, but this will require a new type of reactor. There is a concentrated international effort to develop such a reactor, but uranium usage always goes together with the production of long-lived nuclear waste, so we are talking about storage periods of ten to a hundred thousand years,' he continues. Thorium reactors work differently. As with all nuclear reactions, they produce fission products, but the waste from thorium only needs to be stored for a few hundred years. 'After three hundred years, the radiotoxicity will have decreased considerably, to about the same hazard level as uranium ore that occurs naturally in the ground,' says Kloosterman.

Combination advantage

The advantages are even greater if you use thorium in molten salt reactors (MSRs). 'These reactors convert even more thorium to uranium-233. This artificial isotope is highly fissile. All this uranium can be recycled in the reactor, whereby almost no plutonium is produced: only a thousandth to a one ten thousandth of what the current reactors produce.' Moreover, an MSR is much safer. The thorium is dissolved in a liquid salt, which simultaneously acts as a coolant. The nuclear reaction is brought to a standstill if there is a leak or if the cooling system fails. The reaction also takes place under normal atmospheric pressure (the disaster in Fukushima was caused by a combination of high pressure and a failure in the cooling system). 'It is this combination of two technologies that makes this reactor so special. If you apply them separately then the advantages are nowhere near as big,' says Kloosterman. The advantages are cleaner and safer nuclear energy from a cheap and widely available source. In fact, there is enough thorium on the planet for thousands of years. Thorium is a by-product of mining titanium and other special metals. 'Every year, enough thorium is produced to meet the entire world energy demand for forty years. We need to put this to good use.'

SAMOFAR

His enthusiasm is being picked up elsewhere in Europe. Kloosterman is coordinating project SAMOFAR (Safety Assessment of the Molten Salt Fast Reactor) on behalf of TU Delft. SAMOFAR has a total budget of €5 million, €3.5 million of which in the form of a grant from the European Horizon 2020 programme. A Swiss and a Mexican research institute are even participating at their own expense. 'They are happy to follow the EU rules, because the reward is new knowledge,' says Kloosterman. 'We will also be collaborating with China, Russia and the US. These countries are already conducting major projects into MSRs and we want to jointly take this technology a step further.'
All the partners are highly motivated. 'We came together three times even before we submitted our research proposal. Each partner has their own, clear role and the project objective has been sharply

Director of Education

Professor Jan Leen Kloosterman has been appointed Director of Education of the Faculty of Applied Sciences as of 1 January 2016. Before that he was Programme Director of the Sustainable Energy Technology (SET) Master's programme for six years. 'Three quarters of the SET students come from abroad, that makes for a special atmosphere. They are all highly committed; most had to earn a grant or take out a loan to get here. Nearly ten per cent of them will start their own company after they graduate, and another twenty to twenty-five per cent will continue on to a PhD.' Among others, Kloosterman gives an experimental lecture on problem solving. 'Students often have no problem with the theory, however actually solving a problem is another story. This requires the application of knowledge. During this lecture we teach them different ways to approach a problem. It starts with establishing the essence of the problem. You can do this by asking yourself questions, but you can also try visualising the problem with a drawing. The sooner the students master this technique, the more they will be able to gain from the rest of their studies.'

'There will always be a demand for sources of power that you can turn on and off and the MSR will be perfect for absorbing demand spikes and dips'

defined. Apparently, this impressed the assessment committee.' The objective is to demonstrate that the concept of an MSR with thorium is inherently safe. 'We are considering everything that could possible go wrong with the concept, things that people take for granted as safe. We want to demonstrate convincingly with experiments that the safety mechanisms actually work in practice.'

1960s

Some knowledge is already available on the safety of this system; during the 1960s, a demonstration reactor operated for a five-year period in the US. 'All the knowledge gained back then can be found in reports and in the heads of some of the researchers who are still around, so we don't have to do everything over,' says Kloosterman. But there is still new research required, for example on the materials for the plant. The reactor pressure vessel (RPV) used in the 1960s experiment was made of Hastelloy N, a special steel alloy. 'We know that this material can resist corrosive fluoride salt for five years, however our reactors will need to last for fifty years. This is why we need to find new materials or demonstrate that the materials used back then will last fifty years.' This research will start in 2016 in the high flux reactor in Petten, where they will irradiate capsules containing fluoride salts in combination with various materials. 'The radiation intensity in Petten is ten times higher than in a normal reactor, so if a material can last for five years in a high flux reactor then it is reasonable to expect that it can withstand fifty years of radiation in a normal reactor.'

The chemical composition of the salt will be studied as well. 'The composition of the salt needs to be monitored carefully, so that no corrosion takes place.' Here too, the worst-case scenario is taken as the starting point. In Fukushima, for example, poisonous iodine and caesium were released into the environment. In the MSR, fission products such as iodine and caesium are attached to the fluoride salts by strong ionic bonds, and so in theory this should not happen. 'We will heat the salt solution containing all these elements up to more than 1000 degrees and monitor which elements are released and when. This will provide assurance that no elements will be released under normal reactor temperatures.' These experiments will be conducted by the Institute for Transuranium Elements in Karlsruhe.

Salt plug

An important safety mechanism in this reactor is the so-called salt plug. Pipes under the RPV are stoppered with a plug of solidified salt. The salt plug is cooled externally. 'Imagine there is a power failure caused by a tsunami or a black-out.' says Kloosterman. 'The salt plug will melt and the liquid salt will drain into safely contained storage vessels under the RPV.' The same process takes place if the RPV gets too hot. The salt plug will be subjected to further study by the French National Center for Scientific Research (CNRS) in Grenoble, which is also one of the SAMOFAR partners. 'They are currently building test installations to

Thorium MSR Delft 2015

In April, TU Delft organised a major conference on MSRs, with speakers from the Netherlands, the US, Canada and the UK. There were also a surprising number of start-ups at the event. 'Some of these small companies see a potential in designing their own reactor,' says Kloosterman. 'They think they will have a working reactor sooner, in as little as ten years.' He himself is somewhat more cautious. 'You will need to provide convincing evidence if you want to persuade the safety authorities to let you build. I think that this will take another ten years of research.' But the start-ups do make things more exciting, he thinks. 'Young people with fresh ideas help to keep the pace up. They also have some very good ideas, and as a researcher you have to put these ideas to good use.'

study the behaviour of the salts that flow through the heat exchangers.'
Several advantages are gained from the fact that the reactor works with liquid substances. 'This reactor has a sort of small chemical plant attached that continuously extracts fission products from the salt,' explains Kloosterman. 'Every day, some forty litres of salt solution is cleaned in a special lab and then fed back into the reactor.'
This means this reactor may also be suitable for processing existing nuclear waste, an application for which there is plenty of worldwide interest. Doing this with traditional reactors with fuel rods entails a cumbersome process of dismantling, transport and reprocessing, but with a liquid you can easily add other substances to the process. We are also investigating whether you can swap fuels without having to shut down a plant first, so that a reactor that has been set up to process waste could be converted into a thorium reactor and vice versa.'

Create momentum

As coordinator of this research, Kloosterman travels all over the world to inform both colleagues and the general public about the project. 'I think it is important to do this, and the public has been very enthusiastic. After the presentations, I get lots of responses like: "this really is something new, we have to make this happen". People realise that this concept has huge potential, and that it really looks to be safe as well.'
Kloosterman hopes to generate sufficient momentum during the course of the project to scale up to a demonstration reactor. 'In Europe we are well at the forefront of this technology, but there is a lack of administrative will to push through the major investments required,' he sighs. 'We are still far removed from a go-ahead to start building. Theoretically, we could build a demonstration reactor up and running in ten years from now, and a production reactor in twenty years. But this does mean that the decision to scale up must be made within the next five years or so.' He thinks that now is the right time to make this decision. There is no more avoiding major investments in sustainable energy applications, and the MSR is a prime example of such an application.
However, there will always be people who oppose any form of nuclear power. How does he plan to convince these people? 'It's simple: energy demand is on the increase, as is the world's population. By 2100 there will be eleven billion of us. In Africa alone, the population will grow from one to four billion. In the West, we consume sixteen times as much energy per person as in Africa. Even if we manage to drastically reduce our energy consumption, we will still be using at least ten times as much energy. If four billion Africans need the same amount of energy, this will entail a gigantic increase in demand,' explains Kloosterman. 'Although the wind and sun can potentially provide sufficient energy, you still need a way to efficiently capture and store it. There will always be a demand for sources of power that you can turn on and off and the MSR will be perfect for absorbing demand spikes and dips.'
Kloosterman has personally never had any doubts. He became interested in nuclear reactions and everything to do with them at a young age. 'I could have studied physics in Eindhoven or Leiden, but I came to Delft because of the research reactor,' he explains. After he received his PhD in Delft, he spent six years studying nuclear waste destruction processes at the Energy research Centre of the Netherlands (ECN). In 1998, he returned to Delft to work on new and innovative reactors. 'I came across some blogs on the Internet by researchers who wanted to breathe new life into this technology. This was the start of a small club of a few universities and we have continued to grow ever since.'

