2009.2

Research and education at
Delft University of Technology

Delft Outlook

Dialogue between the port of Rotterdam and TU Delft

Robot ray • **Physicist Nynke Dekker**
Whizz kid • Mission: gravity • **Dust clouds** • Funky flip-flops

Contents

2009.2 Delft Outlook

DO

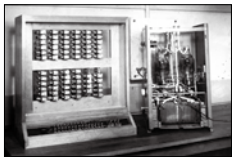
[Edit]DO

Observation lies at the heart of all scientific research, and our methods of observation are becoming increasingly sophisticated. A shiny black 'creature' wearing a blue skirt, Galatea, a robot ray developed by a team of aerospace engineering students, searches the sea bed for potential troublemakers like cyanobacteria and terrorist bombs. This could render robot ray a useful ally in port security operations. A decade has passed since the Port Authority of Rotterdam and TU Delft began collaborating in the Port Research Centre Rotterdam-Delft. At the time, the co-chairman of the project's programme council observed that TU Delft was a rather 'tunnel-visioned' organisation, but since then this partnership has become more professional, with future research programmes set to focus on energy and sustainability. The port as a test bed. The living cell, meanwhile, is a garden that remains relatively uncultivated and in which observation is a comparatively recent activity. Physicist Nynke Dekker is developing technologies that will help us understand how biological molecules work. These hi-tech gadgets include magnetic nano tweezers, which Dekker hopes will be ready for use this summer. In years to come, the observations made possible by her fundamental research could contribute to the development of improved cancer growth inhibitors. Observations from space by the Goce space probe will help map the Earth's gravity structure, thus providing fresh impetus to discussions on climate change, as we gain a better understanding of what exactly is occurring in our oceans. Observation teaches us to take a different look at the world around us. I wish you a wealth of fascinating observations during the summer holidays.

Frank Nuijens
Interim Editor-in-Chief
Delft Outlook

20

10



26

COLOPHON

coverphoto

Photo: Nout Steenkamp/fmax

Volume 26, № 2

Delft Outlook is published four times a year
by Delft University of Technology.
ISSN 0926-7212

editorial staff

Frank Nuijens (*Interim Editor-in-Chief*),
Dorine van Gorp, Pascale Warners (*managing editors*),
Tomas van Dijk, Erik Huisman, Maaike Muller,
Sam Rentmeester (*image editor*),
Connie van Uffelen, Jos Wassink

office

P.O. Box 139
2600 AC Delft
The Netherlands
T (015) 278 4848
F (015) 278 1855
E delftoutlook@tudelft.nl
www.delftoutlook.tudelft.nl

contributing writers

Frans Godfroy, Joost Panhuysen, Angèle Steentjes,
Marcella Tabeling

translations

Margareth Clegg, Marcus de Geus, David McMullin

subscriptions

Willy Abramsz-Witte
(015) 278 8598
w.m.s.abramsz-witte@tudelft.nl

design & typesetting

Cok Francken – MultiMedia Services, TU Delft

photography

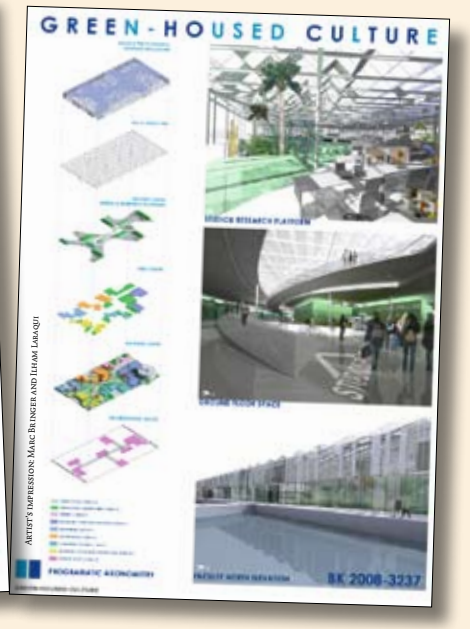
© TU Delft, unless otherwise noted

printing

DeltaHage BV, The Hague

Architecture in a greenhouse

The TU Delft's former main administration building along the Julianalaan with its extension.



The top floor of the greenhouse called Bouwkunde.

BK City: The making of the future. That was the title of a symposium on rehousing Bouwkunde held on Wednesday, May 13th, exactly one year after the fire that destroyed 'Bouwkunde', the Architecture faculty building. The winning plans of the competition, Building for Bouwkunde, were presented with ideas ranging from an enormous greenhouse, a mall in Mekelpark, and an extension to the existing Julianalaan building, serving as a source of inspiration for the new accommodation. The same day saw the presentation of the results of a think tank. What the faculty building will eventually look like, and where it will be located, remains to be seen. "These ideas and the think tank conclusions serve as the foundation blocks for the next stage," says Agnes Wijers, the competition supervisor.

The best ideas to replace the destroyed Bouwkunde building come from architects in Rotterdam, Amsterdam and Paris. They were selected from 466 entries from 50 countries.
For his design, a World without Objects, award-winning Rotterdam architect Gijs Raggers was inspired by the famous post-war Rotterdam shopping mall, the Lijnbaan, created by the architect who also designed the original Bouwkunde building, J.H. van den Broek.
Raggers superimposed the Lijnbaan, a mall measuring 500 by 5 metres, onto the Mekelpark. Low-rise buildings lining the long street ('lifts can be replaced by bicycles') offer room not only for auditoriums, studios, and reading-rooms, but also for a bar, a restaurant, and sports facilities. The only high-rise building is the library with its 24 floors.
Competition winner Laura Alvarez from Amsterdam based her plan, Amalgam, on the Bouwkunde faculty's current accommodation along the Julianalaan. Nine out of ten users are satisfied with this building, but they don't like its dead-end wings and they miss the long corridor of the original building, the architect discovered. Alvarez designed a new extension to the existing building that does away with the dead ends. The wings will house studios and offices ('improved contact between students and staff') that look out onto large courtyards. Auditoriums, exhibition rooms, a bookshop, and a restaurant are located along a corridor.

The design from the Paris-based duo Marc Bringer and Ilham Laraqui, Green-house Culture, is based on a gigantic greenhouse that alludes to the market-garden greenhouses that cover much of the surrounding countryside. Solar energy provides part of the heating during the winter, and rain water is used to flush the lavatories and water the green indoor gardens.
The Bringer and Laraqui design uses two large, curved platforms that have been subdivided into separate islands with park-like areas. The second floor houses studios, offices, and meeting rooms. The ground floor with its auditoriums invites people to cycle or walk, which is why bicycle sheds have been provided near the entrance.

More information
www.buildingforbouwkunde.nl

Cover stars

It sounds like a Hollywood disaster movie, with a section of the enormous West Antarctic Ice Sheet collapsing into the ocean, and to make matters even worse, causing a slight shift of the Earth's axis of rotation. The rising sea levels resulting from all this will hit the U.S. the hardest.

This is the scenario that TU Delft researchers outlined in the 15 May edition of *Science*. Their research results were featured on the magazine's cover.
The West Antarctic Ice Sheet has been a source of worry to climatologists for decades. If the glaciers that float off the continent were to drift away, a section of the adjoining ice mass could end up in the sea.
The effect of such an enormous mass of ice shifting would be a five to sic metre rise in global sea levels. Or at least that was the established opinion for decades. Researchers Dr Bert Vermeersen and Dr Riccardo Riva of the Delft Institute of Earth Observation and Space Systems, together with their colleagues at Bristol University, mapped the ice masses that pose a threat; their calculations reveal that the average sea level rise would be 'only' 3.3 metres. They also predict large regional variations, which will occur because the Earth's gravity field isn't uniformly distributed, and because of a slight shift in the rotational axis of the planet when part of the Arctic ice disappears into the sea. Bearing the brunt of the assault will be North America, where the sea will rise to a quarter above the average. Along the Dutch coast, the melting ice will cause sea levels to rise by an average value of 3.3 metres.
Vermeersen expects even more accurate forecasts in the near future. His hopes are pinned on the recently launched ESA satellite, Goce (Gravity field and steady-state Ocean Circulation Explorer), which will soon be helping to map the Earth's gravity fields with unprecedented accuracy.
In June, researchers at the Kavli Institute of Nanoscience could also bask in the glory of a cover publication in the prestigious journal, *Nature Nanotechnology*. The article's main author, Dr Gary Steele, and the team of Prof. Dr Leo Kouwenhoven, were the first to capture a single electron in a tunable carbon nanotube. The nanotube acts as a quantum dot, because it can be considered a 'box' in which a controllable number of electrons can be stored. The researchers even succeeded in using a tunable electron to create a double quantum dot.
Jonathan L. Bamber et al., Reassessment of the Potential Sea-Level Rise from a Collapse of the West Antarctic Ice Sheet, *Science*, 15 May 2009.

More information:
Dr Bert Vermeersen, L.L.A.Vermeersen@tudelft.nl.
G.A. Steele, G. Gotz, L.P. Kouwenhoven, 'Tunable few-electron double quantum dots and Klein tunneling in ultraclean carbon nanotubes', *Nature Nanotechnology*, June 2009. Dr Gary Steele, G.A.Steele@tudelft.nl.

Eco-friendly tuk-tuks

They spent a whole year fiddling with petrol engines, injection systems and exhausts. The student teams of TU Delft, Hanzehogeschool Groningen, Hogeschool Arnhem/Nijmegen, and TU Eindhoven who are competing in the Hybrid Tuk-tuk Battle have been trying every trick in the book to make the Indian auto rickshaws as eco-friendly as possible at a bargain price.

The Delft team are banking on their special silencer. "The exhaust is our main modification," says mechanical engineering student Paul Ouweham (20). "It reduces a tuk-tuk's fuel consumption by fifteen to twenty percent. In two-stroke engines a lot of fuel escapes unused through the exhaust system. Our exhaust design creates a resonance that pushes the fuel back into the cylinder." The gleaming pipe costs just under 18 euros. According to Ouweham, an Indian tuk-tuk driver should be able to recoup the cost of the investment in 26 days thanks to lower fuel costs.
Most of the other vehicles are less thirsty. The tuk-tuk entered by Hogeschool Arnhem/Nijmegen, for example, which runs equally well on LPG and on bio-ethanol, and uses only half the fuel of its Indian cousins. On the other hand it takes about seven months to recover the cost of the engine modification, roughly 250 to 300 euros.
In July the teams will go to India to compete against each other and against three Indian student teams. Their task will be to convince a panel that they have a business case with their eco-friendly modifications. The Enviu Foundation, which organises the event, intends to market the winning system in India.

More information:
www.enviu.org

PHOTO: ROLAND PUPUPIN

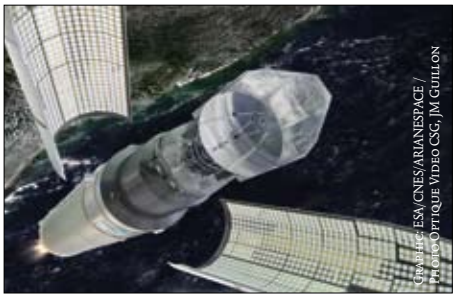
Funky flip-flops

They will be available in a shop near you very soon. They're called Plakkies, and they are brightly coloured flip-flops made from old car tyres in a factory in Durban, South Africa. Students Arnoud Rozendaal (Aerospace Engineering) and Michel Boerrigter (Industrial Design) launched the project to create jobs for the underprivileged inhabitants of the slums. And to sell more funky flip-flops, of course.

A kick up the backside

With the launch of ESA's Herschel space telescope last May an important piece of Delft engineering was sent up into space. The European probe investigates the dust clouds that permeate the universe using a sensor developed by the Kavli Institute of Nanoscience in Delft, among other equipment. "The sensor lets the telescope detect radiation particles in the deep infrared range," says research supervisor Professor Dr Teun Klapwijk. "This enables the telescope to tell which materials are out there in space. Since star dust forms the basis for the creation of stars and planets, it is a research project of major importance." The sensor, which consists of two 'barriers' only two nanometres thick between two superconducting materials, makes good use of a quantum-mechanical phenomenon known as tunnelling. "Normally, electrons cannot pass through the barrier," Klapwijk explains, "but when a radiation particle from space hits the sensor, it is detected because an electron is suddenly allowed to pass through the barrier. The electron in the superconductor receives a kick up the backside, so to speak." The Atacama Large Millimeter Array, a super telescope currently being constructed in Chile and scheduled for completion in 2012, will also feature the Delft superconducting tunnel junctions.

More information:
Professor Dr Teun Klapwijk, T.M.Klapwijk@tudelft.nl.


GRAPHIC: ESA/CNES/ARIANESPACE / PHOTO OPTIQUE VIDEO CSG, JM GUILLON

True hue

The art world was in turmoil last year when material scientists of TU Delft and Antwerp University used an x-ray technique to show that Vincent van Gogh's canvas 'Patch of grass' was hiding a painting of a woman's face. However, what the colours were that Van Gogh had used to portray the woman remained a matter of conjecture.

Material scientists are now trying to fill the hiatus by using a completely different technique, photo-acoustic spectroscopy. This summer, DelftChemTech (faculty of Applied Physics) will be starting research into this technique, which uses rays of light to induce vibrations in the canvas. Sensitive microphones will then pick up these vibrations to help reveal the hidden colours. Last year the painting was scanned with an x-ray beam produced by a synchrotron radiation source. This technique reveals the chemical composition of the hidden pigments.

Illustration: Floris Wiegerinck

"But even so, undetectable trace elements in the pigments can cause enormous variations in the colours," says materials scientist and art historian Dr Joris Dik, who became famous when he discovered Van Gogh's face of a woman. Using simple experiments, his colleagues at DelftChemTech, Professor Dr Andreas Schmidt-Ott and one of his students, Dana Zeelenberg, managed to demonstrate that colours can be accurately deduced using photo-acoustic spectroscopy.

The two scientists directed a laser beam through a sheet of paper with two coats of green paint, and a second laser beam through a sheet with some red paint and some green paint. Microphones picked up the acoustic signals produced as a result of the heat waves in the paint. The two signals were definitely different.

"Using an advanced set-up, with the laser beam's pulse frequency and the wavelength of the light freely adjustable, it should be possible to detect all the colours in a real painting," says Schmidt-Ott. "The thing is, our only output consists of sound. The correct interpretation of those noises will take some advanced mathematics. It will be some years before we will see the first results."

More information:
Prof. Dr Andreas Schmidt-Ott, A.Schmidt-Ott@tudelft.nl;
Dr Joris Dik, J.Dik@tudelft.nl.

Photo: Sam Rentmeester/FMAX

Praise for RID

In May the Reactor Institute Delft (RID) received major recognition from the International Atomic Energy Agency (IAEA). For the next four years, the Institute can call itself an IAEA Collaborating Centre, an honour that has been bestowed on only fourteen nuclear physics institutes worldwide that maintain their own research reactors. The Collaborating Centres supply information on various aspects of nuclear physics to the other 260 research institute associated with IAEA which also have research reactors of their own. Each centre has its own specialist field. The RID provides expertise on neutron research, and in particular research focused on what is known as neutron activation analysis, in which neutrons are used to look inside materials.

"This is a great stimulus for our neutron research," says commercial manager Rik Linssen. The recognition of the RID comes at just the right time, now that the institute is seeking government funding to the tune of 42 million euros to acquire a better neutron source – one that supplies cold neutrons – and to build an extension to the research facility.

More information:
Rik Linssen, R.J.Linssen@tudelft.nl.

IN·BRIEF

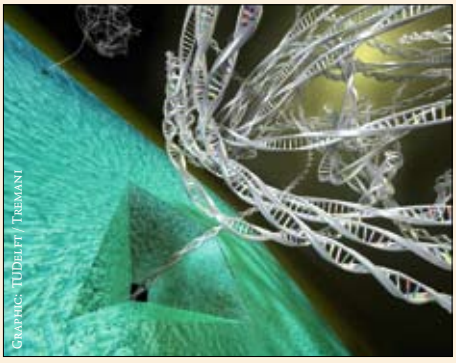
Just feel that DNA pull

In a recent article in Nature Physics, researchers at the department of Molecular Biophysics (faculty of Applied Physics) described a force which until recently remained shrouded in mystery and which makes DNA difficult to pull though nano holes. Thanks to the discovery they are now able to reconstruct the structures of pieces of genetic material with greater accuracy.

