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Research and education at Delft University of Technology

Delft Outlook

Ruling the microbes

Rational design of biotechnological processes

Mathematics for soccer coaches • **Fine dust on Mars**

Moonlight for Cambodia • Magnetically cooled wine • **Frosty gripper**

Contents

DO 2008.4

22

28

Delft Outlook

[Edit]DO

Young versus old. Prior to the 1960s, at TU Delft as elsewhere, differences in age and status often precluded normal social interaction between teachers and students, as you can read about in ‘Looking back’. ’Normal’, that is, according to the egalitarian conventions of 2008. Old-style professors didn’t think twice about marking student drawings with indelible pencils, even if that meant the students then had to work through the night redoing their drawings. Professors wouldn’t speak to stewards, and they had to have their own bicycle racks. How different things are today. In ‘Mastermind’ you will discover just how deep the admiration between students and teachers can be, and how much they can learn from each other, without necessarily dodging conflict. It’s the result that counts, not the most prestigious title.
Today students no longer have to stand up when a professor enters the room. No, they can start contributing to research even as students. In ‘Focus’, meet a group of students working on a project that involves designing the DNA that will turn bacteria into miniature biological thermometers. These students are already contributing to a world-wide DNA database, called BioBricks.

Saskia Bonger
Interim Editor-in-Chief

COLOPHON

cover photo
Photo: Sam Rentmeester/fmax

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Photo: Sam Rentmeester/fmax

A roof for Bouwkunde

Having spent the last six months camping out in tents and at other faculties, the students and staff of the Faculty of Architecture ('Bouwkunde') are gradually moving into their own accommodation, even if it's only temporary.

The faculty departments are currently moving one by one into the university's former main administration building on the Julianalaan. A month after the original faculty building had been destroyed by fire, Architecture faculty dean Wytze Patijn said about the temporary accommodation: "We'll make it so good that in five years' time nobody will want to leave". In the meantime the building has undergone a total metamorphosis: the old narrow corridors and scores of separate rooms have been transformed into bright and airy open spaces, enhanced by rows of high windows and 'work islands' separated only by low storage units.
Staff no longer have their own desks, and instead use flexible workplaces with limited personal storage space. Although some people were none too pleased in the beginning, most can now see the advantage having an uncluttered desk and contact with hitherto unknown colleagues. Those who want peace and quiet can retire to special quiet rooms, furnished with floral carpeting. On the ground floor is the 'Bouwkunde Street', which consists of a wooden facade behind which are housed the Waltman bookshop, Stylos (the Bouwkunde society), ICT support and an espresso bar offering eco-friendly coffee. The top floor is for first-year student, where hundreds of students can work in groups on models and portfolios. The open space means that everyone can see what other people are making.
For those who want to keep the memory of the burnt-down faculty building alive for a while yet, there is the 'Herbouwkunde' ('Rebuilding Bouwkunde') initiative. Former Bouwkunde architecture students Barend Jan Schrieken and Saskia Knoop asked people write down their memories of the old building. The result has just been presented in the form of a parcel containing letters from famous and not-so-famous architects and structural engineers.

More information:
www.herbouwkunde.nl.

IN•BRIEF

Moonlight for Cambodia

At the Design Week event in Eindhoven, four industrial design students received the Toon van Tuijl Design Award for their MoonLight solar-powered lamp. The students designed the lamp on location in Cambodia, together with the people who will be using it to light their houses. Cambodians in remote areas still depend on dirty, dangerous, and relatively expensive kerosine lamps. Soon, fifteen to twenty dollars will buy them a six-LED MoonLight.
The lamp will 'burn' for 2.5 hours, or four hours at reduced power, before it needs to be recharged. Manufacturer Kamworks expects to start producing the lamp sometime in the spring of 2009.

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Photo: Doortje van de Wouw

RID radioisotopes quicken cancer tests

A new technique developed at TU Delft could prevent the worldwide shortage of radioisotopes available for cancer tests, according to Professor Dr. Bert Wolterbeek of the Reactor Institute Delft (RID).

Hospitals regularly face shortages of radioisotopes, meaning that patients must wait longer for cancer tests. Only a handful of the world's reactors make the isotope technetium-99m that is used to scan some 40 million patients each year. The main technetium-99m supplier for Europe is the Dutch reactor at Petten.
The current production process requires enriched uranium; however, enriching uranium requires a special license under the non-proliferation treaties currently in place. Professor Dr Bert Wolterbeek is developing a method to make the technetium isotope without using uranium.
If his experiments prove to be suitable for industrial application, many more production plants will be able to make this vital material.

"The current method of making technetium-99m is to split highly enriched uranium," Wolterbeek explains. "One of the resulting products is the radioactive molybdenum-99, which forms the basis for technetium-99m."
However, molybdenum-99 can also be formed from molybdenum-98, a naturally occurring stable isotope of molybdenum. Wolterbeek has patented a technique that involves bombarding the base material with neutrons to turn it into molybdenum-99. Not only are the molybdenum atoms 'activated' by the colliding neutrons, but the energy transferred in the process also releases them from the surrounding atoms. This means that the resulting molybdenum-99 dissolves in water, allowing the isotope to be extracted in high concentrations.
In collaboration with the Urenco enriching plant, Wolterbeek will look for ways to scale up this process.

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IN·BRIEF

Heating experiment

Physicists at the department of multi-scale physics are turning the heating system in their new offices into an experiment. They will install a new type of heat exchanger devised by TU Delft alumnus Noor van Andel.

Earlier this year the first piles were driven in for the new office building located behind the Faculty of Mechanical, Maritime and Materials Engineering. After completion – scheduled for summer 2009 – the building's rooms will be without air conditioning units or radiators. Instead, a room's temperature will be controlled by discs suspended from the ceiling.
This new type of heat exchanger is called FiWiHex, or Fine Wire Heat Exchanger. The name stems from the thin copper wires running around the outer edge of the disc. These hollow wires have water flowing through them. "The system can heat or cool a room even if the water temperature is only five degrees above or below the ambient temperature," says Eur van Andel of the FiWiHex company.
The discs will be installed in every room, and the occupants will control the room's temperature by adjusting the speed of the fan inside the disc.

"We wanted to include a special sustainability feature in the new building," says André Groenhof, secretary of the multi-scale physics department. "We opted for an invention by an alumnus of our own department, Noor van Andel." Heat pumps use the higher and lower temperatures in groundwater to adjust the temperature of the water inside the FiWiHex to the required level. The system saves a lot of energy, Groenhof states.

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Photo: Andre Groenhof

Close up of water-circulating wires

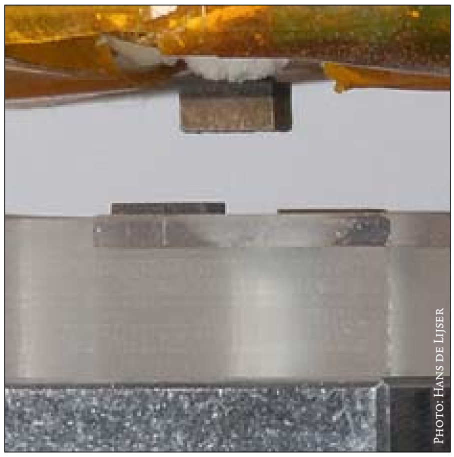
Photo: Hans de Lijser

Frosty freezing gripper

A micro-sized components gripper that uses the freezing principle has been developed at the Faculty of Mechanical, Maritime & Materials Engineering (3mE). This gripper can freeze onto components and release them in about one second.

As products get smaller and smaller, the demand for tiny grippers grows, precision mechanics researcher Defeng Lang has found. Miniaturisation is an industrial trend in the electronics and mechanical engineering fields, and in the chemical and biochemical industries. Handling components that vary in size from a few millimetres to a fraction of a millimetre requires special grippers, simply because standard-sized grippers are too large and unwieldy.
In his doctoral thesis 'A Study on Micro-gripping Technologies', Lang (33) lists the most commonly used gripping principles: friction, vacuum, electrostatic attraction, surface tension, and freezing. At 3mE, Lang developed a gripping system that uses the freezing principle.
A flat thermoelectric cooling element the size of a credit card plays a key role in Lang's system. The element's hot side is in contact with a cooling reservoir with a temperature of minus 10°C. The cold side has been fitted with a copper plate that ends in a pointed tip. This tip acts as the gripper. When the cooling element is activated, the temperature at the tip drops to 30°C below zero within a few seconds. A droplet of water ensures that any small components the tip touches freeze onto it in an instant.
The speed and strength of the ice gripper depends on the material to be picked up. Metals and other good conductors of heat require a lower tip temperature than plastics. Plastic parts also become attached quicker (in less than half a second), while metals, at 1 newton per square millimetre, are gripped more firmly than plastics (0.5 N/mm²).

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Space sickness alert

The 'Ockels hypothesis' appears to be correct, according to the results of research conducted by medical biologist Dr Eric Groen at TNO.
In 1990, Professor Dr Wubbo Ockels (Aerospace Engineering) proposed that the transition from three times normal gravity to normal gravity feels the same as the transition from the Earth's gravity to weightlessness in space. He discovered this after an hour's spin in a Royal Netherlands Air Force centrifuge with an acceleration rate of three times normal gravity pressing down on his chest. Once he had both feet back on the ground again, Ockels found that the world appeared to be dancing before his eyes when he moved his head - an unpleasant experience that was surprisingly similar to space sickness, or so Ockels, Holland's first astronaut, thought.
About half of the astronauts leaving Earth suffer from space sickness. The transition to weightlessness affects their powers of orientation, which can leave them feeling seriously ill for two or three days. No test has yet been devised that is capable of determining in advance which astronauts will suffer from space sickness, but if Ockels' hypothesis is correct, an hour in the centrifuge will be enough to spot potential sufferers. And his hypothesis does appear to be correct. Groen: "We've tested fourteen astronauts, and those who suffered from sickness in space were also affected during the test."

Photo: TNO Human Interfaces

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Photo: Sam Rentmeester/FMAX

Stunning suspended space

An open, inviting space that shoots upwards, is how industrial design student Jaap Breeuwer describes the new exposition stand he and fellow student, Jort Nijhuis, designed for TU Delft. The size of this suspended structure can be adjusted as needed, and the stand uses brightly coloured lights to attract people from far away. The area below the stand is open and guides visitors to a two-metre wide screen showing videos of successful TU Delft student projects, like Nuna and Formula Zero racing. Beneath the screen is a pantry and table with slots for promotional folders. TU Delft has already used this eight-metre high colossus at the University Fair in Utrecht.

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Photo: Jort Nijhuis

Winning soccer model

Dutch national soccer coaches may be getting some support from an unexpected quarter. Dr Almerima Jakamovic and Dr Rob Kooij of the Faculty of Electrical Engineering, Mathematics & Computer Science have developed a computer model for soccer players, which allows soccer coaches to see how often players have played together during international matches and what the results were. In other words, how good was a certain combination of players? "Statistically speaking, that is," says Kooij, himself a forward on his second employer TNO's amateur soccer team
"I had some students enter the line-ups of all the Dutch international teams in a matrix," he explains. "We're talking about 700 players, starting with Holland's first international match in 1905 against Belgium." In her doctoral thesis, Jamakovic reduced various complex networks, including the Internet, friendships and proteins, to mathematical formulas, which she also applied to soccer teams.
Kooij intends to discuss possible applications of this model with the Dutch Soccer Association: "Visualising the networks of other national teams wouldn't be too difficult either."

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IN•BRIEF

Magnetically cooled wine

The first magnetic refrigerator could be on the market in 2012, with an internal mechanism that will be much cleaner and energy-friendly than the noxious gases currently used to cool refrigerators and air conditioning units, says Professor Dr Ekkes Brück of the Fundamental Aspects of Materials and Energy group at the Faculty of Applied Physics.

Cooling systems using a magnetic field and magnetocaloric material have been around since 1933. And while these systems are used in laboratories, so far they haven't made it into our kitchens. "We're currently looking for a magnetocaloric material that would allow us to devise a cooling system for higher temperatures than those commonly found in a laboratory. Temperatures between minus 20°C and plus 20°C," Brück says. The material must be able to cool sufficiently while only making slight alterations to the magnetic field strength, and the material must also be cheap and in plentiful supply on our planet.

Other researchers are working on magnetic refrigerators using the chemical element gadolinium. This approach works, but it makes the equipment four times as expensive. Some years ago, Brück discovered an alloy of manganese, iron, phosphorous and arsenic that looked promising. The breakthrough earned him a publication in the science journal Nature, and he is currently investigating the crystal structures of his alloy, as well as the effect the granule size of the various particles has on the cooling properties. The chemical company BASF is now trying to find ways of producing the material in large quantities. "To begin with the cooling system will be a little more expensive, but that needn't be a problem for a luxury good," Brück says. He thinks his cooling system will initially be used in wine cooling cabinets. "Normal refrigerators vibrate, which is bad for the wine. A magnetic cooling system doesn't have that problem."

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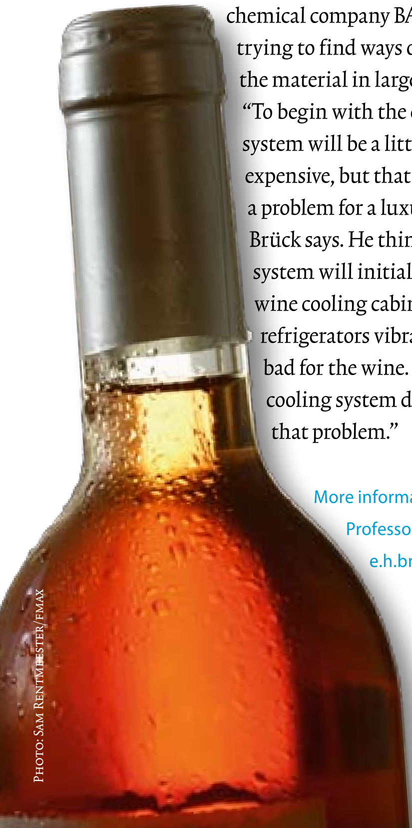

In Sir Fleming's footsteps

The DNA sequence of the penicillin fungus was published last September in the scientific journal Nature Biotechnology. Professor Dr Jack Pronk and lecturer Dr Jean Marc Daran supervised TU Delft's historic contribution.

Although DSM started the research four years ago with partners from the United States, Spain, Germany and the Netherlands, the research results were published in September, the same month eighty years ago in which Sir Alexander Fleming famously discovered the antibiotic properties of a fungus, Penicillium chrysogenum. Researchers had previously determined the DNA sequences of two microbiological workhorses: baker's yeast and Aspergillus niger. Unravelling the DNA sequence for the penicillin genome however represents "a stepping stone for the research," Professor Pronk says.

In terms of genetic complexity, the penicillin fungus' fourteen thousand genes place it somewhere between a yeast cell (six thousand genes) and a human being (thirty thousand genes). More surprising than the extent of the genome are the patterns the researchers discovered in it. Pronk: "Now that the genome is known, you can see changes throughout the cell's network that resulted in improved production."

Pronk says that knowing the DNA sequence offers new opportunities for creating variations of penicillin: "These used to be part of a separate chemical process. But thanks to the knowledge we now have of the genome, we can use synthetic biology to produce these substances more quickly and cleanly using the organism itself."

The mold *Penicillium chrysogenum*.