Weinberg

They are following in the footsteps of Alvin Weinberg, the nuclear scientist who led the American Oak Ridge National Laboratory (ORNL) for several decades. This institute was responsible for running the first MSR between 1965 and 1970. 'If that development had continued, we would now have much cleaner and safer nuclear energy... and less controversy,' thinks Kloosterman. Ironically, it was probably the demand for plutonium that killed the clean thorium reactor project during the Cold War. Weinberg has always regretted this. In an interview in 1985, he predicted that this reactor's time was still to come. Kloosterman: 'I think his prediction will come out; I'm doing my best in any case.'

Chris Hellinga

The campus as sustainable testing ground

Sustainability is a leitmotif of research at TU Delft. But what about sustainability on the campus? And how can you connect the research with the actual practice at the university? Chris Hellinga is the person to ask. As sustainability coordinator, he is the driving force behind such projects as the installation of 10,000m2 of solar panels on the campus roofs. And that is not all.

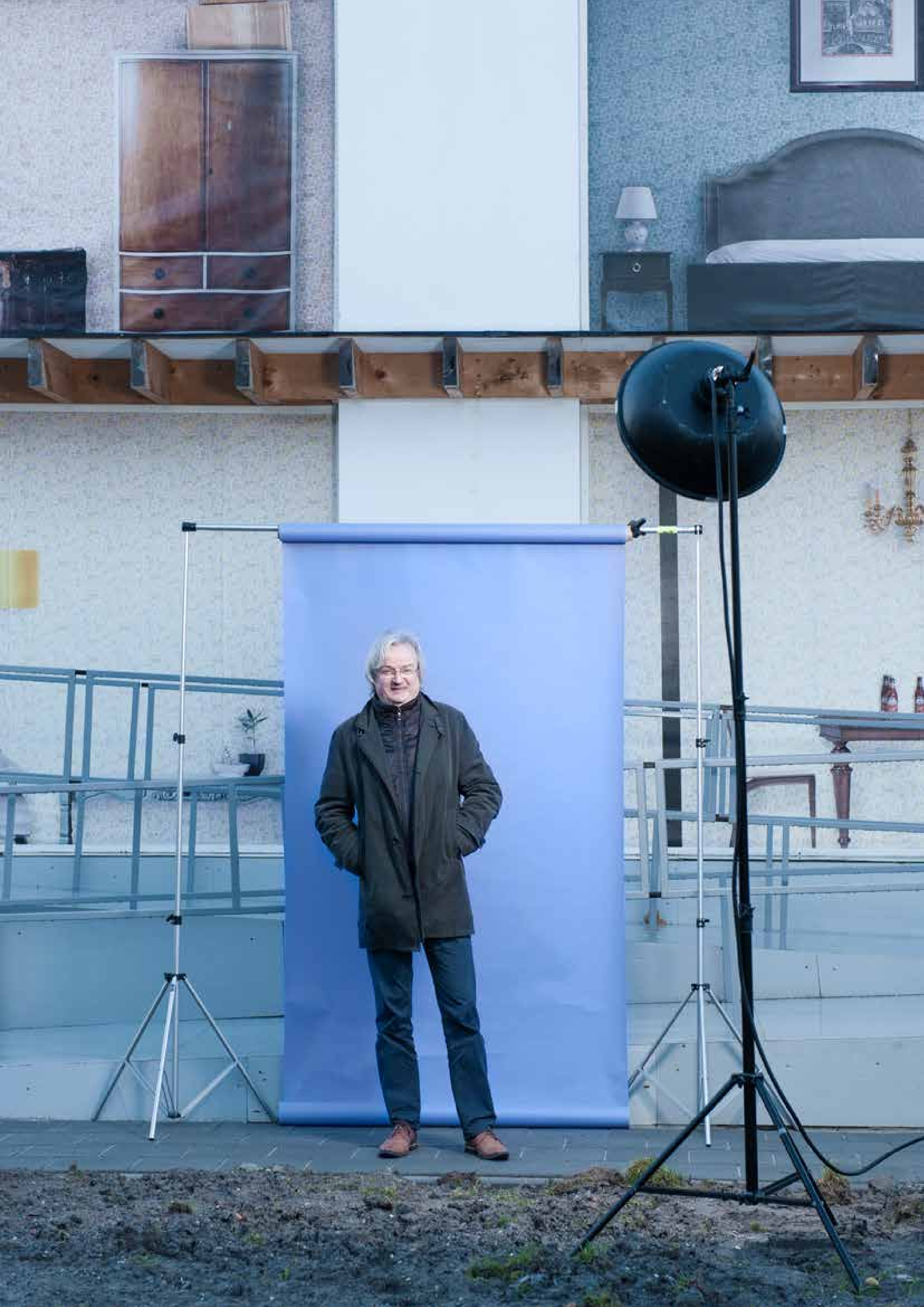
Many TU Delft buildings date back to the 1960s and 1970s and are not very energy efficient. This prompted the university to embark on an extensive redevelopment of the campus. Hellinga drew up the necessary energy plan in cooperation with the Facility Management and Real Estate (FMRE) department. 'We took all of the planned renovations and new construction projects and calculated how each contributes to conserving energy and reducing CO_2 emissions. We also looked at what else we could do without major investments. That leads you to things like installing solar panel and LED bulbs.' Other crucial elements of the plan are the introduction of cogeneration – simultaneous generating heat and electricity – and geothermal energy.
The plan is quite ambitious. 'When you add everything up, it turns out that a 50% reduction in CO_2 emissions by 2020 is feasible, and that we can save 40% energy. Furthermore, we can sustainably generate a quarter of our energy, with geothermal energy playing a major role,' Hellinga says. The solar panels make a contribution, too, but that is not the only benefit. 'We're showing students and society as a whole that sustainability means a lot to us. It's an important signal.' Putting words into action, which is something at which Hellinga excels. He applied for the grant for the solar cells before the energy plan had been completed. TU Delft received €1.5 million. It may sound like a lot, but probably just covers the costs of operating the solar cells, according to Hellinga. 'The number work is tricky. You receive a grant based on what you are going to produce, which in our case is 1 million kilowatt hours a year. But we're a wholesale customer, which means that we are already paying very little for our electricity. That's why it takes three times longer than a private customer to recoup our investment.'

Delft Solar City

Incidentally, the 1.2 megawatts power is not the limit. 'We would like to make extra roof space available to staff. If you are thinking about buying solar panels, you can have them installed on the TU Delft rooftops. Financially, it's not as attractive as putting them on your own roof, but not everyone can accommodate the panels. Still, your money is not doing much for you in the bank right now, either,' Hellinga says. He contacted energy cooperative Qurrent, which has experience with similar formulas, to help make it happen. 'This allows us to include every member of staff, without the paperwork hassles.'
In the meantime, the plan has expanded to all of Delft under the 'Delft Solar City' name. Solar panels on all suitable roofs are contributing to the municipality's goal of achieving zero energy status by 2050. The enthusiastic approach did not go unnoticed: last year, Delft came from nowhere to third place in the annual rankings of the best cities for using and encouraging solar power.

Geothermal energy

The introduction of geothermal energy on the other hand was not as smooth, at least in the beginning. At the time, student Douglas Gilding was the driving force behind a plan to install a geothermal source on the campus. 'A study of the substratum showed that it was definitely feasible,' Hellinga says. 'The idea was to use it to heat newly-built houses; you can directly fit them with heating systems suited to the relatively low temperature of geothermal energy. Unfortunately, this coincided with the construction sector slump and the new construction project was scrubbed, effectively putting an end to our business case.' Gilding won a thesis award when he graduated in 2011, however.
Fortunately, the plan was given a second chance. 'We went looking for a way to



About Chris Hellinga

Chris Hellinga arrived at TU Delft in 1985 after studying food technology in Wageningen and working as a process technologist for Melkunie for three years. In Delft, he started out on the mathematical side of biotechnological processes before moving to water treatment. ‘One of my publications in those days was about nitrogen removal. Although it was fifteen years ago, I still receive e-mails from a research network every week that it is one of the best cited publications from the group.’ Hellinga did not wish to grow old in the university, however, and together with a colleague he founded a company that develops sophisticated measuring tools for biotechnological process. Later, he started an environmental consulting firm. He became interested in energy in the process of conducting countless life-cycle analyses (LCA). ‘Energy and CO_2 emissions are factors that you can effectively quantify for an LCA; other aspects are much more difficult.’ In 2005, he returned to TU Delft and was involved in national energy initiatives including the Dutch Research Platform on Sustainable Energy Supply (Nederlands Onderzoeksplatform Duurzame Energievoorziening – NODE) and Advanced Dutch Energy Materials (ADEM) in the early stages. At TU Delft, he is closely involved in the Delft Energy Initiative and the associated Energy Club for students.

install the source on campus ourselves. By doing so you show that it’s possible to use geothermal energy in existing buildings,’ Hellinga says. Once again, balancing the budget proved tricky. ‘A greenhouse gardener, for example, uses energy all year round: in winter to heat and in summer to control humidity. On our campus, energy consumption shrinks to practically nothing during a couple of months in summer.’ For a bank, this makes lending money less attractive, but after years of working out the numbers a potential solution is now in sight. It remains suspenseful: ‘We will find out at the end of 2016 whether the geothermal source will really happen.’
Meanwhile, the technical preparations are in full swing. The old heating system uses water at temperatures as high as 130 °C to heat, which requires fossil fuels. Newer, more sustainable systems can heat at lower temperatures, making them suited to the geothermal source, which delivers water at 70 °C. This is called mid-temperature. Existing systems must be revised. Hellinga: ‘Right now, the buildings are used to much hotter water. In current renovation projects we are going ahead and making the necessary adjustments to accommodate those lower temperatures.’
The necessary adjustments might very well be less work than anticipated. Or at least according to the latest figures produced by the calculation model in which all of the pipes and buildings on campus are incorporated. Using the predicted temperature, the heat demand for each building can be calculated, followed by the sources that can supply it. ‘The model anticipates that you will be able to lower the temperature just by making modest adjustments to the buildings. Now we want to carry out a test in a building to make sure this is not accompanied by a loss of comfort; in other words that we don’t get too cold. The model prediction must correspond to reality, of course.’