The scientists are investigating DNA by pulling pieces of the genetic material through a small hole with a diameter ranging from ten to one hundred nanometres that has a small voltage applied to it. The resulting electrical field exerts a force on the negatively charged DNA molecule. The measure of this electrostatic force reveals a lot about the structure of the DNA to biophysicists.

However, electrostatic forces alone cannot explain the resistance the DNA encounters. This was noticed for the first time as early as 2006. Lemay worked on a theoretical explanation of the phenomenon. "The negatively charged DNA attracts positive ions from the surrounding liquid, causing it to become surrounded by a cloud of anti-ions." This neutralises the charge. However, when the strand of DNA passes into the hole, the electrical field pulls the DNA strand one way (but it is held in place) while the positive ions are pulled in the other direction.

"For our research we have developed a unique test set-up that enables us to exert forces locally on any spot along DNA and RNA molecules we like to pick," says co-author Professor Dr Cees Dekker. "This lets us measure the force needed to open an RNA molecule, which is all coiled together like a hairpin shape".



Graphics: TUDelft | Tremani

Serge G. Lemay et al. 'Origin of the electrophoretic force on DBNA in solid-state nanopores', Nature Physics, 29 March 2009

More information:
Professor Dr Serge Lemay, S.G.Lemay@tudelft.nl.

Robot ray the bloodhound

Searching underwater for cyanobacteria, terrorists, and mines is all in a day's work for a robot ray developed by a team of aerospace engineering students.

Maaike Muller

"This is our creature," says aerospace engineering student Alwin Wilken, pointing into a large box he has just opened. Inside is shiny black contraption wearing a blue skirt. Meet robot ray.

"It's a nature-inspired underwater sensor platform," Wilken explains. He is one of the students who developed Galatea, as the robot ray is also known. In the belly of this robotic beast are various sensors that can be used for a variety of different purposes, such as searching underwater for mines. For robot ray's propulsion, the designers decided to forego the standard propeller-driven solution; instead, robot ray moves through the water by slowly undulating the sides of its body, which is how a real ray swims. Or, as Wilken's teammate Remco Jutte puts it: "It uses an undulating movement to push water backwards, which propels it forward."

The prototype built by the eight-member student team has just completed its first swimming lessons. "At first it veered off course a bit," Jutte says, "but by adding lead to the body in the right places, it can now swim pretty straight." Long before robot ray took its first swim in the test tank at the maritime technology faculty, the students had already completed 18 months of intensive study and testing.

Gold

"Underwater robots are hot," says Dick Simons, a professor of earth observation at the Faculty of Aerospace Engineering, explaining why, back in 2007, he and lecturer Hans van der Marel decided to assign two groups of students the task of designing a port patrol system. The system was to consist of a swarm of autonomous, unmanned submersibles, each of which would guard a small section of a harbour and transmit information to a buoy. On shore, the information from the buoys would then be used to compile a picture of the entire port system. Simons: "Individually, each robot wouldn't be capable of much, but in large numbers they can protect a harbour against terrorist attack."

One group of students designed a yellow, torpedo-like mini-sub. "But machines like that already exist," says Simons, who consequently was much more interested in the original design produced by the other team. He points to a drawing of a rather bulky predecessor of Galatea: "That ray can lie on the bottom to conserve energy, and whereas a propeller would soon become entangled in debris or vegetation, this robot simply flaps its fins twice and is ready to swim again."

It was a nice concept, Simons agreed: "But it was still nothing but a study on paper, so I decided to see if I could put together a team to build such a robot." He put aside the idea of providing port security, as this would require a whole swarm of robots. "Just one of them is enough to get started," Simons explains. "I thought I'd struck gold. And now I really think we're getting close."

With its speed of only one to two metres per second, the robot ray cannot keep up with other underwater robots. Nonetheless, it does have a few major advantages, according to Jutte and Wilken, who promptly show a short film in which the Galatea glides quietly and smoothly through the water. "This is exactly what makes it so useful for underwater inspection work," Wilken says. "It's also extremely manoeuvrable; it can rotate around its own axis with ease."

Empty box

These properties are among the reasons why the Dutch navy, the Ministry of Transport, Public Works and Water Management, and Fugro, a geotechnical surveying company, have all expressed interest in Galatea. "The number of applications is vast," says Simons, who then has no trouble spending an hour listing them. The robot ray must be an 'empty box' capable of containing a variety of sensors. "A simple camera, a sonar system, or a chemical sensor, for example," Simons says, ticking them off.

"Inspections that are now being done using ships loaded full of equipment and crew may soon be done much more inexpensively and efficiently with our robots."

'Robot ray can rotate around its own axis with ease'

Using sonar sound waves, the robot ray could help the navy locate the many mines left on the bottom of the North Sea after the Second World War. Or the robot ray could use its sonar to map a riverbed, which would assist the department of water management in deciding where to start dredging in order to keep rivers navigable. "And the fishing industry is also interested," Simons adds. "Features of the sea bed can be used to deduce where certain species of fish have their habitat."

A robot ray equipped with a chemical sensor could help the authorities monitor the growth of cyanobacteria in the lakes and ponds where people swim during the summer months. Moreover, equipped with a camera, robot ray could inspect pipelines located 300 metres beneath the sea

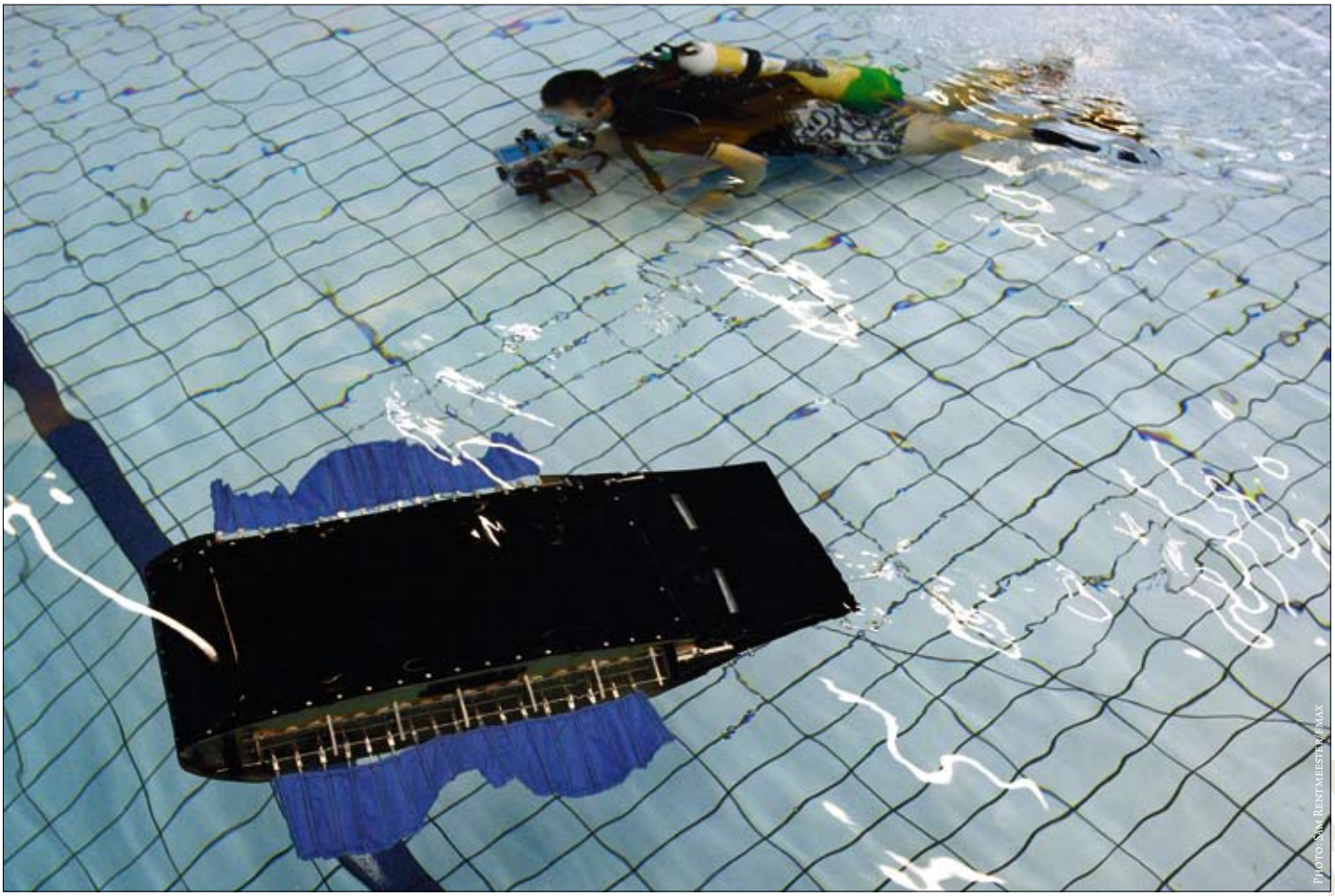


Photo: Sjaak Rentmeester/VOFMAX

More tests and research will be conducted before the robot ray can be marketed and sold.

for companies like Fugro. "I also recently got a call from customs, asking whether the robot ray could help them search for the drugs that traffickers sometimes attach to the outside of a ship's hull," Simons adds.
Simons is now looking for the investors needed to develop one of Galatea's applications within the next year. "If we can prove that robot ray works, we can take it from there. Put it on the market." The students of the Galatea team are already thinking of setting up a company to sell the robot ray when the time comes. First, however, more research and tests must be conducted before their first prototype becomes a marketable product.
The shape of the ray's hull, which is based on an aircraft's wing, will require little changing: wind tunnel tests have shown the hull to be hydrodynamically correct. "We will probably be able to control the ray using just its fins," Wilken says, "but to be on the safe side, we divided the rear trailing edge into two moveable flaps, which we can also use to control the ray during our tests."

Watertight

The designers admit however that the next prototype will have to be more user-friendly. Jutte: "Each time we conduct tests, we must spend half an hour with tape and screws to make the ray watertight enough to swim. But even then, water sometimes gets in." The vessel's controls also need some rethinking. "GPS and standard radio communication don't work underwater," Simons explains. "Other technologies exist, but we must apply the right one."
Three of the team's students have made the robot ray's propulsion method their graduation project assignment; they are trying to improve the undulating motion of the ray, in collaboration with Wageningen University's department of experimental zoology and TU Delft's Faculty of Aerospace Engineering's aerodynamics group. The robot ray's current design features 17 ribs on each side, with each rib capable of being individually controlled.

'Customs asked us if robot ray could help them search for drugs underwater'

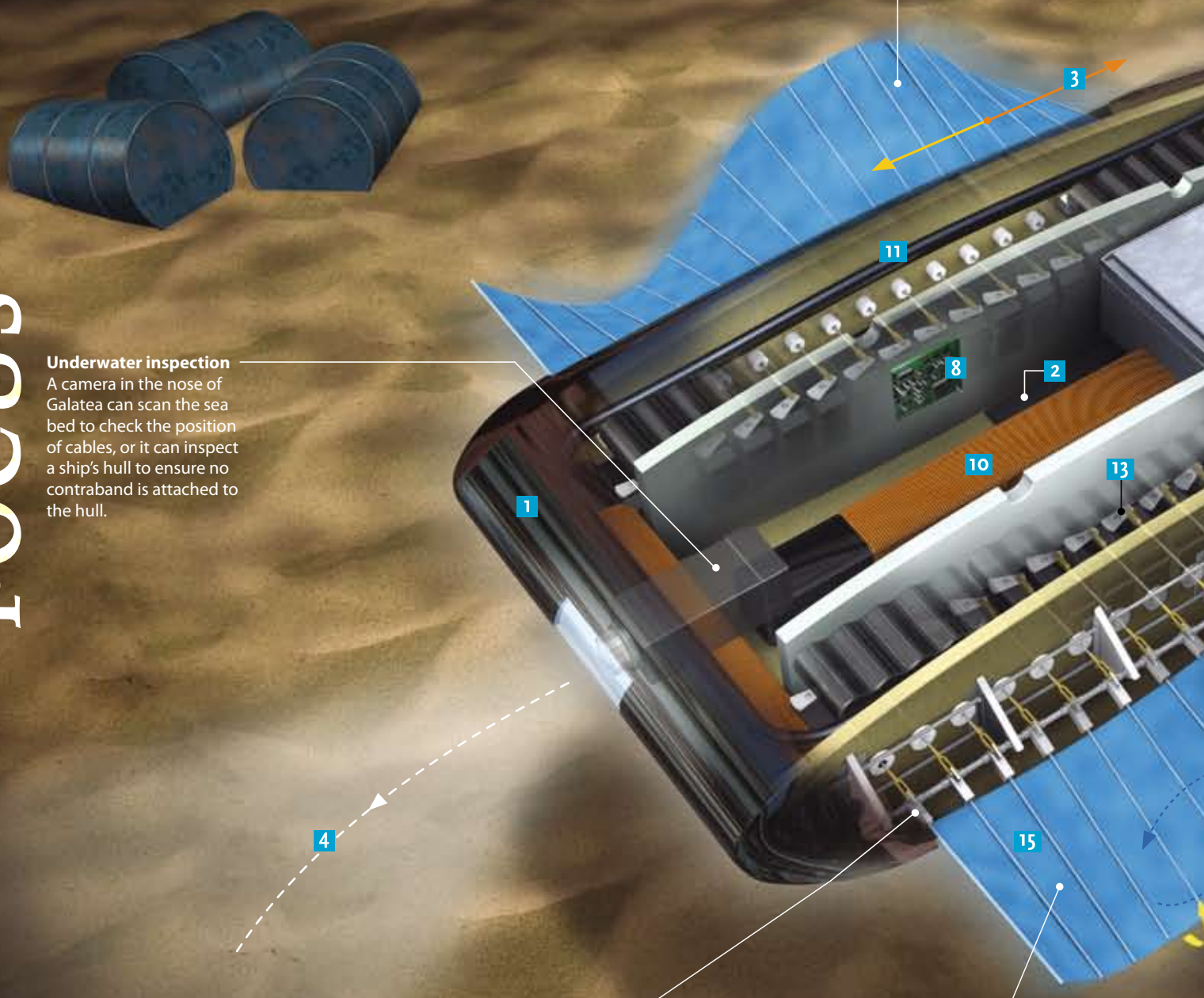
Simons believes there must be a simpler way: "The current system is ideally suited for conducting research, however." Initially, the students were not even sure if their idea for an artificial ray would work. To test their idea, they fashioned a fin out of 17 metal ribs and a piece of cotton fabric. This contraption was then suspended in a pool in the workshop, and the ribs made to move in succession, rather like a Mexican wave in a sports stadium. The students almost started their own wave of joy when they saw the fin slide along the metal suspension rack. The principle had been validated: the fin was able to propel itself through the water. Wilken: "That was certainly a moment for cheering."
(see also infographic on the following pages)

Robot ray

Hull structure
The shape of the hull 1 is based on an aircraft's aileron. The wing shape combines low drag in water with enough storage space inside the hull to accommodate all the various subsystems and sensors. The hull is made of fibre-reinforced plastic (glass-fibre and epoxy resin), shaped around a PVC foam core.

Lead ballast
The lightweight hull, with its 65-litre volume, enables the robot to carry heavy sensors while still being suspended under water. In the current prototype, which carries no sensors, the payload is simulated by 12 kilos of lead 2 placed on the hull's bottom. The lead weight provides the balance that the robot ray needs to swim in a perfectly straight line.

Fins for direction
Varying the frequency or amplitude of the waves in the fins produces a differential thrust 3, causing the robot ray to veer in one direction 4. By producing thrust in opposite directions (one wave pushing forwards, the other backwards), the ray rotates in its place.



Underwater inspection
A camera in the nose of Galatea can scan the sea bed to check the position of cables, or it can inspect a ship's hull to ensure no contraband is attached to the hull.

How a ray swims
On each side, the robot ray carries 17 servo motors 13 (angular velocity 300 degrees/s, maximum static torque 2.4 Nm) that together drive a fin (63 cm × 10 cm). Each motor sweeps between its two extreme positions, driving an arm 14 that moves up and down outside the robot. The 17 arms move in succession to create a sinusoid wave that runs backwards (or forwards). The arms are linked together by means of a cotton fabric fin 15. As the fin's wave pushes a mass of water backwards, the robot moves forwards. The robot propels itself by pushing against the water 16. If the motion of the sinusoid wave is reversed, the robot moves backwards.