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Fine dust on Mars

When the Phoenix Mars Mission successfully completed a soft landing on the north pole of Mars last August, TU Delft's Professor Dr Urs Staufer was on hand to witness the occasion at NASA's Jet Propulsion Laboratory in Pasadena, California. Professor Staufer, of the Faculty of Mechanical, Maritime and Materials Engineering's precision and microsystems engineering department, had earned his invite by supplying a remote-controlled atomic force microscope, which was built under his supervision at the University of Neuchâtel in Switzerland.

This microscope, which uses a sharp probe to scan objects and produces three-dimensional images of unprecedented resolution, was built into the Phoenix Mars Lander and used on Mars to examine the fine dust particles that play a role in forming the red dust cloud that envelops the planet.

Dr Tom Pike, of Imperial College London, supplied the silicon dish containing a pattern of wells that kept the dust particles in place during the scanning process. The first Mars dust image revealed a clay particle measuring one micrometre (1/1000 of a millimetre) in diameter in the top left well. The particle's dimensions match predictions that were made based on the colour of the sunset on the Red Planet.

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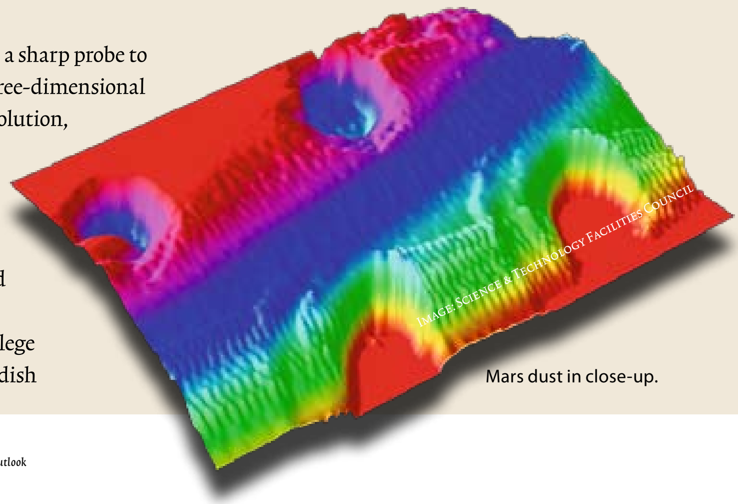

Mars dust in close-up.

Rationalisation – a biotechnology mantra

For the production of pharmaceuticals, food, plastics and fuel, industry is increasingly turning to organic raw materials. Unlike the chemical industry, biotechnology remains the domain of traditional skills and experience, imperfectly understood living cells and a veritable mountain of unwanted by-products. Ambitious new research at TU Delft aims to lay the foundations for the rational design of biotechnological processes.

Jos Wassink

The test setup at the Kluyver Laboratory on the Julianalaan is miniscule. The clear plastic frame is as small as a credit card and has two small dimples, or wells, on its short edge. These wells are sealed with a cover that has two very fine tubes inserted into it. Oxygen is fed into the setup through one tube, while carbon dioxide is removed through the other. A magnifying glass reveals a tiny stirring rod suspended from a shaft, and a microchip below each of the wells.

According to professor of bioseparation technology Dr Luuk van der Wielen, miniature fermentation vessels like this one have a great future in store for them. “Industry can’t wait to get their hands on them,” he says. “They can be used to screen micro-organisms for suitability of purpose, but they can also help determine the best operating conditions for a catalyst. In both cases, you want to look at sets of different micro-organisms. These systems offer the advantage of smaller volumes, which allows you to look at large numbers in parallel.” The micro-organisms may include yeast cells, bacteria, fungi or animal cells, depending on the required product.

Miniaturisation, parallellisation and rationalisation are the mantras driving biotechnological processes research at TU Delft, which is being conducted in collaboration with industrial partners DSM, Shell, AKZO Nobel, Organon (now Schering Plough), and instrument makers Applikon. The dream is to achieve fully controlled biotechnological processes with optimum yield.

Van der Wielen, a sturdy, wavy haired man wearing steel-rimmed spectacles, calls the development “a shift from empiricism to control”. The driving force is the quest for efficiency. “Cost-cutting sounds so humdrum,” he says, “but it’s important, especially when we’re talking about bulk quantities or biofuels that mustn’t cost more than a few cents per kilo.” It’s not only about money, though. The environment also counts. Anything that is not converted into an end product represents a loss of raw materials and energy. Although the differences can be measured in low percentages, they represent enormous amounts of material or energy when bulk quantities are involved. “Both routes are important,” the professor stresses, “sustainability and economic competitiveness.”

Two droplets

Dr Michiel van Leeuwen recently received his doctorate for developing a microbioreactor that has a capacity of 100 microlitres – a volume amounting to two or three droplets. He now works for Centocor, a biopharmaceutical company in Leiden. We meet in a lively yet loud sandwich shop, where the young doctor, fresh from defending his thesis this past summer and sporting a close-cropped beard and twinkle in his eyes, sits stirring his coffee before remarking: “This would be hard to do in a microreactor.” Stirring such minute volumes of liquid is difficult, because the surface tension holds the fluid together. You could shake the liquid as you would shake a flask, but there’s not much point to doing this on the microscale. Not only would you have to shake extremely hard to achieve any effect at all, but such vigorous shaking could also very easily spell disaster for all the tiny wires and tubes connected to the microreactor. “All you see is that tiny vessel,” Van Leeuwen jokes. “Nobody tells you that there’s a whole table full of equipment next to it.”

Van Leeuwen received his doctorate on 11 June, under the supervision of Dr Sef Heijnen, professor of bioprocess technology (Applied Physics), for his thesis ‘Development of a bioreactor with integrated on-line sensing for batch and fed-batch cultivator on a 100 μL-scale’. Having put yeast cells to work inside the tiny reactor, he then checked to what extent ▸▸

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Photo's: Sam Rentmeester/FMAX

the behaviour of the organisms matched that of yeast in a standard 4-litre fermenter.
Even before taking a sip of his cappuccino, Van Leeuwen mentions two other doctoral students whose work underpins his own: Dr Xiaonon Li built the microbioreactor, and Dr Erik Krommenhoek (University of Twente) provided the integrated measuring chip.
The microbioreactor is a small dimple in a plastic carrier that can hold 96 of these wells. Van Leeuwen used two adjacent wells, but in principle there is no reason why a single carrier couldn't contain nearly one hundred microbioreactors, thus making it possible to compare various strains of yeast cells in competition with each other under operational conditions. Strains are commonly selected on the basis of their growth rate in a Petri dish, but does this also make them the most productive in an

'You're there waiting ten hours for this one drop to go through, then you can go home'

industrial reactor? A carrier holding a large number of microbioreactors would enable researchers to compare the performance of dozens or even hundreds of different strains.
Matters have not progressed that far yet, however, because the microbioreactor is still very much a prototype. At the bottom of the well sits a multifunctional chip that measures the solution's acidity (pH level), temperature, concentration of active yeast cells and oxygen level. In addition, the microchip contains a heating element, all on a surface measuring only seven by seven millimetres. A small shaft drives a magnetic stirring rod, and the whole assembly is sealed with a cover with connections for the nutrient (a sugar solution), oxygen and carbon dioxide.
The reactor worked, and Van Leeuwen was indeed able to demonstrate that yeast cells in the microbioreactor behave in virtually the same way as those in a 4-litre fermenter. In other words, yeast cells can be tested perfectly well on a submillilitre scale. Some challenges still remain, of course. The sensor for instance turns out to be affected by pollution. Special coatings may help to solve this problem. Another problem is the great difficulty in establishing a controlled feed at a rate of one microlitre per hour. Van Leeuwen: "You're there waiting ten hours for this one drop to go through, then you can go home."
Although carriers holding dozens or hundreds of fully equipped microbioreactors aren't commercially available yet, industry cannot wait to get its hands on one, says Professor Van der Wielen. The technology would enable industry to rapidly select the most productive strains and then optimise the production conditions by slightly varying the temperature and acidity for each reactor. If that happened, then all you would have to do is sit back and watch the creatures do their stuff.

Continuous process

The chemical industry prefers fully continuous process operations, but biotechnological processes do not lend themselves well to this. A patent application by biotechnologist Dr María Cuéllar Soares however may change all that. Biotechnological production processes usually always work in batch mode, using and producing set quantities in succession. This is owing in part to tradition, Cuéllar Soares explains. Nonetheless, a continuous process nearly always turns out to be cheaper. It's hardly surprising then that right from the start, industrial partners like DSM and Organon were involved in the Columbian process designer's doctoral research, which is partly funded by the STW technology foundation and the Dutch organisation for scientific research, NWO.
TU Delft alumnus Dr Emile van de Sandt, the downstream processing competence manager at DSM who supervised Cuéllar Soares' research, believes the best motivation for the research is preventing 'product inhibition'. "We can train the creatures to the point where they produce more of the required product," Van de Sandt says, "but the higher concentrations induce inhibition [due to the creatures poisoning themselves, as it were, *ed.*], thus halting production. If you can find a way to remove the product from the solution during fermentation, the concentration will remain low and the organisms will keep on producing."
Van der Wielen calls it in-situ product recovery. He, together with Professor Heijnen and Dr Adrie Straathof, approved Cuéllar Soares' thesis, 'Towards the integration of fermentation and crystallisation'. The process that is the subject of the patent application handles the recovery in a number of separate steps. The setup consists of a closed system of two connected vessels. Inside the fermenter, bacteria produce phenylalanine, an amino acid that incidentally is also used in the production of the sweetener aspartame, but in this case the interest is in the process, not the product. The mixture leaves the fermenter through a microfilter, which keeps the bacteria inside. In the next step, water is extracted by pumping the mixture through a semi-permeable membrane. In a second vessel, favourable conditions cause the amino acids to crystallise, after which the remainder flows back to serve as nutrient for the bacteria. ▸▸

TU alumnus Dr Emile van de Sandt: "It remains a complex process."

[Back]GROUND

Biotechnologist Dr Maria Cuellar Soares: "Biotechnology production processes usually always work in batch mode."

At least that's how things should work in an ideal world. One of the chemicals involved, phenylalanine, turns out to be rather critical as far as crystallisation goes. To begin with, phenylalanine produces two types of crystals: one needle-like and one flat. The flat form is the most suitable for extraction, but to produce it, crystallisation must take place within very narrow concentration and temperature ranges (between 37°C and 50°C).

As if that weren't complicated enough, contamination adds to the difficulties, prohibiting the preferred crystals from forming, despite the accurately maintained temperature and concentration levels. Any one of the components in this mixture of nutrients and by-products could be the culprit disrupting the crystallisation process. Further research will have to reveal which of them is responsible.

Despite taking part in the patent, DSM has reservations about the continuous process. Van de Sandt says that long-term tests with pilot plants will be needed to verify the reliability of the process. On top of that, there is an increased risk of contaminating the micro-organisms, due to the nutrient medium being fed back into the fermenter.

Van der Wielen expects continuous production to be of particular interest for the bulk production of bioplastics and biofuels, as it could help lower costs. He believes the pharmaceutical industry will be less keen however, owing to its long experience with batch production methods and the industry's high standards for purity.

Pure, but simple?

"The production of proteins is no longer a problem," says TU Delft alumnus Dr Tangir Ahamed, "but the concentration tends to be low (typically 0.1 milligrams per millilitre) and the solution contains lots of other proteins that look just like the one you want. What's more, the biomolecules can be slightly unstable." Extracting and purifying (medicinal) proteins is today's big challenge, says Ahamed, smiling brightly. He originally comes from Bangladesh and now works for the biopharmaceutical company SynCo Biopartners. In professional circles, the extraction of products is known as downstream processing. As an example of pharmaceutical proteins, Ahamed mentions the manufacture of monoclonal antibodies. These are proteins that attach themselves to specific cells, offering new prospects for the treatment of cancer, rheumatoid arthritis and numerous other diseases. Ahamed's thesis, 'High Throughput Technologies for Bioseparation Process Development', argues that protein separation technology is still being developed along very traditional lines, based on experience and trial and error methods. "They simply go by gut feeling in choosing one of the options, and then wait to see what happens," Ahamed says. Consequently, developing a biotechnological separation process takes a long time and rarely yields optimum results. "There is still no general strategy for purifying molecules produced in biotechnological processes," his thesis states. Ahamed and his supervisors, Dr Marcel Ottens and Professor Van der Wielen, intend to change all this. What Ahamed proposes boils down to rationalising the purification process: the research will no longer be based on experience, rules of thumb and trial and error, but rather on the biochemical analysis of all the elements floating around in the mixture.

'Cost-cutting sounds so humdrum, but it's important, especially when we're talking about bulk quantities'

"We're being very ambitious," replies Van de Sandt, of DSM, when asked. "What Ahamed proposes is almost a pipe dream. You have a fermentation jar and then you sample its contents using a high-throughput device [which can automatically perform many parallel tests, *ed.*]. The device then analyses the composition of the mixture, looks at the properties of the components and uses the results to develop

the ultimate purification process. This is what it amounts to in the end."
Ahamed intends to forge a link between the properties of the fermentation mix and the range of available separation techniques. He characterises the properties of the mixture using eight to ten parameters. "A bioreactor contains lots of proteins, and we want only one of those," he says. "I measure the concentration, size and identity of the various proteins. After about two weeks I will have collected all the values I need for a complete characterisation. Based on that, my computer model can find the best separation process. Two weeks may sound like a long time, but in today's pharmaceutical industry the process usually takes a year."
Van de Sandt again: "As you get to know more about the composition of your mixture, you can use this knowledge to decide things like which pH [acidity, *ed.*] to choose, and which binding resin and which conductivity for binding your main component and keeping the rest of the process going. That's the idea, but it's still one hell of a complicated process."