Direct current
Ideally, you want to design a sustainable building from scratch, of course. The new Pulse teaching building scheduled to open on campus in 2017 provided this opportunity. ‘We set the bar extremely high,’ Hellinga says. For starters, the building must be a net zero energy building, which means it generates enough energy in summer to supply itself in winter.’ The use of direct current is likewise being studied at Hellinga’s request. This would make Pulse the first office building in the Netherlands with a direct current network. He explains: ‘All of those sustainable sources such as solar panels and windmills are supplying direct current, which is converted into alternating current. Batteries and fuel cells use direct current, just like all of our appliances. Alternating current only comes from outlets. That’s why we need all those devices to switch it back to direct current.’ Although this evolved over time there is clearly room for improvement here. After all, every conversion results in energy loss. ‘Direct current means less energy, less material for all of those converters, less space because you don’t need as much equipment, and less heat loss. Some data centres are already operating entirely on direct current.’

Green Village and Office
Research, design and the actual situation

'We set the bar extremely high. For starters, the building must be a net zero energy building, which means it generates enough energy in summer to supply itself in winter'

on campus are closely knit in each of these topics. For example, some of the solar panels will be used for studies on improving efficiency. Professor Andy van den Dobbelsteen, professor of Climate Design & Sustainability, was involved in the design of the new teaching building, along with his colleague Erwin Mlecnik, who specialises in passive houses. Work is also underway on the Green Village, the on-campus living sustainability lab where students, researchers, entrepreneurs and governments will work together on radical innovative, sustainable technology such as a hydrogen car that can furnish homes with power: the Car as Power Plant project.
A special Green Office will be set up to prevent the various initiatives from developing in a vacuum. 'It will be the authority on sustainability at TU Delft,' Hellinga says. With 900 researchers working on energy-related topics at the university, it is not surprising that there is so much attention to it. But there is more. The Green Office's first order of the day is to draw up a sustainability plan for the next ten years. 'This also shows that we as a university are consciously choosing this path, including on our own campus.'

Biomass

A feasibility study on installing a biomass gasifier in the CHP plant is another example of interaction between the research and the developments on campus. Hellinga was recently approached by the A. Hak piping company, which sees a new market opportunity. Together with the Torrgas green technology company they are working on a test system for gasifying biomass. In this type of system, the pre-treated biomass is rendered into a gas that can serve as green fuel for generating our heat and electricity and a green raw material for the industry as a by-product. 'A study was already underway in the 3mE faculty to determine whether you can also use actual waste streams for the biomass raw material, such as grass clippings or kitchen and garden waste. These two developments go together beautifully.'
Something nice to know is that the old coal tanks on the roof of the CHP plant are ideal for storing biomass. Hellinga is enthusiastic: 'We are the ideal university to study the added value for that installation. For example, our chemists can determine how you can effectively make longer molecules from the CO and H_2 in biogas. If we can drive more of these kinds of projects we will truly help advance the energy transition.'

Innovation Programme Intelligent Networks (IPIN)

The campus heat model was created in the Innovation Programme Intelligent Networks (IPIN), which the Netherlands Organisation for Scientific Research (NWO) designed to accelerate the implementation of intelligent networks in the Netherlands. TU Delft is one of the eleven IPIN test locations. Chris Hellinga: 'With intelligent networks everyone automatically thinks "electricity" but a smart grid is just as important for heat. We will be receiving heat from a variety of sources and at different temperatures. You have to be able to buffer it and use it flexibly according to demand. The very questions that come into play with sustainable energy.' The heat network on campus is currently still supplied by the CHP plant, and a couple of buildings have an independent aquifer thermal energy storage system. With the advent of new sources such as solar and geothermal energy, it is time to turn the heat network into a smart network. To this end, TU Delft is working with the water and subsurface applied research institute Deltares, Deerns consultancy, installation company Kuijpers and Priva, which specialises in climate control.

Maarten van Ham

Invest in people, not bricks

Maarten van Ham is a professor of Urban Renewal and Housing in the Faculty of Architecture and the Built Environment. In 2014, he received an ERC Consolidator Grant for DEPRIVEDHOODS, his study on neighbourhood effects. The initial findings were recently published in the book Socio-Economic Segregation in European Capital Cities.

In the 1990s and 2000s, significant investments were made in our country in demolition and new construction in deprived neighbourhoods. The idea was that a wider mix of more expensive owner-occupied and rental properties in combination with social housing would be accompanied by a dramatic reduction in problems such as unemployment, school dropout rates and crime. Governments attached great importance to the neighbourhood effects phenomenon; that is, the causal connection between living in an deprived neighbourhood and individual outcomes such as health, your chances for work and your children's education. All sorts of mechanisms were believed to play a role. People living in an area with widespread poverty and unemployment may lack positive role models, for example, and a culture might arise in which receiving benefits is actually a source of pride.

Exactly how significant are these factors, I wondered; after all, the literature offers very little in the way of solid evidence. Obviously there is a connection between your income and where you live. If you don't earn a lot, then you will end up in the parts of the city where it is cheap to live. And our cities tend to be designed so that those homes are clustered in certain neighbourhoods. Take the 1960s neighbourhoods with a lot of high-rise buildings: poverty tends to be concentrated in these. I do believe living in an impoverished neighbourhood has negative effects. The one reinforces the other. But when you look at what causes the poverty in the first place, the primary causes are still things like a lack of proper training required to get a better job that will enable you to move. These individual aspects play a much greater role than the neighbourhood effects.

If you're talking about solutions for problem neighbourhoods this is very important. You can invest in areas, or you can invest in people. In the Netherlands, area-based policies – investing in the built environment – have strongly prevailed over people-based policies for the last twenty years. Original residents of impoverished neighbourhoods supposedly would benefit from increased socio-economic diversity in their neighbourhood, achieved by replacing cheaper homes with more expensive ones. In practice this is not the case. Demolition and new construction bring some other people to the neighbourhood. Ten years later more people do indeed have a job or a car. But those tend to be the people from outside who bought the newly constructed owner-occupied homes; in other words, you haven't done anything for the original residents. They have dispersed to other parts of the city whilst nothing has fundamentally changed in terms of the underlying poverty issue.

In order to create support for the demolition of old neighbourhoods, residents were sometimes given return guarantees and could move into one of the new homes with a discount on rent. Ten years later, these people are much more satisfied with their living environment, yet you don't see any improvements with respect to their income or work. Take the Hoogvliet neighbourhood in Rotterdam, in which over a billion euros were invested: had you put half of that amount into better salaries for the best teachers and halving school classes you would have seen tremendous results for the local children. But that's a long-term strategy, of course, and politicians seldom have the patience for those.

How exactly do you study these neighbourhood effects? Ideally, you allocate a thousand random people in a wealthy neighbourhood and a thousand in an impoverished neighbourhood, hermetically seal them off, and see what happens after ten years. Not exactly feasible, of course. What you can do is collect data by tracking people over a longer period. You can interview them and ask retrospective questions. Still, who remembers their postcode or exactly how much they earned a decade ago? There are a lot of errors, in other words. You can also send people a survey to fill in each year, but that's terribly expensive and over time a lot of people will drop out.

We use data from the municipal personal records database for our study. In that sense we're fortunate to be in the Netherlands: almost everywhere else in the world all you have are censuses;

About Maarten van Ham

Prof. Maarten van Ham studied Economic Geography at Utrecht University, where he obtained his doctorate in 2002. He worked as a researcher at the Max Planck Institute in Berlin, Utrecht University and the University of Amsterdam. In 2006, he joined the University of St Andrews in Scotland as a lecturer and was subsequently appointed full professor in 2011 at the age of 39. He maintains a part-time professorship there. In 2011, he was also appointed professor of Urban Renewal and Housing at TU Delft.

you only get data once every decade. In the Netherlands, we've had the Municipal Personal Records Database since the 1990s. Statistics Netherlands compiles all of this data and links it to information about households, work, home ownership, you name it. This allows us to track people and examine the effects of living in a particular environment on individual outcomes. Obviously, our study is bound by all kinds of rules and restrictions in order to guarantee privacy.