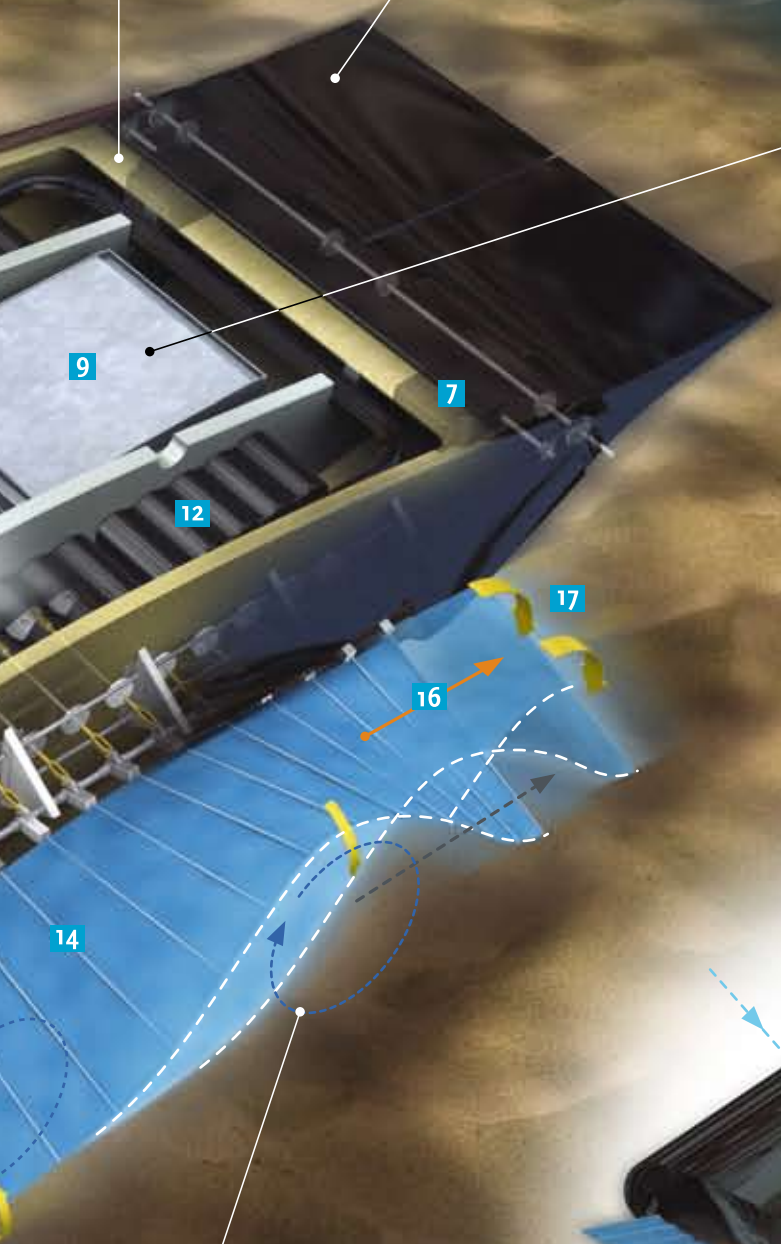
Maximum propulsion 16
Static force tests show that propulsive power peaks if the fin's undulations cover 1.5 sinus periods. The thrust rises with the increasing amplitude of the fin's motion. With the fin's ribs waving up and down at a frequency of approximately 1 Hz (covering an angle of 40 degrees), the total thrust generated by the robot is 2 N.

Galatea
The underwater robot ray was named after a sea nymph from Greek mythology. Galatea was the daughter of the sea god Nereus.

Tailplane
The tailplane is not intended to provide thrust, but instead acts as a hydroplane. By changing the angle of the two surfaces, the robot ray can be made to move towards the bottom or towards the surface 5. Differential positions of the tailplane surfaces cause the ray to roll about its longitudinal axis 6. The tail planes need to be relatively large, because the directional force they provide is proportional to their surface area and the square of the robot's (low) speed. Each tailplane is driven by its own servo motor 7.

Follow-up research
Galatea is a successful proof of concept. The students are now focusing on analysing the flow around the fins, using computer models and wind tunnel tests to optimise the propulsion. In addition, the robot will have to be able to complete a pre-programmed course on its own. A number of structural improvements have also been devised. The current design uses a separate servo motor to operate each of the ribs in the fins. Using a single motor to drive a camshaft operating all the ribs simultaneously will considerably improve motor efficiency.

Remote control
A controller 8 handles communication with the pilot on shore and controls the operation of the servo motors. The data exchange with the pilot is conducted through a cable or a wireless modem 9. The modem contains two rod and coil assemblies 10 that comprise the receiver (12 kg per rod), a ring 11 for transmitting (2 kg) and an electronics unit. Because the underwater modem is heavy and cumbersome, and signal transmission is error-prone and slow (with 2.5 seconds delay between transmission and reception), wireless testing has not yet been started.



Galatea Prototype

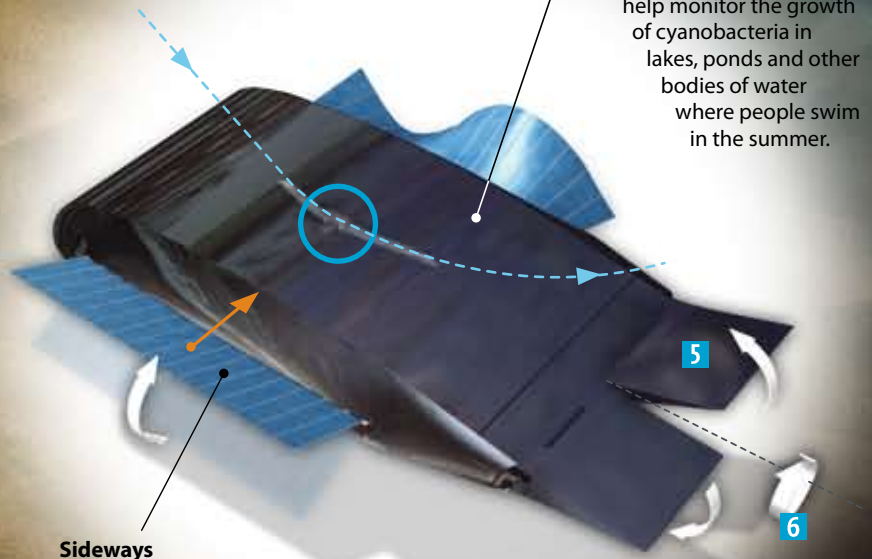
Dimensions l × w × h
120 × 80 × 18 cm

Volume
65 l

Top speed
30 - 40 cm/s

Batteries 12
The servo motors are powered by 6 battery units with a total capacity of 540 Wh. The power consumption is approximately 240 W at a speed of 30 to 40 cm/s. In normal operation a full battery charge lasts about 5 hours.

Testing the water
A robot ray carrying a chemical sensor could help monitor the growth of cyanobacteria in lakes, ponds and other bodies of water where people swim in the summer.



Vortices
The fins induce a rotating motion in the mass of water between each fin. At the end of the fin, this vortex 17 provides extra thrust. These vortices (caused by differences in pressure around the moving fin) also occur along the sides of the fin, but the resulting forces cancel each other out along the fin's length.

Sideways
A flat, waving fin enables the robot ray to move sideways.

Illustration: ESA - AOES Medialab

The missing link

Ocean currents, tectonic shifts, and climate change. Goce, a recently launched gravity probe, is expected to provide a major boost to the study of these forces of nature. TU Delft is closely involved in this European Space Agency (ESA) project. "They call us the Delft Mafia."

Tomas van Dijk

"So when did the champagne corks fly? Well, we were very relieved just to see the rocket lift off without any mishaps. Its destination was quite a change from its original target, which would have been a city like Washington D.C. We reached the high point when the third stage separated smoothly. That was when we uncorked the champagne, because that was stage where things had gone wrong during the previous ESA launch."
With a fine sense of understatement, TU alumnus and current mission manager of the Goce satellite, Dr Rune Floberghagen, describes Goce's launch on 17 March 2009. The last time ESA used a similar rocket – a modified Russian long-range missile (Rockot) – to launch a space probe, the commands to separate the second and third stages went unheeded, causing the CryoSat probe to plunge into the Arctic Ocean in 2005.

Grace

Goce is not the first satellite to measure the Earth's gravitational fields. The American-German satellite Grace (Gravity Recovery And Climate Experiment) has been doing this since 2002. Grace consists of a pair of satellites that follow each other at a distance of 220 kilometres and at an altitude of approximately 450 kilometres. Using radio beams in the microwave range, the rearmost probe monitors the minute changes in distance from its twin brother that are caused by variations in the Earth's gravitational pull.
"Grace and Goce are complementary," Vermeersen says. "Grace can be used to monitor variations over time, showing the changes that, for example, magna flows cause in the Earth's inner regions. It can also be used to observe hydrological phenomena, such as the seasons in the Amazon region. During the wet season, the forest mass increases as the vegetation sucks up water like a sponge and grows more foliage. The gravity readings from Grace also show whether ice has melted at the poles. Grace's drawback, however, is that it's like looking through frosted glass: the resolution is much lower, so you cannot see exactly where the changes took place. Any changes that you measure are spread out across 500 kilometre stretches. Grace is also less suitable for accurately measuring the differences in the level of the geoid, as it is always several centimetres off. Goce meanwhile delivers an instant snapshot with a much higher resolution."

This time round the launch went perfectly, even if it was held a day later than originally planned. On 16 March, the launch tower's automatic doors failed to open; the relays controlling the door mechanism turned out to be faulty.
"The mind boggles," Floberghagen sighs.
In 2001, Floberghagen received a doctorate degree from TU Delft for his research on lunar gravity measurements. Since then, his impressive career trajectory has taken him up to the position of mission leader at ESA. Floberghagen watced the Goce launch from the Esrin communication centre in Frascati, Italy, from where he supervises the mission.

Low Earth Orbit

In the afternoon of 17 March, Goce rose from the Russian space centre at Plesetsk to assume its orbit around the Earth.
"Just to be sure, we requested that the launch tower doors be opened five hours in advance. Fortunately, we were able to do this because there was no wind blowing that day," Floberghagen recalls.
Less than 90 minutes later, having crossed Greenland, Alaska, the Pacific Ocean, Antarctica, and the Horn of Africa, the probe was picked up by the ESA earth station in Sweden. Goce had entered a good orbit, at an altitude of approximately 280 kilometres. Eventually, Goce will descend to its destination orbit of 260 kilometres, to which the satellite is now slowly descending.
Earth scientists are now eagerly awaiting the data Goce promises to provide. Goce, which stands for Gravity Field and Steady-State Ocean Circulation Explorer, is currently mapping the structure of the Earth's gravity field. A better understanding of this structure will allow scientists to study ocean currents in greater detail, and to predict and calculate sea levels rises and major geophysical processes, such as earthquakes.
The Goce gravity mission traces its roots back to TU Delft, where Dr Reiner Rummel, professor of space geodesy at TU Delft up to 1993, first took the initiative for this research satellite. Rummel currently supervises the High Level Processing Facility, a consortium of ten European research institutes that will analyse the gravitation data Goce gathers. Among the consortium partners are the Delft Institute of Earth Observation and Space Systems (DEOS), and the Netherlands Institute for Space Research (SRON).
"The concept dates back 25 years," Rummel explains over the telephone from the Technical University of ▸▸


PHOTOGRAPHER UNKNOWN

Prof. Dr Reiner Rummel

Munich (Germany), where he currently works. "We were already studying the possibility of a satellite mission for gravitation measurements at TU Delft's geodesy faculty in the 1980s. We had contacts at ESA, so we submitted the plan to them. The project was called Aristotle, and the satellite would be used to measure the Earth's magnetic field. However, the plan failed to materialise."

According to Rummel, ESA's decision in the late 1990s to proceed with Goce was influenced by the rapid rise of the climate change debate. Goce is an important tool for climate change research, such as studying the effects on the rise of sea levels. Also during the 1990s, ESA launched the Living Planet programme, a major research initiative focusing on the way the Earth works. Goce was a perfect match.

Goce must lead us to the Holy Grail of earth science, the geoid, which is the shape the Earth would have if it were entirely covered by a stationary layer of water; in other words, a completely blue planet devoid of the effects caused by wind, temperature, tides and other currents. As such, rather than a smooth globe, the Earth would resemble a dented apple.

Because mass is not equally distributed inside and on the surface of our planet, gravity varies from place to place, and with it the gravitational acceleration, resulting in different water levels. Sail, for example, from Spain to Turkey, and without realising it, you actually pass through a 30-metre deep trough.

In order to model the climate, tectonic shifts, and ocean currents, as well as dynamic processes, such as wind, tides, and temperature fluctuations, the variations in gravity and gravitational acceleration must also be taken into account. Dr Bert Vermeersen, of TU Delft's Faculty of Aerospace Engineering's astrodynamics and satellite systems group, calls Goce the "final piece and the missing link" of earth observation.

"The water level of the geoid, also known as equipotential,

FOCUS

Rebounding Earth

While the world is worrying about rising sea levels, the water level appears to be dropping in the Scandinavian Bothnian Gulf, where 200-year old boathouses now lie perched two metres above the shoreline. The water level is shifting by one centimetre every year; however, this is not a case of sea levels dropping, but rather of the sea floor being lifted. The driving forces behind this change are the molten rock flowing in the Earth's upper mantle, between 100 and 700 kilometres below the surface. The rock is flowing back to fill a depression that was formed during the last ice age. Some 20,000 years ago, Northern Europe was covered by a 2.5 kilometre thick crust of ice that pressed down on the surface. Now that the ice has gone, the Earth's surface is springing back into shape.

Dr Bert Vermeersen is researching this phenomenon, known as post-glacial rise. He is studying the gravity images of the area produced by the American-German satellite Grace (Gravity Recovery And Climate Experiment). These images show that the gravity fields are relatively weak, which is to be expected when the ice has pushed the surface away. The problem, though, is that these images are very vague. Vermeersen hopes that Goce will make it easier to see the fingerprints left behind by the ice mass, which would allowing him to model the post-glacial rise more accurately.


PHOTO: BRAND OVERBEEKD

Along the coast of the Gulf of Bothnia, 200 year-old boathouses now sit two metres atop the shoreline

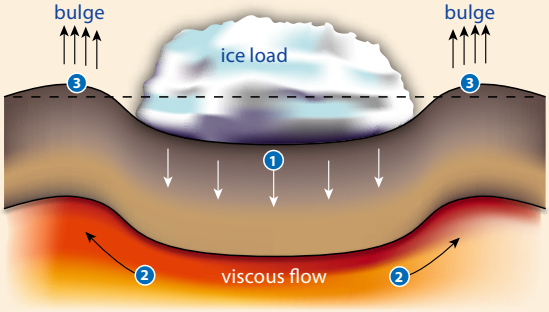


ILLUSTRATION: MULTIMEDIA SERVICES

Effects of the ice age on the Earth's crust

"This is also very useful for research into the rise of sea levels along the Dutch coast," Vermeersen says. "Because the Netherlands at that time was situated at the edge of the ice mass, the presence of the ice in our region resulted in an elevation rather than a depression. Therefore, as a result of the post-glacial movement, instead of rising, the surface of the Netherlands is subsiding at a rate of several tenths of a millimetre each year."

"There is something else, as well," Vermeersen adds. "We are tilting. During the last ice age, the bed of the North Sea between the Netherlands and Great Britain was dry. The area is now under great pressure from the column of water over it. As a result, the bottom of the North Sea is subsiding and the west coast of the Netherlands is tilting into the sea."

Vermeersen uses another example to illustrate the relativity of rising sea levels. Ice melting at the poles will not result in rising sea levels all over the world. Vermeersen: "Within a radius of about 2,200 kilometres from the melting ice masses, the water levels will in fact drop, because the strength of the gravity fields will decrease locally with the disappearance of the ice."

Vermeersen recently calculated that if all the ice on Greenland were to melt, the sea along the Dutch coast would not rise by six metres – which is the average sea level rise across the planet if Greenland were ice-free – but by only two metres. In the southern hemisphere, sea levels would rise by more than six metres, however. Exactly how much though depends on the gravity fields that Goce is currently mapping.