Miniaturisation, parallellisation, and rationalisation. Are these just academic pursuits, or will this new biotechnology catch on in industry?
Van der Wielen expects that as industry increasingly turns to organic raw materials, it will become more interested in making biotechnological production processes as efficient as possible. The university is sometimes far ahead of the pack with its explorative research, such as genetics research on micro-organisms, the development of a microbiochip for studying all the 'ins and outs' of the organisms, and the development of advanced microscopic techniques. Ahamed has no doubt in his mind that commercial laboratories will buy systems containing microbioreactors attached to fast biochemical analysis equipment to improve their processes. He estimates that systems like these will be on the market in about five years' time. The first components are already available, including a chromatography microchip that can be used for determining a protein's weight. The rest is bound to follow.
DSM's Van de Sandt is more circumspect. "I can't see it happening for a few years yet," he says. Nonetheless, certain techniques developed by Ahamed are being tested by DSM. "I think that miniaturisation and parallellisation are of prime importance to the industry," Van de Sandt says, "but the new methods must offer benefits in terms of time when compared with traditional process development methods." Which of course hits the nail squarely on the head.
◂◂

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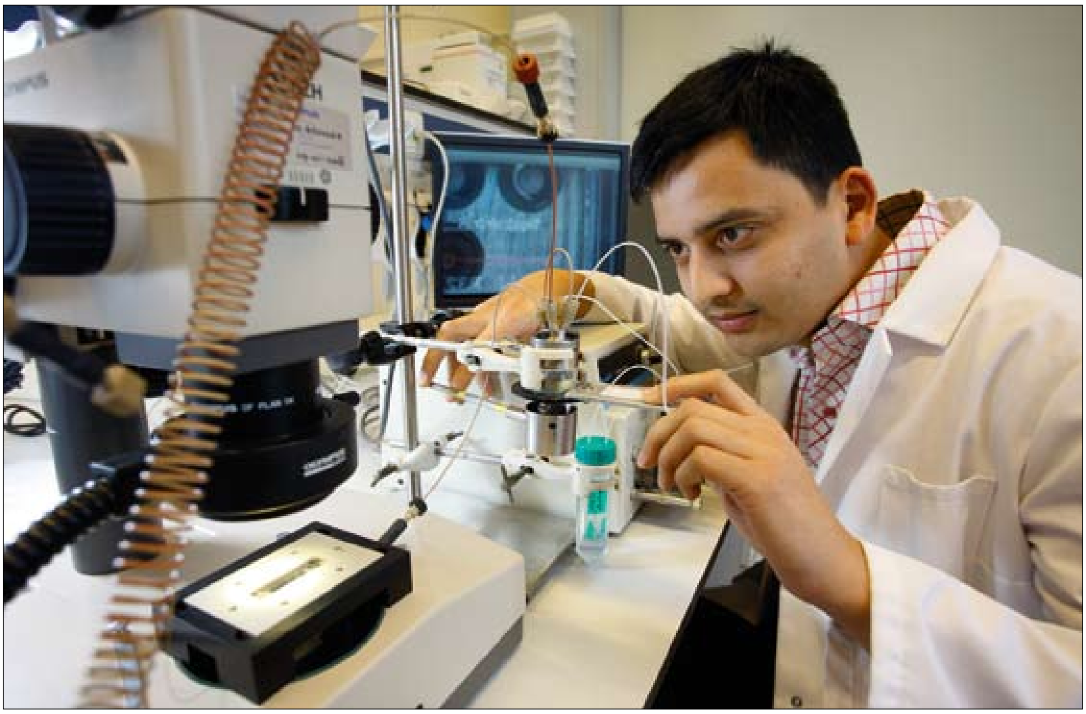

Researcher Kader Deshpande allows fluid to flow through a chip.

Students design DNA for thermometer bacteria

Building bacteria

Six students at the Kluyver Laboratory have designed the DNA that will turn bacteria into miniature biological thermometers. This month they will present their results at the Massachusetts Institute of Technology (MIT).

Maaike Muller

"This place is a bit like a big kitchen," says 23-year old life science and technology student Oscar Stassen. On the way to his test setup he passes three fridges and a microwave oven. On one machine, some sort of planter filled with ice is vigorously shaking. Stassen arranges the wads of tissue paper that prevent the ice from smashing the test tubes. The shaking motion aerates the bacteria inside the test tubes. Without the air they wouldn't survive. Although Stassen has no qualms about hurting or freezing bacteria, he intends to keep this particular batch alive for a while yet. These bacteria still must show whether they have turned out right, which will be the case if they impart the right signal at 27°C.

Together with five fellow students, Stassen designed a section of DNA that is to turn a common or garden species of bacteria, Escherichia coli (E. coli, which occurs naturally in the large intestine of mammals), into a miniature biological thermometer. The idea was to create bacteria that will turn red if their ambient temperature exceeds a certain limit. The students designed the DNA for three different temperatures. One thermometer is for 27°C, one for 32°C and one for 37°C.

Biothermometers can for example be useful for monitoring the temperature in a reactor vessel. It is difficult to maintain a constant temperature throughout the entire volume of large vessels, but doing so is crucial for the quality of the end product - take the omega fatty acids used in butter for example.

It is no problem for Oscar Strassen to destroy or freeze the bacteria.

The six TU Delft students – together with a student team from the University of Groningen – will be the first Dutch contestants in the iGEM (international Genetically Engineered Machine) competition. This is an annual competition organised by MIT in Boston. During the competition, the students will tinker with DNA, the object being to enable engineers to construct organisms that can perform a specific task, like indicating temperature, signalling the presence of cyanide or producing a biofuel.

BioBricks

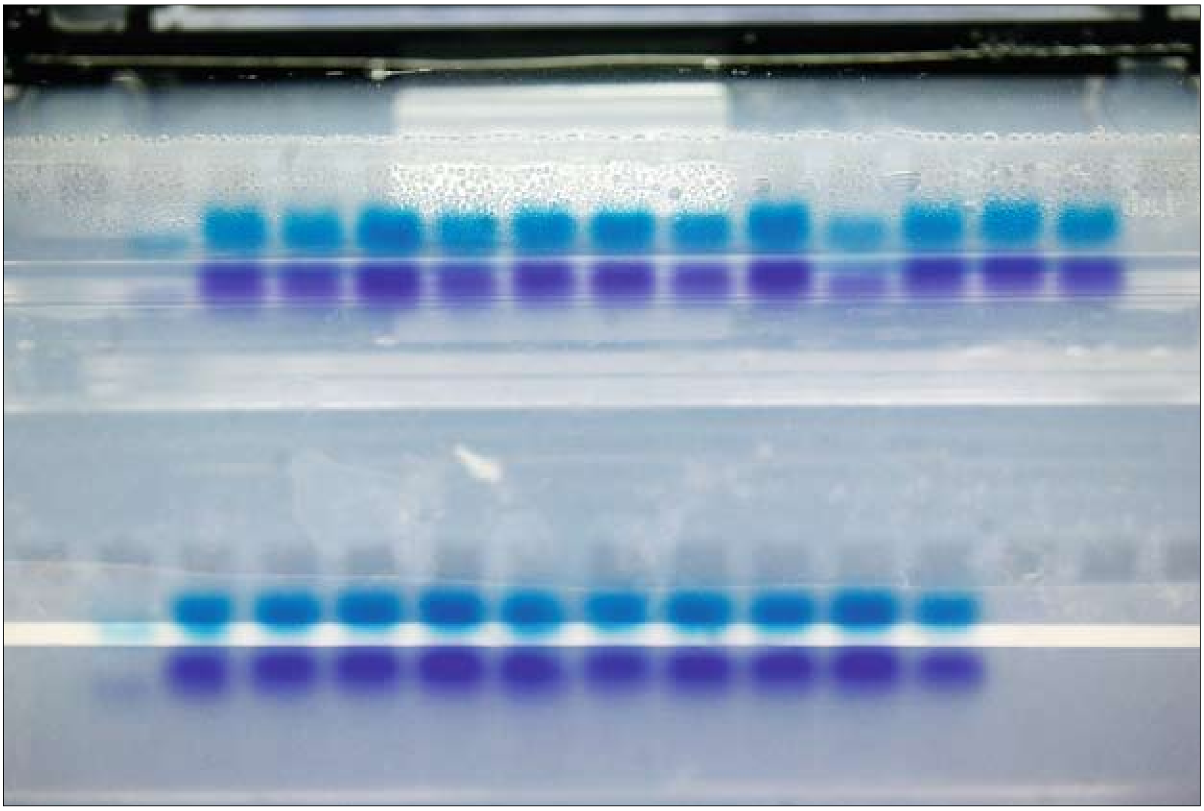
The iGEM organisers hope to create something that can best be described as a large public library containing standard pieces of DNA - or BioBricks. "The idea is that in the long term, BioBricks from the library can be used to compose the DNA for bacteria that will do exactly what you want. You will be building miniature factories, in fact," says student supervisor Domenico Bellomo (Applied Physics and Electrical Engineering, Mathematics, and Informatics). Researchers at MIT wanted to save manufacturers and others working with bacteria from the vagaries of nature. "But we haven't reached that point just yet," Bellomo adds. "Biological systems are very complex."

In May, a ring binder arrived at the Kluyver Lab, full of sheets of paper with yellow dots all over them. The yellow dots contain plasmides, the bits of genetic material that hold the existing BioBricks. They are the starting point for a miniature factory. But what would Stassen and his fellow team members make their BioBricks do? The brainstorm sessions produced all sorts of wild ideas, including probiotics capable of making dog turds light up. The students finally decided however to design BioBricks that would turn bacteria red when they got too hot.

This turned out to be an ambitious target. Too ambitious in fact given the few months they had to do it in, says life science and technology student Ruud Jorna (25), while deftly filling the wells in a clear plastic tray with liquid, his thumb still aching from wielding the pipette for days on end. "We'd be very happy just to be able to prove that the principle is viable," he admits.

The students' first target was to create bacteria that would produce an enzyme, luciferase, at a certain temperature. Not quite as much as a firefly, which brightly lights up in the dark, but enough to become visible with the use of a little extra equipment.

Before starting to design your own bacteria, it's best to look around to see what Mother Nature has to offer in the



The house, garden and kitchen bacteria Escherichia coli (E. coli) becomes a mini-thermometer when containing a DNA strand put there by TU Delft's iGEM team. If this is successful, the students see a striped pattern in the small dish containing gel and the DNA

way of DNA sequences. For the 37°C thermometer, a section of DNA from Salmonella bacteria had to be only slightly adapted to be ready for use as a BioBrick. For the 27°C and 32°C thermometers, bioinformatics student Bas van den Berg (26) had to do a lot more designing. The team had the building bricks produced commercially, after which the

Biothermometers can for example be useful for monitoring the temperature in a reactor vessel

students joined up the DNA with the iGEM building bricks, which involved long, painstaking hours of laboratory work. Jorna picks up a plastic dish with dots on it. He points out one of dots, the size of a pinhead. This is a colony of bacteria that he knows has incorporated BioBrick for the 27°C degree thermometer. To achieve this, the students had to knock the bacteria around a bit. “If you heat bacteria to the point where they almost die, as a kind of survival strategy they will incorporate all the DNA around them, on the off chance that something in there might help save them.” They used this same trick to create colonies that signal temperatures of 32°C and 37°C degrees – or at least, in theory they do.

To find out whether the process had worked, Stassen again donned his white coat and headed back to the laboratory. The plan now was to break up the bacteria they had gone to such lengths to produce, and then freeze them in order to discover how much luciferase they contained. The problem was that breaking up the bacteria, while keeping the luciferase intact, is a very tricky process. And this is why the students were unable to discover whether the 27°C thermometer worked.

“It was frustrating, because a lot of our work went down the drain,” Jorna says, “but the ones for 32°C and 37°C appear to work, so we’re now focusing on those.” Although they were unable to produce thermometer bacteria that turned red, Jorna considers the project a success. “It’s a pity, but it’s not often that something works out exactly the way you planned. It’s still biology after all.”

See also infographic on page 10-11 ▸▸

More information:
http://2008.igem.org/Team:TUDelft

Gold at iGEM!

Gold for the TU Delft student team at the International Genetically Engineered Machine (iGEM) competition! Just before Delft Outlook went to press, news arrived from the United States that our students had won a gold medal at MIT’s iGEM competition for their research on thermometer bacteria. Their ‘wiki’ - the website where they described their research and maintained a logbook - also impressed the jury: the team won first prize for the best wiki. The TU Delft student team competed against fifteen other university student teams from around the world.

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BACKGROUND INFORMATION

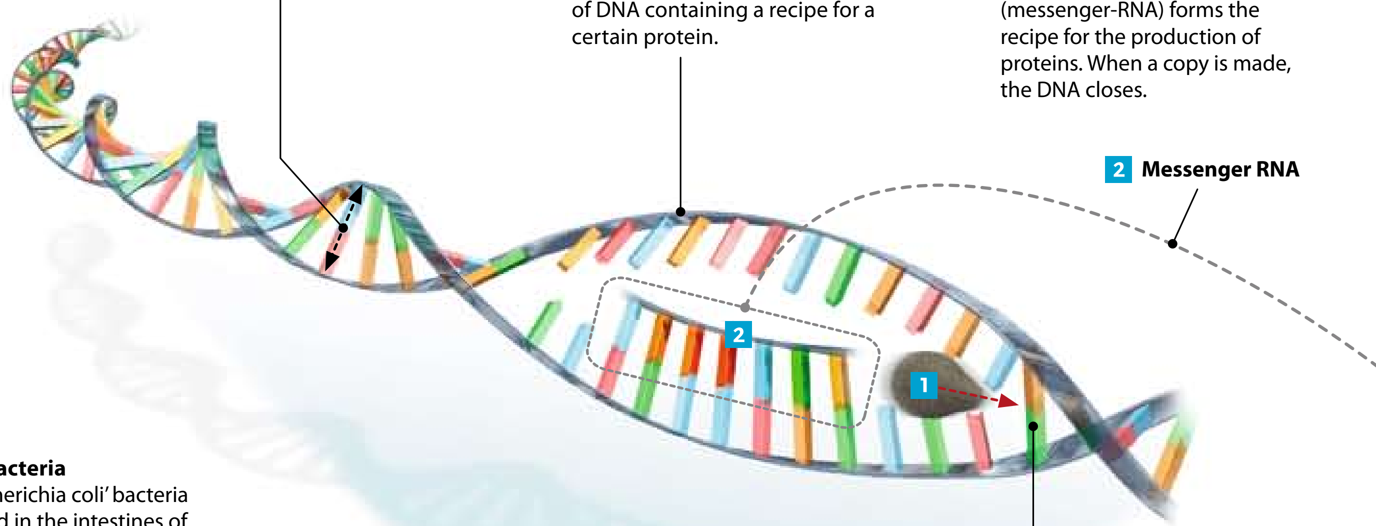
Recipe for producing protein

An enzyme 1 splits the DNA spiral into two separate strands. A copy 2 of the DNA strand is then made. This mRNA (messenger-RNA) forms the recipe for the production of proteins. When a copy is made, the DNA closes.

Scale
A DNA-strand is circa 24 Ångström wide (1 Ångström = 0.1 nm = 0.1 x 10-9 m).

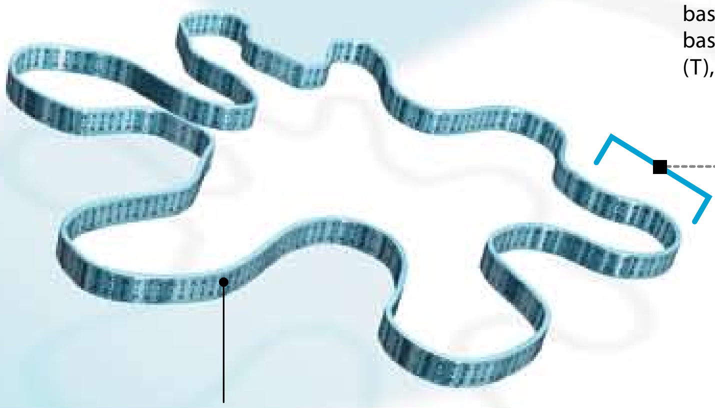
DNA
DNA is found in the cell of every organism. A DNA molecule consists of two chains of nucleotides that are entwined in a double spiral. The order of nucleotides is a recipe for producing proteins. A gene is a piece of DNA containing a recipe for a certain protein.

2 Messenger RNA

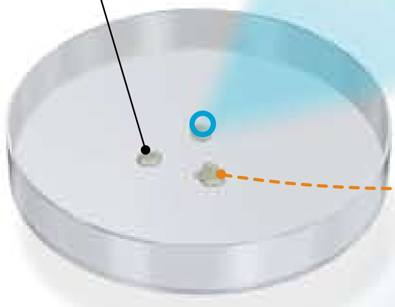


E. coli bacteria
The 'Escherichia coli' bacteria are found in the intestines of livestock and are needed for digesting food. E. coli is often used for laboratory experiments, because the bacteria is safe and can be quickly cultivated. Researchers change how the bacteria functions by adding or removing (a mutation) a DNA strand. The bacteria multiplies itself, after which the functioning of the added DNA is tested.