Sociological and spatial research using large databases is what we do. The complexity and scope of the data is what makes it so interesting. Along with the high spatial resolution. In our models, the Netherlands is divided into squares of 100 by 100 metres. There are four million squares. We have about 100 characteristics per square, such as unemployment and population demographics. We link all of that data to the 20 million people in the municipal personal records database, which gives you more than 100 million pieces of data. In addition to each individual square, we can also look at the surrounding squares and the squares surrounding them; in other words on different scales.

How do neighbourhoods change over longer periods, and what are the histories of the residents? And do these histories affect people's outcomes? Looking at where someone has lived for the last ten, fifteen years, you see for example young people from well-off neighbourhoods who live in a less privileged neighbourhood for a couple of years while they are students and go on to get their first job and move up again. You also see young people in deprived neighbourhoods who never leave these. When you subsequently establish as an outcome that living in a poverty-concentration neighbourhood for ten years have a more negative effect on your income than living in such an area for only two years, you start heading in the direction of a causal connection.

The value lies in studying those patterns. That's fundamental research. You can then strengthen those findings by linking them to data from other studies. For example, Statistics Netherlands conducts annual research on the working population as well as the housing market. One hundred thousand people are interviewed, in which they are asked questions such as: are you happy, do you suffer from work stress, do you have contact with your neighbours, does your home leak? That is all information that is not a standard part of the database. We know a lot more at regular intervals, in other words. This is how we look at the relationship between personality and neighbourhood effects, for example. The premise is that your personality affects whether you suffer from living in a deprived area rife with problems such as poverty and crime. If you are highly resilient, the assumption is that you would not be bothered by it. We are studying this by using a survey that tracked young people for the past 15 years, which we link to the register data. This enables you to look back 15 years just like that.

Only Sweden offers us the same wealth of data as the Netherlands. Consequently, we rely on census data for our European research. Using this, we compared at the neighbourhood level where rich and poor were living in 2001 and 2011 in thirteen European capitals. Segregation between rich and poor increased in eleven of the thirteen cities. The growing segregation is a result of the increasing inequality caused in part by

'Segregation only becomes a problem when living in a certain neighbourhood has negative consequences for individual households'

globalisation. The manufacturing industry in Europe has shrunk dramatically. As a result, middle class jobs are disappearing and the only new jobs are at either the bottom or the top of the labour market.

Segregation increased tremendously in three cities: Vienna ,Stockholm and Tallinn in Estonia. Although these cities are very different, they reflect the same trends. In Tallinn, you see extreme excesses of capitalism. Inequality has increased significantly after the fall of Communism, and is now taking the form of massive segregation. Vienna and Stockholm are traditionally cities that place a strong emphasis on income redistribution and social rented housing. You are seeing a decline in investments in social housing construction there. From the 1980s onward, neo-liberal policy has led to increasing privatisation and the dismantling of social services including social rented housing. That only leads to more inequality, which you see in the spatial distribution of the inequality. Stockholm in particular was very amenable to immigrants. Yet in 2013 riots broke out in those neighbourhoods of the city that are home to many immigrants who have no prospects. You could learn a lesson from this to apply to the rest of Europe: ensure that immigrants are given training and jobs, and that their children go to school.

The response to our book about this was overwhelming. It started with a huge amount of attention in the Dutch media. In the meantime, we've been mentioned more than 50 times in European media such as El Pais and The Guardian, but also in The Washington Post. We presented the book in Brussels to the European Commission and the OECD, the Organisation for Economic Co-Operation and Development. I get visits from politicians, and shortly I will be interviewed again for the Vienna radio. It's just a book, I think to myself sometimes. And yet it doesn't surprise me. Inequality is a theme that strikes a chord with everyone.

Segregation is not bad by definition. Most Dutch people live in neighbourhoods that are extremely homogenous in terms of income, education, family structure and so forth, and are perfectly happy. The Netherlands is still a very equal country compared to the rest of Europe.
Segregation only becomes a problem when living in a certain neighbourhood has negative consequences for individual households. Companies no longer want to invest, shops close or children do not get the education they deserve. Residents are denied services and opportunities. It is like that in some areas. I don't believe that investing in bricks is the solution; it's investing in people. Look at the Paris suburbs: they invested 44 billion in them over the years. It is 10 years since violent riots broke out there in 2005. Journalist Peter Giesen was prompted to write an article in de Volkskrant. "The bricks are doing well, the people much less so", he concluded. That's exactly my story.'

DEPRIVEDHOODS

In 2014, Professor Maarten van Ham received an ERC grant for his research on the relationship between socio-economic inequality, poverty and neighbourhoods. A total of ten researchers in four countries (the Netherlands, the UK, Sweden and Estonia) will be working on this in the coming years. 'The grant changed a lot; it allowed me to significantly expand my research group. Gaining access to the required longitudinal datasets in the Netherlands and other countries costs a lot of money too,' says Van Ham. The book 'Socio-Economic Segregation in European Capital Cities' drew a great deal of media attention to the research being conducted by Van Ham and his colleagues. Now that the commotion has subsided, they continue to devote themselves to the essence of the study; fundamentally improving the understanding of neighbourhood effects. 'In addition to segregation in the residential neighbourhoods we are now also looking at segregation in workplaces and during leisure time. Our new approach will provide us with much more insight into the influence of segregation on people's lives.'

Maja Rudinac

Dancing rollator cares for the elderly

Dr Maja Rudinac started her company Robot Care Systems just over a year ago. Things have been moving fast ever since. She won the prestigious Herman Wijffels Innovation Prize 2015 in the Vital Communities and Care category. On 3 December she was also awarded the Shell LiveWIRE Award. More importantly, her ingenious care robots are now being tested by groups of patients, prior to coming on the market.

The offices that Robot Care Systems share with business partner Lobeco are somewhat hidden away in a quiet street in the affluent part of The Hague. Once inside, however, the place is all you would expect from a high-tech start-up company. Lots of young people working in the labs, a testing ground where robotic systems can be put through their paces, and a basement leisure room. The latter is largely deserted this late Friday afternoon, as most of the company's forty employees are still hard at it. Clearly, CEO Maja Rudinac is not one to faff about.

'I studied Electronics and Control in Belgrade, Serbia, and did my MSc in Artificial Intelligence,' Rudinac begins her story. During her Master's, she got involved in a large European research project on video retrieval in cooperation with Google. 'That opened many doors for me; it also made me aware of the beauty of research.' After graduation she stayed on in the project. In this period she also worked on signal processing for ECG analysis. 'This gave me some medical background. It also brought me in touch with patients who were recovering from a myocardial attack. I liked working with people and with equipment in real life; I realised data retrieval was just a bit too passive for me.'