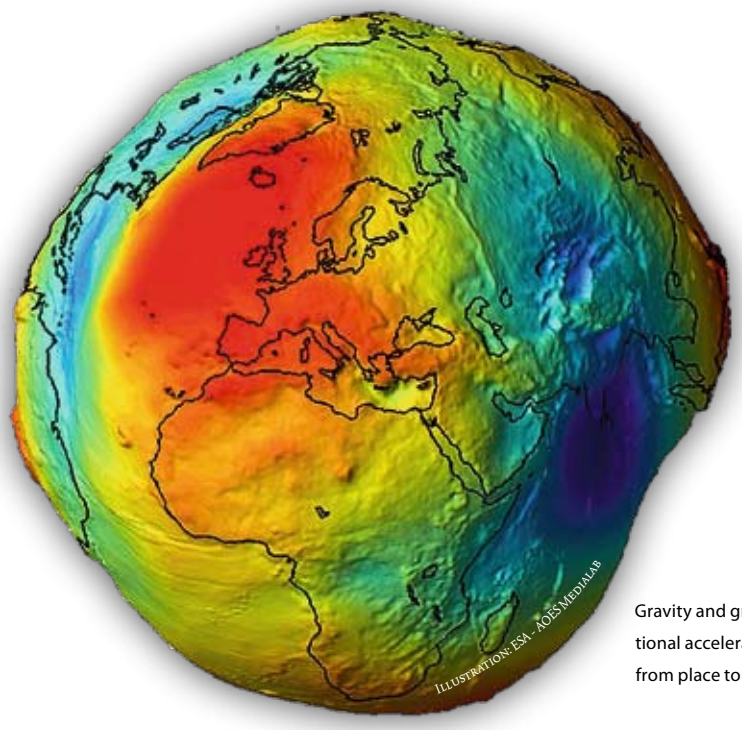
is like a reference point, and we really need to know what it is," Vermeersen explains. "We need this information in order to calculate the extent to which dynamic ocean forces contribute to the shape the oceans will eventually take. Thanks to Goce, we will soon be able to reconstruct the geoid down to the nearest centimetre. For some time now, we are already capable of using satellite laser altimetry to accurately measure the actual sea levels."
Vermeersen is also closely involved in the Goce project; he is one of the ten members of the project's Mission Advisory Group. Members of this group – who hail from the various participating countries – have shaped the project over the course of the many years leading up to the launch date, advising ESA on the instruments needed onboard the satellite, the satellite's orbit, and the way in which the data needs to be analysed.

Delft Mafia

Dr Pieter Visser, of Deos, calculated the optimum orbit altitude for the satellite as 260 kilometres. He is also a member of Goce's Mission Advisory Group, and as such is responsible for calculating the satellite's orbit. Visser is moreover a member of the High Level Processing Facility, the consortium that will analyse the gravitation data. "They call us the Delft Mafia, because we're so well-represented in the advisory group and have alumni in various key positions," Visser says, laughing.

At this very moment, the probe is mapping the Earth's gravity structure

Visser has tailored Goce's orbit to follow a track over the poles, circling the Earth roughly every 90 minutes. During each successive pass, the probe scans the Earth along a slightly different longitude. "In one month it will measure the gravitational fields of the entire surface of the Earth, with a resolution of a 100 kilometre square," Visser explains. "Goce will then continue to follow the same routine for another year, in order to provide us with enough data to filter out any noise."
Goce carries six ultra-sensitive gravity sensors that together form what is known as the gradiometer. The gravity sensors, which are arranged in pairs along three orthogonal axes, measure the relative variations in acceleration, from which they can calculate deviations in the gravity field to an accuracy of one thousandth of a Gal (Gal is the unit of gravitational acceleration).
Once Goce has completed its mission, the satellite will slowly descend into the atmosphere and burn up. Until that time, two ion motors will ensure the probe remains at the correct altitude. The motors provide a thrust of between 1 and 20 millinewton, and are needed to compensate for the friction caused by the thin air that remains at 260 kilometres above the Earth's surface. The thrust is comparable to the thrust a person generates when exhaling, or to the weight of a snowflake.



Gravity and gravitational acceleration vary from place to place

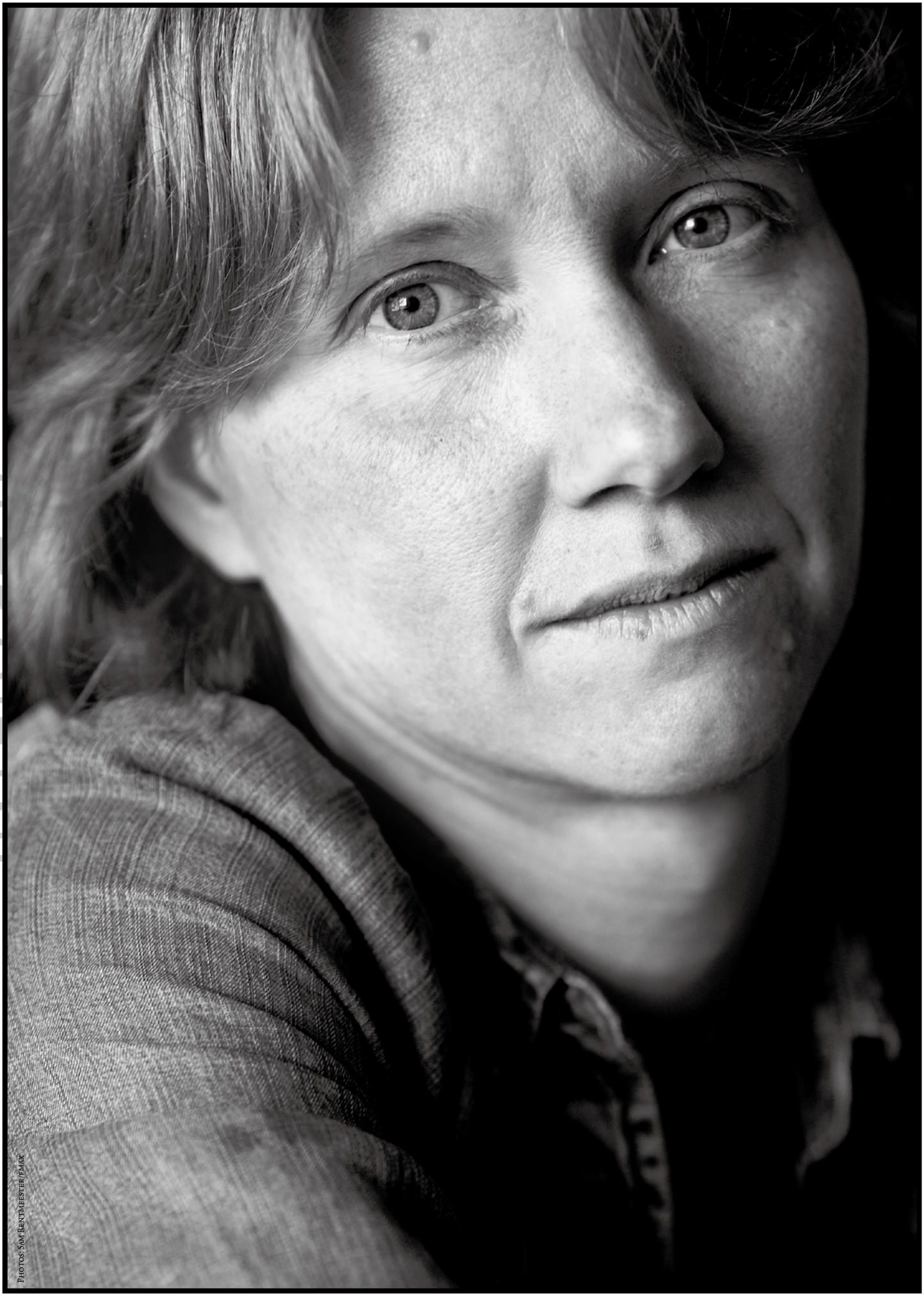
Visser's main job is to track the probe's position as accurately as possible. "If we are to use the gravitation readings successfully, we need to know the location of the satellite at each moment the measurements were taken, down to the nearest couple of centimetres," he explains.
Visser certainly has his work cut out for him. Goce carries onboard GPS receivers, but the GPS satellites themselves, which Goce uses to determine its position, do not know exactly where they are located. There is an error margin of several metres in the transmitted GPS positions. This is because, although they radio down a prediction of the orbit they will be following, their position is affected by gravitation and solar radiation. Visser and his team will therefore have to apply all kinds of corrections.
Nonetheless, Visser is confident that this arduous task will be done in just a few months time. By then, the instruments will be sufficiently calibrated to enable Goce to be tracked in space accurately enough for its data transmissions to be used to calculate the geoid's shape to an accuracy of one centimetre.

Laser

As an added position check, Goce also sports laser reflectors along its exterior. Across the world, some 40 laser stations use laser beams to locate and track satellites. Until now, only one station, in Yarragadee, Australia, has proved capable of locating Goce.
"That isn't very surprising," Visser says. "In order to be able to track Goce, the laser station must be very high-tech. Since the satellite follows such a low orbit, it flies past at a considerable speed - eight kilometres per second. To locate a satellite, the laser stations must know a satellite's path to within 50 metres. The Goce satellite travels so fast that those 50 metres are traversed in only six milliseconds. I'm very happy the Australians have managed to track Goce."


Photo: Sam Rentmeister/fmax
Dr Pieter Visser

FOCUS



Photos: Sam Rentmeester/FEMAX

‘This type of research requires patience’

Physicist Nynke Dekker is conducting research on single molecules.

Her research has already led to a cover article in Nature. “A cell is such a large and complex system!”

Joost Panhuysen

As the daughter of a Dutch UN diplomat, you grew up mostly abroad. How has that affected your life? For instance, did you ever dream of a diplomatic career?

“Not really. My father was also more involved with technical subjects, like demographic surveys and information technology. He was also a physicist, so you could say I’m a chip off the old block. Even so, my younger years certainly influenced me. It was never certain that I’d eventually come to work here in Holland. I spent most of my teenage years in the United States. I then studied physics at Yale, and later went to Harvard for my PhD. When I arrived in Delft, my English was easily better than my Dutch.”

It seems that has changed.

“Yes, I managed to get my Dutch back. My American background still makes it easier for me to come into contact with American researchers. I come across as totally American.”

Why is that?

“I speak English with an American accent, and share many of the same points of reference. Consequently, invitations to conferences are more forthcoming, things like that. So, my background is a great help to me.”

Were you always certain about wanting to study physics?

“I did hesitate for a while. I knew it had to be one of the sciences, though. In my final year at school we were living in Holland, and so I did take a look around Twente University and TU Delft, but I decided that the courses they offered were terribly dull. The curriculum was completely set, with no option for making your own choices. And things were also rather formal. At Yale you didn’t immediately have to decide on a specialist subject. Biophysics and biochemistry both appealed to me, but because the physics classes proved to be so inspirational, I ultimately opted for physics – and I’ve never regretted that choice. Physics gives you a proper foundation for pursuing other things later. I finally ended up in molecular biophysics. So I’ve come full circle.” (Laughs)

In your inaugural address as professor at TU Delft, you described yourself as a physicist with an interest in biological systems, and said, “There is also a trend in biology to look at increasingly smaller details of biological systems.”

“Yes, but you’ll never hear me claim to be a biologist. We use physical methods and technologies to try to understand how biological molecules work. Even so, I did get some extra training.
Biology is steadily moving towards the molecular level, which is a development that started in the 1950s. Biologists are always finding better ways of isolating certain molecules, of getting more to grips with the smallest matter. Physicists on the other hand are good at making minute structures and getting very accurate measurements. We can now see the two coming together.”

Are there also biologists in your research group?

“Yes, there are, and that’s a good thing too, because if we had to make do with just physicists who received some extra training... (laughs). This can work up to a certain level, but to properly work with cells and molecules, you also need biologists. Their broader view of biology is especially useful, as this leads to other perspectives.”

Over the past couple of years, your group managed to unravel the ‘dance’ between the topoisomerase IB enzyme and DNA, with an existing cancer growth inhibitor providing interference in the background. While being copied, the double helix of the DNA molecule tends to get tangled up. Topoisomerase IB acts as a molecular motor that stretches the loops and knots back into shape, allowing the DNA copying process to continue. You have been looking at how the cancer growth inhibitor disrupts the process by slowing down the enzyme, an effect that might retard the division of cancer cells. Is your current research along the same lines?

“We are now in a slightly different phase. I’ve been working as a researcher at TU Delft for six years, and when we started, we built two test set-ups in which we conducted many interesting measurements during the first four years. We looked at how the topoisomerase proteins rotate with the DNA, and how cancer growth inhibitors can affect the process. For such measurements we developed magnetic nano tweezers. Eighteen months ago we started improving and testing those tweezers with a view toward conducting new measurements. I expect our new nano tweezers to be finished this ▸▸

Who is Nynke Dekker?

As a young professor of single-molecule nanoscale biophysics, Nynke Dekker (Amsterdam, 1971) says she doesn’t suffer the pressure of great expectations. On the other hand, she does regret the fact that these days she often finds so little time to read articles, have discussions, sit and think, and thus generate the good ideas that fuel any leading research group.
Dekker studied physics at Yale. As a nuclear physicist, her PhD research at Harvard involved using magnetic fields to control the paths of caesium atoms, although she later made the switch to studying living matter.
In 2003, TU Delft enticed her to return to the Netherlands. Two years later, her research group published a cover article in Nature, on the interaction between topoisomerase and DNA. In April 2009, she delivered her inaugural address as a professor at TU Delft.

INTERVIEW

'Young scientists should be given more freedom to select their field of research; that's how science advances'

summer. I hope we can start the measuring phase as soon as possible, so that we can stay ahead of the competition."

Is it a race?

"Certainly, even though researchers in the United States started this kind of research a decade earlier than we did in Europe. The research groups breathing down our necks – or the other way round – are at universities like Berkeley and Stanford. Fortunately, there are people in our group who have brilliant ideas and deliver excellent work."

What will you do with those nano tweezers?

"We're already quite good at measuring the length of dna, and the number of twists we induce in the DNA. Some parameters keep eluding us though, such as the rotational rigidity and the rotational density that determine the torsion in the DNA molecule as it gets itself tangled up during the copying process. Until now, to get a rough idea about the torsion, we had to use figures measured by other researchers to fill models that didn't really do justice to the complexity of the process. With the new nano tweezers, we hope to be able to measure the stress and the torsion ourselves."

Are you conducting fundamental research, or is the purpose of the research to improve cancer growth inhibitors?

"This is fundamental research. People sometimes feel the need to stick a label on research to appeal to the masses, and then suddenly it's being said that we're going solve the problem of cancer and discover new drugs, which of course is nonsense. Because we can study a single molecule very accurately, we may be better able to understand how a cancer growth inhibitor can be improved at the molecular level, with the consequence being a reduction in side-effects, for example. But that is something altogether different from developing new drugs.

Of course there is the hope – which I share – that one day we will have 'specific' drugs, but to my knowledge there isn't a single example yet of a drug developed on the basis of molecular principles and then actually prescribed. The current cancer growth inhibitors were discovered in the 1960s by means of massive screening methods, with researchers adding tens of thousands of different substances to cells, just to see if they

could find some that acted against cancer. It may sound old-fashioned now, but it was certainly effective."

Could your research have indirect benefits for the development of new or improved cancer growth inhibitors?

"Absolutely. Our research group could perhaps contribute by finding out how a certain molecule works at a very detailed level. An improved cancer growth inhibitor will of course have to be tested for any new side-effects – and that would cost millions."

You discovered an interaction between an enzyme and a DNA molecule, in which the cancer growth inhibitor slows down the action of the enzyme. Is this effect of the cancer growth inhibitor also what causes a cancer cell to ultimately die?

"That is indeed our hypothesis. We shall have to conduct further research in order to prove it, though. But if we're right, it could be an important starting point for the design of new cancer growth inhibitors."

Does your research improve your insight into the basics of life itself?

"Well, life...I have trouble defining what 'life' is exactly. We want to discover how the cell works. And just one cell is already such a large and complex system! Granted, the object itself is minute, but so many things are occurring inside it."

You intend to get to the bottom of the cell's complexity?

"Hundreds of thousands of researchers are all trying to get to grips with various processes inside the cell. Our research cannot shed light on all the cell's processes, but the molecular motors we're studying are very important. If they stop working, the cell usually dies. We don't want to just describe the interaction between molecules, we want to understand the underlying physical principles. The greater the number of different things you can measure, the more precisely you can characterise a molecular motor. Only then will we really understand how these molecular interactions work. And, eventually, we will help other researchers find out how they can control these molecular interactions with specific drugs."