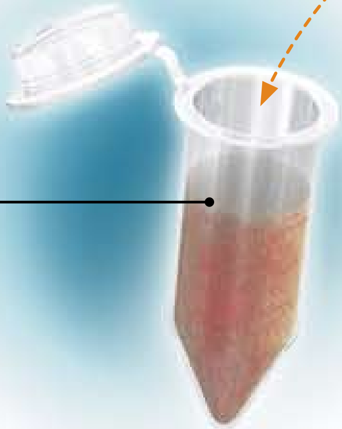
Base pair
Two opposingly positioned nucleotides are connected by a base pair. DNA has four nitrogen bases: adenine (A), thymine (T), guanine (G) and cytosine (C).



DNA of E. coli bacteria



Reactor vat



Application of mini-thermometer
When the modified E. coli bacteria are added to a large reactor vat, wherein chemical reaction occurs, and an operator takes a small 3 liquid sample, he/she can immediately see, from the color (for example red) of the sample, what was the highest temperature the liquid reached in the vat. The particles in the reactor vat can also be 'mutated' with the thermometer DNA with color production, so that the E. coli bacteria are no longer needed.

DNA makes a biological Mini Thermometer

The objective of the research is to 'make' a DNA 4 strand that ensures the bacteria functions as a thermometer. To do this, the researchers must add two DNA strands – each with a specific function – to the (E. coli) bacteria. The first DNA strand must function as a temperature-dependent changer that activates the second DNA strand, so that a chosen temperature can be reached. This second DNA strand must ensure that the bacteria will produce a pigment that allows the bacteria to change color.

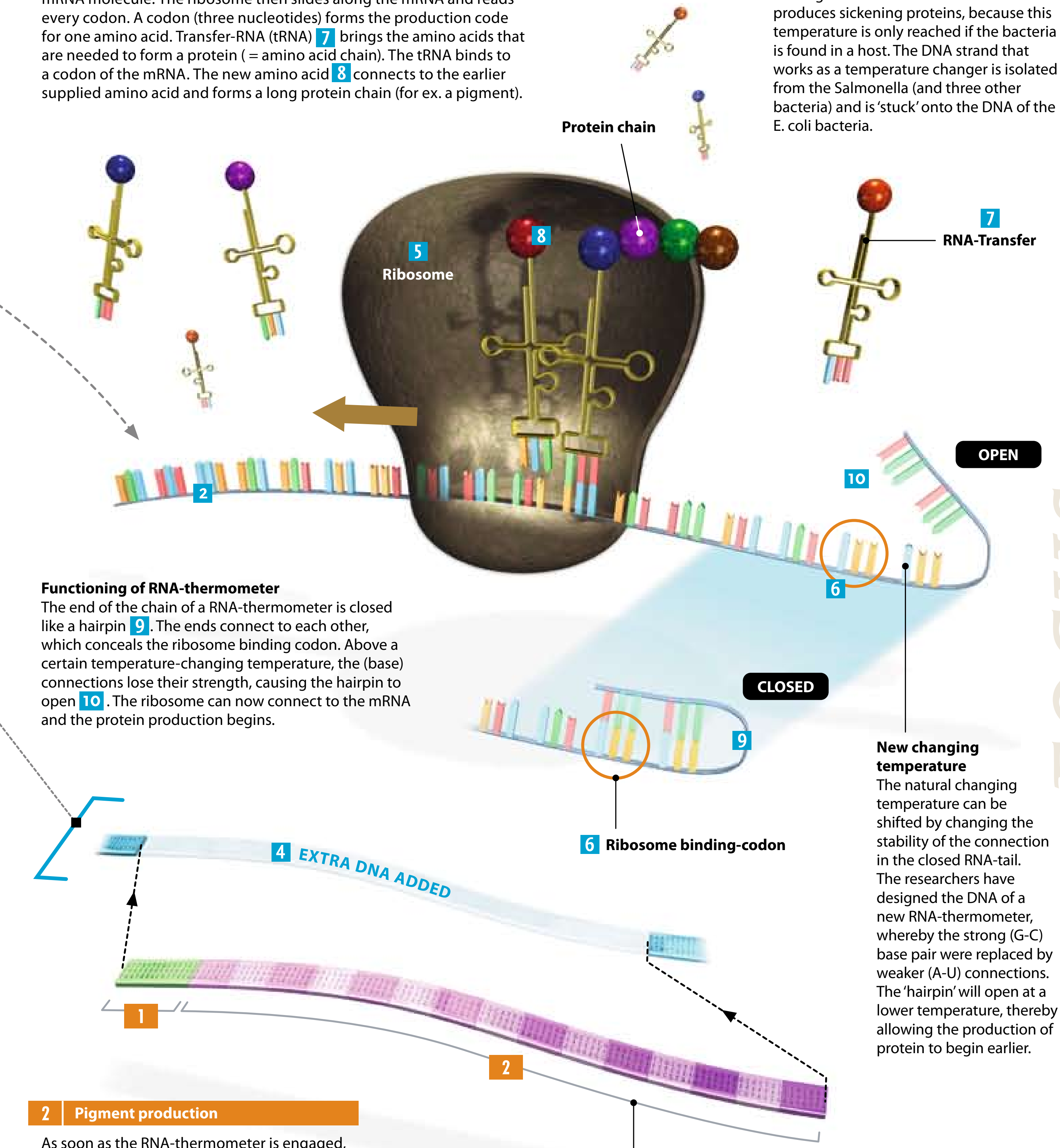
BACKGROUND INFORMATION

Production of protein

A ribosome 5 is connected to a special binding codon 6 of the mRNA molecule. The ribosome then slides along the mRNA and reads every codon. A codon (three nucleotides) forms the production code for one amino acid. Transfer-RNA (tRNA) 7 brings the amino acids that are needed to form a protein (= amino acid chain). The tRNA binds to a codon of the mRNA. The new amino acid 8 connects to the earlier supplied amino acid and forms a long protein chain (for ex. a pigment).

1 RNA-thermometer

There are organisms in nature that react to temperature changes; hence, at 37°C and higher the Salmonella bacteria produces sickening proteins, because this temperature is only reached if the bacteria is found in a host. The DNA strand that works as a temperature changer is isolated from the Salmonella (and three other bacteria) and is 'stuck' onto the DNA of the E. coli bacteria.



Functioning of RNA-thermometer
The end of the chain of a RNA-thermometer is closed like a hairpin 9. The ends connect to each other, which conceals the ribosome binding codon. Above a certain temperature-changing temperature, the (base) connections lose their strength, causing the hairpin to open 10. The ribosome can now connect to the mRNA and the protein production begins.

New changing temperature
The natural changing temperature can be shifted by changing the stability of the connection in the closed RNA-tail. The researchers have designed the DNA of a new RNA-thermometer, whereby the strong (G-C) base pair were replaced by weaker (A-U) connections. The 'hairpin' will open at a lower temperature, thereby allowing the production of protein to begin earlier.

FOCUS

2 Pigment production

As soon as the RNA-thermometer is engaged, the E. coli-bacteria proteins must begin production, which changes the color of the bacteria. To achieve this, a DNA strand is added that - depending on the temperature- will produce three natural pigments: lycopene (the red coloring in tomatoes), beta-carotene (the orange in carrots) and zeaxanthin (the yellow in corn). Below 27°C, the E. coli bacteria are virtually colorless; At 27°C and above, the enzyme producing lycopene is activated and colors the bacteria red.

Between 27°C and 32°C, the E. coli colonies are orange. Above 37°C, the bacteria are colored yellow. 13 enzymes (proteins that function as a catalysator) are needed to produce (from the carbohydrates present) the red pigment lycopene. Two extra enzymes convert red to orange, and orange to yellow. The added DNA strand must be comprised of 15 DNA strands (or genes) that are each responsible for producing one of the 15 enzymes.

Three of these DNA-strands are from the E. coli bacteria, the other 12 are found in the DNA-sequence of yeast (a fungus).

illustration & text: Eric Verdult
www.kennisinbeeld.nl © 2008

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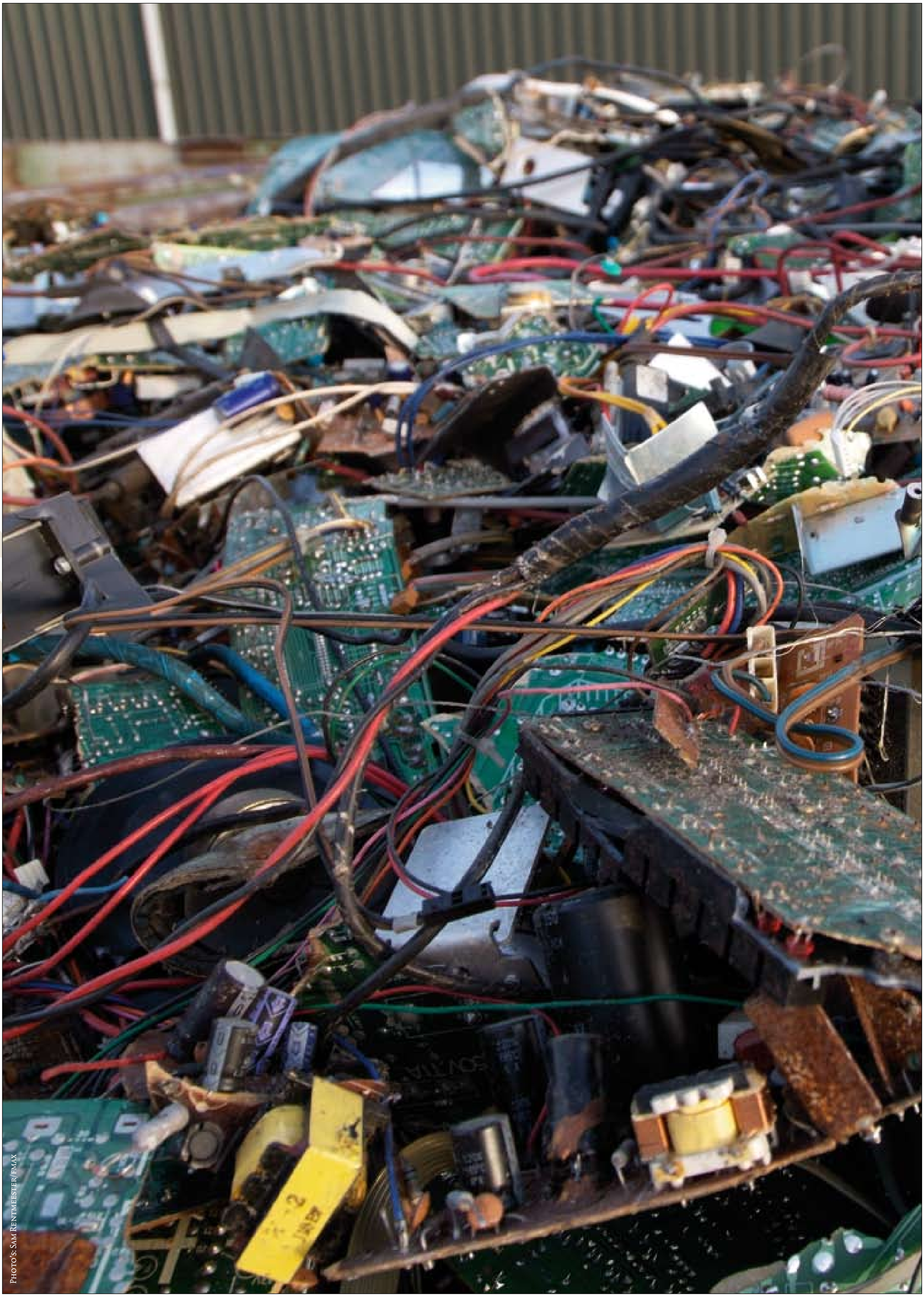


Photos: Sam Rentmeester/fmax

Scrap is a gold mine

China must be an ideal place for the high-quality recycling of electronic waste, or so the recycling experts at the Faculty of Industrial Design Engineering thought. Graduate student Feng Wang put the theory to the test by starting his own recycling plant in China. There was just one problem: no waste.

Maaike Muller

"I've seen incredible things," says Dr Jaco Huisman of TU Delft's Industrial Design faculty. While in China, Huisman witnessed people using acid to remove valuable metals from printed circuit boards in computers. Not the healthiest of materials to be inhaling, or worse, discharging into the river, but many poor Chinese have no other choice. The money they earn from selling reclaimed materials is their sole means of survival.

To put it mildly, China isn't exactly renowned for its proper handling of e-waste, a view supported over the years by the shocking pictures and stories Greenpeace has published about the way China deals with electronic waste. Even so, Huisman and Professor Dr Ab Stevels see ample opportunity for high-quality recycling operations. "We can combine the best of both worlds," Stevels asserts. "Technology from the West and many cheap hands from China."

Stevels, an Industrial Design faculty professor of applied eco-friendly design, knows China well. He visited the country many times during his long, forty-year career working for electronics manufacturer Philips. Stevels has since retired from Philips and will also be retiring from TU Delft in December. In 2005, at the invitation of the Chinese government, Stevels spent three months as a visiting professor at Tsinghua University in Beijing. "That's when I saw their enormous informal recycling operations, a cottage industry with people dismantling electronic equipment at home in the most primitive ways," he recalls. "It was worlds apart from the expensive high-tech recycling operations we have here in Europe. I came up with the idea that in China an intermediate form might be most eco-efficient."

Eco-efficiency, that's what Stevels, Huisman and other recycling experts are looking for. In simple terms, the discussion centres on the level of ecological improvement per unit of money spent. In China, Stevens saw how the quantity of landfill waste and the emission of noxious materials could be considerably reduced, while maximising the yield of recycled materials, and all for the cost of just a few yuans. One commodity that is expensive in Europe but cheap in China is the manual labour you need to disassemble scrapped equipment.

"Deep disassembling is a much better way to remove recyclable components from an appliance," Stevels says. "It accounts for lots of jobs, and it results in a better separation of components from which valuable materials, like copper, can easily be reclaimed." Certainly more easily than from scrapped appliances in Europe, where manual labour is expensive and machines are used to chop up the scrap.

Quiet

Stevels is credited with bringing the research on modernising China's recycling industry to TU Delft. Stevels: "Science shouldn't be conducted from an ivory tower." Huisman, who Stevels asked to join the research team, wanted a student to investigate what the ideal recycling plant in China should look like, so he simply had the student, Feng Wang, set up a recycling plant of his own. For Wang, this meant a graduation assignment that was anything but standard or dull.

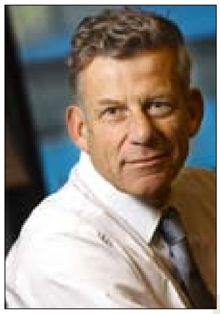
Wang, who is Chinese and completed his MSc degree in Industrial Ecology in September, set up an electronics recycling unit in Taizhou, a few hundred kilometres from Shanghai. The unit was part of Chiho Tiande, a Chinese-

One commodity that is expensive in Europe but cheap in China is the manual labour you need to disassemble scrapped equipment

Dutch company which disassembles electric motors. "Money from investors enabled me to buy a building and hire ten employees," Wang says over the phone. He imported a good-quality disassembly workbench from Germany, and within a few days he had a plant full of copies of that workbench. And then the plant fell silent, not because there weren't enough people willing to work at those workbenches, but rather because there simply wasn't any electronic waste.