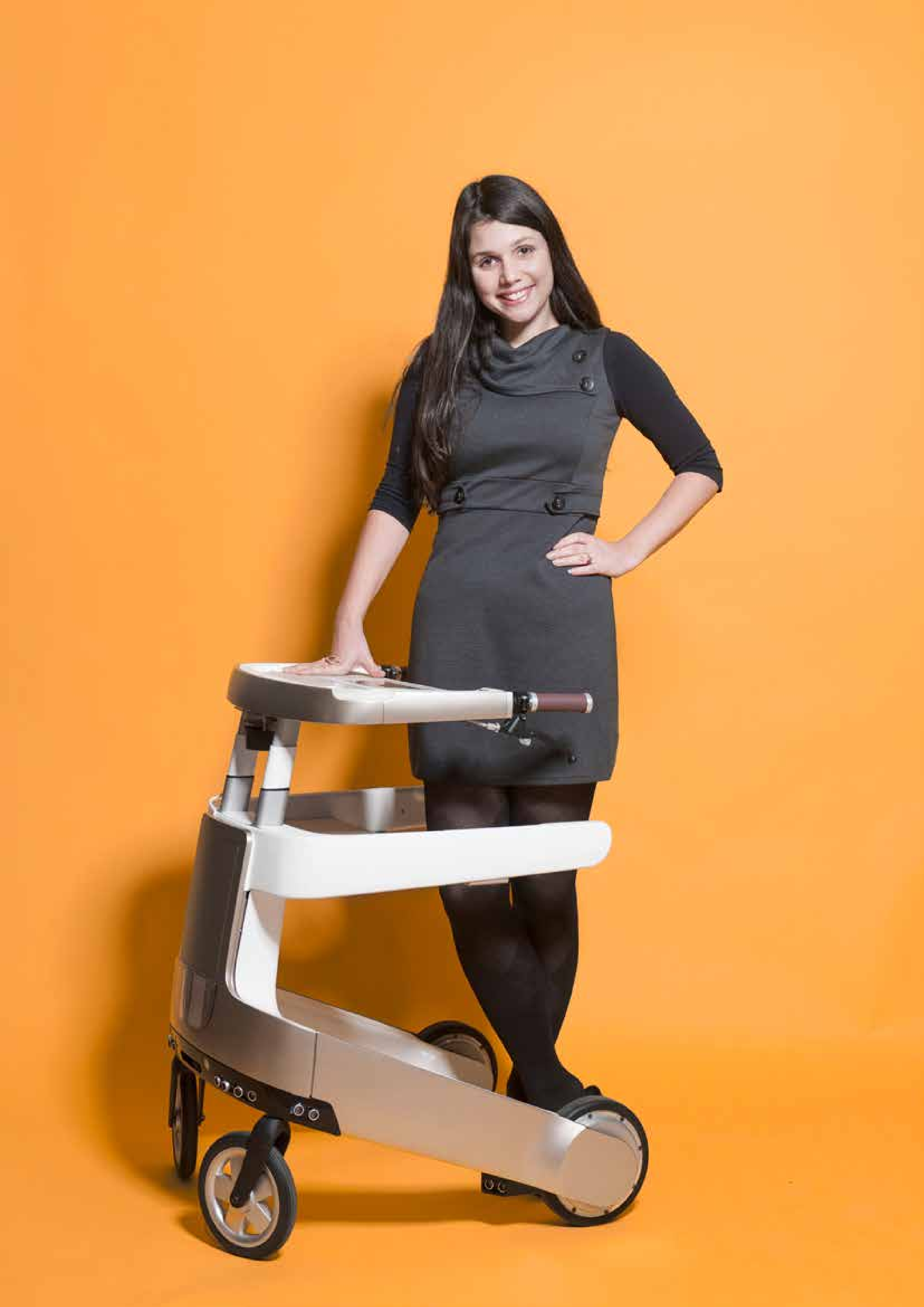
Robot learning

A chance to do something new arrived when Professor Pieter Jonker invited her to do a PhD in vision-based systems at TU Delft. Soon after she started, Jonker's research group became part of the Delft Biorobotics Lab that develops biologically inspired robots. 'They were building these amazing walking robots with very complex mechanical systems. That really gave me ideas. Why couldn't I build robots to test our vision systems? That is how I got involved in robotics.' She started focussing on robot learning. 'I tried to analyse how small children learn from their environment and I tried to mimic that in robotic systems. So how can a robot learn to recognize objects, the actions of people, or faces? And if it is faced with the unknown how can it apply previous knowledge?' Rudinac explains.

'How can you make it understand its surroundings, how can it learn from them, and so on,' she continues. Making robots adapt to new environments and users is one of robotics' challenges. That is the first reason why robots have so far been mostly confined to controlled environments, such as the factory floor and the operating theatre, or to those environments that are virtually inaccessible to human beings, such as the deep sea and outer space. The second reason is financial. 'We did not have household robots yet because robots were far too expensive. The robots that were being designed were really too complex.'

Autonomous skills

Rudinac decided to change tactics. 'I said to myself, why don't I reverse the problem and analyse how people live in households? From there I can then deduct how robots can assist them.' She gathered a group of enthusiastic students and set about proving that idea. 'We came up with Robby and Leah, robots that could perform a lot of complex tasks with a simple body. They were voice-controlled, so you could say "Leah go to the kitchen and find out what grandma wants to drink", and it would do that.' The robots needed advanced autonomous capabilities in order to do this, such as navigation, speech and object and facial recognition skills. Robby and Leah also looked a bit humanoid. 'I wanted them to look friendly, but still recognizably a robot.' Friendly-faced Robby and Leah generated a lot of media attention, but they were only prototypes. Rudinac wanted to design technology that people would actually use. 'That will not happen at a university; you need to set up a business for that,' she says. 'So with my



Sam

Sister company Robotic Security Systems also has a product going on the market soon: SAM (Secure. Autonomous. Mobile). 'Our partner Lobeco has long years of experience in the safety industry, and they saw clear possibilities for robot technology,' says Maja Rudinac. 'Take a large factory hall. At night there is usually no more than one guard insides. Often these halls contain hazardous materials, there are fire risks or intruders can come in. SAM can inspect these areas and alarm the guard if necessary. In case of an incident, SAM can also check if the area is safe for people to enter.' SAM has bigger brother, called SAM Outdoor, that can do the same in outside areas.

What we want is to see a change. With less and less care homes, who can help people that cannot really be left alone? So what we want is to use this technology to help people in need'

TU Delft team we started discussing if we could open a start-up to build robots that would actually reach people's homes.
It was another research project that brought her to patients in care homes. 'At the time, I was also researching a detection system that registers when people fall, and testing it out at care homes for the elderly. I spoke a lot with these people. They were so happy that somebody came to see them; they didn't mind my Dutch wasn't up to much. In fact, they helped me improve it.' These visits got her thinking. 'I felt sad after these visits. You see people that have been active all their lives, and then when they are old, there is not much help for them. If we can just get them to move around and exercise more, that would enrich their lives.' She did some market research and realised there was little or no technology available that could achieve this, and she decided to do something about that.

SILVER

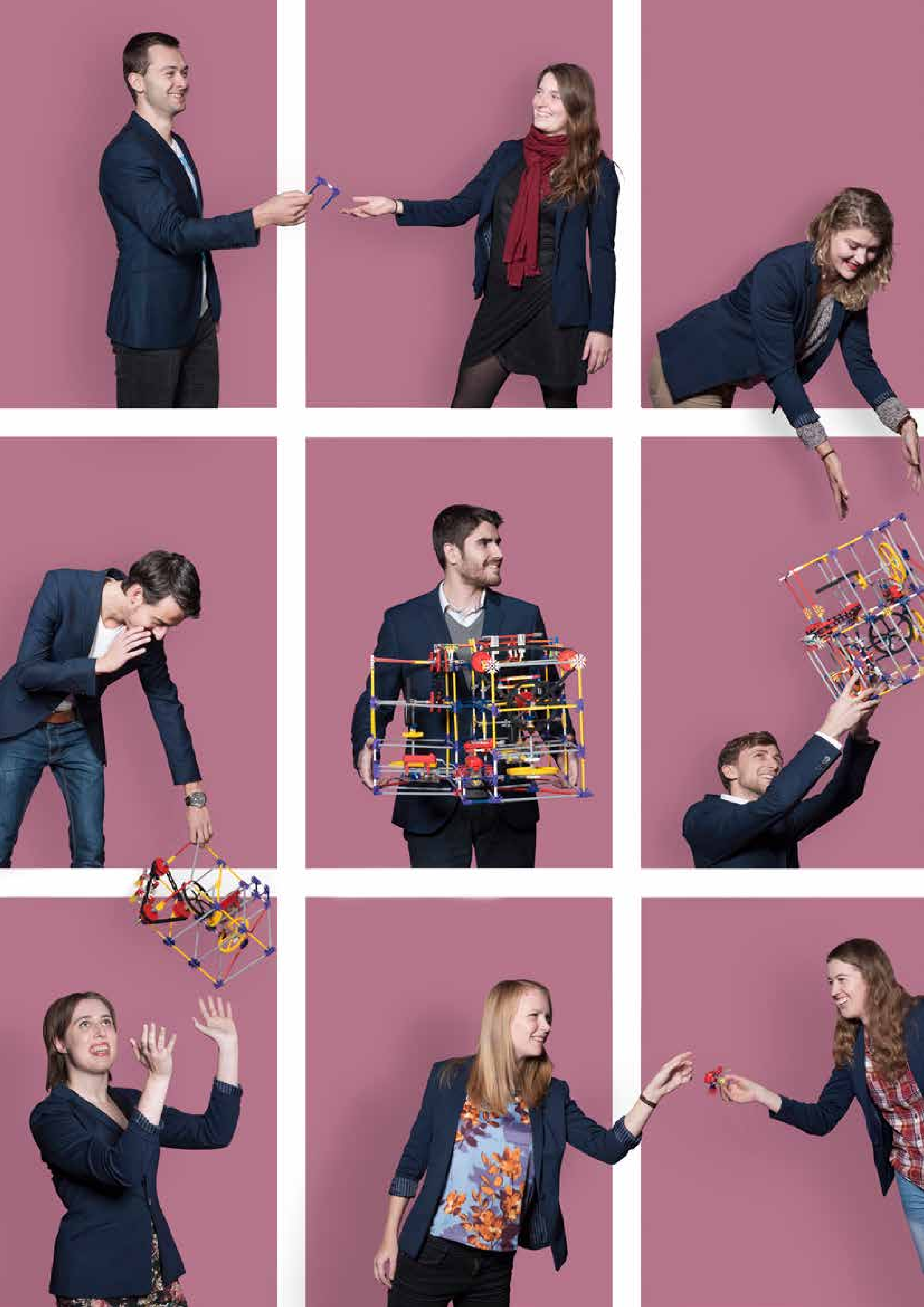
Her ideas were exactly in line with European development project SILVER (Supporting Independent Living for the Elderly through Robotics) that aims to find new technologies that can assist elderly people in their everyday lives. She applied for and was awarded a SILVER grant to do a feasibility study. 'We said, let's give it a shot. And after talking for a year with elderly people and their caregivers we came up with a product that can help them both.' That is when she set up Robot Care Systems, together with Lobeco Fire + Security and entrepreneur Martin Roos. The product they designed is another LEA, short for Lean Elderly Assistant. 'We grew rather attached to the name,' admits Rudinac.
Unlike its predecessor, LEA looks nothing like a human being. It looks very much like its dumb relative, the rollator – an all singing, all dancing rollator, that is. This LEA can assist three groups of people, those with mobility problems, patients with dementia, and tremor sufferers. 'Users can wear a button they can press, and then LEA will come and find them and position itself so they can get up.' LEA can also detect how fast people are walking and assist them accordingly. Another feature are the sensors for obstacle detection that will steer you in the right direction. 'We tried to get rid of