Nanotechnology is a controversial subject. Some expectations are exaggerated, with visions of hunger and disease becoming things of the past. Apocalyptic visions are also conjured up, with whole armies of nanobots, viruses that escape from laboratories....

"We don't use nanoparticles, we just observe things on a nanometre scale. Even so, I approve of the discussion. When genetically modified crops were first introduced, we saw how the general public opposed the new technology simply because they had been poorly informed. That is something we should try and avoid this time. The nanobots story is hard to take seriously. I don't foresee a future in which nanoparticles will wipe out the human race! And it goes without saying that researchers must take steps to prevent viruses escaping from laboratories. It's also reassuring that nanoparticles are subjected to toxicological tests to ensure they don't jeopardise our health."

Can you say that the risks of nanotechnology are small?

"I think the risks are easy to control."

Is nanotechnology being demonised?

"I get the impression that the media sometimes greatly exaggerates the risks. Everything is still contained in the research laboratories, with no risk at all to the general public. I often think we would do better to solve some of our more pressing problems first. We have known for years that soot particles emitted by diesel-engines end up inside our lungs and can shorten our lives by several years, but soot filters still haven't been made compulsory for all heavy diesel vehicles. Why would we be more afraid of nanotechnology than of things that ruin our health, and that we've known about for years without doing much about it? I fail to see the logic in that."

You are a member of 'The Young Academy' of the Royal Netherlands Academy of Arts and Sciences. You sit on a committee that has reported on recommendations for improving the career policy for young researchers. Are young researchers being denied opportunities?

"It varies considerably between universities and faculties. You sometimes find systems that make it impossible for anyone but a certain person to get a professorship. This way you not only block the way for young talent, but also for new ideas – although I'd be the last person to suggest that young researchers are the only ones who can come up with new ideas.
If Dutch researchers have been abroad and gained experience in types of research that haven't yet been started in the Netherlands, make sure they get the opportunity to start a similar line of research in this country, rather than fitting them into existing structures. Young scientists should also be given more freedom to select their own fields of research; that's how science advances. At the moment, they often have to conduct research dictated by the professor who holds the departmental chair."

Speaking of career policy, in your inaugural speech you said that universities should ensure that female researchers don't become disillusioned and quit.

"One way of doing so would be to approach people who aren't on the shortlist when you go looking for someone to take up a new professorship. At TU Delft, the great majority of professors are males, so when they start making their shortlists, they automatically tend to think of other males. I'm not saying they're doing it on purpose, but I do think this is how it works. At 'The Young Academy', for example, members could only nominate a single new member. When the rule was relaxed to allow two nominees, it resulted in a disproportionate rise in the percentage of female nominees. But nobody is going to admit that they will only nominate a women if they can name two candidates."

Was the cover article in Nature in 2005 the high point of your career – at least, so far?

"Each new paper is fun, it's always another piece of research completed. And of course, if we think we've got a winner, we try to get it published in *Science* or *Nature*, simply because we know it's the best way to get everybody's attention. But that's not to say that I think publications in other journals are less interesting, far from it."

So there are no Hollywood-style highs in your career?

"That's not how it works. It's more of a gradual process. It's still relatively easy to come up with new ideas, but realising them has become a much harder and slower process."

So it takes patience?

"Yes, this type of research requires patience."

INTERVIEW

Photo: Sam Rentmeester/fmax

Welding

They may look pretty, but the sparks that fly all over the place when zinc-coated steel sheets are welded do present a problem. Zinc evaporates before iron melts. "During the welding process, the zinc vapour blows spatters of liquid steel about," PhD student Yu Pan (Mechanical, Maritime and Materials Engineering) explains. "It cuts down into the material and affects the quality of the weld." Pan is searching for ways to improve the welding process. He noticed that a thicker layer of zinc gives improved results. Pan: "Now all we have to do is find out how it works exactly."

More information:
y.pan@tudelft.nl
+31 (0)15 278 60 71

A dot on the horizon

This spring will mark ten years since the Port of Rotterdam Authority and TU Delft started collaborating in what is known as the Port Research Centre Rotterdam-Delft. A look back and a selection of some of the current research projects.

Jos Wassink

The view from the 17th floor of the World Port Center is breathtaking. Off in the distance, the Noordereiland connects to the shore by means of an old railway bridge, while to the north high-rise buildings stretch all the way from the city centre to the river. Just below lies the Erasmus Bridge, under which speedy ferryboats and sluggish river barges pass each other in a dance that seemingly never ends. To the west, far beyond the old harbour district, the international Port of Rotterdam stretches all the way to the horizon.

This office on the Wilhelminakade is the workplace of company strategist Henk de Bruijn and senior advisor Teun Tuijtel, men whose broad views have allowed them to command such lofty positions. "We are about to face new challenges," says Tuijtel, who from the start has been involved in the collaboration with TU Delft. "The current recession is an incentive for forward thinking." Long-term planning, vision, and strategy – Henk de Bruijn likes to test his ideas in a dialogue with TU Delft: "Just hold up a mirror to us, whether we ask for it or not."

'When we started, we considered TU Delft rather tunnel-visioned'

"The collaboration between TU Delft and the Port of Rotterdam Authority is still defined in a very general way" stated an article published in Delta, TU Delft's university newspaper, on 6 June 1999. "Together we are in search of new concepts for the infrastructure of the Port of Rotterdam. According to spokesman Dr Rob Stikkelman, of the Delft research institute Interduct, the aim is sustainable improvement: 'How to make the area more profitable, while reducing its impact on the environment.'"

The work plan of the Port Research Centre (PRC), published in 2009, states this slightly differently in its mission statement: "Generating, coordinating, and executing innovative, strategic research projects for use in the Rotterdam port and industrial area to strengthen its international competitiveness."

The project kicked off in 1999 with a brain-storming session, during which the two parties jointly tabled 90 new ideas. "At first, the Port delegation appeared to be controlling matters," recalls Stikkelman (Faculty of Technology, Policy, and Management), who serves as the university's liason with the PRC. Stikkelman's initial role was to 'shop around' the research questions among the various TU Delft research groups. He recalls that one of the research subjects included 'multiple use of space'. Oranges and crude oil don't go well together when stored on the same quay, but each new successful combination saves space in the port area. They also looked at low-noise, clean transport for the port (using electric vehicles powered by fuel cells running on methanol), and collapsible containers (a product now being offered by Holland Container Innovations).

"When we started, we considered TU Delft rather tunnel-visioned," says Tuijtel, who, together with Professor Han Ligteringen, a hydraulic engineer at the Faculty of Civil Engineering and Geosciences, is the co-chairman of the PRC programme council. "Collaboration between different faculties was awkward, but that has improved a lot. For the first two years we were simply testing the water, but after that the collaboration became professionalised – on both sides."

This professional approach is reflected in the work plan, in which research projects are arranged according to theme, listing the responsibilities of TU Delft and the Port Authority. The research themes are Space, Access, Energy, and Miscellaneous. Every quarter a progress report is published in which a column lists the various projects, with smiley or sad faces indicating the progress of each project. Additional explanations include: 'Project leader has left TU Delft' and 'Concept still to be finalised', which the programme council must then decide about.

"We decided to use a project-wise method," Tuijtel explains. Each research proposal must include a strategy plan, and must be approved by the programme council. Tuijtel: "It's not quite as rigid a way of doing things as we're used to in Rotterdam, but you need to be able to set deadlines and make ▸▸

Photo: Nout Steenkamp/fmax

Photo: Nout Steenkamp/fmax

mutual arrangements. We simply tightened the reins a bit."
Henk de Bruijn, the current director of corporate strategy for the Port of Rotterdam Authority, will soon take over Tuijtel's position as co-chairman of the programme council. In De Bruijn's view, the collaboration with TU Delft is mainly exploratory: "We place a dot on the horizon, and then retrace our steps to see what we can do about it today. The projects are more intended for setting the agenda than being realised." De Bruijn says that collaborating with the university is especially useful during the early project stages, with both parties working together to narrow down the questions

Highs and lows

Captain Leeuwenstein had already struck bottom three times that morning: an old bicycle, a piece of wood and various debris posed serious threats to his boat's propeller. It was August 2003, and the low water level had forced river barges to reduce their speed and take detours. Whenever ships passed each other in the narrow, summertime channels, they would suck the water from around the groynes, all the way to the bottom. Ladders were needed to reach the quaysides from the decks of ships. Admittedly, the summer of 2003 was extremely dry, but still, climate scenarios predict that future summer droughts in Europe will become more frequent and last longer, and that water levels will sink even lower. Seventeen times over the past 14 years the amount of water flowing into the Netherlands via the Rhine fell below 1,000 cubic metres per second. According to the medium climate scenario for 2050, this figure will rise to 25 times, while the dry scenario predicts 60 times, which would render the dramatic scenes of 2003 yearly events.
Little wonder then that the Port of Rotterdam Authority commissioned a strategic study of the effects climate change will have on inland shipping, an industry that accounts for 35 percent of the tonnage transported throughout the Netherlands' provinces. The study resulted in a graduation project thesis, 'Climate change and inland shipping' by Caroliene Bosschieter (2005). She found that trends such as larger vessels and river levelling will exacerbate the effects of climate change.

Photo: Nout Steenkamp/fmax

Bosschieter's graduation project supervisor, hydraulics engineer Professor Han Ligteringen (Civil Engineering and Geosciences), explains how a research programme, 'Space for the River', has been launched in an effort to reconcile the conflicting demands of safety and navigability. The outer (winter) dikes must be moved back to provide more room for the river, while the summer bed must also be maintained. The aim is to establish a narrow, deep channel as a climate-proof navigation route, flanked by open space on each side to accommodate extremely high water levels. "A tight summer bed and a spacious winter profile," is how Ligteringen describes it. There is however a risk that the narrow summer river will start meandering all over the wide winter bed. Meandering can be prevented by building groynes, or low dams that project into the river at right angles to the shore. "The challenge is to get the dimen-

to a point where consultants and engineering companies can get to work on the construction stages. Tuijtel: "That's the right way of doing things. You need to clearly define the boundaries together." While De Bruijn adds: "If you ask a professor or a teaching assistant a question, you get an answer, but above all you get lots of answers you didn't ask for."

'For the next decade, Space and Access will remain the main themes'

As the collaboration progressed, mutual understanding grew. The Port Authority started to see that researchers – obstinate though they can be – sometimes said things that made sense, and vice versa, with the university community developing a better appreciation of applied research. "We grew closer," De Bruijn summarises. Last year, the renewed collaboration agreement between TU Delft and the Port Authority included the funding of three professorial chairs at the faculties of Civil Engineering and Geosciences; Technology, Policy, and Management; and Mechanical, Maritime and Materials Engineering). An additional part-time chair at the Faculty of Civil Engineering and Geosciences may follow later this year.

The Port Authority is willing to fund research, but also has certain expectations, such as clarity about the organisation, and especially about the results. De Bruijn: "Will we agree to get the right results, or should we be happy whatever the results?" Tuijtel joins in: "There has to be something in it for us. We don't conduct research for its own sake; it has to have added value." ▸▸

sions just right, so they will prevent the river from cutting into its edges, while still allowing it to carry off as much surface water as possible. We're thinking of using underwater groynes. We're developing the idea in collaboration with Deltares," Ligteringen adds.

Another development is the design of future river barges, which will have to be wider and lighter than the current vessels. Aluminium and plastics could be used to reduce the ships' weight.

During the summer, water levels are low because there is less drainage from meltwater, while during the winter, the Rhine's flow increases as the amount of rain and snow in the catchment area increases. Add to this the rising sea levels, and the threat to Rotterdam from having water on both sides becomes alarmingly clear. "You want to keep the Rijnmond area open," says Tiedo Vellinga, director of environmental monitoring for the 'Tweede Maasvlakte' land extension to the coast outside Rotterdam, "but water levels are rising. You can increase dike levels where possible along the approaches, but in the city itself you soon reach a limit. You simply have to resort to a flood barrier." Two of those already exist: the Maeslant Barrier in the Nieuwe Waterweg, and the Hartel Barrier in the Hartel Canal near Spijkenisse. Both protect the Rijnmond area from the sea, but with the danger of flooding in future also coming from the inland side, the construction of flood barriers in the rivers could also be considered. Ties Rijcken prepared a sketch for the Veerman Committee's report ('Working together with water', 2008), in which the Rijnmond area is surrounded by a ring of seven flood barriers. In the recommended

'A tight summer bed with a spacious winter profile'

scenario, 'Open and closed Rijnmond', presented to the Veerman Committee, the water from the Lek river will drain through an artificial 'New Lek' east of the area and be carried south in the Haringvliet, which will act as a water buffer. "It's in the port's interest to have the barriers closed as little as possible," Vellinga emphasises. "We'd rather have high dikes and a barrier that would seldom close. But there is bound to be lots of discussion about this issue over the course of the next few years." One of the consequences will be to restrict building activities outside the dikes, and greater scrutiny and discussion will be given to the status of all the various structures that have spread across the dikes over the years.

Every report concludes with a list of recommendations, and 'Climate change and inland shipping' is no exception. Bosschieter recommends that rivers be made suitable for both high water levels in winter and low water levels in summer. In the short term, problems with inland shipping could best be handled by means of information management. Low water levels can easily be predicted a few days in advance, leaving enough time to book alternative transport by rail or road. In the long run, the new ships constructed to expand or replace the existing fleets should be designed for use in shallow waters. Vellinga summarises matters even more concisely: "Climate change means lots of work."

More information:
Professor Han Ligteringen
H.Ligteringen@tudelft.nl
phone: +31 (0)15 27 84285

For the next decade, Space and Access will remain the main themes. In addition, both parties want more attention given to Energy and Sustainability. "We're trying to get Energy accepted as a discussion point," says TU Delft's Stikkelman. "Think of CO_2 extraction and storage, or coal gasification. Both are of major importance to the Rotterdam petrochemical industry."
De Bruijn would like to establish a high-sustainability container terminal on the new port expansion area, with docked ocean vessels no longer generating their own power from polluting heavy oil, but rather using shore-based power instead. "The port as test bed," as he likes to call it.
The challenge for TU Delft and the Port Authority will be to inspire the major industries in the area, such as APM Terminals (APMT) and European Container Terminals (ECT), to become more innovative.

More information:
Dr Rob Stikkelman
R.M.Stikkelman@tudelft.nl
phone: +31 (0)15 2787236

Beyond traffic jams

PHOTO: ADVANCED TRANSPORT SYSTEMS LTD. – WWW.ATSLTD.CO.UK

The daily gridlock on the A15, the main traffic artery leading to the Port of Rotterdam, is more or less a fact of life. Every morning, trucks destined for Europort, as well as employees of the various local businesses, queue up in one seeming endless line of vehicles. And every evening they do the same in the other direction. According to Professor Henk van Zuylen, of the transport and planning section of the Faculty of Civil Engineering and Geosciences, this a typical example of diffuse traffic demand, which is, characterised by a wide dispersion of destinations, low demand per area, and a transport demand that is distributed across the entire day, even outside rush hours. Moreover, this is a situation in which buses, trains, trams and metros offer no solution to the traffic problem, so everyone simply travels by car and gets in line. Could passenger traffic be handled differently, in order to give heavy goods vehicles more room to move?

Just imagine, at the edge of a large car park, you enter your destination at a terminal, and within two minutes an electric shuttle arrives for you to board. The vehicle seats four and drives itself, following special tracks and passing over and through viaducts and tunnels. En route, this vehicle maintains a favourable speed of 40 kilometres per hour, which is not only faster than travelling by bike or bus, but also beats the average speed of a car. Since each destination has its own branch off the track, the other traffic can pass unhindered. Vehicles join the traffic flow automatically, maintaining a minimum distance of 60 metres (which corresponds to six seconds). No searching, no fuss, safe, fast and always available: the Personal Rapid Transit (PRT) system. The city of Cardiff, in Wales, has PRT running on a test track, and this autumn a PRT system built by the Ultra company will enter service at London's Heathrow Airport.

'The Personal Rapid Transit system could be very useful in the port area'

Van Zuylen, who believes a similar system could solve many traffic problems, including pollution, traffic distress and time loss due to delays, has asked various researchers to conduct a feasibility study.
The researchers will use a questionnaire to present the system to people working in the port area, asking them whether they would want to switch to PRT and how much they would be prepared to pay for the service. The survey's results will be used to estimate the required system capacity and calculate the costs and returns. The final report is expected by the end of 2009.
The system also offers environmental benefits. Weighing only 700 kilos, each vehicle will have an average power of 2 kilowatts. Even at a low occupancy rate of 1.4 passengers, and 40 percent passenger capacity rate, this would mean an energy saving of 75 percent compared with a private car. Even better would be to fit the system with solar panels and the occasional windmill, which would generate 60 to 80 percent of the required power.
Subject to the outcome of the report, Van Zuylen believes a limited PRT system would be ideal for the expanded port area, which includes plans for a hotel. How would guests reach their destinations from there at various times of the day? That is a diffuse transport problem, as we now know.