"Disused equipment is worth a lot of money in China," Wang explains. "A used but serviceable computer in China will easily fetch 100 euros." China has a widespread informal collection system that involves people going from house to house to buy old appliances. These are then sold to people who either use them or take them apart to recover any reusable materials.

All of which means that nobody dumps their old ▸▸



Professor Ab Stevels: "Research shouldn't be conducted from an ivory tower"

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Shocking waste in Europe

So here I am, dumped in the street. Obsolete, passed over for a younger model. Too large, too unwieldy and most of all too slow, the night arrives when I finally find myself dumped on the pavement next to a couple of bin bags. I wasn't dumped here by a top lawyer, banker or politician, so nobody's after my data. A dog comes to sniff me and do his thing. Oh dear, I'll be smelly when I get to the landfill.

Such is the life cycle for many computers and other electrical appliances in Europe. Only 27 percent of all fridges in Europe are dismantled correctly by specially trained waste disposal workers. And virtually none of the smaller electronic devices, like mobile phones, are recycled.

Shocking, is the opinion of Dr Jaco Huisman, a recycling specialist at the Faculty of Industrial Design. Under his supervision, a team of researchers evaluated the WEEE (Waste of Electrical and Electronic Equipment) directive that the EU issued in 2003. All European Union member states are supposed to treat their e-waste in accordance with this directive. Yet sadly, compliance with this directive leaves much to be desired.

Huisman rattles off the numbers in rapid succession. "In Europe we have 8.5 million tonnes of electronic waste a year. In 2005, we collected 2.3 million tonnes. Every year the Netherlands collects over five kilos per member of the population. Sweden, Norway and Switzerland are the winners in this with just over twelve kilos per member per year, but some Eastern European countries collect hardly anything at all."

The important thing is to drive up those numbers, Huisman believes. As properly handled recycling increases, landfill waste and polluting emissions decrease, and more valuable materials remain available. Huisman believes that leading countries should be able to recycle as much as 75 percent of their large appliances, and 60 percent of their medium-sized and small devices. "From a climate change or toxicological point of view, it would be worth recycling all equipment," he says, adding that even in economic terms, recycling all equipment would be cost effective. "However, for some items, like refrigerators and low-energy light bulbs, recycling costs money."

There are no reliable figures about what happens with equipment that is not recycled, Huisman concedes. He suspects however that many mobile telephones, which contain valuable gold and palladium, remain left in a drawer somewhere or are simply thrown into the waste bin. This is not how it should be, but at least we know where they end up. But what about large appliances, like old refrigerators and washing machines? "Again we don't know exactly," Huisman admits. But whatever the case may be, clearly these appliances are not being processed in the way that they should be. Huisman points to a recent photograph he took of a heap of old refrigerators, "Look, a whole mountain of black pots, compressors from refrigerators, that somewhere in Europe were simply put through a car shredder," before remarking that doing this releases the equivalent of two tonnes of carbon dioxide per refrigerator.

Returning old appliances to the shop or a municipal recycling site is no guarantee for proper disposal, however. "Traders often buy up the used appliances," Huisman says. "Many appliances, whether still working or not, are then shipped to other countries, often developing countries." (See the text box, 'Return ticket to Africa for old computers'.)

Before the end of the year, the European Commission, which funds Huisman's research, must submit a proposal for a new WEEE directive. Huisman and his colleagues say the new directive must redefine the recycling target. The current target is to process four kilos per member of the population per year. "In the new EU countries, like Romania, this is not a realistic target, as only six kilos of new appliances are sold annually per member of the population. In other countries that figure is 24 kilos, so the target for these countries is too low."

The researchers also argue that it would be better to assess recycling performance by product type rather than by weight. This would make it easier to set priorities. There would be no priority for non-toxic waste, such as washing machines, whereas there would be for products like LCD TVs and low-energy light bulbs (which contain mercury), refrigerators and freezers (which contain CFCs).

The European Commission has included Huisman's recommendations in its draft for the new WEEE directive, Kurt van der Herten (WEEE policy manager of the European Commission) confirms, but he cannot say exactly what the commission will include in its proposal. Huisman: "I'll be happy if ten percent of the new directive is based on science. Recycling policy is mostly about politics, but after our extensive environmental analysis there's no way round it: collecting more and processing better pays."

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appliances for free. In order to be able to test his plant, Philips China sent Wang two tonnes of broken DVD players and radios. Just the copper wiring from that old equipment alone would fetch a few thousand euros, Huisman calculates. Although the recycling test plant's returns don't yet outweigh the costs, things look promising, Wang believes. "The current plant covers five hundred square metres, but Chiho Tiande plans to build a larger plant next year covering five hectares."

Wand says that starting a recycling plant isn't very difficult, "but without a good collection system the plant will remain empty." In January 2009 he will start his doctoral research at the Faculty of Industrial Design Engineering, focussing on the collection of e-waste. "There are many possible solutions," he says, "but what is certain is that we will have to start buying electronic waste." Wang has high hopes of receiving a grant to do just that. "The Chinese government hopes to pass a law that will force producers to pay for the disposal of the products they market. It would be a good idea to pass this money on to official recyclers."
The unofficial recyclers, the people who risk their health dismantling appliances at home, will be the big losers in Wang's vision of the future, although he can see a future role for those people who for years have gone door to door collecting old equipment. Wang: "They can keep doing the same work, but then in an official capacity, with a stable income and insurance."
For his doctoral research on e-waste collection, Wang intends to avoid getting bogged down in theory. "I will have to start by collecting lots of information, but after that I intend to set up a pilot collection project," he says. "There are bound to be obstacles, and it will involve a lot of work, but I'm optimistic that we will manage to improve the recycling industry in China."

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Return ticket to Africa for old computers

A container full of broken computers, to be shipped from Tanzania to the Netherlands? It was definitely a first for customs officials. Provided the paperwork was in order, the first cargo of e-waste should be returned to Europe in November, in a reversal of the otherwise steady flow of illegal containers en route for landfill sites in developing countries.
The Viafrica foundation normally sends computers - including over a thousand discarded TU Delft computers - in the opposite direction. Viafrica's workers then connect the computers in Tanzania and Kenya and provide support for their new owners. "Providing support is our strength," says Joost Dam, founder of Viafrica. "I often see loads of shiny new computers sitting in a corner somewhere, just because the people don't know what to do with them."
In the schools where the foundation does its work, computers also eventually break down. Dam: "As part of test project, we are now shipping a container back to the Netherlands to recycle the equipment here." Which also makes it perfect research material, according to Dr Jaco Huisman of TU Delft's Faculty of Industrial Design Engineering, who is supervising the TU Eindhoven student running the container test project for Viafrica. "If you know how the shipping works," Huisman says, "you're in a better position to recommend ways of doing it on a larger scale in the future."
Nonetheless, processing the waste in Africa would be preferable. Dam: "That however is not feasible at the moment. They don't have a collection system or a processing line."

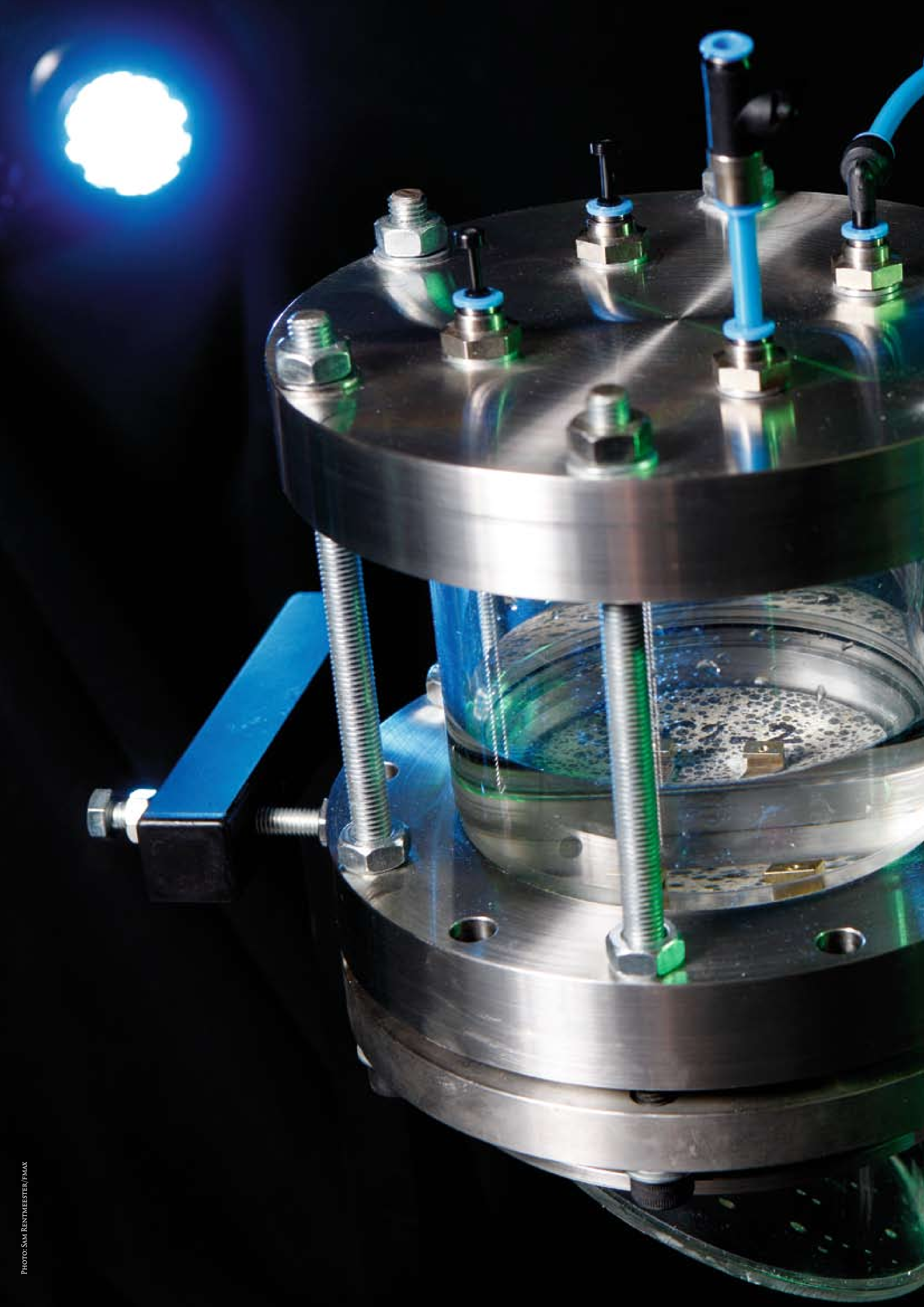

Photo: Sam Rentmeester/fmax

Self-healing concrete

At the Faculty of Civil Engineering and Geosciences' microlab, spores from bacteria packed in black clay granules lie waiting for cracks in the concrete. Awakened by water entering the cracks, the bacteria begin to grow and start producing calcite, filling cracks of up to half a millimetre wide within a day. The research, conducted by Dr Henk Jonkers and his colleagues, formed part of the self-healing materials spearhead at the Delft Centre for Materials.

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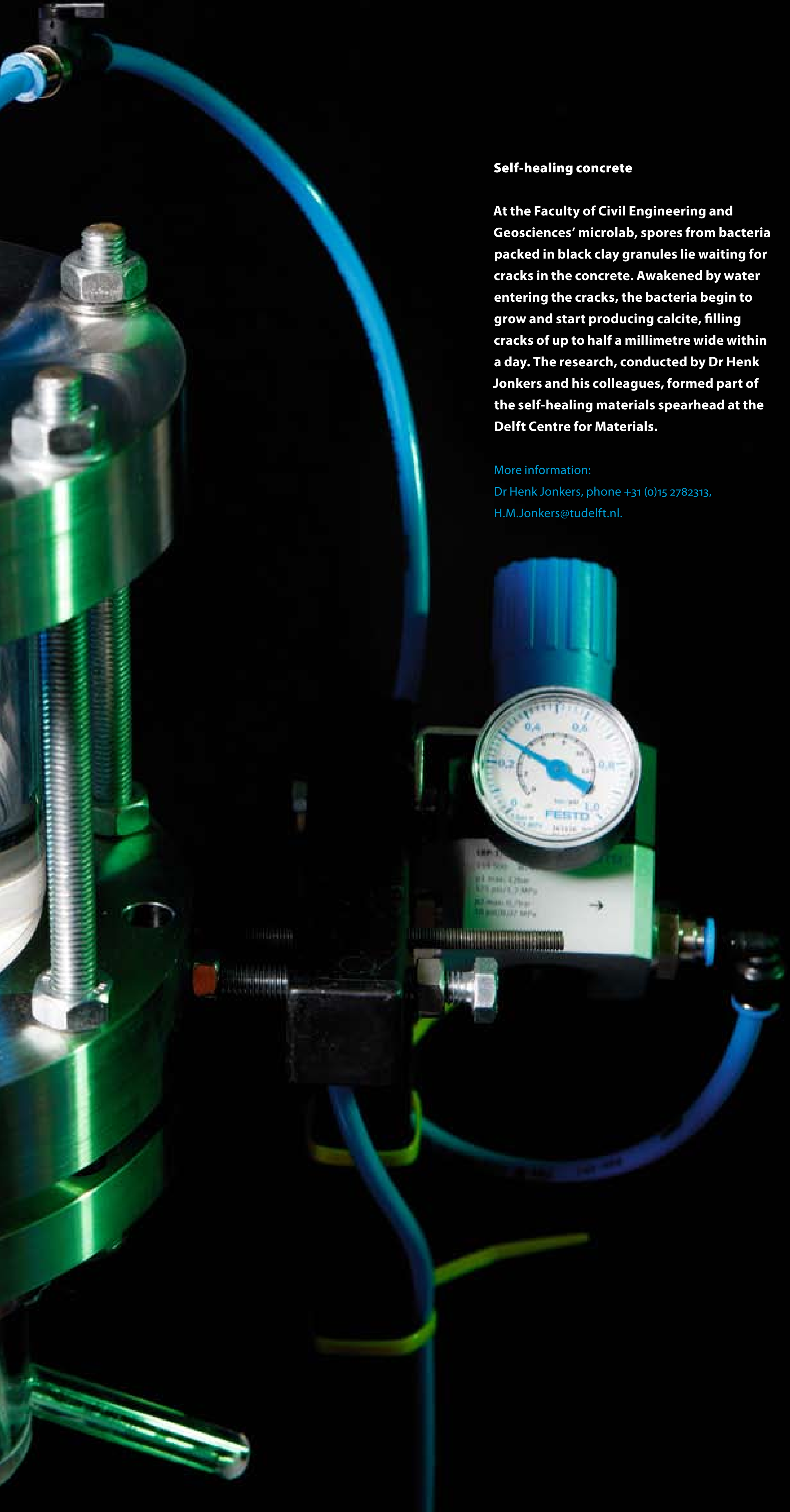
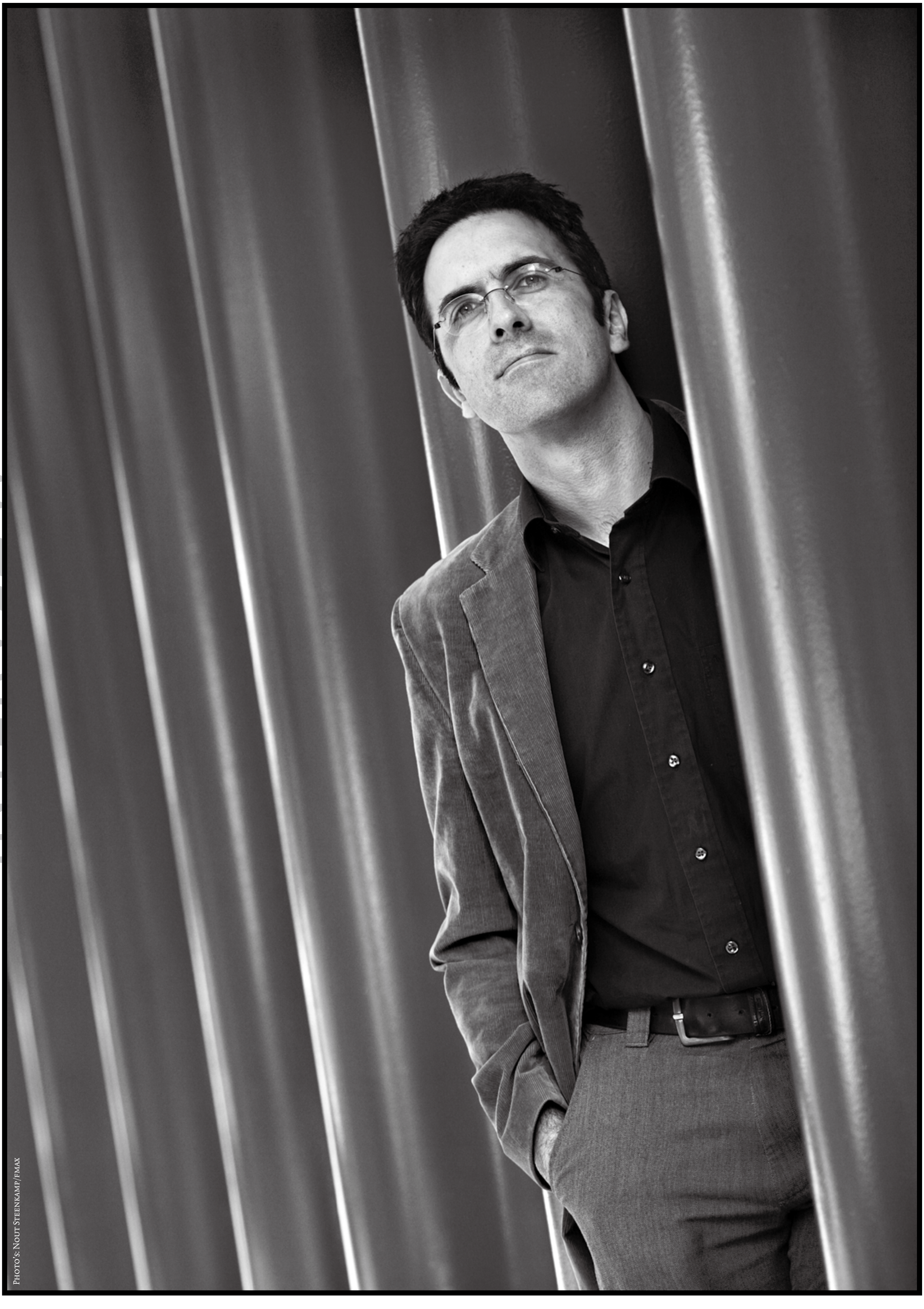