Mutual benefit

'We still have excellent relations with TU Delft,' says Maja Rudinac. 'Almost all of our team are TU Delft graduates or former employees. In fact, I think we are the largest employer for robotics graduates. That is of mutual benefit. I know the education they get and that their knowledge of robotics is good, so I don't have to worry about that when hiring people.'
TU Delft and Robot Care Systems are also involved in a joint project on autonomous vehicles, WEpods. 'Next year, an autonomous shuttle bus will drive between the station and Wageningen University. We are now doing basic tests. We are also working with the Department of Road Transport to get the permission for the public road. This involves a lot certification and security steps, but they are helping us with that.'

traditional interfaces and make operating it as intuitive as possible.' LEA also comes with a built-in exercise module. 'Exercise is very important to stay mobile, that is why we have a qualified rollator dancing teacher working with us. So far, LEA can do the waltz and the samba. You can also use LEA to perform rehabilitation exercises that we have designed with experts.'
The personal assistance module is aimed at patients with dementia. For these people it is very important to keep track of their daily routines and remind them what to do, such as taking their medication. 'LEA will not just remind you, but come and pick you up and bring you where you have to go. We are working with dementia carers to see how we can develop this module further.' Another of the robot's features is the communication module that allows people to alert family and carers. 'This includes a remote care module. When LEA detects that someone has fallen down, it can contact the alarm centre, so help can be sent if needed.'

Consumer electronics
All in all, LEA sounds like an expensive piece of equipment, but that is not the case at all. 'Usually, when people design robots, they put in expensive laser scanners and such. We used very affordable consumer electronics, although that made it a challenge to develop the algorithms. We have also had to develop more than seventy components ourselves, to keep down the price,' explains Rudinac. 'This way, we can produce it at prices significantly lower than anything else that is now available on the medical market.' Moreover, people being healthier and living independently for longer means huge cost savings for insurers and government. This is quite apart from the improved well-being LEA could bring about. 'Investing in prevention actually reduces care costs. We are now busy with insurance companies to see if patients can get LEA in their homes for a small amount of money, but developing a business model for the care industry is not so simple.'
Clearly, Rudinac is not in it to become rich quickly. 'If you want to make millions you wouldn't make something so complex, you would make something simple that can be sold to consumers worldwide' she says. 'What we want at Robot Care Systems is to see a change. With less and less care homes, who can help people that cannot really be left alone? So what we want is to use this technology to help people in need,' she says. It looks like she is about to achieve just that, in part with the help of the Silver Consortium. 'We won the phase three competition and have now signed a contract for the real-life testing of LEA. They are helping us organising clinical trials.' These international trials will be taking place in Finland, Denmark, Sweden, The Netherlands and the UK. Meanwhile, local user groups of mobility patients are already testing LEA. 'We are now going to expand our user groups to include Parkinson patients, dementia sufferers, and perhaps also blind people to see how we can help them.'
All in all, she has found a lot of support for her venture. Insurance company CZ is an investor, as are Rabobank and regional development company InnovationQuarter. Robot Care Systems also won the Herman Wijffels Innovation Prize from among 850 contenders. 'To me that is a sign that society says: these people are important to us.'



Printing biofilms made childsplay

TU Delft's participation in the 2015 International Genetically Engineered Machine competition (iGEM) was no less then a triumph. During the Giant Jamboree in Boston last September, the team won overall first prize with their 3D biofilm printer made from K'NEX. They also scooped up prizes for best hardware, best website and best applied design, along with a number of nominations in other categories. Samantha Basalo Vázquez, Héctor Sangüesa Ferrer and Anne Rodenburg were part of the winning team.

Biofilms are communities of bacteria that are attached to a surface. They are notoriously hard to get rid of and can clog up equipment or ruin your teeth – dental plaque is one of the most common examples of a biofilm. 'Biofilms are getting harder and harder to remove,' explains Anne Rodenburg. 'You have probably heard of hospital bacteria developing antibiotic resistance. They can grow anywhere, even on prosthetics inside the human body.' These detrimental biofilms form a huge and costly problem for human health and industry. 'A lot of research is being done into the prevention of biofilms. For that you need reproducible research samples,' says Samantha Basalo Vázquez.
'Bacteria grow in random configurations. If you can control them and grow them in certain shapes, you can perform tests under the same conditions every time,' explains Héctor Sangüesa Ferrer. The team came up with the idea of printing biofilms so they could control the shape and structure. They also wanted to control the formation process. Bacteria form biofilms with the help of nanowires. 'They do that naturally' says Sangüesa Ferrer, 'but under varying conditions, so that is not really controllable. We aimed at a biofilm that could be created at the moment we wanted it and in the shape we wanted it.' First, the team genetically engineered a strain of bacteria. 'We introduced a piece of DNA into a plasmid so the bacteria would produce a protein called CsgA,' explains Basalo Vázquez. That protein forms part of the extracellular matrix that binds the cells together.

On-off switch

Next, they incorporated an on-off switch in order to time the biofilm formation. 'We used a small sugar molecule, called rhamnose. When you add that, the bacteria will start producing the CsgA and form nanowires,' says Basalo Vázquez. As the formation of the biofilms takes two days, they also needed something to support the cells and keep them in the desired structure during that process. Inspired by the bioprinting of tissues they came up with the idea of a scaffold, for which they used a combination of calcium chloride and alginate that forms a hydrogel. 'Once all the bacteria are connected by the nanowires, you can dissolve the hydrogel again. The cells will then remain attached to each other, without the need for an external structure,' says Sangüesa Ferrer.
Although their 3D printer caught a lot of media attention, it was the combination of synthetic biology and 3D printing that made their project stand out. 'The genetic engineering we did was interesting in itself, but the techniques we used are quite common,' says Sangüesa Ferrer. 'Combining that with printing the structures and the use of the scaffold made it special.' It brought them the victory, but that had been eight months in the making. 'Early in the year we had a number of brainstorm meetings were we all came up with ideas, and we had already selected a top three,' remembers Basalo Vázquez. Like all good ideas, however, the winning one seemed to come out of nowhere one night when team members were going home by train. 'It wasn't even on the shortlist, but we all immediately liked the idea for the printing of biofilms,' she says.

Who are they?

Samantha Basalo Vázquez did a bachelor in Chemical Engineering, and then came to Delft to study Biochemical Engineering. 'I joined the iGEM team because I wanted to learn about biological modelling and to find out more about the synthetic biology sector. During the project I was responsible for the biological-chemical modelling. I will now be doing an internship and then my graduation project.'
Anne Rodenburg joined the team from the Rotterdam University of Applied Sciences. 'I was a third year student of Biochemistry and Molecular Biology when I heard about iGEM. I was honoured to be part of the team. I wouldn't have thought I could keep up with TU Delft students, but my practical experience helped. I was fundraising and budget manager for iGEM. After graduation I would like to do a master in the field of Life Science and research.
Héctor Sangüesa Ferrer studied Biotechnology in Barcelona and came to Delft because he wanted to know more about the technological side of Life Sciences. 'There are also more opportunities here to participate in interesting projects such as this one. For iGEM I was in charge of the lab and safety management. I am now doing my MSc thesis and will then be looking for new experiences elsewhere. There are a lot of existing companies exploring this field and new companies being created every day.'

'The competition is also about sharing biotechnology with the general public. So we had to think about making the idea understandable'

First the team had to get to Boston, though, and by the time they had chosen their project it was April. 'Most other teams had already started working. That got us a bit stressed about timing,' admits Sangüesa Ferrer, 'so we quickly undertook a literature review and started making concrete plans.' An important part of the planning was the fundraising, and here Rodenburg took charge. 'You need to pay for travel and the stay in Boston. The iGEM registration fees are quite high too,' she says. 'I started contacting companies straight away, but it took a while to make the right connections and get through to the right people. Luckily, the TU Delft had already reserved money in their budget for us.'
The team needed a lot of equipment too, including enzymes, cloning kits and fridges. They were pleased with the amount of help they received from the university. 'The Nanotechnology Department lent us a lab. We could also use some of their equipment, such as a centrifuge and a thermal cycler,' Rodenburg says. 'People at the university helped us not only with materials, but with knowledge too,' Sangüesa Ferrer adds. 'They told us which techniques we should and shouldn't use.' Of course, advice and help were allowed, but they had to set up and execute the project by themselves. 'We learned a lot from that,' he says. 'More than we could have learned during normal courses. The competition is also about sharing synthetic biology with the general public. So we had to think about making the idea understandable. We also dealt with modelling, project management, fund raising, PR and lots more.'
It was Basalo Vázquez who was in charge of the modelling. 'We made mathematical models to predict how the proteins and the eventual biofilm would form. We modelled the production of the CsgA to see how long it took for the structures to be formed. We also looked at how strong the eventual structure would be if we used different concentrations of rhamnose.'
The quality of the modelling was another factor in their victory, Sangüesa Ferrer believes. 'Modelling in biology is still new, because biological systems are not easy to model. When you make a motor for instance, you know all the parameters. In biology, a lot of things are uncertain until you do experiments. Most of the iGEM teams have no strong relationship between their modelling and their lab experiments, but we found the proper models to explain our results.'