More information:
Prof. Henk van Zuylen
H.J.vanZuylen@tudelft.nl
phone: +31 (0)15 27 81681

Better than Barentsz

The Northeast Passage is an old dream. In 1596, seafarer and explorer Willem Barentsz undertook his third attempt to sail east, past the northern coast of Scandinavia. His expedition however got caught in the ice at Nova Zembla, forcing the captain and crew to bunk down for the winter. The return voyage couldn't be undertaken until June of the following year, and just two weeks into that return trip, Barentsz died, on 20 June 1597.
Until today, that is. Leon Lammers recently completed his graduation thesis project on the feasibility of shipping containers along the Northern Sea Route (NSR), as the route through the Arctic Sea is known today. Lammers completed the interfaculty Master's course of Transport, Infrastructure and Logistics (TIL), offered by the faculties of Technology, Policy, and Management; Civil Engineering and Geosciences; and Mechanical, Maritime and Materials Engineering. His graduation project was supervised by Professor Bert van Wee (Technology, Policy and Management).
Satellite images reveal that the ice covering the arctic region is retreating at a rate of about three percent per decade. The average ice cover at the end of the artic summer - around October - is now 20 percent less than it was 30 years ago, a trend that is expected to continue at an increasing rate. In 2006, for the first time, the ice pack had retreated far enough for a ship to sail from Norway all the way to the North Pole, which certainly won't please the polar bears, but does offer the perspective of a shipping route to Asia that is 40 percent shorter than the route passing through the Suez Canal. Given the present state of affairs, the Port of Rotterdam Authority wondered under what conditions a shipping route to the Far East would be viable around the years 2030 to 2040.

'It would take great effort to corner just a tiny section of the market'

Lammers based his climate prediction for 2030 on international climate panel (IPCC) reports, while also envisioning a world in which extensive trade and order prevailed. He then explored the effects that such a route would have on the shipping industry in general, and on Rotterdam in particular. Lammers also studied the kind of actions that would be needed to facilitate the scenario of economic progress. This method is known as backcasting – instead of making predictions, one looks back on the present from the future and tries to find out how to arrive at that specific future scenario for the world, rather than some other.
According to Van Wee, backcasting is a popular method for studies with a high 'what if' aspect: "If you want to know the possible relevance of the access to a route, you take access to that route as a given."
Although this may come as a disappointment to many people, in his graduation thesis, entitled 'The possibilities of container transit shipping via the Northern Sea Route', Lammers concludes that any effect on the Port of Rotterdam would be minimal. First of all, ships would need to be smaller and stronger, and adapted to arctic conditions. Lammers: "Suppose a shipping company were to start a weekly shipping service. They would need six ships of 100 million euros each. An investment of 600 million euros is quite something. On the other hand, the volumes involved, given three to six months of ice-free passage, would be about one half to one percent of what currently passes through the Suez Canal. It would take great effort to corner just a tiny section of the market."
What does offer financially viable prospects, according to Lammers, is the export of oil and gas from the polar region. His advice would be to monitor the developments on the ice cover front, as well as those in the northern oil and gas industry. Companies based in the Port of Rotterdam should try to get involved in this development.
In the longer term, while it's conceivable that the Northern Sea Route could someday trace a straight line across an iceless Arctic Ocean, the resulting two to six metre rise in sea levels would be very bad news for Rotterdam. Van Wee: "In such an event, there would be other things to worry about. There would be major implications."

Photo: Nordic Photos / Kristjan Fridriksson

More information:
Prof. Dr Bert van Wee
G.P.vanWee@tudelft.nl
phone: +31 (0)15 27 87186

Number crunchers

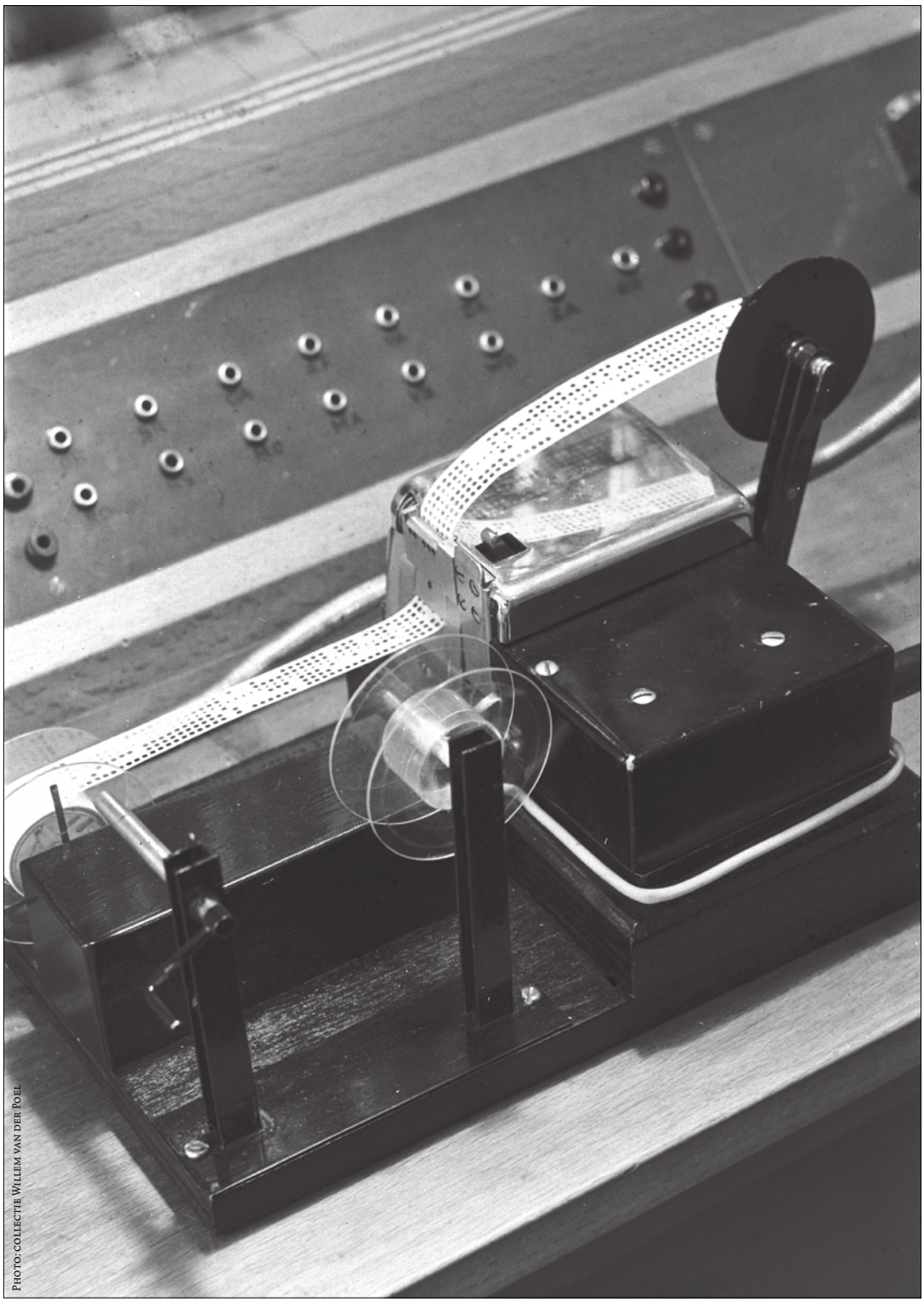


Photo: collectie Willem van der Poel

`At the Amsterdam Mathematics Centre, they turned their noses up at the 'trickology' of Delft computer pioneer Willem van der Poel. Even so, his early computers were reliable and efficient – most of the time.

Frans Godfroy

It was students who presided over the birth of the first Dutch computers. In 1947, Delft graduate Ad van Wijngaarden hired two mathematics and physics students – Carel Scholten and Jan Loopstra – for his recently founded Amsterdam Mathematics Centre. The students, given the daunting task of building an 'automatic calculator', never hesitated for a moment, before embarking on a great adventure that ultimately resulted in the Automatic Relay Calculator Amsterdam (Automatische Relais Rekenmachine Amsterdam, or ARRA).

Meanwhile, elsewhere, a student in Delft, Willem van der Poel, had spent the last few years dreaming of building his own automatic calculator. During the Second World War years, Van der Poel spent his days trawling through the library searching for information, and his nights drawing designs by the light of an oil lamp. His graduation supervisor of applied optics, Professor Bram van Heel, who designed lenses in partnership with local optics companies, was searching for ways of automating his time-consuming calculations. Van Heel had great expectations for his student's pioneering ideas, and thus, in 1947, he asked Van der Poel to work out his ideas into a practical application that could be used for lens calculations. Van der Poel's subsequent invention was called the Automatic Calculator for Calculations in Optics (Automatische Rekenmachine voor Calculaties in Optica, or ARCO), which others later renamed Testudo ('Tortoise'), because of its sluggishness.

The first

"There is some debate about which was the very first Dutch computer," Van der Poel, now 82, recalls. "The ARRA in Amsterdam was in use a bit earlier than ours, but it never worked as promised, and after just fourteen days they decided to modify it into the ARRA II. The Testudo, meanwhile, stayed in use for 12 years, starting in 1952." Van Heel certainly wasn't inconvenienced by the Testudo's lack of speed: "Testudo does its calculations at night, when I'm asleep."

But was Testudo a real computer? Some say no, because it worked by means of relays. Nonsense, replies Van der Poel: "Computers have been constructed that used water. You can direct a water jet left or right to create a flip-flop [elementary digital circuit, ed.]."

Van der Poel argues that Testudo was indeed a real computer, because it satisfied the Von Neumann criterion: "It used an instruction set for calculations. But limited capacity meant that it was used exclusively for the calculation of lenses."

Amsterdam mathematics and information technology historian Gerard Alberts disputes the Von Neumann claim for Testudo: "It's not a computer, it's a calculator, and was programmed by turning a telephone dial, which selected a different set of cables. You could call that a programme, but it was hardwired nonetheless."

But which was the country's first computer is not an important question, according to Alberts, who regards the introduction of calculators and computers as, above all, a step in the development of information technology. In the Netherlands, the history of this field dates back to the start of the 20th century, when calculation became a serious field in its own right.

The hosting of the International Congress for Applied Mechanics in Delft, in 1924, marked a milestone. Two junior Delft professors, Cornelis Biezeno and Jan Burgers, put Delft firmly on the map of world mathematics and mechanics. In one fell swoop, they had managed to get their names noted by the ZAMM community, the scientists affiliated with the authoritative Zeitschrift für Angewandte Mathematik und Mechanik (Journal of Applied Mathematics and Mechanics). In Delft, however, the importance of these proceedings went largely unnoticed: Biezeno and Burgers were and remained teachers in a field that didn't even offer graduate degrees. "The ZAMM community was a subculture in international terms," Alberts explains.

Even earlier, in 1913, a frustrated professor, Frederik van Iterson, after teaching for three years in Delft, decided to resign his post, because the university's Supervisory Board had not only refused him the use of a research laboratory, but had also informed the Dutch Minister of Education that the grant request the professor supported for a establishing a laboratory in Delft, which would also benefit the Dutch Aeronautical Society, did not serve any educational purpose. The concept of a research university in those days was a remote one. Alberts: "The prevailing ideology was that education must serve a practical purpose."

Events during the First World War however would soon drive home the importance of aeronautics, and with it the importance of aerodynamics. In 1918, Burgers was appointed the first professor of aerodynamics and hydrodynamics, and he was given use of a laboratory, in which he also temporarily accommodated Van Iterson's successor, Biezeno, until he too was eventually given the opportunity to set up his own lab.

Burgers and Biezeno used their calculations to tackle the technical challenges of the new age. "Burgers was a totally dedicated number-cruncher," Alberts wrote in his book on the rise of information technology in the Netherlands. Nevertheless, the professors simply lacked computational power: mathematical models often proved to be too simplified to serve as the basis for reliable predictions. In other fields as well, such ▸▸

'In 1953 Van der Poel completed Ptera, the first Dutch electronic computer'

looking BACK

as research on tidal currents, engineers were similarly hindered.
Van Wijngaarden, who in the early 1940s spent long days and nights doing calculations in support of his tutor Burgers' hydrodynamics research, eventually gave up. He later said of this period: "It didn't yield the degree of insight I was looking for." He'd had it. It was time for a different approach. After the Second World War ended, Van Wijngaarden went to work at the Amsterdam Mathematics Centre, where he would help develop the ARRA.

Computer nursery

In 1947, Leen Kosten, head of the mathematics department of the central laboratory of Dutch telephone company PTT, was asked by his bosses to build a computer. This computer's intended purpose was to help test the capacity of the telephone network. Kosten regarded Van der Poel as the ideal person to help him realise this project. Kosten had also helped Van der Poel in the past, by supplying 600 relays from the PTT laboratory for Van der Poel's Testudo machine. Once the youthful researcher had graduated in 1950, Kosten hired him. Van der Poel completed the assignment in 1953, when the first Dutch electronic computer, the PTT Electronic Calculator (PTT Electronisch Reken Apparaat, or Ptera), entered service, with 700 vacuum tubes serving as the Ptera's humming brain. Memory capacity was provided by a rapidly rotating drum that could store and retrieve magnetic signals.

Unfortunately, Ptera proved to be rather unreliable. Problems with falling valve emission levels required constant attention, which, in practice, meant 50 percent uptime and 50 percent downtime. Van der Poel dedicated himself to designing a successor, the Very Simple Binary Calculator (Zeer Eenvoudig Binair Reken Apparaat, or Zebra). Gone were the days when a designer could cobble together a computer by himself. Van der Poel therefore considered producing his design in a series. He went in search of a company that could see the commercial benefits of such an undertaking. Electronics giant Philips passed on the offer, "due to lack of vision", Van der Poel says. In exchange for a guaranteed purchase of components, Philips had agreed with IBM not to market any computers of its own.
Opportunity beckoned abroad, however. While designing the Zebra, Van der Poel had been in regular contact with the company of German computer pioneer Konrad Zuse, whose chief designer, Theodor Fromme, was working on the Minima and the Z22. Van der Poel and Fromme exchanged many ideas, and it therefore was no coincidence that the Z22 and the Zebra were similar in many ways. Zuse, however, was not interested in producing the Zebra, preferring instead to stick to his own line of designs.
Van der Poel was more successful at the British company, Standard Telephone and Cables, which started series production of the Zebra in 1957. Van der Poel remained responsible for the software. His star rose. He had gained his doctorate in 1956, and in that same year had taken over Kosten's job of running the mathematics department of PTT's central laboratory. Kosten meanwhile had accepted a post as professor of pure and applied mathematics at TU Delft.
The launch of the Zebra sounded the death knell for Ptera. The concept of computer heritage had not yet been developed. Van der Poel: "The room that housed Ptera had just about enough space left to accommodate the Zebra. But then we thought how much better and how much faster Zebra was, so that same day we demolished Ptera with a fair degree of sadistic pleasure."
Between 1958 and 1967, some 55 Zebras were sold worldwide, nine of them in the Netherlands. TU Delft was one of the first customers: in 1958, a Zebra computer was installed on the second floor of the main administration building on the Julianalaan. Other institutions followed: the universities of Groningen and Utrecht, TNO, the Dutch navy, the National Aeronautics Laboratory, Philips, Heemaf, and, of course, PTT, where the computer had started life. Together with the manufacturer, Van der Poel continued working on improvements. This resulted in the Zebra II, which featured the addition of extra fast registers, and transistors instead of vacuum tubes.