INTERVIEW



Photo's: Nout Steenkamp/fmax

‘We can see Holland’s Green Heart beating’

Back when he was an aerospace engineering student, Professor Dr Ramon Hanssen wasn’t really into aircraft. Spacecraft were more his thing, particularly the way satellites could be used to observe the Earth. This field of science has undergone unexpectedly rapid development over the ensuing years. In September, Professor Hanssen delivered his inaugural lecture as professor of earth observation at TU Delft.

Jos Wassink

INTERVIEW

In 1987 you enrolled in the BSc aerospace engineering programme, yet two years later you switched to geodesy. Why the change?

“I was very interested in the space aspect of aerospace engineering, but at the time this aspect had hardly been developed at all. But around that time Professor Karel Wakker, of the Aerospace Engineering faculty, and Professor Rainer Rummel of the Geodesy faculty, began collaborating on a project in which they showed how spacecraft could be used for earth observation. This was what I had wanted to study at university, so it was at that point that I also knew where I could study the subjects that really interested me.”

Who is Ramon Hanssen?

In 2008, Professor Dr Ramon Hanssen (39) was appointed Antoni van Leeuwenhoek professor at the Faculty of Aerospace Engineering. This special professorial post allow ‘excellent scientists’ to become professors at a relatively young age, without having to assume all the usual professorial responsibilities, such as management and teaching. Last September, during his inaugural lecture, entitled ‘Geodesy. A Space Odyssey’, Professor Hanssen questioned Europe’s ambitions for manned space missions to the Moon and Mars. Hanssen believes that earth observation should be the primary objective of space missions. Information returned by satellites can form the basis of a whole range of services. His spin-off company, Hansje Brinker, which provides information about dike subsidence, is one example. Professor Hanssen studied aerospace engineering and geodesy at TU Delft, and in 2001 received a first for his doctoral thesis on radar interferometry, his current research field.

When did you first learn about earth observation using radar?

“In late 1994, a year after I graduated. The history of radar interferometry is very interesting, because we used satellites that weren’t developed for that purpose. The ERS-1 satellite, which became operational in 1992, had been developed for other applications, like radar measurements of the sea surface, with the idea being to use the satellite to detect oil spills or measure wind forces. Then, in early 1993, the first publications appeared showing how interferometry could be used to very accurately calculate the distance between the satellite and the Earth’s surface from the phase of the signal (see text box). The first incredible subject that made the cover of *Nature* magazine was an earthquake in California [28 June 1992, Landers, *ed.*], with colours graphics showing the ground movement caused by the quake. They had used one image taken just before the earthquake, and another from just after. This allowed the distance between the satellites and the Earth’s surface to be calculated to within a few millimetres, with each colour cycle representing a movement of 28 millimetres. This was the breakthrough, because it was the first time that the effects of an earthquake were visualised in such measurable quantities.”

Was that when you realised this was the subject for you?

“Yes, I had the opportunity to conduct doctoral research on the subject. It was all completely new. In the Netherlands, we were gradually becoming interested in measuring ground movement, for example as a result of natural gas extraction in the province of Groningen. The way it’s now done takes years and costs lots of money. But just imagine being able to do it using a satellite measuring reflections off the Earth’s surface from satellites that are already up there. This was a fascinating idea. It appeared to be a powerful technique, offering major application possibilities.”

But it also meant you had to go to the United States.

“I started here, in collaboration with TNO, but nobody was really working on this in the Netherlands. At the time, the US was leading the pack, although now it’s the other way around. Back then the gurus were at Stanford University, so that’s where I spent a year doing my doctoral research.”

You can now show images of subsidence over gas reservoirs, mounting stresses in the southern parts of the country, and shifting dikes in the northwest, in millimetres per year. It’s fantastic, but how much time and effort does it take?

“The first time is very difficult, but once you know the tricks it becomes increasingly simpler. This is all cutting-edge when compared with earthquakes, which cause shifts of several metres, while in our case we’re talking millimetres. The signal is only just above the noise level. A second issue is the terrain in the Netherlands. In California, you’ve got desert, and each time the satellite passes over it looks the same: rocks, sand and stones. While here, in the Netherlands, everything changes. The satellite passed over yesterday. When it returns in 35 days time, Technopolis Innovation Park will have had a few more buildings constructed and the trees will have lost their leaves.”

I can see the department of public works being interested in shifting sea dikes, and the Wadden Sea Association wanting to know about seabed subsidence. Can they process the satellite data themselves, or must they come to you? ▸▸

INTERVIEW

'In the Alps, Italy and Spain, whole areas are slowly sliding down the mountain. Entire villages are gradually slipping away'

"For the moment, the subject appears to be a bit too specialised to start training people within those organisations. In the Netherlands, we're the only ones to specialise in this field."

But you did start your own company, Hansje Brinker, to supply the data?

"As for the dikes, we're now trying to make the transition to the end users, the water boards and department of public works, which are both keen, but we're still waiting to see if operational use is possible. Scientifically speaking it's always rather touch and go, which makes it less interesting for commercial entities. As for oil and gas extraction, this is about to change, and international providers are now appearing on the scene who can also do this kind of analysis."

How did the department of public works react to subsiding the dune in the sea defences at Petten? Did they know about it?

"It was known that such processes could occur. There was an argument over it in 2005, when someone said that subsidence could increase to forty centimetres per century. The department couldn't really respond to that assertion, because there hadn't been enough measurements taken and the processes involved weren't sufficiently known."

Was that argument your cue to start focusing on that area?

"Yes, we wanted to see what was happening there. The advantage of using a satellite is that you compile records. The data are stored somewhere, and if you were to go looking for it now, you could go back as far 1992. This gave us the lead. We found subsidence of two millimetres per year, which is twenty centimetres per century, if you assume a linear progression. This is comparable with the order of magnitude of the rising sea level, and it's half of the original claim made in 2005."

You are now able to measure ground movements to an accuracy of a few millimetres per year. Greater accuracy would appear to be pointless. Does this mean your job's finished?

"I think that history shows that a job is never finished. Take GPS for example. Once we got that working, we all thought it had reached the end of its development. Yet with GPS, the signal is delayed by moisture in the atmosphere, resulting in all sorts of errors. We have now reached the point where we can remove the errors and tell meteorologists how much water vapour is in the atmosphere. We will be seeing similar processes in ground movement measurements. The main signal is the result of natural gas extraction, but we can also see the natural subsidence of peat. In southwest Holland we saw the Green Heart area moving up and down some two centimetres with the changing of the seasons and groundwater levels. Behind our building here we had some reflectors that we monitored for five years, and they also showed a plot of land moving up and down. You could say that we can see Holland's Green Heart beating."

Radar measuring down to the millimetre

Satellites circle the Earth in fixed orbits. As the Earth rotates inside the satellite's orbit, after a certain period of time, say twelve days for example, the satellite will reappear above the same point on the planet. During each passage, radar pulses are transmitted. These pulses are reflected off the Earth's surface and then picked up again by the satellite. For each pixel of the radar image, this results not only in an intensity, but also in a phase of the reflected wave. Since the phase is related to the distance of the satellite to the reflection point, a time sequence of distance measurements can be recorded, the relative precision of which is in the order of magnitude of a few millimetres. This allows for the detection of minute surface movements arising from tectonics, volcanic activity, natural gas extraction and the like.

So the technology has reached the end of its development, but a lot can still be gained from interpreting the data?

"We can now conduct an earthquake analysis by just pressing a button. This gives you an instantaneous view of what has happened because of the quake. Interpretation and technological development go hand in hand."

The real question of course is whether you can see the stresses mounting?

"Yes, we can, and they're mounting. Take for example the North Anatolian fault, which is the 1500 kilometre-long fault line running from eastern Turkey to Athens, Greece. Continents are rubbing against each other along this fault line at a rate of about two centimetres per year. It's not a continuous process, but rather happens in spurts. The stress builds up and then suddenly it's released at one particular point. Later the same process will occur further down the line. This is what causes earthquakes, like the big one in Izmit, Turkey in 1999, when a few hundred kilometres-long section suddenly shot loose and shifted four and a half metres, resulting in 30,000 dead. After the last earthquake, the stress starting mounting elsewhere. I've likened this process to the bristles on a pair of brushes: if you put their bristles together and push one brush along the other, the bristles will be released one by one. This process is now hanging on by the last bristle, so to speak. And just down the line is Istanbul. We know that all the preceding bits have already shot loose."

So Istanbul's next?

"We know that the area has four and half to five metres of stress built up. The question is: will it all be released in one big bang, as happened in the past, or will it be released in a series of small shifts that gradually reduce the stress?"

What is your opinion about that?

"I'm not a geophysicist. I just observe what occurs. And I don't see any small shifts occurring."

You also act as a consultant to the European Space Agency (ESA) on the design of new satellites. What are the current trends?

"The most important change is that one operational satellite is now on its way, Sentinel-1."

What's an operational satellite?

"Until now, satellites were mainly prototypes and spin-offs of applied research. Using the measuring data from those satellites is often difficult, because most of those projects are one-offs. It's different in meteorology. There is the Meteosat series, which has been up there since 1977. The second and third generations of weather satellites are now on the way. These are good examples of operational satellites. Not only is there a community of users buying the data, but the supply of data is ensured."

Will radar measurements go the same way?

"Yes. The EU and ESA combined to launch the GMES (Global Monitoring for Environment and Security) programme, which has now been renamed 'Copernicus' and involves a series of five missions using satellites equipped with radar, and later, other technologies as well. Those missions are intended for operational use with applications, including emergency response, fishery, agriculture, security and shipping detection."

What will be detected here on Earth?

"In the event of natural disasters, like floods, detailed information will be rapidly made available. And ships will have to be more careful about discharging oil on the high seas, because they're sure to be spotted now. Fishery fleets can also be tracked to ensure they don't venture outside the allotted fishing zones. Europe spends a lot of money subsidising various crops, which can now be checked from space. There are dozens of applications."

And in your own field, radar interferometry?

"In interferometry, landslides in southern Europe are a major application area. In the Alps, Italy and Spain, whole areas are slowly sliding down the mountain. Entire villages are gradually slipping away, damaging tunnels and pipelines, and we will now be able to see this happening. In an economic sense, there will be extra spin-offs in the technological and service industries. My view is that when Europe decides to release the data – like the Americans have been doing for years – people will develop and market applications. It will then belong to all of us. Until now, satellites belonged either to space agencies or to the realm of science, but the man in the street had little use for them. The results will now become more tangible. The Continuon power company for instance wants to map subsidence in towns, in order to spot stresses on gas pipelines. Such stresses have already caused explosions. I hadn't realised that our data could be applied to a field like that. And for our students, this offers an interesting perspective for designing new applications themselves."

Won't that mean much more business for your spin-off company, Hansje Brinker?

"I don't have any ambition to expand the business. I like exploring the border zone between research and application. A company enables you to give more direction to the applications. It's a fascinating process that I learn a lot from, but it's not something I want to expand further."

Another possible career switch would be music. You are a successful scientist, as well as being an accomplished percussionist. Have you ever wished for the reverse?

"During my school years that was indeed a question I asked myself, but today I consider this the ideal combination. To earn a living in music you must make many more compromises about what you will or will not do, but I'm now in a position where I can just to do the things I really enjoy."

◂◂

1968 student protests in Delft: noisy but restrained

When student protests broke out in Paris, Amsterdam and Nijmegen forty years ago, TU Delft students followed suit, but they did so in their own way. Gratuitous violence was not in the cards. Instead, the students set about achieving democracy in education in a very earnest and organised fashion.

Robert Visscher

Photo: Ad Volker, December 1970

Architecture faculty, 1970: after the board of governors left, a group of mainly student activists voted on a motion to dissolve the board.