K'NEX

With the biological part of the project progressing so well, choosing a printer proved harder than they had imagined. 'We thought of using existing inkjet or 3D printers. But they were difficult to reprogramme, especially since we are no software engineers. Plus, with an inkjet printer you cannot print in three dimensions. At least a 3D printer solves

Outreach

'We really like to engage with the public,' says Anne Rodenburg. 'We took part in the Delft Festival of Technology where we explained to children concepts like a microscope and plasmids. Not the easiest thing to do.' Their 3D printer will be on display at the TU Delft Science Centre too. 'Under glass, so visiting children are not tempted to take it apart,' she admits. 'We also organised a business case for students and asked them to think about applications for our printer. They came up with imaginative ideas, such as printing insoles for smelly feet.' There is a need for more outreach on the subject of synthetic biology, the team believes. 'If people do not know what it is all about, they will use their imagination and start running scared,' says Sangüesa. 'Of course you can do scary stuff, but you should use it to save lives,' adds Rodenburg. 'In the past we have been doing similar things, like crossbreeding to get the ideal lettuce. We are now doing much the same, only faster and on a much smaller scale.

that, but they are really expensive and too large. They also have a heated nozzle that will kill the bacteria,' explains Basalo Vázquez. So they decided to make their own printer. 'One day Samantha came to the office and started building with K'NEX,' says Rodenburg. Basalo Vázquez explains: 'I had a lot of K'NEX growing up and I used to build cranes and cars with it. I had kept it all at my parents house.'

Eureka

This was the Eureka moment. 'You just need something that moves in three dimensions,' says Basalo Vázquez. 'The initial idea was to make a rotational printer with a nozzle that moves in circles. That makes a cylindrical biofilm of which we can print several layers on top of each other.' However, despite Basalo Vázquez bringing in all her K'NEX, the team did not have enough of the right parts. So another team member, Marit van der Does, went on national radio and asked for people to donate their K'NEX to science. The result was overwhelming. 'A lot of people came on the radio saying that they wanted to donate their K'NEX,' says Rodenburg. 'It was amazing how many people wanted to get involved in a project for the TU Delft,' adds Sangüesa Ferrer. In the end, they received far more then they needed; they plan to donate the surplus to charity.
Now they were all set to go to Boston, where the Jamboree started on 24 September. Every team had to hold a twenty minute presentation, and with 285 teams taking part, that alone took three days. 'Our turn came on the third day, so we had a lot of stress getting it perfect,' says Rodenburg, who held the presentation together with team member Max van 't Hof. 'The judges would score you on that, but also on your website, modelling and so on.' With no idea of their scores, they did not hold high hopes. 'We weren't even going to bring our official jackets.' They were finalists, however, meaning Rodenburg had to present again, this time in front of over 2,000 people. 'I was really calm that second time; by then I had practised about twenty times.' And to their great surprise, they won. 'It is such a large competition, we didn't even expect to be finalists,' says Basalo Vázquez.

Oscars

During the Oscar-like ceremony, they kept being called on stage. 'We won first prize, plus a few of the technical prizes that every team competes for: best Wiki, best applied design, and best hardware project. We had also been nominated in the categories. best modelling, best policy and practice, best DNA part, and best collection of parts.' It had been a huge effort, but in the end it was all worth it. 'The last week before the competition was hectic, we worked from 8 am to 1 am to finish everything,' says Rodenburg. 'The jamboree was a lot of work too,' adds Sangüesa Ferrer. 'We wanted to share our project with as many people as possible, not only the experts, but also students from around the world. That was very rewarding. I would recommend this experience to everyone.'
Back in Delft, they are continuing the project. 'We have recently successfully dissolved the hydrogel scaffold. For the competition we only had to prove that the hydrogel would stay in the required form,' says Rodenburg. 'We are also automating our printer, which now still works with three motors that you have to manoeuver manually. Then, we want to publish a paper on what we've accomplished.' This should ensure their promising work can be carried on in the future, when they have moved on to graduation and careers. Although the production of samples for reproducible tests were the main goal of their printer, other applications are not far away. 'In Boston, experts who came to see us also regarded this as a promising technology to make "good" biofilms, such as bacterial structures that can be used to produce pharmaceutical compounds,' says Sangüesa Ferrer.' Who knows? Synthetic biology is a field that has only just been discovered, so anything is possible.'

Michel van Eeten

Innovative by neccesity

Professor Michel van Eeten is chair of the Economics of Cybersecurity group at the Faculty of Technology, Policy and Management (TPM). Together with his colleague Dr Carlos Gañán, he set up an online course that attracted hundreds of professionals worldwide. 'Occasionally someone still comes up to me at an industry meeting and says "hey, I saw you on the course",' says van Eeten.

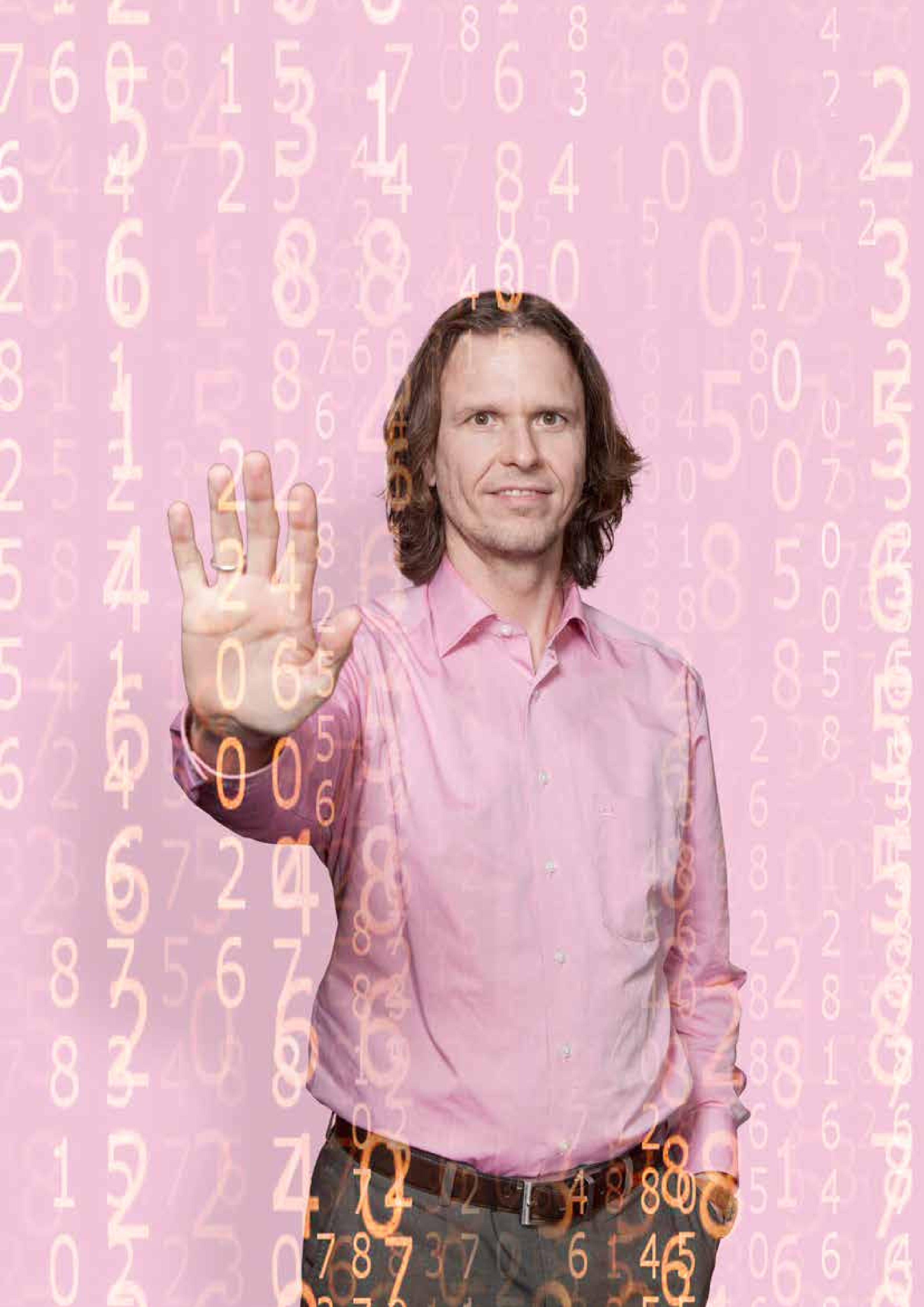
With more and more of our lives being conducted over the internet, cybersecurity is a key priority for organisations. Twenty years ago, however, cybersecurity meant little more than installing antivirus software on your computer. Hence, it is still a new academic field. 'Only now does TU Delft have a master programme in cybersecurity,' says Professor Michel van Eeten. 'With so few people trained in the field, most of them come at it from a different background.' Van Eeten himself has a background in Public Administration Theory. He became interested in cybersecurity some ten years ago. 'I first took a rather qualitative approach to the subject, looking at the companies' incentives and the policies involved.' A student with a background in computer science changed all that. Commissioned by the OECD, they undertook an empirical analysis of spam data to see what internet access providers could do about the spread of malware. To Van Eeten's surprise, this turned out to be a novel approach. 'Computer scientists had been collecting these large datasets with their technical tools, but nobody was really analysing the data from a policy and economics point of view.'