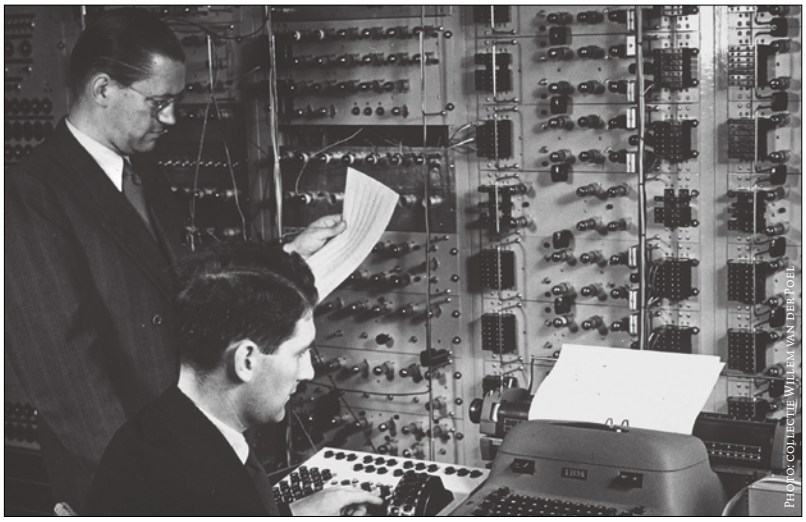


PHOTO: COLLECTIE WILLEM VAN DER POEL

Underwater programming

The rivalry between the Amsterdam Mathematics Centre and TU Delft did not compromise the mutual respect Van der Poel and Van Wijngaarden had for each other, and it was self-evident that Van der Poel would ultimately pursue a doctorate in Amsterdam, which he did in 1956, under the supervision of TU Delft trained Van Wijngaarden. Years later, Van der Poel would return the favour, acting as honorary supervisor when TU Delft bestowed an honorary degree on Van Wijngaarden in 1979.
Such was the special relationship between these two men that they also travelled together to Cambridge in 1950 to attend a computer programming course, a new phenomenon at the time. The knowledge Van der Poel gained there stood him in good stead when he came to build the Zebra. A prerequisite for the Zebra was that the hardware should be as simple

as possible, and that the software should conduct the majority of the calculation work. While the Zebra was under construction, Van der Poel wrote a programming language, called Simple Code, which was followed soon thereafter by an Algol compiler. In his work, Van der Poel was assisted by a deaf and blind assistant, Gerrit van der Mey. To make it easier for these two men to communicate, the PTT laboratory built a variety of instruments, including a Braille telephone and a mechanical Braille typewriter. The highly gifted Van der Mey remained with Van der Poel up to his retirement in 1978, even after the latter had been appointed professor at TU Delft in 1962. Van der Poel followed a different course than his colleagues at the Amsterdam Mathematics Centre. He had bet everything on simplicity of design, not

'Cobol may be an awful language, but it works'

least of all because of the fragility of the computer's physical construction. Van der Poel: "Radio tubes would suffer from falling emission levels, so you had to do as much as possible with the least number of tubes. This meant that we had to pull out all the stops, use every trick in the book." An amateur magician himself, Van der Poel coined the term 'trickology' and its synonym, 'underwater programming'.

One of the principles successfully applied in the Zebra was the use of functional bits, a technique Van der Poel had tried earlier in 1952 on the Very Simple Calculation Device (Zeer Eenvoudig Reken Orgaan, or ZERO), a temporary small test computer he had constructed from parts intended for the Ptera. The ZERO machine used four functional bits, while Zebra had 15, each of which controlled its own port with an attached function. Every combination of bits was allowed, providing access to a vast number of different operations.

Like the Ptera, the Zebra featured a drum memory device; however, the access time presented a real problem, because each additional revolution between writing and reading operations increased the delay. Van der Poel sidestepped this problem to some extent through clever programming: he allowed the instructions and data to be written to alternate memory lines on the drum, which considerably reduced the access time. At the Amsterdam Mathematics Centre, such optimised programming techniques were frowned upon. Van der Poel's counterpart in Amsterdam, Edsger Wybe Dijkstra, regarded programming tricks that worked around hardware delay problems as inelegant. To the more pragmatic Van der Poel, this was amply offset by another ideal of beauty: optimum efficiency. Conflicting opinions about the principles of programming would feature high on the agenda over the ensuing years, in particular when different languages evolved to vie for supremacy. In 1961 and 1962, a committee of the International Federation for Information Processing (IFIP), which included Van Wijngaarden and Van der Poel, met to discuss the Cobol programming language. Dijkstra did not attend.

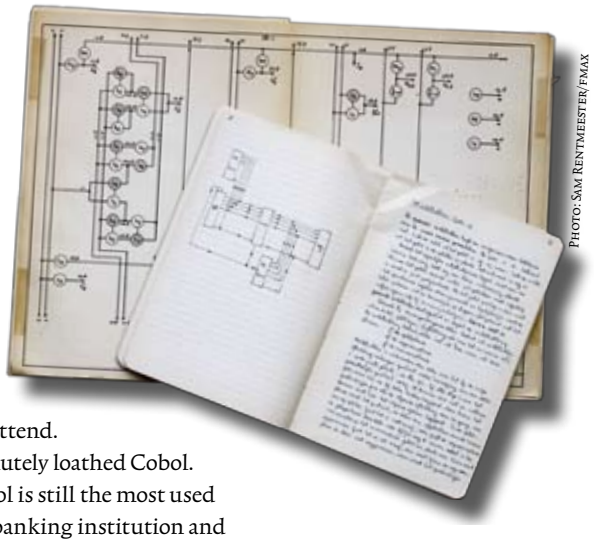


PHOTO: SAM RENTMEESTER/FMAX

Graduate report and orginal design drawing of W illem van der Poel.

Van der Poel: "Dijkstra absolutely loathed Cobol. But let's not forget that Cobol is still the most used language. Practically every banking institution and all financial administrations run on Cobol. It's easy to say that Cobol is an awful language, but creating columns and tables, which is what banks want, simply works. Pretty or not."

In 1962, the IFIP established a study group to further develop the Algol scientific programming language. Friend and foe alike attended this time. The Dutch delegation included the patriarch Van Wijnbergen, Dijkstra, who had since been promoted to a professorship at TU Eindhoven, and Van der Poel, who was made chairman. For the next six years, until 1968, the group worked on establishing rules for Algol60 and an improved version, Algol68. Unfortunately, the group failed to agree on the introduction of Algol68, so Swiss IFIP member Niklaus Wirth, Dijkstra, and five others split from the group and developed Pascal. Dijkstra severed all contacts with his former boss, Van Wijngaarden. Wirth was able to write a machine-independent compiler relatively quickly, and this greatly contributed to Pascal's popularity. Algol68 never made it, although it did much to influence the C programming language, which was used to write Linux, among other software.

Van der Poel, the IFIP's former chairman, recalls the era with mixed feelings: "Van Wijngaarden, Bauer from Munich, Dijkstra, they all had such huge egos. The way they fought over semicolons, you wouldn't believe it. It certainly taught me how big a role emotion can play in a scientific committee."

More information:

A. van den Bogaard (ed.), H. Lintsen, F. Veraart, and O. de Wit, *De eeuw van de computer. De geschiedenis van de informatietechnologie in Nederland* (Deventer, 2008)

E. van Oost, G. Alberts, J. van den Ende, H. Lintsen, *De opkomst van de informatietechnologie in Nederland* (Den Haag, 1998)

J. van den Ende, The Turn of the Tide. *Computerization in Dutch Society, 1900-1965* (thesis Delft, 1994)

www.math.leidenuniv.nl/~naw/serie5/deel06/dec2005/pdf/vanderpoel.pdf

Prof. Dr W.L. van der Poel
w.l.vanderpoel@tudelft.nl

Photos: Sam Rentmeester/fmax

Professor Ben Ale

"Simone likes to dive in at the deep end; she's not one to sit on the sidelines watching."

Honest, open

Professor Dr Ben Ale (61) has been professor of safety science and disaster abatement at TU Delft since 2002. After studying chemistry and mathematics in Amsterdam, in 1976 he became a doctor of chemical technology. From 1976 to 1980, he worked for chemical company DSM. By 'sheer coincidence' his career path veered towards safety. "One year after I had joined DSM, a plant exploded." Ale then worked at the Ministry of Public Health, and from 1994 to 2002 he was manager of external safety at the National Institute for Public Health and the Environment. Until April 2006, he was research manager at the Dutch Institute for Physical Safety, formerly Nibra. He considers his personal peak to be his work for the Oosting Committee, which investigated the fireworks disaster that levelled part of the town of Enschede in 2000. "Fascinating research, even though you know you're dealing with a disaster. You do your utmost to prevent such grief."

Erik Huisman

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?

Ale: "Simone is a hard-working, intelligent PhD student who takes her job seriously. She's also a nice person, a joy to have in the group."

Sillem: "Ben doesn't mince his words. He's doesn't cut you down though, he's constructive. He's also very accessible, and always makes time for you. And he doesn't make you feel subordinate."

What sets the other person apart?

Ale: She isn't afraid of getting stuck in, taking the first step. You often see young doctoral students teetering on the brink of the new wide world. Simone is a go-getter. I like that. It will produce a good thesis."

Sillem: "Again, the honesty. For example, when a client tries to control the direction of the research, Ben will come straight out into the open and say they can't."

What has the other done for you?

Ale: "Oh dear, that's not so simple. No, I couldn't try to answer that."

Sillem: "First of all, he showed me the importance of scientific integrity, which became evident to me during my research, through hands-on experience. And then there is the importance of getting published in papers and journals."

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

Ale: "A teacher, in the first instance, helps students find their way by asking questions rather than providing answers. I've had to do this with Simone on a few occasions, when her research needed a bit more depth. She was looking for ways of successfully developing an alarm method for civilians in the event of emergencies or accidents. In the science of safety, even a test has a major impact. People don't want disasters. In order to minimise the need for experimentation, Simone investigated the importance of parameters, in order to see which alarm system would work."

Sillem: "A teacher should always have sufficient time to listen and discuss matters. And to read a student's papers. He needs to be able to give constructive advice and leave room to construct a paper together. Room for autonomy, as well as creativity. Ben managed to do that. I think that many PhD research projects are much more fixed than mine was. This had to do with the nature of my research, which was to see how instructions affect the behaviour of people in an emergency. Not much was known about this in connection with disasters and emergencies."

Was your relationship like that of a father and daughter, or more like husband and wife?

Ale: "I don't think in those terms. It was more like

Simone Sillem

"When I did my doctorate, I found out personally how important scientific integrity is."

Nice

In 1997, Simone Sillem (1979) finished school at the Libanon Lyceum in Rotterdam. From 1997 to 1999, she studied psychology at Leiden University, before continuing her studies at Utrecht University, and graduating in 2003. She did her graduation project research at TNO in Soesterberg, where she evaluated a simulator that enables a person with normal vision to experience what a colour-blind person sees. In 2003, Sillem started her PhD research at the safety science section of the Faculty of Technology, Policy and Management, where, on 1 January 2009, she took up a post as lecturer. "I like teaching, but I'm new to it, and it's difficult to pass on your knowledge really well."

colleagues, like a master and mate. The relationship with Simone doesn't do justice to what a father-and-daughter or husband-and-wife relationship should be."

Sillem: "More like father and daughter, although I don't look at him as my father, even though he has children my age. Ben likes you to feel at home here, and he feels he has to make sure you do. And he's always happy to see you. He'll say things like, 'I know you', and 'Hi there, Simone!'".

Have you ever argued about the direction of research?

Ale: "Never. There was no reason to with her research. What Simone did, was completely new - there just aren't any existing directions, literature or points of view. In circumstances like that, it's as if you're crossing a new ocean and rewriting the map as you go along."

Sillem: "No! Definitely not. Perhaps it's because he comes from a totally different discipline than I do. He's a technologist, I'm a psychologist. He indicates the general direction in which he wants to go. How I get there using my knowledge of psychology is up to me. He takes it as a given that I know my business. Our difference in backgrounds had another benefit, too, which was that I had to explain everything really well. I won't be missing many steps in my thesis."

Can you recall a stroke of good or bad luck that stuck in your mind?

Ale: "It turned out to be much more difficult than I thought to observe behaviour without affecting it. If you tell people you're watching and there is no real disaster, they will behave differently. Technology also let us down, with sms messages arriving scrambled, too late, or not at all. It's time-consuming, and leaves holes in your results. We spent longer than anticipated getting reliable results. A stroke of good luck was that the Ministry of the Interior was willing to put up a lot of money, which enabled us to do our research on a large scale. And this still made it a good piece of research."

Sillem: "The good luck was that two projects occurred early during my doctoral research, which allowed me to collect lots of data very quickly. The first was a sms texting alarm service for the town of Vlaardingen. The purpose of this was to determine if there was any point in sending text messages with instructions, in addition to sounding a siren. The second was a cell broadcast for the Ministry of the Interior, which involved sending a text message to a cell antenna inside the affected area, which in turn sent the message to all the mobile phones in the area. I looked at the effectiveness of the message and the willingness of the population to use such a system, which would mean having to carry a mobile phone with you at all times, and having it switched on with the battery charged. I really can't think of any bad luck I've had."

Photo: ANP Photo, Marten van Dijl

Marital status:
Ale: married
Sillem: live-in partner

Best book:
Ale: 'Against the Gods. The remarkable story of risk' by Peter L. Bernstein
Sillem: 'The Discovery of Heaven' by Harry Mulisch

Favourite newspaper and magazine:
Ale: De Volkskrant.
No magazine.
Sillem: NRC Handelsblad and Bit, a magazine for horse lovers

Invention you'd like be yours:
Ale: The wheel, or black thread, because of the eternal fame.
Sillem: The dishwasher. Brilliant machine.

Do you socialise?

Ale: "No. It's nothing personal, I just don't socialise. Weekdays I live in Delft, and I spend the weekends in France. And I have a 70-hour working week."
Sillem: "We went along to Ben's once or twice, to have dinner."

What is the other person's best habit?

Ale: "She doesn't have very pronounced habits. In any case, Simone communicates with everybody. And she keeps her promises."
Sillem: "Again, the way he's easy to reach, although that's more of character trait. I don't think he has any obvious habits."

And the worst?

Ale: "She doesn't have any. At least not one I've seen. Perhaps I'm not the right person to judge."
Sillem: "He speaks rather loudly, but to call that a bad habit.... It's usually simply enthusiasm."

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

Ale: "In the end, she did manage to find out how you can get people to do what you want them to do in the event of a disaster just by sending them a 120-character text message. 120 characters is not very long. She laid the psychological foundations for the responsible introduction of this type of alarm technology. In two years' time people will consider it normal to receive instructions by phone text, in addition to the alarm sirens."
Sillem: "Ben is into so many things. He chairs conferences, he's on television a lot. His enthusiasm helps reel in many projects. Within the faculty, he stimulates us to attend conferences, to be visible in our field and to the outside world, in order to have attention given to safety."

What else can we expect from the pair of you in the future?

Ale: "Simone will remain here working in the field of safety and emergency. And even though the budgets have collapsed as a result of the recession, these remain major social issues. We haven't solved them yet."
Sillem: "To begin with, a good thesis. And thanks to Ben I'm now a lecturer in the field of safety, which means more teaching about the behaviour of people and the interactions between people and the environment."

And what else can we expect from your field?

Ale: "Solutions for three major issues that affect us all in a big way: climate change and flooding, our increasing dependence on infrastructure, which makes us vulnerable, and finally, geopolitical globalisation. Any country can become involved in a local conflict."
Sillem: "There is an increasing emphasis on security, preventing harm as a result of intentional actions. The emphasis used to be on safety, preventing harm from accidents."

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

On 1 April, aerospace engineering student **Ahmad Bakkar** won the 2009 WO award, which is one of the Echo awards, a national prize awarded annually to outstanding international students at higher professional and academic education institutes. Bakkar, from Lebanon, impressed the jury with his enthusiasm for all things technological, as well as for his passion for writing. Like the other prize winners he will be given the opportunity of attending a summer course at the University of California. **Michiel van Schravendijk**, another aerospace engineering student, will also be going to the USA, to attend summer school at Harvard University. This is because on 20 May, Schravendijk won the 2009 Best Graduates award. In addition to the summer course, the student received 10,000 euro.

On 20 April, **Professor Dr Wubbo Ockels** of the Faculty of Aerospace Engineering received the RAI Mobility Award, 'The Golden RAI Wheel', from the Dutch minister of Transport, Public Works and Water Management, Camiel Eurlings. Ockels received the award on the occasion of the annual RAI Mobility Dinner held at the Mauritshuis in The Hague. One of the reasons the recommendation committee gave for honouring Ockels was for his work on the 'ladder mill', a project in which kites harvest energy from the wind to generate electricity. Ockels' work on the 'Superbus', a new, futuristic type of sustainable vehicle, also contributed to his receiving this prestigious award. The committee also praised Ockels for the way he has managed to instil enthusiasm for sustainable technology in young scientists.