In Paris in 1968, students marched screaming through the streets, bearing aloft homemade banners with poetic slogans like, 'Power to Imagination'. In Delft, things remained calm, although some minor changes occurred. TU students increasingly abandoned their jackets for pullovers, and many let their hair grow long. But there was no protest in the air as yet.
"Looking at it from the outside, things in Delft were still more or less the same," says Dr Leo Waaijers, a retired TU Delft librarian who was teaching mathematics at the time. "After the Second World War, the pre-war regime had been reinstated, and professors had taken up their former posts, which they considered only natural. But the students thought otherwise, because they distrusted those people and the old system. So something was definitely brewing."
This apparent peace turned out to be the calm before the storm. "In the post-war period of reconstruction, engineers were in great demand. Students increasingly came from the lower classes, rather than academic circles," says Waaijers, who was a communist in those days. "These students in particular were looking for change."
One of these students was Jan Ilsink, who was also a communist. Ilsink, an architecture student, became the leader of the 1968 protests in Delft. "We had been closely watching the Paris demonstrations," he recalls. "In the summer of 1968 we arranged to meet a group of students in Les Rousses in the French Jura. That was the start of a close alliance. We knew that together we were in a very strong position, as Paris had already demonstrated. And we needed an ideology, because that would provide a sense of cohesion. But we had difficulty deciding on which ideology to follow, because we were critical of the Soviet invasion of Prague in the spring of 1968."
All across campus, increasing numbers of students were becoming active in the various faculties. Posters were put up demanding more equality. Such actions were expected at progressive faculties like Architecture, and among students like Ilsink, but less so at faculties like Electrical Engineering, Mathematics and Physics, and at the recently established Faculty of Industrial Design, where students were also making themselves heard through pamphlets and posters.
The students and younger staff members believed that change was long overdue. In their view, most of the old professorial ranks were offensively authoritarian. "They formed a caste that considered itself a cut above the rest," Ilsink says. "When a professor entered the auditorium, everyone was supposed to stand up. Professors grading architectural design drawings would use a 6B pencil to mark items they thought could be improved. Those marks were indelible, so you had to work through the night to do the whole thing again. Ridiculous! Non-academic staff were treated like dirt. One example was a steward who would run the slide shows during lectures. The professor would just bang his pointer on the floor to get the next slide. The steward was completely ignored. It was an utter farce. Another example of their arrogance was that professors had their own bicycle racks."

One man, one vote

Discontent about such matters and the very restricted say students and non-academic staff had in university affairs finally led to a sit-in at the Faculty of Architecture in 1969. "We all met in the restaurant," Ilsink says, "where we riled ourselves up, and then we took over the building. The authoritarian professors soon left. What our criticism boiled down to was that as artists-cum-architects, we didn't want to just build villas. We also wanted to solve the housing shortage problem that was still prevalent twenty years after the war. Many of the younger professors agreed with us. After the sit-in, the authoritarian behaviour was gone. Professors had the courtesy to ask the steward to show the next slide, and the 6B pencil became a thing of the past. Some of the professors faced their lecture audiences with some trepidation."

'Students in Delft weren't very extreme'

After this velvet revolution, the students introduced the new 'one man, one vote' system, in which students and non-academic staff also had a say along with the professors. Meanwhile, however, professors in the senate were still meeting behind closed doors. "We thought they would be discussing very important issues," says Waaijers, "so we did everything we could to lay our hands on the minutes of those meetings. But all they showed was that, in many cases, the professors didn't agree with each other, and that in fact the meetings were actually pretty dull. We had imagined all kinds of things about them, simply because they were secret."
Many people were closely following the ▸▸

Photo: Sam Rentmeester/FMAX

Architect Jan Ilsink, 1968 student protest leader at TU Delft

Occupying the main building, 1972

developments at the Faculty of Architecture and the student protests generally. At the Faculty of Industrial Design, students and non-academic staff were also given a large say in faculty matters. "Consequently, the meetings became absolute bedlam. The noise was terrible," says professor emeritus and former rector, Professor Dr Hans Dirken. In 1968, Dirken had just started as an industrial design lecturer. "I've always been opposed to the 'one man, one vote' system, because it doesn't work. I also thought that students and non-academic staff should not be plotting our academic course. I did want students and staff to have a bigger say in matters, but no more than that. Yet, as it was, I certainly wasn't on the side of the senate either."

Dirken didn't oppose the students very actively. "I tried to avoid antagonising students," he recalls. "I'd allow them some slack, so I'd be able to nudge them in the right direction - that was the best way to get results. I recall how the students' influence got us to the point that we were actually designing an anti-authoritarian toy. The meetings about what that toy should look like went on for ages. That really irritated me. The final design for the toy was a square object made from some soft material that was very safe but utterly useless."

The relationship between the rebellious students and the senate worsened each day. The academic administration reform act introduced in 1971 had led to the replacement of the board of governors and the senate, so hated by students, with an executive council and governing body. One of the student political parties in particular, Democratisch Beleid (DB), led by Leo Waaijers, among others, together with a student activist group, AAG, demanded more of a say in the executive council. Although the administrative changes meant that students and non-academic staff had more influence on the university's policy, DB and AAG felt that the process of democratisation stopped far short of their goal.

When university fees shot up from 225 to 1,100 guilders, there was no stopping the upheaval this caused. Rebellious teachers and students immediately called for a boycott. There was no government grants system for university students in those days; instead, parents received additional child benefit payments. Anyone who refused to pay the increased university fee in protest would no longer receive their child benefit payments. "That was a government decision," says Hans van Nauta Lemke, the then rector of TU Delft (1971-1974). "In the Netherlands, the universities are funded by the government; they are not private institutions. Protesting against the universities rather than directly against the government was a display of ingenuousness or lack of courage."

Students nonetheless felt threatened and abandoned by their own governors. It was the final straw. "Van Nauta Lemke thought the law was like a machine," Waaijers says. "You feed an algorithm into a computer, turn the wheel and out comes a solution. But that's not how the law works; it has to be interpreted. The university's governing body failed to protect its own students, and that was a big mistake. To their mind, we were just being unruly, and never the twain would meet."

Sit-in

On 12 December 1972, some five hundred students, Ilsink among them, took over the university's main administration building on the Julianalaan. "We entered the building and groups of us went round to all the rooms ordering people out of the building," says Professor Dr Jan Kees Maan, who was physics student at the time and also a founding member of AAG. "With some of my fellow students I ordered the executive secretary, an ex-soldier, out of the building. It was all done in a very calm and orderly fashion. As a good soldier, he understood that he was up against overwhelmingly superior numbers."

One of the rooms in the main building was that of university rector Van Nauta Lemke: "I wasn't afraid for a single moment. I'd spent the Second World War in a Japanese internment camp, where I'd witnessed all sorts of atrocities. That's probably why I wasn't afraid."

During the sit-in the rector was bombarded with solutions from all sides. "The minister of education wanted me to call in the riot police, but that would have meant a confrontation between young policemen and their student contemporaries, which I just couldn't contemplate," Van Nauta Lemke recalls.

'Professors were so authoritarian. They'd mark our architectural design drawings with a 6B pencil, which was indelible'

"The Delft Student Union also offered to restore order, but this, too, I turned down. They were turbulent times. One of the professors wanted to be demoted to lecturer to avoid being harassed by students. Another world-famous professor tendered his resignation. I managed to stop both from going through with it. Despite all the tumult, I didn't feel the university was slipping from my grip, so consequently I didn't feel insulted."

The sit-in was tightly organised. "We didn't break anything," Maan says, "and we weren't drunk in the corridors. We had learnt a lot from the Amsterdam sit-in at the Maagdenhuis. If we had broken anything, rightwing newspapers like De Telegraaf would have blown it out of all proportion. Meetings were held throughout the building, there were heated debates, and we were also printing pamphlets. It was all done in a very Delft-like manner: quiet, organised and with a serious undertone and common purpose. Students at TU Delft weren't very extreme. During the sit-in we had bands playing, and there were lots of communal sing-songs. We sang the Internationale and songs from the 'Threepenny Opera' by Bertolt Brecht and Kurt Weill. That was about it as far as entertainment went. If you wanted to party, there was the pub."

Following intensive talks between the governing body and the students, a compromise was reached. The governing body would send out the child benefit letters. However, this did not end the uneasy relationship between the students and the governors. On one occasion Van Nauta Lemke was pelted with tomatoes. "When I said what a waste it was, they immediately stopped," he says. "Other protests did frighten the staff. At one point students took over a building and held staff on the first floor. Those people were very afraid they might be thrown from a window. I then proposed to take their place. I just thought, it's only one floor up, that's a drop I'd survive."

Almost forty years hence, it remains clear how different the perceptions of these confrontations were. Jan Ilsink and Leo Waaijers remember Van Nauta Lemke as an extremely rigid, frustrated and humourless man who did not know how to deal with the protests. But according to Van Nauta Lemke, that was far from the truth. "On the contrary, I entered into discussions with all sorts of people. Students could stop by for a talk, and I'd often reply with a joke. Perhaps they weren't always appreciated for what they were. I was a stickler for manners, which could have given an impression of rigidity." The former rector is far from bitter. "And I wasn't bitter then, either. I even played ping-pong with one of the protest leaders. He was astonished. I just couldn't understand what the students wanted. They were asking for more influence, but what was it they wanted to know about the senate meetings? Students today are far too passive for my liking. They don't go out to protest, and that I don't understand, for they are no better off now."

Although the protests in the late 1960s and early 70s were lively, there were also many staff and students who didn't care one way or the other. Professor Dr Rob van den Berg, who was then working on his doctorate in electrical engineering and today teaches physics, recalls that there was nothing vicious about the proceedings. "Our department had two people with leftist tendencies. They'd put up posters. There were lots of discussions with them in our group. But about matters scientific, we talked as one club."

Robert Bleekrode, a student of electrical engineering in 1968, also largely ignored the goings on in Delft. "Of course there were demonstrations, but many students like myself didn't join in. Life just went on. You crammed for exams, attended lectures and went to wild parties. In that respect student life then was exactly like it is today."

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Most of the old professorial guard were offensively authoritarian. "It was a caste that felt itself above everyone else."

Photo's: Sam Rentmeester/FMAX

MASTERMIND

Professor Dr Jan Dirk Jansen

"If there's friction, you should be able to discuss it"

Honest to the bone

Professor Dr Jan Dirk Jansen (1958) graduated from Delft University of Technology (TU Delft) in 1986. His subject was mechanics and steel structures, focusing on structural failure in drilling rigs, which naturally brought him to the attention of Shell, where collapsing oil prices propelled Jansen to take a closer interest in the drilling process proper. He later obtained his doctorate in technological mechanics and spent two years working in Norway, in a mainland office and offshore in the Barentsz Sea and Norwegian Sea. From 1995 to 1999 Jansen worked in Nigeria on environmental issues and drilling efficiency. He then returned to technology, combining his jobs at Shell and TU Delft equally and shifting his focus to subsurface flow control. He has held a professorship in reservoir systems and control since November 2005.

Connie van Uffelen

In the **Mastermind** series a professor and a (former) student each answer the same questions to create a double portrait.

How would you describe one another?

Jansen: "Enthusiastic, with great powers of judgment, highly capable of separating the essentials from side issues. He addresses important issues with great determination, is creative and likes to knuckle down to work, has a great sense of responsibility and he's big-hearted."

Brouwer: "Honest to the bone, even if being so could land him in a tricky situation. He speaks the truth, even if people don't want to hear it. He's also very energetic. It tires me just hearing about what he manages to take on. He has two jobs, one at TU Delft and one at Shell, both on a half-time basis, but in reality he has two 75% jobs. And I think he works on a book almost daily."

What sets the other person apart?

Jansen: "His powers of judgment. He's very good at saying things like: 'Right, can't be helped, let's drop this.' That's a very special ability."

Brouwer: "He works at a highly academic level, but still manages to focus on applicability. This is the result of his dual role. He's clear about what he's trying to achieve. Most teachers run into something worthwhile during the course of their research. Jan Dirk is committed to a certain target and systematically works to get there."

What do you learn from one another?

Jansen: "I learn from his powers of judgment. I learn that sometimes I must simply drop things and move on."

Brouwer: "I learn from his tenacity. He doesn't go at it for just one week, but rather works very hard on a structural basis. Also, the willingness to learn. Even though he's my senior in age, he's not afraid to learn from younger people. At Shell, as a civil engineer, he worked on drilling techniques. At TU Delft he tried to apply his old expertise on reservoir engineering. So basically he had to start from scratch, but now his group is leading the world, with Stanford and MIT following in his footsteps."

What's the essence of a good teacher-student relationship?

Jansen: "A lack of inhibition, in the sense that you both must be able to admit mistakes without feeling any negative appraisal. The idea that you can learn from one another. If there's friction, you should be able to discuss it. As a teacher, you must be able to provide a guiding hand without cramping your student's style."

Brouwer: "There shouldn't be too much distance. You should be able to have a good hammer and tongs argument. If there's too much distance between you, the teaching doesn't work."

Is your relationship like that of a father and son, or more like a pair of polite colleagues?

Jansen: "We're more like senior and junior colleagues. I knew him as a colleague at Shell. In formal terms, I'm his boss, but we have a very informal relationship."

Brouwer: "Neither, I think. We're too much on equal

Dr Roald Brouwer

"You must be able to have it out with each other"

Enthusiastic

MASTER MIND

terms to have a father and son relationship. The term colleagues doesn't cover the nature of our relationship. We're more than just colleagues. I'd say we're a small team. It was like that at TU Delft, and it's still like that at Shell."

Can you recall an incident of good or bad luck that stuck in your mind?

Jansen: "We developed a technique that later turned out to have been used before, but we did it at exactly the time when industry was waiting for it. It was about systematically optimising the displacement of oil by injecting water. Water is injected into additional wells to push the oil upwards. The process, known as secondary extraction or water flooding, uses controllable valves and has now been implemented in a reservoir simulator at Shell. Roald's name is now forever linked to this method. Roald also spent three months at Stanford, and that left such an impression that the technique became a new line of research. I'm rather proud of that."

Brouwer: "I can remember how he developed a way of tackling problems, but all the books said it couldn't work for the problem I was working on. In the end the books were right. We had quite an argument about that, but once you've clashed like that, you emerge a better man."

Do you socialise?

Jansen: "We do, occasionally. My son Bram particularly liked Roald very much. When Bram was just learning to speak, he kept talking about 'Robot' for weeks."

Brouwer: "Yes we do - not every week, but now and then. I know his children slightly."

Name one another's best habit.

Jansen: "Looking on the bright side of things. Releasing tension with a joke, and putting a good face on things. He's very direct, and so am I, which does bother some people, but I'm perfectly happy with it."

Brouwer: "His honesty, I'd say. There are no hidden agendas with him. And although it can sometimes be hard to hear the truth or his opinion, his honesty is a good character trait."

And the worst?

Jansen: "Would lack of patience count as a bad habit? He tends to take occasional shortcuts, jumping to conclusions when science dictates a more calculated approach."

Brouwer: "His drive and energy can translate into unusually violent responses when something goes wrong. Some people don't take easily to his fierceness and get put off by it, but it's just his dedication showing."

What is the other person's significance in professional terms?

Jansen: "Optimising secondary oil extraction. He made it happen. Controlling subsurface flows by combining readings and models."

Brouwer: "Such a lot. In five or six years he managed to develop a whole new approach to oil production that is second to none in the world. This is a breakthrough in ▸▸

Dr Roald Brouwer (1974) studied geochemistry at Utrecht University. In 1999 he embarked on his doctoral research at TU Delft's Faculty of Mining Technology, under the supervision of Jan Dirk Jansen, who was a lecturer at the time. Brouwer investigated ways of optimising subsurface oil flows with a view to increasing oil yields. He developed an algorithm for calculating optimum process control parameters. Having obtained his doctorate, Brouwer went to work for Shell as a research reservoir engineer, an expert who focuses on the subsurface aspect of oil extraction operations. At Shell he worked with his former TU Delft supervisor, Jan Dirk Jansen. Last summer Brouwer left to work on the largest oil reservoirs in Canada.