The resulting publication found wide appreciation. In the wake of that, Van Eeten was able to write a number of successful proposals for grants from Dutch and international funding agencies. This gave him the opportunity to expand his team, and what started as a single project has since grown to a group of twelve researchers. Carlos Gañán, who joins the conversation as co-organiser of the course, is one of them. 'What attracted me was the combination of economics and cybersecurity. Not many research teams in Europe are doing that,' he says. 'I was used to a more theoretical approach; here at TU Delft we are dealing hands-on with problems in society.' A unique approach also means unique knowledge, and Van Eeten and Gañán came up with the idea for an online course to share their knowledge with the rest of the world. Originally the plan was for a Massive Open Online Course (MOOC), open to everyone. From there the idea grew, and after joining forces with research teams from the UK, Germany and the US, it was decided to opt for a course for professionals instead. 'Cybersecurity is a cross-disciplinary field, so we aimed the course at professionals in the fields of economics, cyber security, psychology and computer science,' explains Gañán.

Of all ages

The eventual five-week course attracted around 400 professionals from all over the world, from very different backgrounds and of all ages. 'We had people from China to Africa, and from teenagers to octogenarians,' says Ganan. The lectures for different weeks were recorded by different partners in the project. At the start of the course, Professor Ross Anderson from Cambridge gave a brief history of the field and how it has evolved over the past fifteen years. 'He is really the founding father of this field within cybersecurity research.'

Van Eeten and Gañán's course topic was security metrics. 'Some companies still think the way to measure your cybersecurity is to count how many firewalls and other solutions you have installed. So they think that having more, or newer, firewalls means they are more secure,' explains Gañán. 'Bottom line is that there is no universal way of measuring how secure you are.' Therefore, they got their students to think about what is actually informative and what is not. 'We discussed what data sources are out there, and what you can learn from them. We also taught them how to make sense of numbers they are presented with and what they actually measure,' says Van Eeten. 'For example, that number of firewalls is probably saying something about the budget of the security department, and might also be something that vendors like to count, as they like to sell more of these controls.' They also discussed maturity models; a way for organisations to assess their methods and processes against a set of benchmarks. Van Eeten explains: 'The



About Michel van Eeten and Carlos Gañán

Professor Michel van Eeten studied Public Administration at Leiden University, and did a PhD in Public Management at TU Delft, where he has remained since. He was appointed full professor in 2009. With his team, he analyses large-scale Internet measurement and incident data to identify how the markets for Internet services deal with security risks. He has conducted policy studies for the ITU, the OECD, the European Commission and the Dutch government. He is also a member of the National Cyber Security Council.

Dr Carlos Gañán holds an MSc in Telecommunications and a PhD in Information Security from the Polytechnic University Catalonia (UPC) in Barcelona. He also holds a diploma in Business Studies and a degree in Administration and Business Management from the Open University of Catalonia. Before coming to Delft he was a member of the Information Security Group of the Department of Telematics Engineering at UPC. As a postdoctoral researcher at TU Delft, he researches the economics of information security and the impact of cybercrime.

idea is that you go through certain stages of development when dealing with cyber security. A maturity model describes your growth, from very simple counter measures like cleaning up infected machines, to having elaborate policies in place and highly trained staff.'

Another important topic was investment. 'Of course there are standard investment approaches,' says van Eeten, 'but these assume that you know all sorts of things about the business you are trying to tackle with your investment. That is often not the case with cybersecurity.' Unless you are dealing with incidents that occur very often, such as viruses. 'For such a standard problem you can estimate what the impact will be. That allows you to make reasonable investment models.' What often complicates matters is that you are facing a human opponent. 'Human opponents are hard to predict; there are some patterns, but they are not deterministic. And even if you can predict that a certain incident will occur, it is still difficult to gauge what the impact will be.' So rather than teaching their students how to estimate potential impact and necessary investments, they taught them to think about the subject conceptually. To this end, students had to use an investment model based on game theory. Gañán explains: 'They had to answer questions such as what are the relationships between the attacker and the defender, what are their respective resources, how do they interact, and what strategies does the defender take after the attack? This was a subject that needed some background, as most participants were unfamiliar with it.' What students were also unfamiliar with was the actual cost of investing in security. Van Eeten: 'That cost is typically more than buying new security solutions.

Hidden costs

It also involves training staff, and maybe the new security measures take more time on the side of users, meaning loss of productivity. That is why even if the specific tool that is supposed to fix the problem is not that expensive, companies are still not buying it. Most students had never thought about such hidden costs.'

In all 22 video lectures were produced. 'We also did live webinars in Google Hangouts, where we answered questions on the week's topic in real time,' says Gañán. Quizzes and additional resources completed the course material. 'Because of the heterogeneity of the participants, we could not assume anything in terms of prior knowledge,' adds Van Eeten. 'This game theory, for example, must have been really hard on some of the students. Luckily, there is a lot of material available on the internet, so we could tell them where to look if they did not understand the basics. Some participants were

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techies, who realised that just looking at the technology alone is not enough to approach some of these problems. They knew nothing about what markets are, or how incentives operate, or how firms make investment decisions.’ Others participants came from a consulting or economics background and had to be brought up to speed with the technological side of things. Gañán: ‘We even had lawyers taking part. Because of all these data breaches, there is a legislative side to the subject too.’
It was the first ProfEd course TU Delft has offered and Van Eeten was pleased with the overall level of the participants. ‘There was a lot of good discussion on the forum and people were answering each other’s questions with very thoughtful replies.’ Their dedication also showed in the final assignment. ‘We set no hard requirements for this, so regular students might have been tempted to take the minimalist approach. We wanted them to really think about what they had learned, and these people did that. They wrote well thought-out pieces on how they could apply their knowledge in their own business or for their customers.’ The course also helped participants build up a professional network. ‘We set up a dedicated LinkedIn group where they interact, even now after the course. All in all, it has been a success,’ concludes Gañán.

Part of that success lies in the practical approach Van Eeten and Gañán took to the subject. ‘Cybersecurity courses are normally very theoretical, telling you what the technologies are and how you design for them. The complexity of the real world never shows up. Then people leave school with a toolkit of approaches and find out that reality has moved on, or at the least is much messier,’ explains Van Eeten. ‘If you are a cryptographer you may be able to stay away from how cryptograpy functions in practical settings. But the work we do is all about the interaction between technology, economics, and law. We have to get into the messy empirical reality.’

Hosting market

On one such occasion, they were contacted by the Dutch police who were trying to clean up the hosting sector. ‘The Dutch hosting sector has traditionally been on the list of countries with the highest concentration of criminal activity in the world. This is in part because we have a lot of hosting companies and infrastructure, but it could also mean companies are getting paid for facilitating crime,’ says Van Eeten. Again they found that a new approach was needed. ‘We realised that nobody in the field had ever looked correctly at the hosting market.’ Gañán explains: ‘Everybody was using routing data to identify hosting companies. But routing data only shows you how traffic on the internet is handled, not who is responsible for the machines generating that traffic. That is more accurately captured via WHOIS data, a database that registers who owns what IP addresses.’ This led to the first ever accurate map of the hosting sector, but the story did not end there. ‘To our surprise, the public prosecutor sent out letters to the ten most polluted hosting companies that we identified,’ says Van Eeten.
This led to interesting discussions in the sector. ‘Companies on the list contacted us to find out why they were on it and we explained how our metrics were developed. They are now organising themselves to clean up the sector; our report has really contributed to that momentum.’ Their findings also have scientific value. ‘This is sensitive information which will not be made public. However, we published our methodology and now other countries can copy our approach.’ All cutting-edge work, according to Van Eeten. ‘It is not the kind of mature research that is being put into practice after years of academic work. We still have to solve a lot of fundamental questions, so most of our innovation is done by sheer necessity. I enjoy that tremendously, figuring out what the world really looks like.’

Delft University of Technology

T: +31 (0)15 27 89111
E: info@tudelft.nl
www.tudelft.nl

Postal address:
P.O. Box 5
2600 AA Delft
The Netherlands