A special honour befell associate **professor Hans de Ruiter** of the Faculty of Civil Engineering and Geosciences near the end of his academic career. In April he was made a Golden Honorary Member of the Mining Engineering Association; he is only the fifth honorary member since the association's founding 117 years ago. "I'm usually the first to know about everything, but this time, nothing!" De Ruiter exclaimed. In a colourful procession of some 150 mining engineering students and alumni, De Ruiter was carried in a sedan chair to the association's club, where he was instated. Since January 1997, De Ruiter has worked at TU Delft as associate professor of mining engineering, with the particular task of facilitating the internationalisation of raw materials education.

Owing to his voluntary work for the Old Catholic Church in IJmuiden, **Jaap Wijker** of the Faculty of Aerospace Engineering was featured in the Queen's Birthday Honours List. He is now a Knight in the Order of Orange-Nassau. Wijker said he was "pleasantly surprised" to have this distinction bestowed upon him. The municipality of Velsen, of which IJmuiden is part, praised the TU Delft researcher for his ability to "use vigour and vision to combine tradition and history with a feel for the future."

In May, TU Delft **professors Dr Jo Coenen** and **Winy Maas** were in San Francisco to receive honorary memberships in the American Institute of Architects (AIA). Coenen has worked as professor of restoration at the Faculty of Architecture since 2004, and is a former government architect. He also runs his own architect's firm, JCCA. Maas is a professor of architecture at the same faculty, and is a co-founder of the architect's firm MVRDV.

Having served TU Delft for 27 years, Professor Dr Ted Young has retired. On 20 May, Young, who was professor of quantitative imaging (Applied Physics) delivered his farewell address, in which he discussed the decline of educational standards in primary and secondary schools. Young was also chairman of the Imaging Science & Technology department, in which capacity he has been succeeded by Professor Dr Lucas van Vliet. After his retirement, Young will continue to work for TU Delft in a teaching support capacity, and for Medical Delta, a major collaboration effort between TU Delft and the universities of Leiden and Rotterdam, of which Young is the chairman.

The Faculty of Applied Sciences is to have a new dean. Currently, Professor Dr Raoul Bino is still the director of the plant sciences group at Wageningen University, but on 1 September he will succeed Professor Karel Luyben as the Faculty of Applied Sciences' new dean. Bino will also take up a post as TU Delft professor of plant metabolites. Previously, Bino had worked with TU Delft researchers at the biotechnology department on solar cells based on photosynthesis.
"I have the ambition of applying technology research to improve the world's food situation, prosperity, and public health," Professor Bino recently said.

The shortlist for the position of rector of TU Delft has been pared down to three names. The current rector, **Professor Dr Jacob Fokkema**, will hand over the keys to his office at the end of the year. Although the names of his potential successors have been kept secret, more news is expected to be revealed this summer, as the next rector designatus will be formally announced in September, according to Fokkema, who will then have until the end of the year to show his successor the ropes.

[HORA·EST]

Propositions

If human life is a result of coincidence, then philosophy is meaningless.
Thanh Mung Lam
Aerospace Engineer

In the coming fifty years the potential consequences of flooding in The Netherlands will increase more than the probability of flooding, just like in the past fifty years.
Gerrit Raadgever
Civil Engineer

The versatility of mobile phones increases the reponse time of rescue workers.
Kim van Schagen
Physics Engineer

Incandescent light bulbs should stay!
Jan de Vries
Aeropsace Engineer

In contrast with general wisdom, cartoons and comics are effective long-term investments for children. Boys who yearned for 'Atom boy', 'Doraemon' and 'Gundam', have become engineers and created robots.
Hirokazu Shibata
Chemistry Engineer

It is the urge to make a personal discovery, that makes people ignore manuals. Scientists who do read manuals are not curious enough or don't have time.
Jeroen Plomp
Physics Engineer

Smoking free laws do not result in negative economic effects.
Jelan Kuhn
Chemistry Engineer

Incandescent light bulbs should stay!
Jan de Vries
Aeropsace Engineer

[Sound]bites

"Take Shell's recent decision to cancel wind energy research. 'No money in it,' CEO Jeroen van der Veer said. He may well be right, but in a broader social context it's an example of 'Big Oil' stupidity. I can't believe Shell hasn't been publically held accountable for this! The prime minister should have said: 'Just give me 10 billion of your profits and I'll make sure it gets spent well'."
Professor Dr Wubbo Ockels in Trouw.

"The current network peak loads occur during the morning, when people wake up, and during the evening, when people come back home from work. The power cables have been dimensioned to deal with those peak loads. But if everybody starts plugging in their electric cars at 6 o'clock in the evening, the country's transformer stations will be on fire by five minutes past 6."
PhD student Michiel Houwing in Het Parool.

"The idea is for Plakkies to become a trendy fashion brand, and not just a charity sandal. By marketing Plakkies as funky flip-flops, they'll remain attractive for years to come! This is what will create real job opportunities in South Africa."
Aerospace engineering student and one of the initiators behind Plakkies: Arnoud Rozendaal (22) in Trouw.

"The fuel economy of new cars has not improved at all in the past year. Any technical improvements went towards added luxury and power. In addition, demolishing cars for recycling also consumes lots of energy, as much in fact as leaving those cars on the road."
Dr Bert van Wee, professor of transport policy in De Volkskrant.


Photo: Sam Rentmeester/fmax

Proposition
A designer's own experiences in life are essential to the design process.

Defence
"Many industrial designers want designers to exclude their own experiences from the design process. I don't agree with this at all. For example, if you're asked to design a hospital bed, and you once spent some time lying in hospital, you will have much more feeling for the design. On the other hand, you shouldn't be tricked into believing your own experience is the ultimate experience. People all experience things and events in their own unique way. But even so, some experiences are indeed best understood from our own, subjective experience. If designers are aware of the differences and similarities in how they themselves and other users experience objects, they will gain a better understanding of who they are actually designing for."

Froukje Sleeswijk Visser
Industrial Design Engineer

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

I can still remember my professor's response when I told him about my post-graduation plans: "Patent attorney? What for?" Now, I must admit that patent law is not an obvious choice for someone who's graduated as a mechanical engineer in the field of measuring and control systems. In fact, I got there more or less by accident, but in the 12 years I've been a patent attorney, I've never once regretted my somewhat bizarre career choice.

To become a patent attorney, you must have first completed an academic, scientific or technological training. The course itself starts with an internship with a registered patent attorney, where you learn such skills as writing patent applications, offering infringement consultancy, and defending your client before the patent office. At the same time, you attend national and international training courses that provide you with in-depth knowledge of patent law and other intellectual property issues. After two internships of three and four years respectively, and successfully completing a number of exams, you are then sworn in as a Dutch Patent Attorney. And finally, you can call yourself a European Patent Attorney. These protected titles indicate that you're qualified to represent your clients before the Dutch and European patent-issuing authorities.

During my training I worked for Arnold & Siedsma in The Hague, where as a trainee patent attorney I became part of the organisation, with my own clients and portfolios. When I'd completed my training, I transferred to the office in Breda, where I further expanded my portfolio. I worked for freelance inventors and small and medium-sized companies. The independence and the diversity of my clients, and their various technical backgrounds, appealed to me. In late 2005, I moved with my family to Geneva, where I now work as an Intellectual Property Attorney at the European head office of the American multinational, Eaton Corporation. Together with two colleagues I'm responsible for the intellectual property affairs of our European internal companies, which numbers more than 50 companies in all. I'm now discovering a totally different aspect of the work: reviewing and negotiating contracts, such as development contracts and licensing contracts.

My profession is a constant challenge, in which I combine technological, linguistic and legal skills. The best part of it is how my creativity in constant demand. Whether it's about a patent application getting rejected by the patent office, or a contract being turned down by the other party, it's a constant challenge to come up with creative solutions. My analytical skills, which were honed in Delft, also come in very handy! And as a pleasant side-effect, I am able to keep up-to-date with the latest technological developments, without doing any of the calculations myself.

Marcella Tabeling works as a patent attorney for Eaton Corporation in Geneva. She studied mechanical engineering at TU Delft. Marcella passes the baton to Chrétien Verheijen.

Surgical suction

Erik Huisman

Having surgeons fiddle around inside your belly is nobody's idea of fun, which is why video links, and remote-controlled tools inserted through small incisions in the abdominal wall, are usually used to perform abdominal surgery. Even so, laparoscopic operations can be painful procedures, and abdominal tissue easily damaged by the medical instruments it comes in contact with. The graduation project assignment given to Durandus Vonck (31) – to improve the atraumatic gripper used in laparoscopic surgery – was therefore no mere academic exercise. Vonck began by taking a fundamental approach to his assignment: "I didn't immediately read all the available literature, but rather first simply allowed ideas to come to me. For instance, I drew up a list of how you can hold on to things - grip them, but also use glue, Velcro or suction."

Vonck meanwhile had read a thesis on gripping techniques in which suction was dismissed as being impractical. "But this thesis didn't explain why," says Vonck, who subsequently proposed suction during a meeting held to discuss his graduation project. A surgeon attending the meeting liked the idea of using suction to grip tissue.

Vonck's 'eureka' moment didn't come until later, however. "Initially, I couldn't get enough grip with my suction tube," he explains. "But then one day, while sitting at home fiddling with a small pump, a suction tube and a balloon, I turned the suction tube around, so that the wide end attached to the pump and the narrow end touched the balloon. And it worked. The balloon was sucked through the narrow tip and into the wider section, and this increased the grip." The next question to answer was whether human tissue could withstand such treatment. Two prototypes were used to test the principle on animal intestines. "Each time, the suction tubes got a good grip without causing any damage," Vonck recounts. "Less extensive tests were then conducted on other types of tissue, like spleen, gal bladder, and liver, which were not so easily sucked in, but I got a good grip nonetheless. The suction marks were more pronounced, but there was no visible bleeding."

Vonck has since patented his invention. "Initially, the patent application was rejected, because it wasn't entirely new, but it has now been patented as a product for industrial application."

This is certainly understandable, given that one aspect of Vonck's doctoral research involves trying to further improve the suction tube. He is now working with a group of Master's students to develop a grip containing a pumping mechanism, which would allow the system to be used in operating theatres without the need for pumps and tubing. Vonck: "Operating theatres are already full enough of electronics and tubing."

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.

TU Delft
P.O. Box 139
2600 AC Delft
The Netherlands
telephone +31-15 278 9111
telefax +31-15 278 6522

Disciplines

Aerospace Engineering
Kluyverweg 1
NL-2629 HS Delft
Telephone +31 15 278 2058

Applied Earth Sciences
Mijnbouwst raat 120
NL-2628 RX Delft
Telephone +31 15 278 1423

Applied Physics
Lorentzweg 1
NL-2628 CJ Delft
Telephone +31 15 278 7774

Architecture
Berlageweg 1
NL-2628 CR Delft
Telephone +31 15 278 4184

Chemical Technology & Bioprocess Technology
Julianalaan 136
NL-2628 BL Delft
Telephone +31 15 278 2667

Civil Engineering
Stevinweg 1
NL-2628 CN Delft
Telephone +31 15 278 5440

electrical engineering
Mekelweg 4
NL- 2628 CD Delft
Telephone +31 15 278 4568

Geodetic Engineering
Kluyverweg 1
NL-2629 HS Delft
Telephone +31 15 278 3289

Industrial Design Engineering
Landbergstraat 15
NL-2628 CE Delft
Telephone +31 15 278 4750

Life Science & Technology
Julianalaan 67
2628 BC Delft
Telephone +31 15 278 8271

Marine Technology
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 6666

Materials Science
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 6666

Mechanical Engineering
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 6666

Computer Science
Mekelweg 4
NL- 2628 CD Delft
Telephone +31 15 278 4568

Applied Mathematics
Mekelweg 4
NL- 2628 CD Delft
Telephone +31 15 278 4568

Technology, Policy & Management
Jaffalaan 5
NL-2628 BX Delft
Telephone +31 15 278 7100

Multidisciplinary Centres

Adhesion Institute
Kluyverweg 1
NL-2629 HS Delft
Telephone +31 15 278 5353

Biotechnological Sciences Delft Leiden (BSDL)
Julianalaan 67
NL-2628 BC Delft
Telephone +31 15 278 5140/2342

Centre for International Co-operation and Appropriate Technology (CICAT)
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 3612

Centre for Transportation Engineering
Stevinweg 1
NL-2628 CN Delft
Telephone +31 15 278 6634

Dutch Institute of Systems & Control (DISC)
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 7884

Koiter Institute Delft (Institute for Engineering Mechanics)
Kluyverweg 1
NL-2629 HS Delft
Telephone +31 15 278 5460

Netherlands Institute for Metals Research (NIMR)
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 2535
Fax +31 15 278 2591

Wind Energy Research Group
Kluyverweg 1
NL-2629 HS Delft
Telephone +31 15 278 5170

Reactor Institute Delft
Mekelweg 15
NL-2629 JB Delft
Telephone +31 15 278 5052

OTB Research Institute for Housing, Urban and Mobility Studies
Jaffalaan 9
NL-2628 BX Delft
Telephone +31 15 278 3005

Open Building Working group (OBOM)
Berlageweg 1
NL-2628 CR Delft
Telephone +31 15 278 5400

Delft Institute for Microelectronics and Submicrontechnology (DIMES)
Feldmannweg 17
NL-2628 CT Delft
Telephone +31 15 278 3868

Interduct Delft University Clean Technology Institute
Rotterdamseweg 145
NL-2628 AL Delft
Telephone +31 15 278 7233

J.M. Burgerscentrum Centre for Fluid Mechanics
Mekelweg 2
NL-2628 CD Delft
Telephone +31 15 278 3216

Netherlands Schools for Advanced Studies in Construction
Stevinweg 1
NL-2628 CN Delft
Telephone +31 15 278 3332

Advanced School for Computing & Imaging
Mekelweg 4
NL-2628 CD Delft
Telephone +31 15 278 8032

Trail Research School
Kluyverweg 4
p.o. box 5017
NL- 2629 HT Delft
Telephone +31 15 278 6046

Central Library

Delft University of Technology Library (dutl) supplies information and provides services, particularly in the area of the technical sciences. It comprises a central library and twelve sub-faculty libraries housed at the respective sub-faculties and institutes. The dutl is intended for students and staff at the Delft University of Technology. However, as the task of the library is to provide scientific and technical information at a national level, its facilities are also available to the general public. As well as all areas of technology and natural sciences, the library also contains a general collection in the social sciences, economics etc. This relates not only to books or periodicals, but also to standards, reports, reference works and congress proceedings. Literature not in the collection or not on hand can be obtained through Delft University's Central Library from other libraries in the Netherlands or abroad.

For further information:
Delft University Central Library
Prometheusplein 1
p.o. box 98
NL-2600 MG Delft
Telephone +31 15 278 5678

Delft University Press IOS Press
Nieuwe Hemweg 6B
NL-1013 BG Amsterdam
www.iospress.nl
Telephone +31 20 688 33 55
Fax +31 20 620 34 19
E-mail order@iospress.nl

Information

General information:
Information office
p.o. box 5
NL-2600 AA Delft
Telephone +31 15 278 5404

Information on facilities for foreign students:
Student Advisory Office
Jaffalaan 9a
NL-2628 BX Delft
Telephone +31 15 278 4670

Liaison between business and research:
Liaison Office
Mekelweg 2
NL-2628 BX Delft
Telephone +31 15 278 1500

Information on research fellowships:
Mrs. M.Y.M. Spiekerman-Middelplaats
Stevinweg 1
NL-2628 CN Delft
Telephone +31 15 278 3773

General information on university education in the Netherlands:
Min. of Education, Science & Culture
Central Information Dpt.
p.o. box 16375
NL-2500 BJ Den Haag
Telephone +31 70 412 3456

(Post Graduate) Courses

Delft TopTech
(vocational courses)
Mekelweg 2
p.o. box 612
NL-2600 AP Delft
Telephone +31 15 278 8019
Fax +31 15 278 1009
www.delft-toptech.nl

Institute for Biotechnology Studies Delft Leiden (BSDL)
Julianalaan 67
NL-2628 BC Delft
Telephone +31 15 278 2355

For information on courses in the Dutch language:
Language Laboratory
Jaffalaan 5
NL-2628 BZ Delft
Telephone +31 15 278 4124