Photo: Nout Steenkamp/FMAX

Marital status
Jansen: Married
Brouwer: Married

Children
Jansen: two daughters and a son
Brouwer: one infant son

Hobbies
Jansen: reading, hockey
Brouwer: sports, canoe polo

Favourite newspaper and magazine
Jansen: NRC Handelsblad, Opzij
Brouwer: NRC Next, Technisch Weekblad

Invention you'd like to be yours
Jansen: horizontal drilling
Brouwer: a pedalo that can do 100 kmph on manpower alone

Favourite book
Jansen: 'Beyond sleep' by W.F. Hermans
Brouwer: 'A Short History of Nearly Everything' by Bill Bryson

oil field management, a methodical way of improving production yields over the long term."

What is your favourite television programme?
Jansen: "I never watch television."
Brouwer: "We've just had a baby, so there's just about enough time to watch the news."

Which television programme would you scrap?
Jansen: "None of them need to go, as they don't affect me. I do watch the occasional film, and I could do without the commercials that interrupt them."
Brouwer: "RTL Boulevard. It's utterly depressing to see how people can make a career out of patronising other people. Nonsense TV."

What could ever force you to resign?
Jansen: "If I could no longer work with integrity, and had to become involved in things that went against my conscience, like corruption."
Brouwer: "If there should ever be a fundamental difference between what I think should be done and what the company thinks."

Whom do you admire?
Jansen: "People who dare to stick their necks out in the political arena, and people who, on a personal level, do the right thing without any personal gain. In Nigeria I saw people who managed to make a go of things despite their problems."
Brouwer: "So many people. There's something in everybody."

What is the effect of your work on society as a whole?
Jansen: "I help to find the energy we need."
Brouwer: "The result should be that oil prices go down, or at least rise more slowly. We're trying to ensure that the demand for oil can be met for some time to come."

What is today's greatest challenge to your profession?
Jansen: "In a restricted sense, increasing the yield factor, as two-thirds of all oil are still being left behind. At a higher level, the transition to more sustainable forms of energy without us ending up fighting each other over it."
Brouwer: "Increasing the quantity of oil that can be extracted from a reservoir."

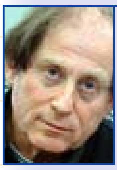
What did you fail to see coming in your profession?
Jansen: "The rate at which oil prices went up."
Brouwer: "That oil prices would increase at quite the rate they have. When I graduated in 1998, the price of oil was $9 a barrel; today it's $135 a barrel."

Which question are you happy not to have been asked?
Jansen: "What I would do if I could live my life over again."
Brouwer: "No idea."

PEOPLE

An overview of the most important awards, appointments and other remarkable personal milestones at TU Delft

Professor of hydraulic engineering **Han Vrijling** has been appointed an honorary member of the Dutch engineers' association, Kivi Niria. This honorary title was bestowed on him for his international scientific work in the field of hydraulic engineering. Vrijling is one of the critical voices who, over the past couple of years, and especially following the New Orleans hurricane disaster, warned that the Netherlands should also be worried about its safety from flooding. In his opinion, an additional 1,000 million euros a year must be spent on upgrading Dutch flood protection.



He has been working for almost twenty years with Moscow State University, which in October honoured him with an honorary professorship. Professor **Salle Kroonenberg** received this honorary title for his research on sea level changes in the Caspian Sea. "It's a bit quieter now, but until recently that sea level was changing a hundred times as fast as those of the oceans." Kroonenberg is proud of his appointment, which does not bring any extra work with it. He has given many lectures in Moscow, and he has supervised both Russian and Dutch graduate and doctoral students doing research on the sea level of the Caspian Sea.

Shortly after his retirement as professor of environmental design, **Kees Duijvestein**, of the Faculty of Architecture, received a sustainability award from Jacqueline Cramer, the Dutch Minister of Housing, Spatial Planning and the Environment. Duijvestein, who was recommended for the award by more than ten people, was described by the jury as a 'modest pioneer'. He is delighted with the recognition: "I've been working on sustainability for a long time, and interest in the environment tends to vary. There were times when I wondered why I kept at it." Since his retirement, Duijvestein has been working on setting up a new professorship for smart architecture.

'Going with the flow' is the title of the acceptance speech that Professor Dr **Fulvio Scarano** will deliver on 3 December. The new professor of aerodynamics uses unique techniques to look at flows, in order to learn more about turbulence. Plenty more experiments are just waiting to be carried out and provide more insight into how airflows affect, for example, an aircraft wing or a cyclist, Scarano says. Earlier this year the European Research Council awarded him 1.5 million euros for research on using images to predict the noise created by an airflow passing an object, e.g. an aircraft.

The Piet Zwart Prize is awarded biennially. This year the prize went to Professor **Bruno Ninaber van Eyben**, of the Faculty of Industrial Design Engineering. Van Eyben received the prize for his complete works, the best known of which are perhaps the designs for the last series of guilders and for the Dutch side of the euro coins. His design vision of 'no need for more, can't do with less' has previously brought him acclaim. This year he was also awarded a prestigious lifetime achievement award by the Foundation for the Visual Arts, Design and Architecture.

After more than 25 years, Professor Dr **Geert Jan Olsder**, of the Faculty of Electrical Engineering, Mathematics and Computer Science, retired from TU Delft. On 14 November he delivered his farewell address. Olsder was appointed professor of mathematical system theory in 1983. In that capacity he "navigated" – as he said in his speech – "between applied and theoretical mathematics". Together with his doctoral students, he applied mathematics to subjects ranging from population policies to the timetable of the Dutch railways. Olsder also held the post of deputy-rector since 1999.

On the occasion of his farewell reception in October, Dr **Sjoerd Dijkstra**, of the Faculty of Mechanical, Maritime and Materials Engineering, was made a Knight in the Order of Orange-Nassau. Dijkstra received this honour for his role in education and within the TU Delft organisation. As a professor and education coordinator at the Delft Centre for Systems and Control, Dijkstra trained many generations of students. He made major contributions to the field of control engineering and, among other duties, he managed a faculty department and was secretary of the Works Council.

High-tech equipment in operating theatres should be easier for surgeons to use, and engineers could help, according to Professor Dr **Jack Jakimowicz**. In November he gave his acceptance speech as part-time professor of safety in health care at the Faculty of Industrial Design Engineering. The professor, who hails from Poland, is also a consultant to the Catharina Hospital in Eindhoven. The knowledge he gained from his work as a surgeon at Catharina Hospital will now be very useful to his research at TU Delft.

[HORA·EST]

Propositions

Adapting to the Dutch way of life is fairly easy as long as you cook for yourself, don't really miss the sunshine and never have to talk to the 'Belastingdienst'.
Xinyang Wang
MSc, BA in Electrical Engineering

Dutch people seem to complain about everything except food.
Hao Liu
MSc in Engineering

Although cynicism is the defecation of the soul, it will never fertilise a fruitful seed.
Koos Huijssen
MSc in Electrical Engineering

Trying to re-write a bad part of your thesis is like preparing a Boeuf Bourguignon with an overly dry Côtes du Rhône. Four hours later, the result is still awful.
Läslo Gerardus Evers
MSc in Geophysics

The taste of Dutch beer can definitely not explain why Dutch students, on average, take more time completing their education than students in Belgium.
Arne Verliefde
MSc in Engineering

Scientists should be more aware of what Dutch comedian Herman Finkers once said: "At times you're thinking for hours without anything popping into your mind, while at other times you come to exactly the same conclusion within five minutes...."
Frank Wiertz
MSc in Process Technology

Following a BSc, MSc and PhD program in succession takes less time to complete than it does to make a tram line and a park on the TU campus
Jacob Willem Hijmissen, Mathematical Engineer

[Sound]BITES

"These days the building industry is much more interested in sustainability than it was in the 1990s, when the government took the lead and industry dragged its feet. Now everybody must follow suit. Soon there will be no demand left for the old technologies. They will have become too expensive, or there just won't be enough energy left."
Sustainable building specialist Dr Andy van den Dobbelsteen in DE VOLKSKRANT

"I design no-nonsense products, certainly. A candlestick that becomes so dirty that you can hardly get the candle out is not a good product."
Professor Bruno Ninaber van Eyben in DE VOLKSKRANT

"Then there's Diederik Samsom [Labour party MP, *ed.*], claiming that only two percent of the people in Holland can get solar panels subsidised. What nonsense! The Dutch government lacks essential knowledge. Well-founded recommendations by the energy platform not to build coal-fired or nuclear power stations are being ignored completely. The Netherlands is lagging behind where environmental policy is concerned. We cannot save the world, but we can save our own country!"
Professor Dr Wubbo Ockels in HET PAROOL

"Consumers and designers are often unfamiliar with the possibilities of industrially processed bamboo. I've done consumer research, and they associate bamboo mostly with curios, not with large-scale applications. Bamboo suffers from a lack of image: it's still perceived as a colonial item, a product with round stems that are of little use."
Architectural engineer Pablo van der Lugt in DE VOLKSKRANT

Photo: Sam Rentmeester/fmax

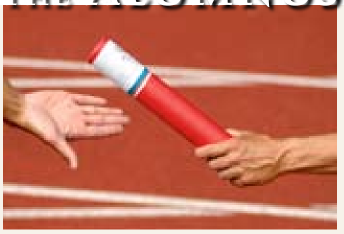
Proposition

To stimulate the communicative skills of doctoral students at TU Delft, half of the doctoral committee should consist of people who do not have a technical background.

Defence

"It is important for a researcher to be able to present his plans and results favourably, particularly to those who decide whether or not to financially support the research. The people funding the research often know little about the research field itself, and thus demand a different level of communication than do fellow scientists. Doctoral students work on a subject for a couple of years. When I'm asked what my research is about, I've found how easy it is to go into unnecessary detail - the things that occupy your mind every day. Financial backers however want to hear the broad outline and about possible applications. I would welcome it if each doctoral committee had two professors on it from a totally different field. They would be able to tell if the doctoral candidate is capable of explaining his research to people outside his own field."

Thomas Ooms
Physics Engineer



An alumnus of TU Delft writes a column and then passes the pen on to another alumnus of his or her choosing.

When I went to university, I chose my course of study because I wanted to learn something I didn't know much about. Mechanical engineering turned out to be a good choice. It covered a wide field, was a technical subject and involved lots of maths. All the other subjects I could learn from a book, I thought. I particularly liked the maths, and it was an essential requirement for so many subjects. I found that many technical problems could be modelled as a mass-spring system, which in turn could be resolved using calculus.
I still remember how I finally passed my mechanics exams once the application of the energy balance was explained to me. It was much easier than the method I had previously been taught.
System thinking still helps me in my daily job, although I'd find it hard to solve those mechanics problems these days. I use system thinking mainly for corporate processes, in particular the kind involving money being spent or earned on a daily basis. The world of logistics boils down to stock management, production world, and buying tactics. My job? I'm an operational management consultant for ordering processes. I also teach the same subject.

My system diagrams are decision models that are directly connected with the goods flow of a company or goods chain. By seeing them as little machines, accountancy becomes clear even to engineers. Certain products drive your turnover, so if you want to speed that part up, the chain must be properly connected, and then you can improve its efficiency by eliminating resistance and surplus. You will need a high-pressure setting for the times when you must deliver peak capacity. I help companies see how their key performance indicators (KPIs) are parts of the same little machine, and how they affect each other. Just imagine, you are finally able to control your company the way you control your car. You look at the dashboard and see your mileage (turnover), speed (return on investment, or inventory turns), engine RPMs (operating expenses), and fuel level (stock). Most navigation systems and on-board computers also give you intermediate values for profit, risk management and market share.

These days, engine technology is quite complicated, and your average roadside mechanic will struggle to repair some faults. The same goes for companies, which all have something unique and are increasingly integrated in terms of protocols and external factors. It makes it all the more comforting to know that you need only check a few dials to determine if everything is all right.
In my capacity as consultant and teacher I learn new things every day. I still read lots of books, and I'm following the ups and downs of the credit crisis with interest. I'm always on the lookout for the little machine in the process. Turns out there's no perpetual motion in business either, even though many bankers and investors thought there was....

Josanne Heeroma (36) is a consultant for ordering processes in the goods flow of companies. In addition, she teaches logistics and economy one day per week at the Rotterdam Academy. Josanne studied mechanical engineering at TU Delft (1990-1997). She now hands the baton on to a fellow mechanical engineering graduate, Hanneke van Oerle.
www.suchaiso.com

Horse-friendly saddles

Photo: Sam Rentmeester/FMAX

Saddles often injure a horse's back, especially when ridden by recreational riders. For her graduation project, Aafke Kauffman, an industrial designer with a passion for riding, has designed a more horse-friendly saddle.

George van Hal

"The design of the horse saddle goes back centuries, and it hasn't changed in all those years," says Aafke Kauffman. Not only are today's saddles old-fashioned and heavy, but worse, in some cases, they can actually injure the horse. Relatively inexperienced riders tend to leave the girth too loose, Kauffman explains, and this injures the horse: "Injuries can range from skin burns and abrasions to subcutaneous necrosis."
Kauffman loves to ride herself, so the subject for her graduation design project was easy to find: "I started looking for something that was part of my experience." Kauffman asserts that such injuries to horses can be prevented. "A saddle must fit snugly, so that the pressure is evenly distributed," she says. "For traditional saddles, this is done by padding the gaps with wool, which is then moulded into place by hand."
This however is not the most reliable of methods, so Kauffman went in search of a better one. She decided to abandon the traditional wool method: "My new saddle uses padded cushions, and these cushions are attached to sprung arms, which can move up and down." This technique ensures that as soon as the saddle is strapped in place (still using the traditional girth around the horse's body), it will fit perfectly of its own accord. Kauffman: "All the rider then needs to do is fix the springs in place by securing a few clips." Simple enough, but the effect is dramatic. "The saddle actually distributes the rider's weight more evenly," she says, and simulations have shown that consequently her saddle reduces the number of pressure spots on the horse's back that could cause injury.
Another problem with traditional saddles is the amount of maintenance they require. "Leather saddles really need a lot of attention," she confirms. "You often find that a buckle or something else has come loose." Kauffman's new saddle solves this problem too, for it features a removable cover that was apparently inspired by Ikea sofas: "After you use the cover, you can just pop it into the washing machine." Nonetheless, riders who love tradition are also catered for. "The saddle can still be covered in leather. Some people will really love the concept," she firmly believes.
Kauffman meanwhile is busy further developing the saddle at her present employer, Spark design & innovation. "I've ridden the prototype once, but it's still a bit fragile," she says, adding that the plan is to make a series of prototypes. "This will allow more riders to use the saddle, and then we can use their feedback for further development."

More information: www.sparkdesign.nl.

WHO & WHERE

DELFT UNIVERSITY OF TECHNOLOGY *has eight faculties, each of which is engaged in education and research in one or more disciplines. The University was founded in 1842 by King William II. With 13,000 students, 2,800 scientific staff members and 2,000 technical and administrative employees, it is the largest university of technology in The Netherlands.*

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